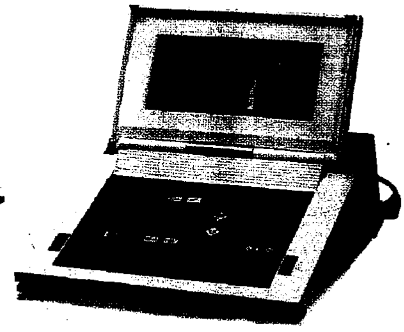
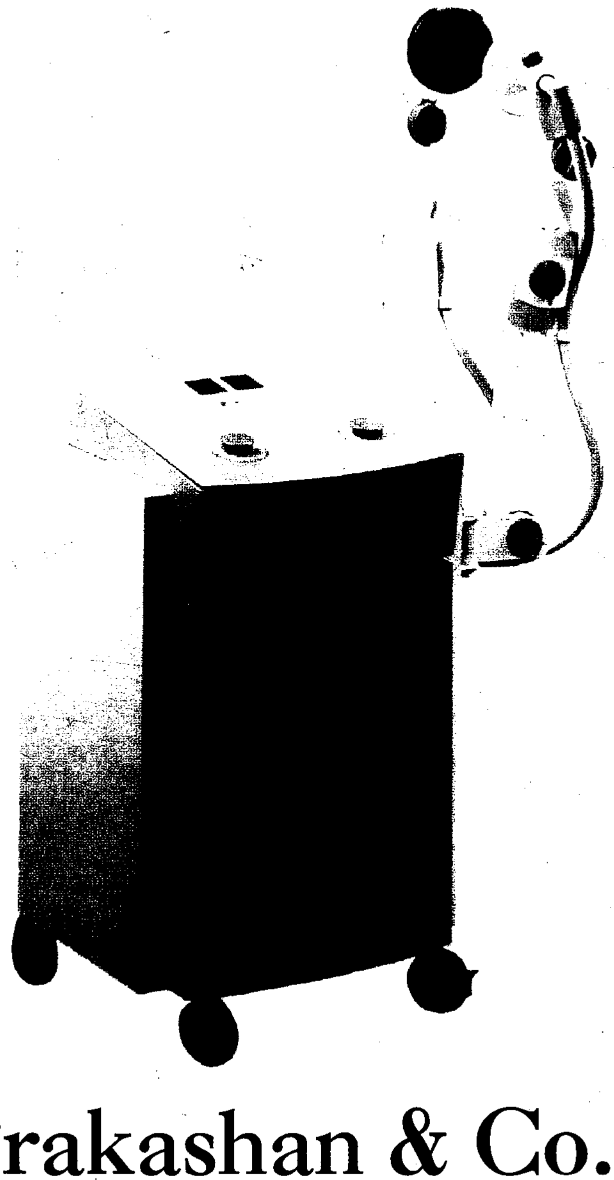
Helpline

Electrotherapy for Physiotherapists



Virendra Kr. Khokhar



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Helpline Electrotherapy for Physiotherapists

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Dedicated

to

God

who has always been by my side,

my parents,

my wife Meenu Khokhar,

my daughter Goodwill

and

my son Aryaman.

Preface

It is indeed a privilege to bring out the inaugural issue of my book 'Helpline Electrotherapy for Physiotherapists'. Putting it up has been a task immensely challenging, yet a pleasurable one. Each moment of doing so has been a new learning experience, an experience of a lifetime. This achievement, being the outcome of constant labour and continual effort from its initiation till the end, gives me a great sense of satisfaction. However, this end heralds a new beginning... as the work must go on. An onward journey is to be undertaken with renewed zeal and enthusiasm as,

"The woods are lovely dark and deep,
But I have promises to keep
And miles to go before I sleep..."

—Robert Frost

Electrotherapy is an essential subject for both the undergraduate and postgraduate physiotherapy students. It is a subject with frequent and often rapid advancements. I conceived the idea of penning this book when I observed that most of the books on this subject are by foreign authors and only a few by the Indian ones. This book will hopefully change the image. Furthermore, most of them, due to excessive irrelevant details of subject matter, fail to evince interest about the subject in the student. Therefore, after many years of teaching Electrotherapy and keeping in mind the frequent questions asked by my students, I felt the need of a complete and a comprehensive book which is a find of knowledge and, at the same time, a ready reckoner during examinations.

Being a teacher myself, I believe it's my moral and ethical duty to assist the students by presenting the subject matter in a simple and lucid manner. I have used a format that makes learning of key concepts easier.

Numerous diagrams, schematic representation, flow charts, photographs and illustrations have been included to reinforce the matter in the text. I have gone beyond convention to include the following topics to make reading interesting and bridge the gap between theory and practice (Section VIII).

- Factors that modify the inflammation & repair
- Treatment Planning
- Application of Modalities and Clinical Diagnosis
- Recent Developments in Physiotherapy
- Splints, Braces and Orthoses

I hope my efforts will be appreciated by the teachers, students and physiotherapy practitioners.

"A perfect Judge will read each work of wit
With the same spirit that its author writ;
Survey the whole..."

—Alexander Pope

Constructive criticism and valuable suggestions would be highly welcomed. Errors, if any, would be rectified in the subsequent editions.

Virendra Kr. Khokhar

Acknowledgement

A project of this magnitude was impossible to be undertaken and completed solely by the author himself. It is, of course, the result of teamwork, collective efforts, expertise and commitment of many individuals.

- I am highly grateful to Dr. Atul Krishna, M.S., Managing Director, Lokpriya Hospital; President, Subharti K. K. B. Charitable Trust, who introduced me into teaching.
- My sincere thanks to **Mr. Indra Agarwal, C.E.O.** of **Bharat Bharati Prakashan & Co.,** whose sustained encouragement was instrumental in transforming my dream of writing this book into reality.
- I would like to express my heartfelt gratitude to my colleagues and students who inspired me and provided me with valuable feedback.
- No amount of thanks is enough to acknowledge the constructive role of Dr. Alka Singh, Inchie Lonial and my daughter, Goodwill Khokhar in the accomplishment of this project by bestowing their precious times, energy and talent. Their dedicated efforts are truly praiseworthy.
- I would be failing in my duty if I do not thank **M/s Bharat Bharati Prakashan & Co.** for their tireless efforts in bringing out this book in time.
- Last but not the least, I thank God for His countless blessings He's showered upon me and for bestowing on me knowledge that's enabled me to fulfil my dream successfully.

Word of Thanks

I would like to express my heartfelt gratitude to all the students, lecturers, professionals and colleagues for the great enthusiasm with which they have received and consumed the first edition of the book. Without their support it would not have been possible to bring out the **second edition** of the book so soon.

Virendra Kr. Khokhar

Foreword 1

DR. H.C.GOYAL

ADDL.D.G. & HOD (PMR) REHAB. DEPTT.
SAFDARJANG HOSPITAL
NEW DELHI

Rehab/1-PF/HCG/2004

Dated: 15.12.2004

Dear Sh. Indra Agarwal,

I have gone through the new book entitled "Electrotherapy for Physiotherapists" authored by Shri Virendra Kumar Khokhar, published by your company. It is indeed a pleasure to write that the author has kept the Indian scenario into picture while writing this book on the subject of Electrotherapy. It does give a complete and comprehensive knowledge and should be a valuable asset for students of Physiotherapy. I must congratulate the author for the excellent effort.

With kind regards.

Yours sincerely,

(DR. H.C.GOYAL)

Sh. Indra Agarwal,
C.E.O.,
Bharat Bharati Prakashan & Co.,
Western Kutchery Road,
Meerut - 250001.

Foreword 2

I am very happy to know that you are bringing out this book of Electrotherapy. I have seen you from the very beginning. You are a good physiotherapist, a good doctor, a good teacher and over and above a good person. Your effort in bringing out this book is worth appreciation. This will help students to understand the subject easily and in an interesting manner.

Accept my heartiest congratulations.

Dr. Atul Krishna
M.S. (Surgery)
– Associate Professor, Subharati Medical College, Meerut.
– President, Subharati K.K.B., Charitable Trust, Meerut.
– Managing Director, Lokpriya Hospital, Meerut.

Foreword 3

Virendra Khokhar is known to me since the very time our college was started. As I've personally been with him since then, I have observed his keen interest in teaching and his tremendous popularity among the students and patients. Helpline Electrotherapy is the best ever book on the subject written by an Indian Physiotherapist and I am glad that it comes from my Head of Physiotherapy Department.

I wish him all the best.

Dr. Yogesh Bandhu
Principal
Subharati Physiotherapy College
Meerut.

Foreword 4

I am very glad to see this excellent book on Electrotherapy by Virendra Khokhar. He has made this very complicated subject simple to understand and practice, for students, clinicians and physiotherapists. His language is explanatory and I'm sure that this book shall contribute significantly in the academic development of many medicos.

I congratulate him for his excellent efforts and recommend this book strongly.

Dr. A. S. Dube
M.S. (Orth.), D.N.B. (Orth.), D.N.B. (Phy. Med. & Rehab.)
Professor and Head, Department of Orthopaedic ,
Subharati Medical College, Meerut.

Foreword 5

I appreciate the depth and thoroughness which the author has shown in writing this book which, I believe, will prove to be very useful both for the students and the practising physiotherapists. I am all the more happy that it comes from Virendra Kr. Khokhar, who in the past has worked with me at the Central Institute of Orthopaedics, P.O.T.S., Safdarjang Hospital, New Delhi.

Praveen Kumar
Physiotherapist
Central Institute of Orthopaedics
Safdarjang Hospital
New Delhi.

Foreword 6

I have found the book excellent for the students as well as for professional physiotherapists. The contents of the book are well organized and thoroughly illustrated. Language is effective and simple to understand. I strongly recommend this book for the students as well as the practitioners.

C. Janardan Reddy
H.O.D., Doon Paramedical College
Dehradun.

Foreword 7

I have gone through the book and found it to be of good quality. Diagrammatic & photographic illustrations are good and indicate elaborate work done by the author on electrotherapy. A book of such nature was required since long.

Sunil Sharma
Principal
Santosh college of Physiotherapy
Ghaziabad, U.P.

Foreword 8

Excellent presentation. Language is lucid. No doubt, the author possesses profound knowledge in the field of physiotherapy. I sincerely wish him all the success for the book. Furthermore, I have recommended the book to all my students, who are finding it of great value both in the theoretical & practical aspects of their studies.

Harish Arora
Director
Sai Institute of Paramedical and Allied Sciences
Rajpur Road
Dehradun.

Foreword 9

The book incorporates the latest advances in the field of physiotherapy. It fulfils the long felt need of the new generation of students and practitioners for such a book. I have no doubt that this book will prove to be invaluable for all those involved in the study and practice of physiotherapy. I congratulate Virendra Kr. Khokhar on the printing of the second edition of the book.

Amit Goyal
H.O.D., Physiotherapy Deptt.
Trident College of Education
Opposite C.C.S. University
Meerut.

Foreword 10

What students have to say...

We've been reading a number of books of Electrotherapy, all by foreign authors. A book of such nature was required since long - so comprehensive, yet so simple. The presentation is excellent and learning has been made easy as the key points have been emphasized well. Inclusion of latest developments and even electrode placements for specific conditions has made the subject more interesting. With Helpline Electrotherapy, Electrotherapy is no more a nightmare.

Inchie Lonial, Final Year B.P.T., Subharati Physiotherapy College, Meerut.

This book is a must-read book for all undergraduate, postgraduate and diploma students of Physiotherapy. All explanations are simple and concise. The diagrams & photographic illustrations, concise approach used and the manner in which the complex concepts have been made simpler to understand, are really worth appreciation. The details of information have been so beautifully presented that this book is useful not only for the study of theory but practicals too.

Anand Veer Singh, Final Year B.P.T., Subharati Physiotherapy College, Meerut.

It is a must-read book for all Physiotherapists. It is truly a marvellous book. Sir, we really congratulate you on bringing out this book.

Rashi Dixit, Suruchi Satija, IIIrd year B.P.T., Subharati Physiotherapy College, Meerut.

It is an excellent book for the Physiotherapy students, and their teachers too. I like the style of writing.

Priyanka Dahiya, MPT (Sports), Forest Hill, Golf Resort, Canada.

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SECTION I

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CHAPTER

1

INTRODUCTION TO ELECTROTHERAPY

Electrotherapy includes various forms of therapeutic applications using electricity as the primary source of energy. Its scope has picked up a lot since recent years. It is a non-surgical treatment approach, characterized by treatment of various diseases and disorders by electrical means.

Basic physics, of which electricity is just a branch, also includes light, heat, cold, and mechanics. As physiotherapists, we use these natural phenomena in our daily practice. Electrotherapy not only alleviates pain and other subjective symptoms but also helps the body to return normal function by making up for over or under compensation, or terminating the vicious cycle of pain and improving circulation.

The electromagnetic spectrum, ranging from radio waves to cosmic and gamma radiations, is the source of most of the electrotherapy modalities. We are able to produce these various band of energy artificially to apply them conveniently in the form of therapeutic tools.

The body works on a complex network of circuitry, redundant systems and ionic exchanges.

Ultrasound, though not an electrical modality, is also included in electrotherapy, since many physical laws pertaining to radiation also apply to sound wave transmission.

Electrotherapy →
- → Low Frequency Currents
- → Medium Frequency Currents
- → High Frequency Currents
- → Phototherapy
- → Electro Diagnosis
- → Biofeedback

Fig. 1.1

LOW FREQUENCY CURRENTS

They are therapeutically used currents whose frequency is in the range of 0–100 cycles per second. Their primary use is the stimulation of nerve and muscle, for instance direct current, interrupted direct current, sinusoidal current, diadynamic current, high voltage pulsed galvanic current, TENS, etc.

MEDIUM FREQUENCY CURRENTS

They are therapeutically used currents whose frequency is in the range of 1000–10000 cycles/second. They are used to stimulate deeply situated muscles and nerves, and for muscle re-education, for instance Russian current, Interferential current, etc.

HIGH FREQUENCY CURRENTS

They are therapeutically used currents whose frequency is more than 10000 cycles/second. They are used to produce deep heat in the tissues, for instance short wave diathermy, long wave diathermy, therapeutic ultrasound, microware diathermy, etc.

PHOTOTHERAPY

It refers to treatment of various diseases with the help of light. The primary effect is pain relief by heat and acceleration of healing by elevation of temperature, counter-irritation and photochemical effect. For instance, infrared rays, ultraviolet rays, laser.

ELECTRO DIAGNOSIS

Electrical currents are used for diagnostic purposes. It means detection of diseases and disorders by the use of electrotherapeutic currents or EMG.

E.g.: Rheobase, chronaxie, S-D curve, pulse ratio, myasthenic reaction, nerve conduction velocity, faradic galvanic test, etc.

BIOFEEDBACK

It is the process of furnishing the information to an individual about the body function to get some voluntary control over it.

The successful practice in electrotherapy requires knowledge of basic physics of each modality. Besides the knowledge of which switch to turn on, it is necessary to know why the treatment is selected.

The goals for achieving competence are:

1. Ability to select modalities skillfully
2. Administration of effective treatment
3. Appropriate adaptation when necessary
4. Evaluation of results correctly.

CHAPTER

2

BASIC ELECTRICAL CONCEPTS

- Conductors and Non-conductors of Electricity
- Static Electricity
- Electric Field around a Charged Body
- Electric Potential
- Potential Difference
- Capacitance
- Current Electricity
- E.M.F. (Electromotive Force)
- Resistance
- Ohm's Law
- Resistance in Series
- Resistance in Parallel
- Electrical Energy
- Power
- Electromagnetic Spectrum
- Electromagnetic Radiation
- Electromagnetic Induction
- Capacitor
- Eddy Current
- Snell's Law
- Waves
- Thermionic Valves: Diode, Triode Valves
- Semiconductors
- Fuses
- Heat
- Joule's Law
- Physical Effects of Heat

CONDUCTORS AND NON-CONDUCTORS OF ELECTRICITY

Conductors are elements that allow easy passage of electricity. Their atoms have few electrons in their outer orbit. It is such conducting electrons which facilitate the passage of electric current.

E.g.: Iron, Copper.

Non-conductors (insulators) do not allow passage of electricity. They are made of atoms in which the electrons in the outer shell are firmly held in their orbits and do not leave the atom in order to conduct a current.

E.g.: Wood.

STATIC ELECTRICITY

A static electric charge is produced by rubbing two suitable materials together.

E.g.: If glass and flannel are rubbed together, a positive charge is produced on flannel and negative on glass. The materials involved are usually insulators. The charges are held on their surfaces and are evenly spread, but concentrated more on points and corners.

ELECTRIC FIELD AROUND A CHARGED BODY

The electric field is an area in which the charged body has an effect. It is made up of lines of force surrounding the body.

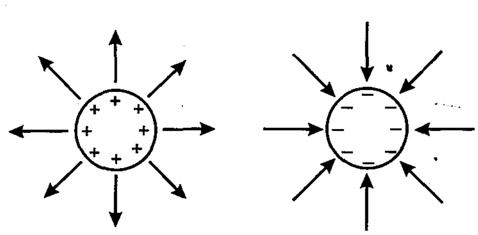

Fig. 2.1

Properties

1. The lines of force surrounding an isolated charged body are straight.
2. Lines of force repel one another.
3. Lines of force pass easily through conductors than through non-conductors.
4. Lines of force concentrate on that part of the surface of a charged body nearest to another object over which they can exert an influence.

Like charges repel and unlike charges attract. There's an electron flow between them till they are at the same potential.

ELECTRIC POTENTIAL

The electrical potential of a body is the electrical condition of that body when compared to the neutral potential of the earth.

Unit of Potential: VOLT.

The magnitude of potential depends on:

a. Quantity of electricity with which object is charged (measured in COULOMBS).
b. Capacitance of object.

1 coulombs = $6.26 \times (10)^{18}$ electrical charges.

There is a direct relationship between potential & electrical charge.

POTENTIAL DIFFERENCE

A potential difference exists between similar bodies charged with different quantities of electricity. Electrons flow from a more negative to less negative one, until both objects are at the same potential.

CAPACITANCE

The capacitance of an object is the ability of the body to hold an electrical charge and depends on:

a. Material of body.
b. Surface area of body.

There is an inverse relationship between capacitance and potential.

Unit of Capacitance: FARAD (F).

CURRENT ELECTRICITY

Electric current occurs when there is a flow of charged particles in a conductor. Conventionally, current flows from positive to negative, opposite to the actual flow of electrons.

Current is the charge flowing per unit time.

Unit of Electric Current: AMPERE.

EMF (ELECTROMOTIVE FORCE)

This is the force causing electrons to move along a conductor connecting points of different potential. Greater the potential difference, greater the EMF.

Unit of EMF: VOLT.

RESISTANCE

Resistance of a conductor is defined as the tendency of a conductor to hinder the electrical flow when it passes through it.

It is also defined as the ratio of potential difference applied to the current flowing through a conductor.

Resistance depends on:

a. Material of conductor.
b. Length of conductor—longer the conductor, greater the resistance.
c. Cross-sectional area of conductor—greater the CS area, lesser the resistance.
d. Temperature of conductor—as temperature increases, there's increased movement of molecules impeding the passage of electrons, thereby increasing resistance.

Unit of Resistance: OHM (Ω).

OHM'S LAW

This law was given by George Sinon Ohm in 1828. It states that provided the physical conditions (temperature, pressure, strain on conductor, etc.) remain constant, the current flowing through conductor is always directly proportional to the potential difference across its two ends.

$$\text{Current} = \frac{\text{Potential Difference}}{\text{Resistance}}$$

$$I = \Delta V/R.$$

RESISTANCE IN SERIES

If resistance are connected in series, the total resistance equals the sum of individual resistances.

$$R = R_1 + R_2 + R_3 \ldots\ldots\ldots$$

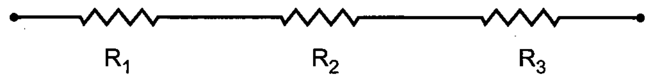

Fig. 2.2 *Resistance in series*

RESISTANCE IN PARALLEL

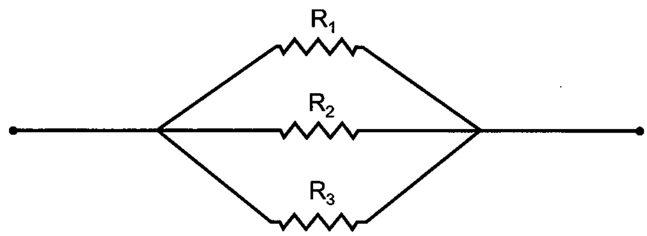

Fig. 2.3 *Resistance in parallel*

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots\ldots$$

By applying Ohm's law, largest resistance carries the smallest current, and the smallest resistance, the largest current.

ELECTRICAL ENERGY

Energy is the ability to do work. Energy can neither be created nor destroyed. The amount of work done in a system depends on:

a. EMF (volts).
b. Quantity of electrons moved (coulombs).

Unit of Energy = JOULES.
Energy = EMF × Quantity of electricity.

POWER

Power is the rate of doing work.

Unit of power: WATT.

If an EMF of 1 volt moves 1 coulomb of electrons in 1 second, then the power of system is 1 watt.

Power = EMF × Current.

The KILOWATT-HOUR is the British unit of electrical energy.

ELECTROMAGNETIC SPECTRUM

This contains different kinds of radiation.

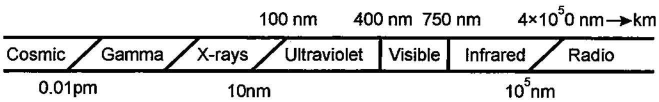

Fig. 2.4 *Electromagnetic spectrum*

Radio waves	0.1mm–100km
Infrared	750nm–0.4nm
Visible light	400nm–750nm
Ultraviolet	10nm–400nm
X-rays	
Gamma	0.01pm–100nm

Wavelength

Distance between a point on one electromagnetic wave and exactly the same point on the next wave. It is measured in nanometres mostly.

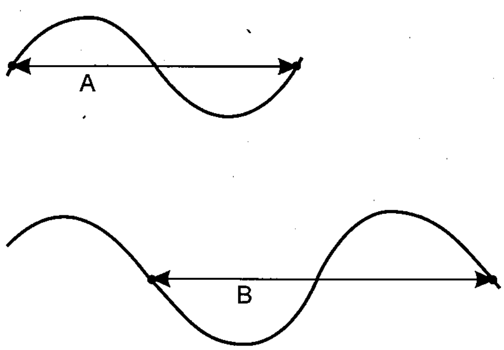

Fig. 2.5 *Wavelength*

Velocity

Same as the speed of light, for all electromagnetic waves (3×10^8 m/sec).

Frequency

Frequency is the number of complete waves passing any fixed point in one second.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation is produced by movement of electrons within the atom. If energy is added to an atom, the electrons become excited and move out to a higher-energy electron shell. When the electron returns to its original level, a pulse of electromagnetic energy is released (PHOTON).

The electromagnetic wave depends on electron shells involved in electron 'jump'.

ELECTROMAGNETIC INDUCTION

Electromagnetic induction is the means by which electricity is produced from magnetism. It is the result of interaction between a conductor and magnetic lines of forces: an EMF is produced in the conductor by the magnetic lines of force surrounding a magnet, without contact between the magnet and the conductor. The factors essential to electromagnetic induction are:

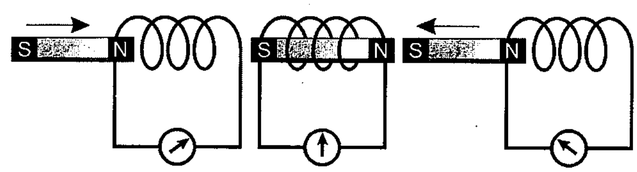

Fig. 2.6 *Experiment to illustrate magnetic induction. A current is generated in the circuit as the bar magnet moves into the coil. There is no current when the magnet is stationary, and a current in the opposite direction is generated as the magnet is moved out of the coil*

1. A conductor.
2. Magnetic lines of force.
3. Relative movement of 1 and 2.

If the conductor is a part of a closed circuit, the magnetic lines of force produce an EMF which causes movement of the electrons in the conductor. This can be shown with an ammeter connected across a coil of wire (Fig. 2.6). When a magnet is moved into the coil, the magnetic lines of force cut across the conducting wire of the coil and cause movement of electrons in the coil. These electrons repel adjacent electrons and so on, and a current is set up in the circuit. Movement of the ammeter needle, indicating current flow, will be seen only when either the magnet or the coil is moving. If the magnetic lines of force are stationary relative to the coil of wire, there is no induction.

Electromagnetic induction also occurs if the magnetic field used is that surrounding a coil of wire. The principles are the same; there must be movement of the magnetic field relative to the conductor. This may be achieved by using an alternative current in the primary coil which causes the magnetic field to build up, fall, then build up in the opposite direction, then fall, etc. An alternating current is represented in

Fig. 2.7. The current builds up to a maximum positive value and then falls to zero. It then drops to a maximum negative value before returning to zero. This rise and fall of current produces movement of the magnetic lines of force.

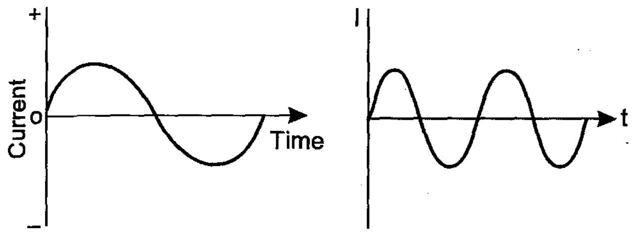

Fig. 2.7 *Alternating current*

In practice, the conductor in which the EMF is induced is usually a coil of wire, while the magnetic field used to induce the EMF is that of a permanent magnet or a current-carrying coil of wire. Movement of one of these, relative to the other, is achieved either by spinning the conductor in the magnetic field, as in a *dynamo*, or by varying the intensity of current in the coil of wire, as in a *transformer* (Fig. 2.8).

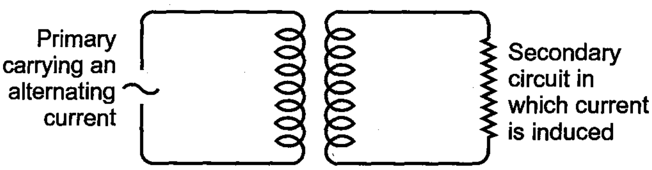

Fig. 2.8 *Electromagnetic induction – basic transformer circuit*

CAPACITOR

The capacitor (condenser) is a device for storing an electric charge. In its simplest form, it consists of two metal plates separated by an insulator. The electric field between the plates has an effect on the atoms of the insulator, causing their electron orbits to distort as they are attracted towards the positive plate (Fig. 2.9). The atoms remain in this state of tension until potential difference across the capacitor is removed when the energy is released.

EDDY CURRENT

When the magnetic flux changes through a loop of wires or a coil, electromagnetic force is induced in it. If the magnetic flux changes through a conductor in the

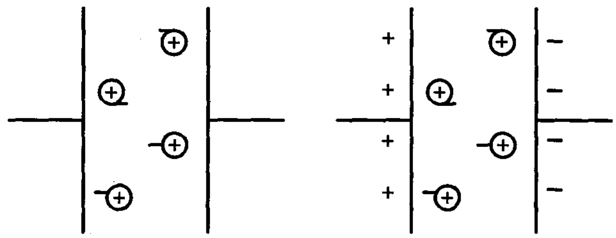

Fig. 2.9 *Distortion of electron orbits in a charged capacitor*

shape of plate or sheet, the induced current will be set up in this conductor too. Such induced circular current is called Eddy current or Focault's current. This phenomena plan was observed by Focault in 1895.

SNELL'S LAW

For a ray of light refracted at a surface separating two media, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant and is known as the refractive index of two media.

WAVES

All the waves – electrical, sonic, ultrasonic, infrasonic, electromagnetic, light – have four main features. These features differentiate the one form of wave to other form and the physiotherapeutic, diagnostic, physiological effects of the wave depend on these features. A brief of these features is as under:

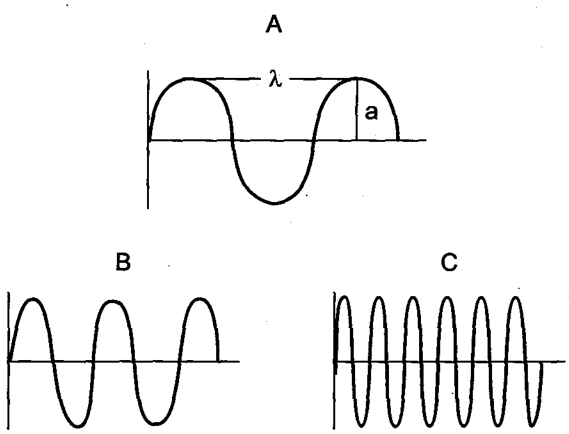

Fig. 2.10 *Diagram A: Showing amplitude (a) and wave length (λ) of a typical sinusoidal wave, B: Showing low frequency, and C: Showing high frequency waves*

1. Wavelength (λ) is the distance between two successive corresponding points on the wave.
2. Frequency (ν) is the number of waves produced per second.
3. Velocity (c) is the distance travelled per second by the wave.
4. Amplitude (a) may be described as the "vigour" of the wave.

The first three of these features are interrelated since the distance travelled by the waves per second (velocity) equals the number of the waves per second (frequency) multiplied by the length of each wave *i.e.*

$$\lambda \nu = c$$

THERMIONIC VALVES: DIODE, TRIODE VALVES

As the name implies, these are devices which allow electron flow in one direction only and work using heat.

Diode Valves

A diode consists of an evacuated glass tube into which are sealed two separate electrodes. The *cathode*, or filament, is so constructed that as current flows through it, a space charge of electrons develops around it as a result of the thermal effect of the current (thermionic emission). The *anode*, or plate, is the other electrode. When positive, it attracts electrons across the valve. Electrons can pass only from cathode to anode, as there is no space charge around the cold anode. Consequently, the thermionic valve is a device which allows electrons to flow in one direction but not in the reverse direction.

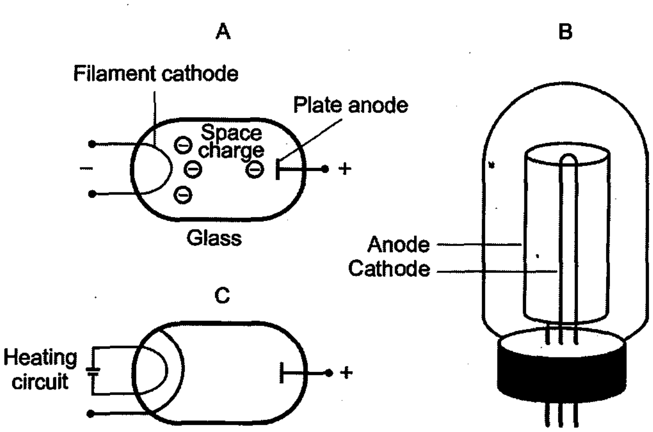

Fig. 2.11 *Diode valve. The valve shown diagrammatically in C has a separate heating circuit for the cathode: the others do not*

In order to reduce the time lag prior to thermionic emission taking place, the cathode or filament may be heated by a separate heating circuit or coated with thorium oxide which releases electrons at a comparatively low temperature.

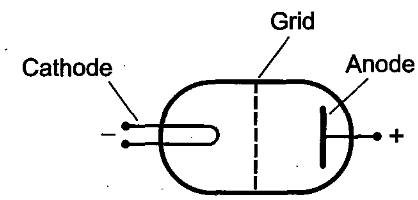

Fig. 2.12 *Triode valve. The grid may be positively or negatively charged, or neutral*

Triode Valves

The triode valve works on exactly the same principle as the diode valve but has a third electrode (the grid) placed between the cathode and the anode (Fig. 2.12). It is possible, using an external circuit, to make the grid negative, positive or neutral. If neutral, the grid will not affect electron flow across the valve. If positive, it will attract electrons away from the cathode and thus amplify the electron flow through the valve. If negative, the grid will repel electrons and reduce or even stop the electron flow. In this case, the valve can act as a switch or regulator.

SEMICONDUCTORS

Semiconductors are usually metals which, because of thermal agitation or the addition of impurities, have electrons free to conduct current, They are either *n*-type, with an excess of electrons, or *p*-type, where a

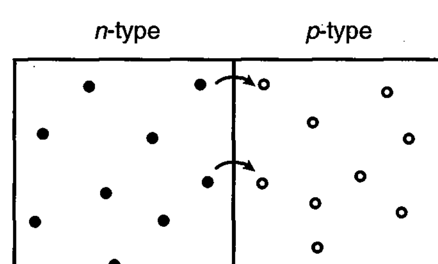

Fig. 2.13 *Movement of electrons in a semiconductor*

deficiency of electrons gives rise to positive 'holes'. If a *p*- and *n*-type of semiconductor are fused together, current can only pass in the $n \rightarrow p$ direction and the semiconductor therefore acts as a valve (Fig. 2.13).

FUSES

A fuse is designed to be a weak point in a circuit which 'blows' if a current of too great an intensity is passed. It consists of a short length of wire of low melting point and if the current passing through it exceeds a certain value, the heat generated melts the wire. This breaks the circuit, preventing further current flow and possible damage to other part of the wiring or overheating which might cause a fire, and gives warning of the defect which caused the excess current. The fuse is placed somewhere easily accessible, and where the heat generated can cause no damage. It is an essential safety device in any wiring system.

The most common type of fuse is the **cartridge** fuse (Fig. 2.14) in which the fusible element is made of silver wire and runs between metal caps through a tube of glass or other suitable non-inflammable insulating material. The whole tube is replaced when necessary.

Main fuses		*Plug fuses*
5 amperes	White	3 amperes – Most appliances upto 700 watts (look for the rating plate, usually on the base or back)
15 amperes	Blue	
20 amperes	Yellow	
30 amperes	Red	
45 amperes	Green	13 amperes – Appliances rated over 700 watts, also some with motors, e.g. vacuum cleaners, spin-dryers.

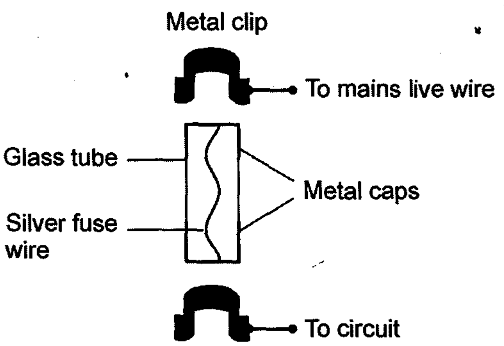

Fig. 2.14 *Cartridge fuse*

In many cases there are fuses on both wires of the circuit, but if only one is provided, it must be on the live wire. The use of one fuse, on the live wire only, has the advantage that if the fuse blows, the live wire is always broken. If there is a fuse on each wire, like that on the neutral may blow, the other is still intact, so the apparatus circuit is still 'live' with consequent danger of earth shock.

Fuses should be included in the circuit of each piece of apparatus used for the treatment of patients, in addition to those in the department wiring. If a fault occurs, blowing of the apparatus fuse affects only one patient, whereas if one of department fuses blows, the current is cut off from all patients receiving treatment from this section of the wiring.

If a fuse blows, the apparatus which caused the damage should be disconnected and the main supply switched off.

HEAT

Suppose there are two blocks of copper, one is cool and the other is hot. If they are placed in close contact, the hot block will cool down and cold block will be hot after some time. This will keep on happening until both are at equal temperature. This example can be explained on the basis of atomic or molecular energy by saying that rapid particle vibrations of the hot copper block transfer some of their energy to the cold copper block. In other words, there is **flow of energy** from one body to another. This particular form of energy is called **Heat**. The level of heat in a body is indicated by its **temperature.** Hotter the material, higher the temperature. Several scales of temperature measurement are there but the most common in the scientific use is **Centigrade** (or Celsius) scale on which 0° is the temperature of melting ice and 100° is the temperature of boiling water. Another scale of temperature is **Fahrenheit**. The relation between Centigrade and Fahrenheit is indicated below:

$$0^\circ C = 32^\circ F \qquad 100^\circ C = 212^\circ F.$$

By the following formula one scale of temperature can be converted into other and vice versa:

$$\frac{C}{100} = \frac{F - 32}{80}.$$

Heat Transmission

It is natural that energy is always conserved. Cooling of a hot material can only be achieved by transferring heat energy to another place, or by converting it into another form. There are three ways of heat transfer—Conduction, Convection and Radiation.

Whatever is the way of heat transfer, the rate of cooling depends on the difference in temperature between hot object and its surroundings. The greater the difference, more rapid will be heat transfer.

JOULE'S LAW

When we pass an electric current through any conductor or wire, after some time there is heat production *i.e.* wire gets hot due to conversion of electric energy into heat energy. The heat produced and applied current passing through the wire or conductor has some relational factors. Various factors of these conversions were correlated and studied by Joule in 1877. He established a law called Joule's Law which says:

1. The heat produced is directly proportional to the square of the current strength

$$H \quad A^2.$$

2. The heat produced in different conductors is directly proportional to the electrical resistance of the conductor

$$H \quad R.$$

3. The amount of the heat produced is directly proportional to the time for which electrical current passes through the conductor

$$H \quad T.$$

PHYSICAL EFFECTS OF HEAT

When heat is added to matter, a number of physical phenomena result from increasing the kinetic energy of its microstructure. These may be summarised as follows:

1. **Rise in temperature:** The average kinetic energy of constituent molecules increases.
2. **Expansion of the material:** Increased kinetic energy produces a greater vibration of molecules, which move further apart and expand the material. Gases will expand more than liquids and liquids more than solids. If, for example, a gas is enclosed so that expansion cannot take place, a rise in gas pressure will occur instead.
3. **Change in physical state:** Changing a substance from one physical state (phase) to another requires a specific amount of heat energy (*i.e.* latent heat).
4. **Acceleration of chemical reactions:** Van't Hoff's law states that any chemical reaction, capable of being accelerated, is accelerated by a rise in temperature.
5. **Production of an electrical potential difference:** If the junction of two dissimilar metals (*e.g.* copper and antimony) is heated, electromotive force or electrical potential difference is produced between their free ends. Conversely, an e.m.f. applied to the junction of two metals can cause a rise in temperature at the junction.
6. **Production of electromagnetic waves:** When energy is added to an atom (by heating), an electron may move out into a higher-energy electron shell. When the electron returns to its normal level, energy is released as a pulse of electromagnetic energy.
7. **Thermionic emission:** Heating of some materials (like tungsten) may cause such molecular agitation that some electrons leave their atoms and may break free of the metal. This leaves a positive charge which tends to attract electrons back. A point is reached where the rate of loss of electrons equals the rate of return, and a cloud of electrons then exists as a space charge around the metal. This process is known as thermionic emission.
8. **Reduction in viscosity of fluids:** Dynamic viscosity is the property of a fluid (liquid or gas) of offering internal friction to the non-accelerated displacement of two adjacent layers. The molecules in a viscous fluid are quite strongly attracted to one another. Heating increases the kinetic movement of these molecules, reducing their cohesive mutual attraction and making the fluid less viscous.

Heating modalities & their primary mode of heat transfer

Conduction	Hot packs
	Paraffin wax baths
Convection	Hydrotherapy
	Fluidotherapy
	Moist air
'Conversion'	Radiant heat
	Laser
	Short-wave diathermy
	Ultrasound
	Microwave

SECTION II

- Laser
- Ultraviolet Rays
- Infrared Radiation

CHAPTER

3

LASER

- Introduction
- Characteristics of Laser Emission
- Types of Laser
- How does Laser Therapy work in the body (At Cellular Level)
- Terms used in Laser Therapy
- Mechanism
- Dosages
- Pain Control
- Modes
- Parameter Settings
- Effects of Laser Radiation on Tissues
- Physical Effects of Laser
- Contra-Indications
- Precautions
- Therapeutic Uses of Laser
- Main Indications for Laser Therapy in Physiotherapeutic Practice
- Main Indications for Therapeutic Laser in Odontology
- Frequency of Treatment
- Principles of Application
- Essentials for Treatment
- Practice of Laser Treatment
- Laser Treatment Case Studies

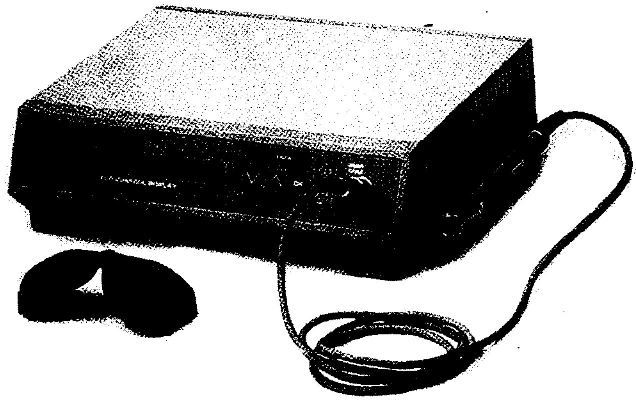

Fig. 3.1(a) *Clinical laser used by author (Courtesy E.M.S., U.K. Bio Med India)*

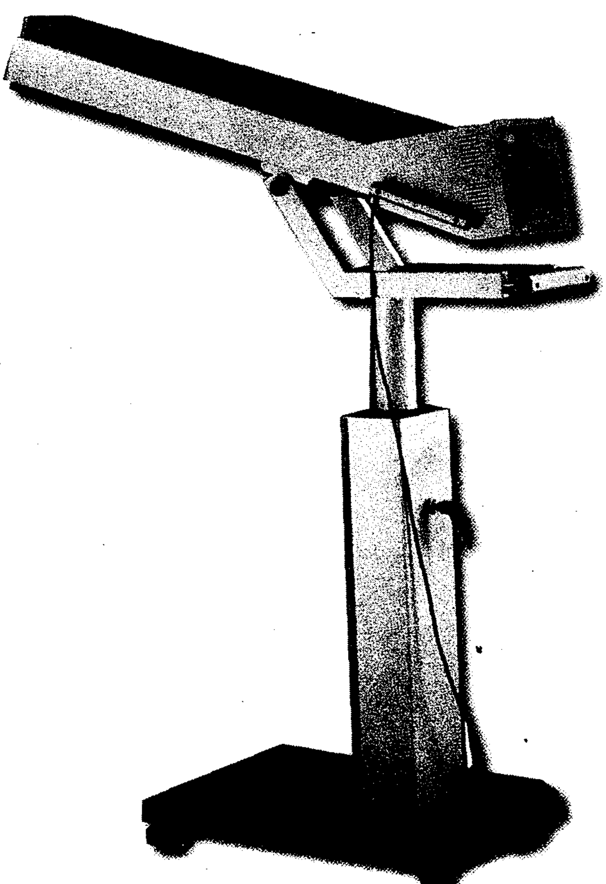

Fig. 3.1(b) *Clinical laser used by author (Courtesy E.M.S., U.K. Bio Med India)*

INTRODUCTION

LASER is an acronym for light amplification by stimulated emission of radiation. Radiation is the process by which energy is propagated through space. The common characteristics of all forms of radiant energy are:

- They are produced by applying electrical or other forces to various forms of matter
- They all may be transmitted without the support of a sensible medium.
- Their velocity of travel is equal in a vacuum but may vary within different media.

The direction of propagation is normally a straight line. They undergo reflection, deflection and absorption by the media through which they travel. They are designated collectively as electromagnetic radiations. A laser is generally used as a source or generator of radiation. The low power laser is used in physical rehabilitation for pain control and soft tissue injury.

Low Intensity Laser Therapy (LILT) is the application of light to injuries and lesions to stimulate healing in tissues. It is believed to resolve inflammation, reduce pain, increase speed, quality and strength of tissue repair and resolve infection.

Bio-stimulating, regenerating and pain killing in its effect, laser treatment opens up an extraordinarily large indication spectrum, and it has uncomplicated, completely painless, fascinating and pleasant effect upon patients and is used in the following:

- **Orthopaedics, traumatology, rheumatology** (treatment of inflammatory or degenerative rheumatic disease, post-traumatic conditions, bone pathologies, oedemas, haematomas).
- **Neurology** (neuralgias, migraines, neuritis).
- **Dermatology** (treatment of chronic ulcers, burns, herpes infections, rhagades).
- **Surgery** (post-operative complications, regeneration of ruptured or severed nerves and tissues).
- **Odontology** (complex treatment stomatitis, aphthae, herpes infections, gingivitis, treatment of the pulp, alveolitis, pathology of the temporomandibular joint).
- **ENT** (treatment of acute and chronic otitis, sinusitis).
- **Gynaecology** (inflammatory diseases of the pelvic region, post-operative complications, conditions after abortions).

CHARACTERISTICS OF LASER EMISSION

There are three characteristics of laser emission that make it clearly distinct from ordinary light.

Monochromaticity

Ordinary light consists of many wavelengths, commonly known as VIBGYOR, *i.e.*, Violet, Indigo, Blue, Green, Yellow, Orange and Red, which merge to form 'white light'. But laser consists of one wavelength only. In a therapeutic unit, the band is 6328 Å units. The laser of 6328 Å units is of bright red color.

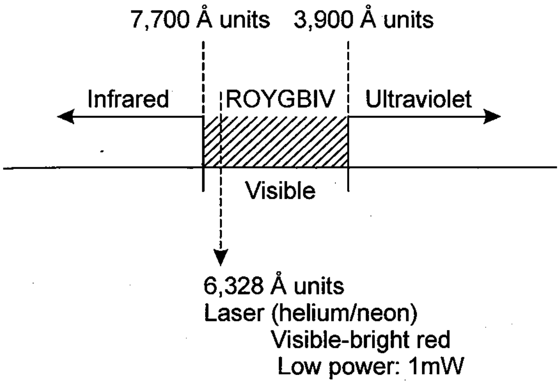

Fig. 3.2 *Monochromaticity: Lasers contain only one wavelength ROYGBIV – red, orange, yellow, green, blue, indigo, violet*

Coherence

Because the wavelengths of ordinary light are so variable and do not "match" in waveforms, frequencies, or shapes, there is much scrambling of waveforms, cancellations and reinforcement of individual waves, and interference in the production of energy in general. This factor minimizes the power of ordinary light as an energy source. The identical wavelengths and forms, that comprise laser light cause it to be greatly amplified. Since the "waves and troughs" of the radiation are reinforced because they are parallel and in line with each other, they are termed **coherent.**

Collimation

As a consequence of spatial coherence, lasers remain in a parallel beam, because the radiations do not diverge

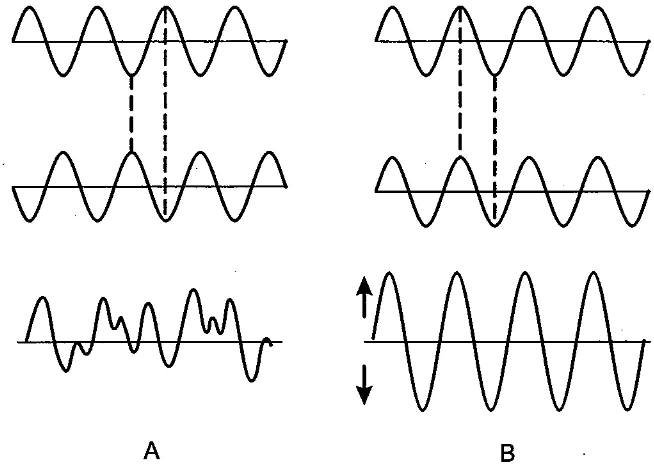

Fig. 3.3 *(A) Cancellation: Waves not in phase do not produce increased power or concentrated frequency responses. (B) Coherence: Laser waves are in phase, increasing power by reinforcement*

the energy even if propagated over very long distance. This property makes it invaluable for measurement and aiming purpose.

This therapy got a boost by the development in 1979 of semiconductor diode laser with production of gallium-arsenide laser diode by Yariv and colleagues at California Institute of Technology. This is the laser used mainly in LILT.

Examples of laser

Laser medium	Wavelength (nm)	Radiation
1. Carbon dioxide (CO_2)	10600	Infrared
2. Gallium Arsenide diode	904	Infrared
3. Gallium Aluminium	860	Infrared
Arsenide Diodes	904	
	650	Red light
	750	Red light
continuous wave	780	Infrared
	810	Infrared
	820	Infrared
	850	Infrared
	1300	Infrared
4. Helium-neon	632.8	Red light
5. Ruby	694.3	Red light
6. Copper vapour	510	Blue-green
	578	Yellow
7. Excimer	351 (variable)	Ultraviolet

TYPES OF LASERS

The application of the foregoing principles will be illustrated by an initial description of the ruby laser.

The Ruby Laser

This consists of a small synthetic ruby rod made of aluminium oxide. A helical xenon flash tube, wound around it, gives an intense flash of white light. Both ends of the rod are made flat and silvered, one end being totally reflecting and the other partially transparent so that some radiation can be emitted.

This brief light pulse (0.5 ms) excites the ruby molecules and raises many electrons to higher levels which they occupy for very short average time before falling to the metastable level where they remain for much longer average time. Thus, for a time, there are more electrons in the metastable level than the ground level and so population inversion has occurred. When the transition from metastable to ground state does occur, a photon with a wavelength of 694.3 nm is emitted. This photon would have exactly the right energy to raise a ground state electron to the metastable level and be reabsorbed, but as there are relatively few ground-state electrons, the photon is much more likely to interact with other metastable electrons, causing them to return to the ground state and so emitting an identical photon. The process rapidly accelerates as more and more photons are released, *i.e.*, stimulated emission of radiation occurs. The photons, having a wavelength of 694.3 nm, which is of course red light, are reflected up and down the short ruby rod, rapidly increasing the effect. Thus all the energy stored in the ruby molecules is released in a very brief time as a pulse of red light of identical photons and so of a single wavelength of coherent radiation. This emerges from the rod at the partially transparent end.

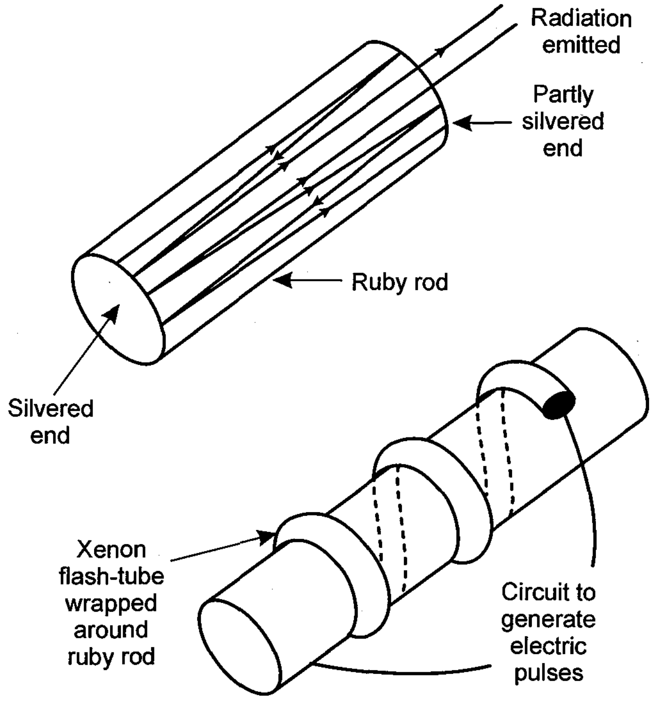

Fig. 3.4

Helium-neon Lasers

Helium-neon lasers consist of a long tube containing these natural gases at low pressure surrounded by a flashgun tube, as described for the ruby laser. Excitation of these atoms leads to different energy levels between them and the transfer of energy, giving off a photon of wavelength equivalent to the energy gap. The photons are reflected to and fro along the tube, giving rise to further photon emission and emerging as a narrow beam (of about 1 mm diameter) from the partially transparent end. Helium-neon lasers give radiation in the red visible region at 632.8 nm. See Figure 3.5 for comparison of helium-neon laser output with the infrared lamp. The output is usually applied to the tissues via an optical guide—a fibreoptic cable—the end of which is held in contact with the tissues. There are, of course, some energy losses in the glass fibre of the cable and the laser beam may diverge to some extent as it emerges at the end of the optical fibre.

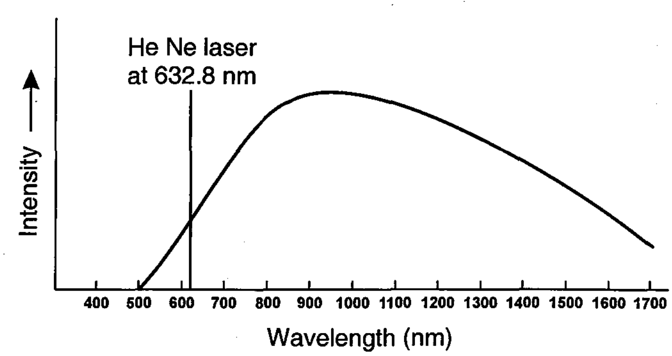

Fig. 3.5 *Comparison of laser output with infrared lamp (Infrared and visible radiations were emitted from typical luminous infrared lamp giving radiations at a range of wavelengths – peak emission around 1000 nm.)*

Diode Lasers

These are specialized light-emitting diodes, based on semiconductor p-n junctions. They are of various kinds, involving gallium aluminium arsenide. In these, electrons can flow more readily in one direction than in the other. The electrons are excited by the application of a suitable electrical potential and their occupation of 'holes' in the crystal lattice arrangement may lead to the emission of a photon which may then stimulate identical photons in the manner already described. The photons are reflected to and fro and emitted as a laser beam from one partially transparent end. These are conveniently small, relatively cheap and robust devices. By varying the ratio of gallium to aluminium, such devices can be built to emit specific wavelengths.

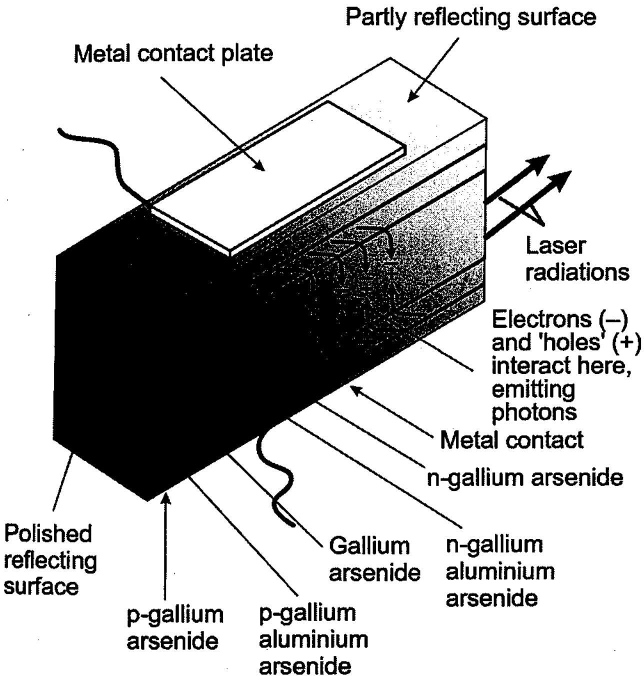

Fig. 3.6 *The structure and principles of a semiconductor laser diode*

Semiconductor laser diodes can give either a continuous or a pulsed output.

Continuous wave diode lasers are usually of relatively low power. Alternatively, they can be pulsed electronically. On some machines the pulse frequency can be varied.

HOW DOES LASER THERAPY WORK IN THE BODY (AT CELLULAR LEVEL)

Laser
⇓
Photons
⇓
Visible red light absorbed within mitochondria
Infrared light absorbed at the cell membrane
⇓
Single oxygen production
(Rate limiting mechanism operate to prevent excess single oxygen formation)
⇓
Formation of proton gradients across cell membrane and across membrane of mitochondria
⇓
Physiological changes
- Changes in cell membrane permeability
- Increased ATP levels—DNA production
- Influences cell metabolism

⇓
Activation of regulatory process
⇓
Patient's well being
(after laser therapy)

Result of laser therapy has shown:

Increase		
Macrophages	⇒	Tissue repair
Fibroblasts	⇒	Tissue repair
Endotheliocytes	⇒	Tissue repair
Keratinocytes	⇒	Tissue repair
Mast cells	⇒	Tissue repair and pain reduction
Angiogenesis	⇒	Tissue repair
Collagen synthesis	⇒	Tissue repair
Myofibroblast activity	⇒	Tissue repair
Serotonin	⇒	Resolve inflammation and pain reduction
Nerve Conduction		
Latency	⇒	Pain reduction (via nerve conduction)
Decrease		
Bradykinin	⇒	Pain relief
Activity in C fibres	⇒	Pain relief (via nerve conduction)

TERMS USED IN LASER THERAPY

1. Wavelength Measured in nanometer (nm).
Higher the wavelength, the deeper it penetrates.

670 nm	Open wounds, ulcers, bedsores
780 nm	Superficial muscular or ligament lesions
820 nm	Muscular or ligament lesions
850 nm	Deeper muscular or ligament lesions

2. Power Denoted by P
Measured in watts (W)

3. Treatment time Denoted by T
Measured in seconds (s)

4. Energy Denoted by E
Measured in joules (J)
This is calculated by multiplying treatment time and power

Energy expressed in joules and the amount of energy on a surface is expressed in joules per square metre (J/m^2).

The rate at which laser energy is produced is measured in joules per second, hence in watts (1 W = 1 J/s). Most laser used in physiotherapy have output powers of milliwatts.

If the laser is pulsed, the temporal average power must be distinguished from the temporal peak power. Temporal peak power is that of each pulse but the average or mean power depends on the pulse length and the pulse frequency. The very short individual pulses may be a few watts, but the mean power will be a few milliwatts. To express the average power per unit area, the term 'power density' is sometimes used. This would be given in watts per square centimetre or per square metre.

The divergence of the laser beam may also be described in terms of an angle, expressed in degrees.

5. Spot size Measured in centimetres squared (cm^2).
This is the area being irradiated by the laser beam.

6. Energy density Denoted by DE
Measured in joules per square cm (J/cm^2).
This is calculated by (Power × Treatment time)/spot size.

The treatment dose in usually given in J/cm^2 (or mJ/cm^2) and called energy density or sometimes radiant exposure.

1. The mean power output in milliwatts is usual fixed (it can be varied on some machines by alterir the pulsing regimen).
2. When divided by the (fixed) area of the beaı it gives the power density or irradiance i mW/cm^2.
3. When multiplied by the number of seconds fo which the treatment is applied, it gives the numbe of Joules/cm^2 or energy density.

Example

1. Mean power = 10 mW
   Beam area = 0.125 cm^2
2. Therefore, power density = $\frac{10}{0.125}$ = 80 mW/cm^2
3. If the treatment is applied for 50 s,
   the energy density = 80 mW/cm^2 × 50 s
   = 4000 mJ/cm^2
   = 4 J/cm^2.

There is a wide variation in the recommendations for optimal energy for different conditions. The usual ranges are from I to 10 J/cm^2 but doses as low as 0.5 J/cm^2 and upto 32 J/cm^2 have been suggested.

MECHANISM

To obtain the laser, a tube filled with a gaseous mixture of helium and neon is stimulated electrically to emission levels. Within the highly reflective polished walls of the tube, the molecules reverberate

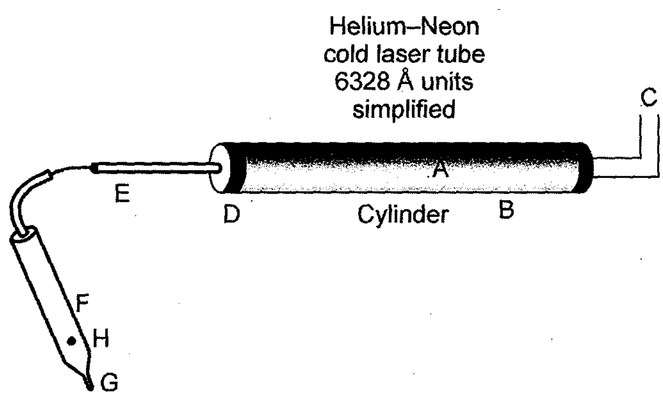

Fig. 3.7 *Laser mechanics: When the He-Ne mixture (A) within the silvered tube (B) reaches maximum excitation levels from external electrical stimulation (C), the laser radiation emerges at the semi-silvered end of the tube (D) passing along an optic fibre (E) into the probe housing (F) to the probe tip (G) where a trigger (H) releases the beam for application.*

the carom off the walls in a highly agitated state, building energy as they do so. When a critical level is reached, the flow of the energy literally 'bursts' through the semi-silvered (similar to a one way mirror) front end of the tube and is channelled along an optic fibre to the beam applicator or probe, for clinical applications (Fig. 3.7).

DOSAGES

Actual dosage with the cold laser depends on the power factor, duration of radiation, and tissue resonance. Focusing the beam properly will bring into play the inverse square and cosine laws, so that distance-to-target and angulation of beam-to-target will affect the dosage administered.

PAIN CONTROL

At acupuncture trigger points, nerve roots and pain sites, a dosage of 15 to 30 seconds for each point is recommended. Unlike for the open wounds, the probe tip is held in contact with the skin at these points during the procedure.

MODES

Current laser equipment offers the clinician two modes —continuous and pulsed beams.

- **Continuous Beam:** The continuous mode is recommended for acute pain and fresh wounds.
- **Pulsed Beam:** The pulsed mode has been found more effective with chronic conditions. Pulsed models vary from 1 to 80 pulses per second, depending on the manufacturer. One suggested technique for chronic pain or long-standing open lesions would be in the range of 4 to 10 pulses per second.

PARAMETER SETTINGS

Current laser units offer manual timing or automatically timed treatment. For longer exposures such as with large open wounds, use of the automatic timer is suggested. For pain control, either manual or automatic timings must be utilized. Power levels are presented by the manufacturer and the FDA at 1 mW. The power is reduced to half (0.5 mW) when the pulsed mode is in effect. Later models will offer high power availability in the 5 mW range. Infrared lasers in the 904.0 nm bands are also available.

EFFECTS OF LASER RADIATION ON THE TISSUES

The interaction of lasers with the tissues is essentially the same as any other radiation in that it can be reflected from the surface or penetrate the tissues in proportions that depend on the angle of incidence, the wavelength of the radiation and the nature of the tissues. When the radiation is applied at right angles to and in contact with the surface, reflection is minimum, so penetration is maximized.

Once any radiation enters the tissues, it can be absorbed or transmitted further in proportions, which depends on the wavelength and nature of the tissues. The penetration depth (*i.e.* the depth to which some 37% of radiations penetrate) of red visible and near infrared radiation is considered to be a few millimetres.

Radiation entering the tissues may be reflected and refracted at various interfaces beneath the skin, which will lead to scattering and loss of penetration. This occurs much more easily when the radiations are not applied at a right angle, when refraction may occur. In fact, the effects of differing angles due to beam shape and divergence, as well as backscattering, are very complex. This can lead to local intensities several times higher than the applied beam at a point just below the surface of the skin.

Different wavelengths have different penetration depths, so it is theoretically possible to adjust the relative amounts of energy absorbed at different depths by selecting an appropriate wavelength, but with considerable uncertainty, as noted above. Thus radiations, which penetrate furthest, *i.e.* those in the near infrared, such as 904 nm, are chosen to treat subcutaneous structures, whereas skin lesions or superficial wound surfaces are appropriately treated by one of the red lasers which will be absorbed largely in the skin.

Since the beam of radiations is very narrow—often about 2 or 3 mm—treatment can only be applied to a small zone of tissue at a time. Although the radiations diverge somewhat in the tissues with distance and considerable scattering, the area treated must still be fairly small. Treatment, therefore, involves a series of separate applications at discrete points, each for fairly short periods of a few seconds to a few minutes. The cluster probe, already mentioned, treats larger areas if required. The area between the diodes is treated because of the scattering.

As noted already, the laser may be applied as a continuous output or pulsed at different frequencies. The pulsing frequency can be varied and is considered by some to be an important parameter of treatment while others point out that there is no conclusive evidence to support this opinion. The latter take the view that the object of effective therapy is to deliver as many photons as possible in the vicinity of the target; hence they use the maximum available pulse frequencies. The pulse length can vary although it may be fixed for a particular machine; it is often of the order of 100–200 ns. Although each pulse may have a few watts power, the average power is very low at less than 1 mW because of the extremely short pulses. Continuous-output low-power laser sources usually emit around 1 mW. Therefore, in all cases there is insufficient energy introduced into the tissues to cause detectable heating.

It is thought that red light is absorbed by cytochromes in the mitochondria of the cell. All cells have these cytochromes, so all may be stimulated by red light.

PHYSICAL EFFECTS OF LASER

Heating

A mild but reversible heat is produced with the cold laser. The tissues revert back to the pre-lasing temperatures immediately following radiation. Although the thermodynamics involved do not produce therapeutic level, cell-wall permeability has been shown to be a favourable result of heat and may play a role in the reaction of the laser on the cell wall.

Dehydration

Loss of water following radiation is another reversible process. Such loss may be attributed to the minor heating and/or the transfer of fluids of distant sites. Apparently, it does not play a major role in the laser's effectiveness.

Coagulation of Proteins, Thermolysis and Evaporation

Coagulation of proteins, thermolysis, and evaporation are irreversible and should not occur with the dosages and techniques used by physical therapists.

CONTRA-INDICATIONS

- Do not radiate the eye directly.
- Whether pregnancy is a contra-indication to use of the laser has not yet been determined, but the laser is suspected due to its mobilizing effect on steroids in the human system.
- Do not use laser with patients who are naturally photosensitive or who are photosensitized by the medications.

PRECAUTIONS

Poor results may ensue in those patients:

- Extreme age
- Under heavy medication
- With thick eschar
- With considerable scar tissue
- With extremely dry skin
- With active infection.

A touch of moisture on the tip of the probe or the target skin may enhance the electrical contact needed for efficient point searching. Perspiration or other skin moisture will naturally give false readout; adjustments must be made in such circumstances. Dry the patient's skin prior to LASER THERAPY.

THERAPEUTIC USES OF LASER

While a variety of professional groups currently employ low-intensity laser, such devices remain most popular within physiotherapy, with over 40% of chartered physiotherapists canvassed for the purpose of a recent survey, indicating clinical experience of therapeutic lasers. In terms of comparative efficacy, respondents in this survey rated low-intensity laser highly against other more established electro-therapeutic modalities such as ultrasound, interferential therapy and pulsed electromagnetic energy for a number of treatment effects including the relief of pain and reduction of oedema. Indeed, laser has achieved premier ranking for the promotion of wound healing and pain relief. Therefore, within a relatively short period of time, laser has become an accepted part of routine physiotherapy management for a variety of conditions.

MAIN INDICATIONS FOR LASER THERAPY IN PHYSIOTHERAPEUTIC PRACTICE

1. **Wound healing.** The photo-biostimulation of wound healing remains the cardinal indication for therapeutic laser in physiotherapy. In this, laser therapy has come to be recognized by many therapists as superior to a range of other alternative electrotherapeutic modalities including ultrasound. For this reason, laser therapy is often the physiotherapeutic modality of choice in a variety of conditions including trophic, varicose, diabetic and decubitus ulcers (pressure sores), particularly where these have become chronic and/or are unresponsive to other treatment approaches. In addition, cases of necrosis, burns and post-operative would also seem to respond favourably to low-intensity laser treatment. In case of scarring, it has been reported by some therapists that laser therapy may not only accelerate remodelling of the scar tissue but also give a more cosmetically acceptable result.
2. **In soft tissue injuries,** including traumatic, inflammatory and overuse type injuries. While variable results have been reported for the laser treatment of bursitis and muscle spasm, other common soft tissue injuries such as muscle tears, haematomas and tendinopathies would seem to respond particularly well to therapeutic laser, which has led to its wide use in sport medicine. To the athlete, whether recreational or competitive, such injuries represent an unavoidable lay off from training with consequent loss of form. For such individuals, there is the prospect of shorter recovery time as a result of low-level laser treatment when attending sports injury clinics. Consequently, an increasing number of sports physiotherapists regard low-intensity laser as an essential part of their treatment repertoire.
3. **For pain relief,** including both acute pain (*e.g.*, post-operative pain) and more chronic pain syndromes such as herpes zoster/post-herpetic neuralgia, laser application is common but for the lack of an obvious mechanism of action and the conficting findings of clinically based research. However, in the experience of clinicians, therapeutic laser is at least comparable, if not actually superior, to a number of other electrotherapeutic agents including interferential therapy and short wave diathermy for analgesic effect.
4. **In arthritic conditions** of various aetiologies, particularly where these have affected the small joints of the hands and/or feet. While variable results have been reported from clinical research in this area, low intensity laser would still appear to offer substantial therapeutic benefits in the management of painful arthropathies.

INDICATIONS FOR THERAPEUTIC LASER IN ODONTOLOGY

1. **Reduction of oedema and hyperaemia:** Principally used in the pulpae during treatment of dental caries. For this, it is usually recommended that the dentine and gingiva of the tooth are irradiated just before filling to reduce inflammation and thus minimize subsequent pain. In cases of gingivitis, irradiation of the affected gingiva, using low-intensity laser, can also help reduce bleeding and pain, thus improving patient comfort and allowing for more thorough depuration.
2. **Promotion of wound healing:** Laser photo-biostimulation has been successfully employed by dentists in the treatment of such conditions as necrosis of the pulpae, where low-intensity laser is used as an adjunctive treatment after the root canals have been effectively cleared of necrotic tissue and treated with an antibacterial agent.
3. **Relief of pain of various aetiologies including dentine hyperaesthesia, acute pulpitis and pre-operative and post-operative pain:** It has even been reported by some authors that laser acupuncture can be successfully used for the induction of pre-operative anaesthesia prior to minor oral surgery. While most commonly applied directly to the painful area, therapeutic laser may also be used to irradiate myofascial trigger points as an effective remedy for orofacial pains.
4. **Treatment of herpes labialis (cold sores) and herpetic gingival stomatitis:** An increasing number of practitioners have come to regard low intensity laser as the treatment of choice for infection of the lips and mucous membranes by the herpes simplex virus.

FREQUENCY OF THE TREATMENT

- Administer treatments daily, if necessary, as indicated by the severity of the pain.
- The patient's reaction and the syndrome being treated should be used as guidelines. As soon as an improvement becomes apparent, therapy should be discontinued.

- Never apply treatment for too long. What is important is that the cells become energetically charged. If therapy is undertaken at high power intensity for too long, blockages form quickly which then prevent the acceleration of the healing process.
- Please pay attention to the results of scientific research in this field which, of course, must also be integrated into the therapy concept. (cf. Joule/cm^2)

Start with shorter sessions and increase in accordance with the patient's reaction.

PRINCIPLES OF APPLICATION

Most low or medium-power laser sources are applied to the skin by a hand-held applicator about the size of a large marker pen. The laser diode is close to the tip, which is a small lens. Direct application to the skin ensures maximum transfer of laser energy and light pressure; squeezing blood from superficial vessels can increase the penetration further.

In other types of laser, the applicator may be held in a rigid but mobile stand and applied about 30 cm away from the patient. This latter type may provide several sources of laser output to cover a relatively large area.

Some versions use laser diodes, called cluster diodes, which all emit at different wavelengths to take advantage of any different effects that may ensue from the use of different wavelengths.

Preparation of the patient: The nature of the treatment and the need to wear goggles or spectacles are explained to the patient.

Preparation of the apparatus: The laser apparatus is conveniently positioned. Protective goggles, designed for the particular wavelength being used, are worn to obviate any risk of accidental application of the laser beam into the eye.

Preparation of the part: The surface of the skin to be treated is cleaned with an alcohol wipe in order to remove any material on the surface that might absorb or scatter the radiation. The part is supported in such a way that any pressure of the laser applicator does not cause movement or discomfort.

Application: A key usually activates the machine and ensures that the unauthorized people do not switch the laser on. The laser applicator is applied to the surface before switching on. There is sometimes a switch on the applicator itself and usually an indicator light to show that the infrared laser - which, of course, invisible - is on. It is important to maintain the laser applicator in contact with the tissues so that the beam is applied at right angles in order to achieve maximal penetration.

If contact is not desired, for example because of an infected wound, the applicator may be held just off the surface or covered with transparent non-reflective film. In all other circumstances, firm contact should be maintained throughout treatment but should not provoke pain where tenderness is present. The position is maintained for the necessary time. If a larger area is to be treated, the applicator is removed and repositioned on a new site, turning off the output during the transfer.

Termination: The device is switched off before removing the applicator from skin contact. The details of dosage and any patient response, such as immediate increase or decrease of pain, are noted and recorded, plus the parameters of dosage.

ESSENTIALS FOR TREATMENT

The following ten treatment tips for laser therapy applications, if systematically applied, will enhance the effectiveness of treatment:

1. **'In contact' technique should be used whenever possible:** Wherever this is feasible, the laser treatment probe should be (perpendicularly) applied directly to the target tissue, using a firm pressure. This should distend the skin overlying the target area, but not cause pain to the patient. This optimises laser penetration (through perpendicular application, distension of the skin and 'approximation' of laser treatment head and target tissue) and blanching of the area due to the pressure applied through the head. The latter reduces the number of red blood cells (photoacceptors) in the local area and thus intensifies the effects of treatment. In addition, the mechanical stimulation at trigger points or acupuncture points enhances the laser-mediated treatment effects.
2. **Treat the site of pain or injury in a comprehensive manner:** The primary site of treatment should always be the site of pain or injury (cases of referred pain excepted). Treatment should be applied comprehensively across the whole lesion or area of injury, taking adequate time to ensure that the recommended or desired dosage is applied at each site of irradiation. Treatment effects are often limited where the therapist 'splits' the recommended dosage across several treatment points to save time.
3. **Use the most appropriate treatment probe for the site and condition:** The cluster unit is useful for irradiating larger areas of tissue and for treating

ulcers. Single diode probes are more effective for irradiating significant points (*e.g.* trigger or acupuncture points) or in cases where the contours of the limb or body part might limit effective use of contact technique with a cluster (*e.g.* small joints in hands).

4. **Use 'gridding' to standardise single diode application over larger areas:** Where circumstances may require the use of a single probe unit (rather than a cluster) over an area larger than 1-2 cm^2, laser application may be standardised by use of 'gridding'. For this, the target area is visualised as a chequerboard of squares of 1 x 1 cm to which measured dosages are delivered to ensure coverage of the entire area.
5. **Where thermal modalities are used, consider the sequence of application:** This is particularly important for thermal modalities, which will alter local blood flow at the treatment site. Modalities, which cause beating of the tissue and thus increases in blood flow, should only be applied after laser treatment, otherwise there will be an increase in the proportion of incident light energy absorbed by red cells (*i.e.* rather than the target tissue).
6. **Use ice/cryotherapy to increase the effective depth of penetration:** Application of ice/cryotherapy packs before laser treatment will reduce the red cell flux in the local area and thus the proportion of incident light absorbed by these cells. This results in a more localised, intensive treatment effect, particularly in highly vascular tissue (*e.g.* muscle) and more effective treatment of deeper seated lesions.
7. **Treatment should be systematically and comprehensively applied:** Apart from direct application to the lesion, injury or site of pain, clinical effectiveness may be enhanced by applying the laser to a variety of other (secondary) sites during treatment sessions. These may include relevant nerve trunks and associated nerve root trunks in the same limb, as well as acupuncture points and/or trigger points.
8. **Progress dosage over the course of treatment:** Dosages can be increased over a course of several treatments to maintain, or in some cases to enhance, treatment response. Particularly where the condition is unresponsive to laser treatment, or effects are marginal, treatment dosages should be increased between subsequent treatments. In most cases, a 50-100% increase in dosage over 2-4 treatments will enhance laser-mediated effects.
9. **Vary pulsing to enhance tissue stimulation:** The output of your unit may be pulsed. Use lower pulse repetition rates (50Hz or less) for more acute conditions (or where patient sensitivity may be suspect), and higher rates (up to 25kHz) for chronic conditions. Where results are marginal or effects have apparently reached a plateau, vary the pulse repetition rate during the treatment. Deliver half the dosage at low pulse rate and the other half at high.
10. **Treat early and often for best results:** Unlike other electrophysical modalities, laser therapy is athermal and can, therefore, be used in the very early stages after injury or trauma. Keep dosages relatively low in the first instance and apply daily treatments, if possible.

PRACTICE OF LASER TREATMENT

Upper Limb: Recommended laser treatment for the upper limb are summarized in Fig. 3.8.

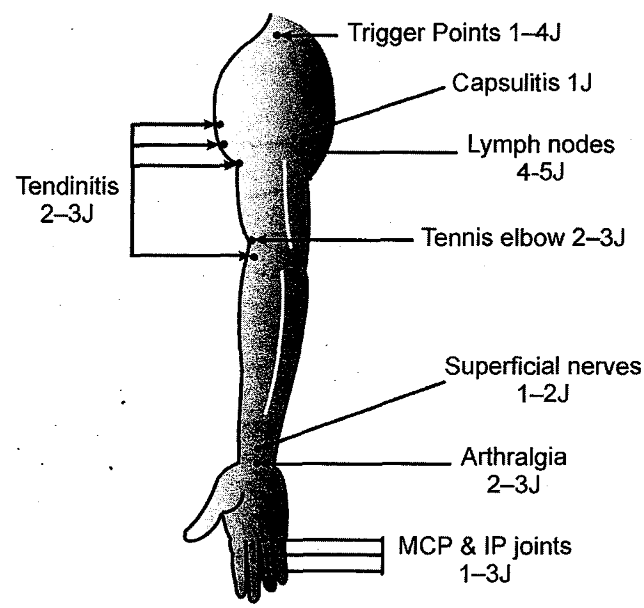

Fig. 3.8 *Summary of recommended treatment for upper limb (figures in Joules are per point irradiated.)*

Capsulitis of gleno-humeral joint: Along with manipulative and exercise therapy, laser therapy should be applied at frequent intervals in the early stages of rehabilitation to a grid of points in the axilla at dosages of not less than 1 J/point. While laser therapy can offer spectacular results in terms of reduction of pain and stiffness, it should be understood that this does not avoid the need for active exercise of the joint in the rehabilitation of such patients.

Supraspinatus/infraspinatus tendinitis: Where these are found to be tender on palpation and resisted exercise causes pain around the insertion of these tendons, therapeutic laser on clusters of points around the tender/painful areas at initial dosages of no less than 2–J/point or 16–24 J/cm^2 can yield significant therapeutic benefits.

Lateral epicondylalgia (tennis elbow): Where laser therapy is to be used for this condition, best results are achieved by concentrating the laser treatment at relatively high dosages to the most sensitive/tender areas upon palpation of the common extensor origin/lateral epicondyle, rather than to the whole area at a comparatively lower dosage. Typical initial dosages should be in the range of 2-3 J/point or 16-24 J/cm^2.

Lower limb: Recommended laser treatment for the lower limb are summarized in Fig. 3.9.

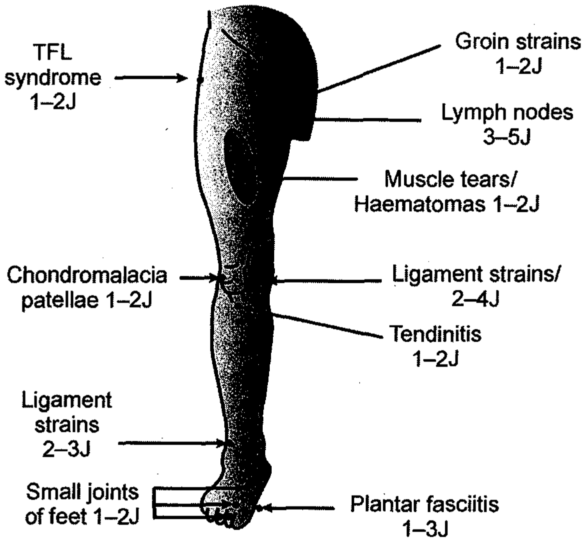

Fig. 3.9 *Summary of recommended treatment for lower limb (figures in joules are per point irradiated.)*

Groin strain/pains: Laser therapy represents an ideal choice for the treatment of lesions in this area, due to the athermic nature of the modality as well as the ability to accurately target treatment on the desired site. For such treatments, a single diode probe is most practical, and should be applied with a firm but comfortable pressure. For the treatment of lesion in the area, irradiation should begin with energy densities of at least 1 J/point or 8 J/cm^2 and progressed as required.

Tensor fascia lata syndrome: Laser therapy may be applied to the most painful areas of the muscle on palpation. A medium pressure is usually sufficient for such treatments and energy densities of at least 1-2 J/point or 8-16 J/cm^2.

Chondromalacia patellae: In such cases, laser therapy can offer results which are quite superior to those achieved with other modalities. However, if laser therapy is to be used successfully, the therapist must ensure that care is taken to move the patella away from the joint (either laterally or medially) and apply the laser probe to the retropatellar surface comprehensively in this manner using dosages of at least 1 J/point or 8 J/cm^2. Patients will usually report significant improvements by the third treatment session, even in long-standing cases of the complaint.

LASER TREATMENT CASE STUDIES

Chronic Ulceration

General Notes: Assess wound area and condition of ulcer, check for presence of infection.

Laser treatment: Stage One: For all open wounds and ulcers, treatment of the wound margin is recommended as a first stage treatment. For this, the preferred treatment head is a single diode probe, which is applied to points on the skin surrounding the wound using 'in contact' technique. Points should be approximately 1 cm from the wound edge, and around 2 cm apart. Initial dosage should be 2J per point (5KHz). The total number of points used will vary depending on wound area and shape.

Laser treatment: Stage Two: The second stage of treatment consists of irradiation of the wound bed, usually employing a cluster treatment unit. Application is this case is non-contact, or light 'contact' where a suitablé barrier is present to prevent soiling of the treatment unit or cross infection. For practical purposes, dosage should be initiated at 4J per square centimetre of wound area. The cluster should be applied repeatedly over the wound to ensure that the whole wound bed is adequately irradiated.

While non-contact technique is used in this case, care should be taken to ensure that the distance between the wound bed and the cluster unit is minimal (*i.e.* not more than 0.5 cm).

Progression of Treatment: Dosages can be increased significantly where results are marginal. For irradiation of wound margin, dosage can be increased up to 10J per point over three-four treatment sessions. For treatment of the wound bed, dosage can safely be increased over a similar number of treatments to 12J cm^2. While increasing dosages beyond the levels indicated is possible, the treatment times necessary may make laser therapy an inefficient management option.

Sprain of the Lateral Ligament of the Ankle

Laser Treatment: Stage One: Use of the single diode probe is recommended due to the contours of the area. Direct irradiation over the ligament and the local area should be performed using an initial dosage of 2J per point. Point should be no more than 0.5 cm apart.

Laser Treatment: Stage Two: Where the therapist is appropriately trained in point location, the local acupuncture points - and any trigger or AHSHI points - may also be irradiated using 1J per point with the single diode probe. Where swelling presents a particular problem, the margins of the relevant area should be treated using 1-2J per point. If this proves ineffective, irradiation over the course of the lymphatic vessels in the lower limb, using 2J per point at 2-3 cm intervals along the course of the vessel (distal to proximal), may also prove beneficial.

Progression of Treatment: Rehabilitation should be commenced as soon as possible, during which time laser irradiation may be increased up to 12J per point over the ligament and local area.

Headache

General Note: The protocol that follows is suggested as a 'generic' protocol, suitable for headache of most aetiologies, including cervicogenic headache. Care should be taken to avoid accidental intrabeam viewing where appropriate.

Laser Treatment: Stage One: Laser irradiation should be applied to a grid of points over the area of headache using a single diode probe to deliver 1-2J per point. Pressure should be firm but comfortable, and points no more than 1 cm apart.

Stage Two: Any identifiable trigger or tender points, in the head, face or neck, should be irradiated with a single probe using 1J per point; in addition, cervical nerve roots should be similarly treated where a cervicogenic component is present or suspected. In the latter case, a higher dosage of 2J may be necessary in some patients depending on muscle bulk etc. In addition, single point irradiation (1J per point) of a series of points (at 1 cm intervals) along the base of the occipital region of the skull is also recommended.

Progression of Treatment: In cases where laser therapy is effective, dosages indicated should be sufficient. In cases of marginal or variable results, treatment dosages may be increased incrementally upto 4-6J per point.

Tennis Elbow (Lateral Epicondylitis)

General Notes: Examination and assessment should confirm diagnosis, excluding cervical involvement.

Laser Treatment: Stage One: The affected area should first be treated with the cluster treatment head, using a dosage of 12J; depending on the size of the affected area (and the patient!). Several applications of the cluster unit may be necessary. Any particularly tender points over the affected area should then be treated using a single diode probe (2J per point) with a firm pressure.

Laser Treatment: Stage Two: Single diode probe irradiation (1J) of local acupuncture points may be performed, and treatment applied over the course of the local/proximal nerve trunks (radial nerve) and relevant ipsilateral cervical nerve roots (2J).

Progression of Treatment: Over the course of therapy, dosages for local treatment (Stage one) may be increased to 24J for the cluster treatment head and 12J per point for the single probe head.

Low Back Pain

General Notes: For simple low back pain, an active management approach, coupled with oral analgesics and (where available) manual therapy represent the preferred option. The protocol recommended here is designed for more painful cases, chronic recurrent back pain and, in simple back pain, to complement the modalities indicated.

Laser Treatment: The paravertebral muscles should be irradiated bilaterally using the cluster unit (20J), taking care to cover the complete area affected. Following this, a single probe unit should be applied (20J) to the relevant nerve roots (plus one proximal and one distal), using a firm pressure. For each nerve root treated, the probe should be applied to a 'cluster' of three-four points (covering an area of no more than 1 x 1 cm) over each root.

Where referred pain is also present, the course of the relevant nerve trunks should be irradiated using a single diode probe (2J) at 2 cm intervals (approximately).

Progression of Treatment: Treatment dosages can be increased over the course of treatment, or in cases where results are marginal after first treatment. 40J may be regarded as an upper limit for both the cluster and single probe unit (determined by efficiency rather than safety).

Herpes Zoster/Post Herpetic Neuralgia

General Notes: Treatment may be applied during the herpes zoster infection, or subsequently, should post herpetic neuralgia develop. In the former case, it has been reported that laser treatment may lessen the duration and severity of the episode, and also reduce the likelihood of subsequent development of post herpetic neuralgia.

Herpes Zoster: The cluster unit may be used in (close; <0.5 cm) non-contact mode over the affected area(s), using 4-8J per area of application. Affected nerve roots/proximal nerve trunks should also be treated using a single probe (1-2J) at 1-2 cm intervals. If possible, daily treatments should be performed in the first instance.

Post Herpetic Neuralgia: All affected area should be treated with a cluster unit (8J per area) applied in light contact and within the patient's tolerances. This should be followed with single point irradiation (2-4J) along the course of all affected nerves (distal-proximal at 1-2 cm intervals), and treatment of all relevant nerve roots.

Progression of Treatment: Treatment dosages should be increased over the course of treatment. In cases of Herpes Zoster, 12J may be regarded as an acceptable upper limit for both the cluster and single probe unit. For Post Herpetic Neuralgia, this figure may be increased to 24J.

Fig. 3.11 *Laser applied directly to skin over a painful hallux and associated points*

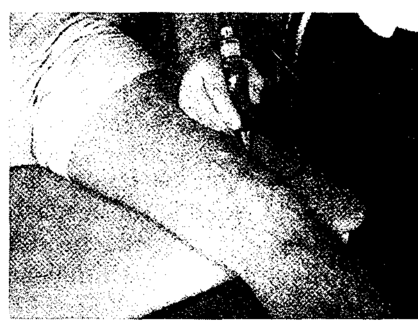

Fig. 3.12 *Laser applied to chondromalacia patellae*

Fig. 3.10 *Laser directed to a painful temporomandibular joint (TMJ)*

Fig. 3.13 *Laser applied directly to tennis elbow/lateral epicondylalgia*

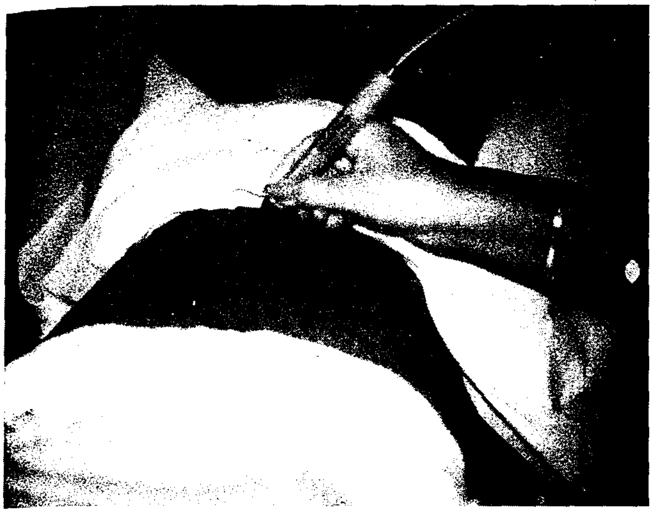

Fig. 3.14 *Laser applied to long term traumatic torsokeloids patients*

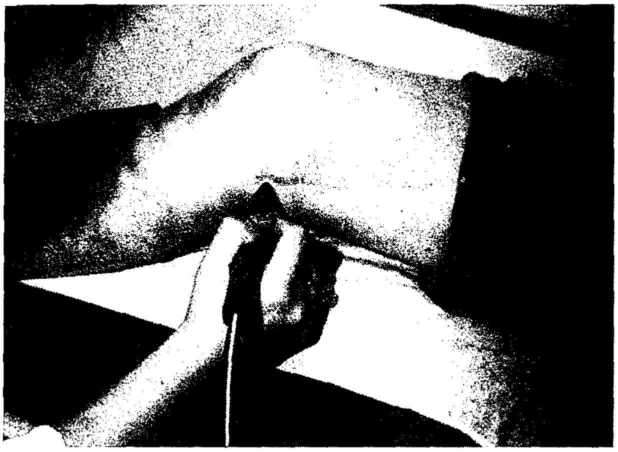

Fig. 3.15 *Laser applied to a post-surgical scar. Sensitivity and discoloration diminish with continued treatment*

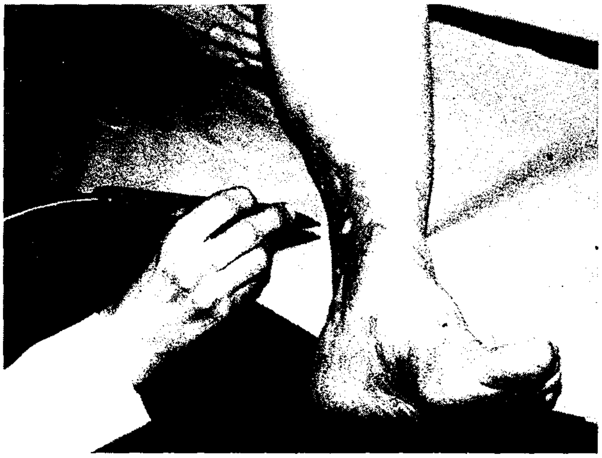

Fig. 3.16 *Laser application to extensive open lesion (cellulitis)*

Fig. 3.17 *Laser applied to slow-healing burn*

Fig. 3.18 *Cold Laser to the lipoma*

CHAPTER 4

ULTRAVIOLET RADIATION

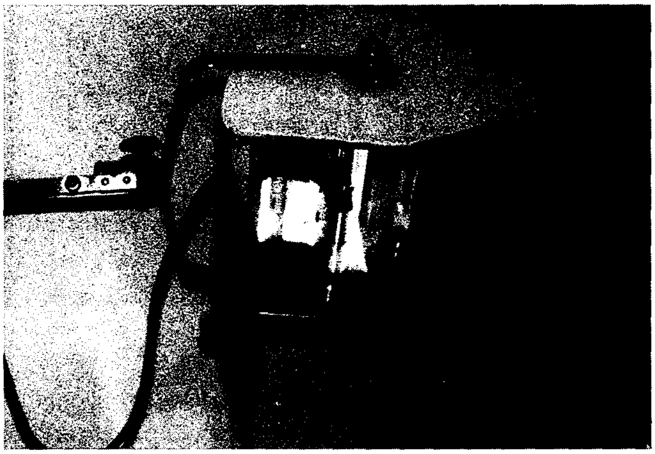

Fig. 4.1 *Ultraviolet lamp*

INTRODUCTION

Ultraviolet radiation is electromagnetic energy, which is invisible to the human eye, with wavelength between 10 nm and 400 nm. Ultraviolet lies between visible light and X-ray in the electromagnetic spectrum.

CLASSIFICATION OF UV RADIATION

Region	Wavelength	Penetration
UVA	400 – 315 nm	Up to dermis
UVB	315 –280 nm	Deep epidermis
UVC	280 –100 nm	Superficial epidermis

PRODUCTION OF UV RADIATION

It is usually produced by the passage of a current through an ionized vapour, usually mercury vapours. Gases do not conduct current well at normal temperature and pressure but can be made to do so at low pressure and high temperature.

ULTRAVIOLET GENERATORS

1. High pressure mercury — vapour burner
2. Kromayer lamp
3. Fluorescent tube for UV production

High Pressure mercury — vapour burner

It consists of a U-shaped tube made up of quartz because quartz can withstand high temperature and has a fairly low coefficient of expansion.

Argon gas at low pressure is enclosed in the tube. Small quantity of mercury is also enclosed in the tube. At both the ends of tube, electrodes are placed, which are covered by the metal caps and across which a high potential difference is allowed in order to ionize the argon gas.

Once the argon gas has been ionized, normal mains voltage between the electrodes causes the positive and negative particles to move through the burner. The electrons move to the positive terminal and positive ions to negative terminal. This two-way movement causes cohesion between moving ions and neutral argon atoms causes further ionization and production of sufficient heat, which vapourize the liquid mercury inside the tube.

Ultraviolet radiation is produced by recombination of electrons and positive mercury ions, and by the photons released when excited electron return from higher energy quantum shell to their normal shell within the mercury atoms. At that time, apart from UV rays, visible and infrared electromagnetic waves are also produced.

The process of argon gas ionization, mercury vaporization and ionization takes some time and a period of 5 min. elapses between starting the burner and UV emission reach its peak.

Tridymite Formation: The production of heat inside the burner causes some of the quartz to change into tridymite. It is opaque to ultraviolet rays. Therefore, total output of lamp gradually falls as the proportion of tridymite increases after 1000 hours of burning, so much tridymite is accumulated in the burner that whole burner tube needs to be replaced.

The Kromayer Lamp

The Kromayer lamp is a medium-pressure mercury vapour ultraviolet lamp designed tube used in contact

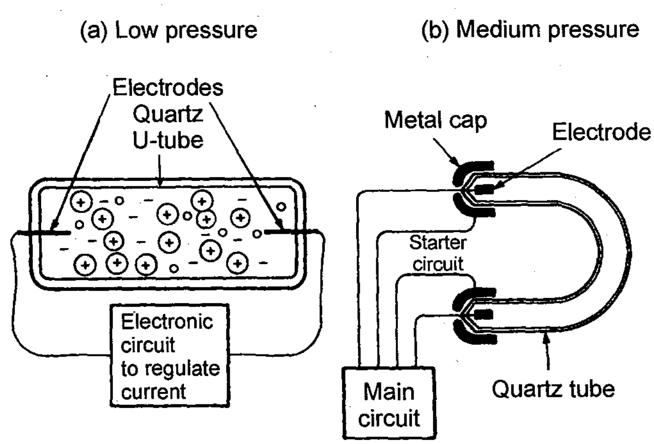

Fig. 4.2 *Mercury vapour gas discharge tube*

with the tissues, both on the skin surface and in body cavities. This is achieved by enclosing the emitting tube in a water jacket which cools it and filters out the infrared which would other-wise cause a heat burn but allowing the visible and ultraviolet to pass. Forced air-cooling has also been used in a system called Acro-Kromayer. The mercury vapour U-tube works in the same way as described above but is enclosed in a waterproof metal container with a quartz window in front. Surrounding this is another metal container and quartz window. Water is pumped between the two windows.

The whole assembly, with an outer case and handle, is connected to the water pump and cooling system in the base of the machine by flexible pipes. The water is contained in a tank mounted in the body of the lamp and constantly recirculated. To avoid deposits forming on the quartz windows and pipes, distilled water is recommended. The water passing between the two quartz windows absorbs infrared, becomes warmer, and is pumped to a radiator in the body of the machine over which air is passed with a fan.

This lamp will also require about 5 min. to reach operating temperature. When the Kromayer lamp is switched off, the water pump should be left running for a few minutes to lower the temperature. If the cooling water flow is stopped while the lamp is still hot, it may damage the seals between the quartz and metal case or other parts.

The UV radiations emitted from the Kromayer lamp are inevitably reduced by passing through two quartz envelopes of the lamp. However, application directly to the tissues or a few centimetres away ensures that the output is many times stronger than that of the Alpine sunlamp, applied at 50 cm. Thus doses of a few seconds with Kromayer can achieve the same effect as those of a few minutes with the air-cooled lamp—but only to a very small area. Although the output of the tubes is the same in both lamps, there is relatively more UVC from the Kromayer since short UV radiations are particularly attenuated in air. This is useful if the Kromayer is being used for a bacteriocidal effect.

In both these 'hot' mercury arc lamps the quartz envelope becomes gradually changed by the heat into tridymite, which is a different form of silica. Quartz is used for these lamps because it allows the transmission of all ultraviolet down to a wavelength of 170–180 nm but tridymite is opaque to ultraviolet and, therefore, the effective output of the lamp gradually diminishes with use. This problem is overcome by incorporating a resistance in the circuit which can be reduced in steps as the lamp ages. This resistor, sometimes called the intensity stabilizer, can be moved over a scale marked in elapsed hours. A record of the total time during the lamp has been in use (*i.e.* burning hours) should be kept and the resistance altered accordingly. After 1000 hours the quartz tube has to be replaced.

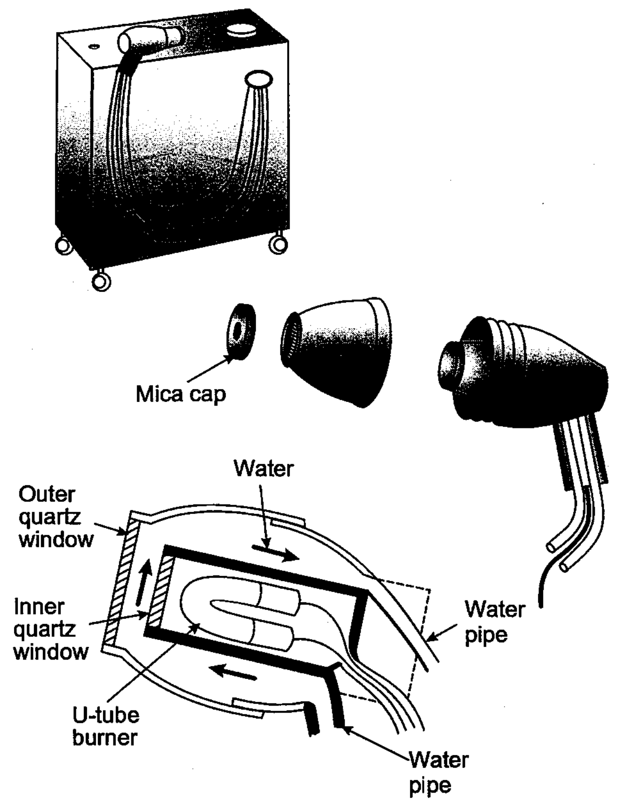

Fig. 4.3 *Kromayer water cooled lamp*

The outer quartz window of the Kromayer is covered by a mica cap which is removed when the lamp is used. This completely obstructs the emission of all UV radiation allowing only some green visible radiations to be transmitted, thus preventing only inadvertent application of ultraviolet.

Various filters can also be used with the lamp. A special holder can be fitted to the front window of the kromayer to support various-shaped quartz rods, often called applicators. These will transmit UV rays to the deeper part of a sinus or ulcer or into a body cavity. There is considerable attenuation of radiations in these rods, so that the dose has to be markedly increased to compensate, but even so most of the ultraviolet is conveyed even in curved applicators due to the strong refraction of ultraviolet between quartz and air which leads to total internal reflection of the UVR.

Fluorescent lamp: These are low pressure mercury discharge tubes with a phosphor coating on the inside. The layer absorbs short UV R notably the spectral line at 254 nm.

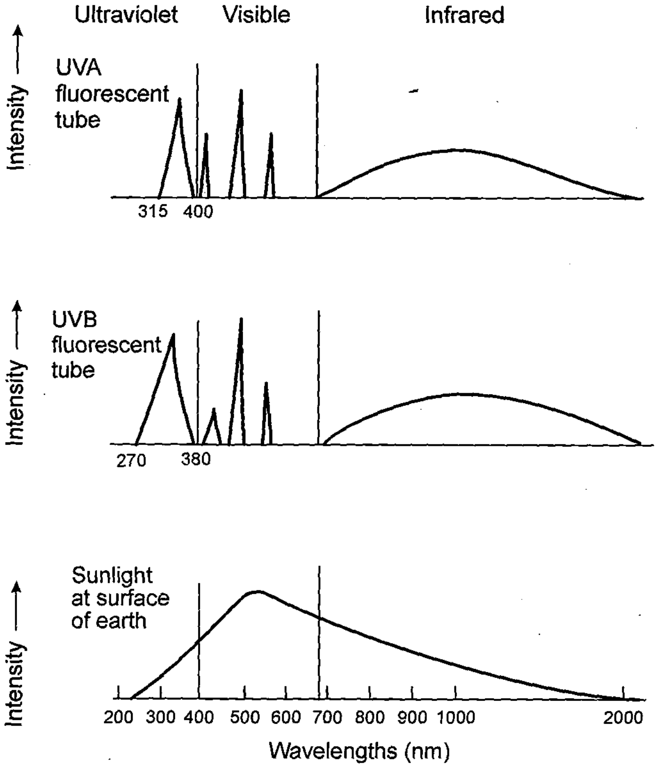

Fig. 4.4 *Spectra distribution of UVA and UVB fluorescent lamps and sunlight*

The particular wavelengths and the amount of each emitted will depend on the composition of the phosphor used (These phosphor coatings are actually mixtures of phosphates, borates and silicates). The output of these lamps also varies with their temperature. Most give an optimal output with the outside of the tube at about 40°C. Such tubes are familiar as standard fluorescent lighting tubes. The tubes used for ultraviolet treatment in physiotherapy are identical in size and shape but have a special phosphor coating in the tube that makes it produce a continuous spectrum between 250–280 nm and 380 nm (with a peak at 313 nm) and lines in the blue and green visible. This gives a considerable UVA & UVB output but no UVC.

For the treatment of patient, long fluorescent tubes are mounted in tunnels, semi-cylindrical or cylindrical cubicles or bed and canopy arrangements, for whole body treatments, and shorter tubes in other configurations for local treatments. The theraktin tunnel, consisting of 4120 cm length tubes mounted in a semi-circular assembly, which can be raised or lowered over a couch or wheeled into position, has been much used by physiotherapist. However, it gives low irradiance and is inclined to give uneven skin exposure, especially at sides of the trunk. More recently, 'narrow band' output fluorescent tubes have been developed whose wavelength is limited to range of a few nanometres; one is available with wavelength around 311 nm.

The same type of tube is used to produce larg amount of UVA radiation for use in the treatment c psoriasis in conjunction with a psoralen coating. I leads to emission of 315 to 400 nm radiation anc several lines in the blue and green visible region. A reflecting layer is applied between the glass envelope and the phosphor layer over more than half the circumference off the tube along its length. This ensures that the radiations are largely directed forward and when several of these tubes are packed together side by side, they provide an approximately uniform emission.

All these fluorescent lamps emit visible radiation giving a bluish-white light when the tube is operating but it must be realized that the visible emission has no relation to the ultraviolet being emitted. All fluorescent tubes have a slight fall in output during their working lives. This is trivial for fluorescent lighting tubes but the ultraviolet lamps use less stable phosphors so that their useful life is usually limited to about 1000 hours. Forced air cooling or air condition-ing achieves a more stable output from the lamp and increased patient comfort.

The low-pressure mercury vapour discharge lamps so far discussed are often called 'cold' ultraviolet lamps to distinguish them from the 'hot' lamps, which work at higher temperature and pressure, and hence are called 'arcs'. These arcs also produce a continuous spectrum of radiations superimposed on the characteristic line spectrum.

DIFFERENT EFFECTS OF INFRARED AND ULTRAVIOLET RADIATIONS

INFRARED	ULTRAVIOLET
1. Physical effect	Chemical effect
2. Absorbed as heat	No heat
3. Absorbed at 3 mm	Absorbed at 1 mm
4. Luminous and non-luminous sources	Luminous sources
5. Immediate erythema	Delayed erythema
6. Lasts 20–30 minutes	Lasts several days
7. Mottled	Sharply defined
8. Dark, reddish	Light pink, Homogeneous
9. Occasional tolerance	Progressive peeling

PHYSIOLOGICAL EFFECTS

1. **Erythema:** Ultraviolet causes reddening of the skin. Oedema and irritation of the skin can also occur if application of UV is intense. UVB and UVC are largely absorbed in the skin which causes the release of histamines and prostaglandins from the keratinocytes and UV radiation also causes release of nitric oxide which is a vasodilators. Erythema reaction has been used to classify doses of ultraviolet given to patient.
   Standard dose of UV classified according to erythema reaction:

Degree of Erythema	Appearance	Approx duration of erythema	Skin Oedema	Skin discomfort	Desquamation of skin
E1	Mildly pink	24 hrs	None	None	None
E2	Definite pink-red	2 days	None	Slight irritation	Powdery
E3	Very red	3–5 days	Same	Hot & painful	In thin sheet
E4	Angry red	One week	Blister	Very painful	Thick sheets

2. **Pigmentation:** Pigmentation of skin occurs as a result of both the formation of melanin in the deep region of epidermis and the migration of melanin already formed into more superficial layers. In already pigmented individuals, some immediate tanning may occur within as little as 10 min. exposure. Pigmentation is strongly stimulated by erythema producing UVB at about 300 nm. The increased melanin content of skin affords protection by preventing UV radiation reaching the lower layers of the epidermis.
3. **Thickening of the Epidermis:** Stimulation by UV radiation provokes uncaused keratinocyte cell turnover so that the skin grows more rapidly for a time, leading to shedding of most of the superficial layers. If the skin recovers, the growth continues so that the final result is skin thickening, which adds to protection due to pigmentation.
4. **Peeling:** The increased thickness of epidermis is eventually lost as desquamation (peeling). When this happens, the resistance of the skin to UV is substantially lowered. Thickening of epidermis and peeling fades over 4–6 weeks if there is no further UV application.
5. **Production of Vitamin-D:** In the presence of UV, 7- dehydrocholesterol in the sebum is converted to Vit. D in the skin. Vit. D is necessary for the absorption of calcium and so has a role to play in the normal formation of bone and teeth. Hospital bound groups of elderly patients may benefit from the administration of UV light in order to promote the production of vit. D and reduce osteoporosis and thus frequency of fractures. The UVB radiation, most effective of producing Vit. D, are in the 280 and 300 nm regions.
6. **Solar Elastosis and Ageing:** The normal ageing process of the skin is accelerated if there is continued exposure to UV. There is thinning of epidermis, loss of epidermal ridges, loss of melanocytes, dryness as a result of poor function of sebaceous and sweat glands and wrinkling from the lack of dermal connective tissue. Prolonged exposure to UV may cause premature ageing.
7. **Carcinogenesis:** Carcinogenesis is a danger if long exposure to UVB or UVC occurs as UV rays have an effect on DNA and thus on cell replication. Prolonged exposure to shorter UV wave should be avoided and course of treatment should not exceed more than 4 weeks.
8. **Effects on Eyes:** Strong doses of UVB and UVC radiation to the eyes can lead to conjunctivitis and to photokeratitis.

Conjunctivitis: Inflammation of tissues over the cornea and lining of eyelids.

Photokeratitis: Inflammation of cornea. It results in irritation of the eye.

UV rays can also cause cataract, which is partial or complete loss of transparency of the LENS or its capsule.

THERAPEUTIC USES AND INDICATIONS FOR UV RADIATIONS

The therapeutic uses of UVR are for skin diseases or to assist the healing of open wounds, particularly chronic slow healing wounds such as venous ulcers of pressure sores. The most commonly treated diseases are:

1. Acne
2. Psoriasis
3. Skin wounds
4. Vitiligo
5. Alopecia
6. Treatment of Vitamin-D deficiency.

1. **Acne:** Acne vulgaris is a chronic inflammatory condition of the pilosebaceous glands especially affecting the face, chest and back. The sebaceous glands become more active at puberty being stimulated by androgens, which coupled with infection by the acne bacillus (Propionibacterium acnes), provoke the formation of blackheads and comedones.

The effects of ultraviolet are to:

a. Accelerate skin growth because peeling of the surface will remove the lesions and open the blocked ducts.
b. Produce a non-specific inflammatory reaction to help control infection.
c. Sterilize the skin surface temporarily.
d. Causes pigmentation improvement, which can sometimes be dramatic or temporary.

2. **Psoriasis:** Psoriasis is a widespread chronic skin discase of unknown cause. This skin condition presents with localized plaques in which the rate of cell turnover from basal layer through to the superficial layer is too rapid. The aim of UV radiation is to decrease the rate of DNA synthesis in the cells of the skin and thus slow down their proliferation. Treatment can be given by using Leed's Regimen or PUVA.

   a. **Leed's Regimen:** In this regimen, the sensitivity of the patient's skin to UV radiation is increased by local application of coal tar prior to the treatment.

   b. **PUVA:** Patients on the PUVA regimen take a sensitizing drug psoralen two hours before the exposure to UV rays. In the nucleus of the cell the psosalens bind to DNA in the presence of UVA and this inhibits synthesis and cell division. Dosage depends upon the patient's skin type.

Classification of the Skin Type

Type 1 : Always burn, never tan
Type 2 : Always burn, tan slightly
Type 3 : Sometimes burn, always tan
Type 4 : Never burn, always tan
Type 5 : Pigmented skin
Type 6 : Heavily pigmented skin.

3. **Skin Wounds:** Ultraviolet is used in the treatment of infected skin wounds such as ulcers, pressure sores or surgical incisions. UV rays destroy bacteria, remove the slough (infected dead natural) and promote repair. UVB is normally used to achieve this. Once the infection is cleared, the aim of UVR is to stimulate the growth of granulation tissue whereas longer UVA stimulate its growth. Filters like uviol or cellophane can be used which will allow the passage of UVA only.
4. **Vitiligo:** It is a condition in which destruction of melanocytes in local areas causes white patches to appear on skin. It is an auto-immune disease. In darker skinned people, it becomes a serious cosmetic problem, which can be treated with topical psoralens and UVR. To try to induce re-pigmentation, gradual exposure to sunlight is advised. Both UVA and UVB can stimulate melanocytes.
5. **Alopecia:** Alopecia means boldness, which can be due to genetic factors, increasing age and inadequate androgen levels.

   There are two kinds:

   A. Areate – Hair falls in patches
   B. Totales – Hair loss includes the whole scalp.

   Mild or moderate doses of UVB can stimulate new hair growth in association with the epithelial cell mitosis.
6. **Treatment of Vitamin-D Deficiency:** Vitamin-D (cholecalciferol) produced in the action of UVB and UVC on 7-dehydrocholestrol. Exposure to sunlight or artificial UVR is curative for vitamin-D deficiency disease. Improvement in dietary habits along with the UV therapy helps in treating vitamin-D deficiency diseases. Bed bound elderly patients may benefit from artificial UVB to maintain Vitamin-D and calcium levels to counteract senile osteoporosis.

SENSITIZATION

Sensitization of the patient can occur with a variety of drugs, both ingested and applied topically. Testing the response would take account of this effect but care needs to be exercised if a patient's drug regimen has been altered during a course of ultraviolet treatments.

So many chemicals can act as sensitizers to ultra-violet in varying degrees that a comprehensive list would be prohibitively long. Commonly encountered groups are:

1. Psoralens – used as sensitizers
2. Sulphonamides – antibiotics
3. Tetracyclines – antibiotics
4. Griseofulvin – antifungal agent
5. Phenothiazine – tranquillizer
6. Chlorthiazide – diuretic
7. Hypnotic drugs (such as Veronal)
8. Barbiturates
9. Gold therapy
10. Various hormones
11. Aspirin and derivatives.

Also substances applied to the surface are:

1. Coal tar
2. Dithranol
3. Psoralens
4. Eosin.

PUVA TREATMENT

The use of psoralens to sensitize to UVA is principally for the treatment of psoriasis. It is also used for some other conditions, such as atopic eczema, vitiligo and prophylactically for polymorphic light eruptions. Some PUVA units are like the Theraktin tunnel—the patient is treated lying; others are in vertical cabinets in which the patient stands. Patients are given 8-methoxypsoralen by mouth and exposed to the UVA some 2-3 hours later. They are given grey or green glasses to wear while sensitized, *i.e.* from the time of taking the tablets until 8 hours afterwards. They are also warned not to expose themselves to the sun for at least 8 hours from ingestion. If there is only a small area of psoriasis or a resistant area, a topical preparation of 8-methoxypsoralen can be applied. The concentration of the drug in the skin is much higher than that with tablets so the dose of UVA is much lower.

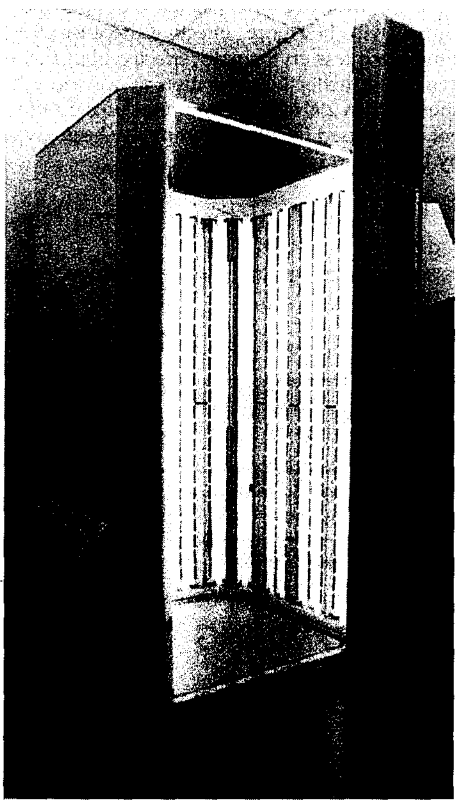

Fig. 4.5

A test dose is usually given to determine the patient's sensitivity and subsequently a whole-body dose of UVA is applied. This can either be sufficient to produce a mild erythema at about 3 days (the erythema due to UVA appears much later than that due to UVB) or suberythemal. Treatment may be given twice a week, progressively increasing the dose at weekly intervals for several weeks. The UVA dosage is measured in J/cm^2 and increases of $0.5–1J/cm^2$ are a usual progression. The principle of basing the dosage on the response of the patient and progressing the dose is the same as for UVB, the difference being that the response to UVA is slower than to UVB.

After 2 or 3 weeks of PUVA treatment, marked pigmentation can develop. UVA stimulates the production of melanin, but the melanosomes are not transferred to the more superficial layers of the epidermis, as with UVB. This, plus the fact that UVA does not result in a thicker stratum corneum, explains why exposure to UVA results in minimum or no protection against UVB. It is important for physiotherapists to recognize this since patients, who are deeply tanned by PUVA or from commercial sunbeds, may not be as well protected as their colour might suggest.

It seems that UVB and low-dose PUVA are successful and very similar in their effect on psoriasis and that high-dose PUVA is best used on selected patients who have not improved with UVB or low-doses PUVA. Van Weelden et al. (1980) suggest that UVB is not only as good as UVA but safer and more economical.

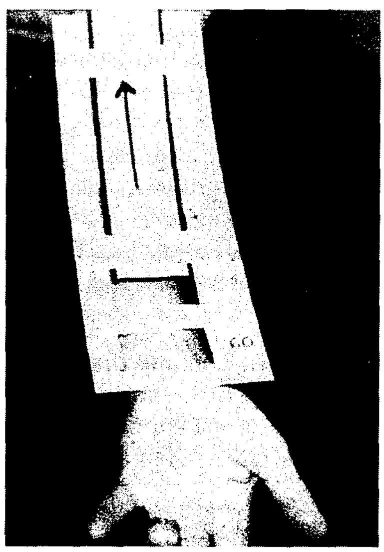

Fig. 4.6 *Minimal erythemal dosage device*

Some regimes for both UVB and PUVA continue as maintenance, that is a moderate dose applied at weekly, fortnightly or monthly intervals in an attempt to prevent the recurrence of psoriasis. The value of this method is difficult to quantity and now most feel that treatment should not be prolonged unless there is good evidence that cessation leads to further development of psoriasis.

Advice to patient on PUVA:

1. Psoralen should not be taken empty stomach.
2. Skin must be covered in bright sunlight and hat should be worn for 24 hours after the treatment.
3. Protective goggles are essential during the exposure. 90% of UVA must be screened by the glasses.
4. Any ointment used during PUVA treatment is prohibited.
5. Oil or lubricating agent is used for dry skin.
6. Contraceptive measures should be used as during PUVA treatment pregnancy is prohibited.
7. Monthly check-up is essential.

Dosages: There are five main doses and one sub-erythema dose

E1
E2
E3
E4
E5

Test Dose: E1 is the test dose which decides the other doses. To calculate the E1 dose, we take a piece of paper and make three holes of different sizes in it. Suppose middle one is about 2 cm × 1 cm, the other one will be smaller while third will be bigger than the first one.

The paper is kept on the forearm or on appropriate surface of body and the rest of the body is covered. The part should be cleaned before putting the paper on the flexor aspect. Suppose UV radiation is given ½ minute to the smallest hole, 1 minute to the middle hole and 1.5 minutes to bigger hole. Instruct the patint to see the erythema which come afterward and disappear first. In this way, E1 dose is calculated and this will be called test dose.

Relation between duration and distance: During the calculation of dose, time and distance are very important. Duration of the exposure can be calculated by universal square law *i.e.* half the distance requires a quarter of the time.

E.g. E1 is 80 sec and distance 100 cm at the time of calculation of the dose, then if you reduce the distance of lamp 50%, means 50 cm, then the duration of dose will be quarter to 80 sec *i.e.* 20 sec.

DETERMINING THE MINIMAL ERYTHEMAL DOSAGES

1. Once the MED is known, treatment may be started with increments of 15 seconds at each successive treatment until a maximum is reached, usually at 2-minute mark for most current lamps.
2. Burning or peeling and signs of too much radiation for an MED and radiation should be reduced.
3. If treatment is effective, peeling and sunburn should not be evident.
4. The patient may become slightly tarred after many exposures, but for the best therapeutic effects, this should be a gradual phenomenon.

DOSAGES—CALCULATION OF DOSAGES

If E1 is 1 min.

Suberythemal dose = 75 % of E1
E2 = E1 × 2.5
E3 = E1 × 5
E4 = E1 × 10
Double E4 = E1 × 2

Dose	Latent period	Appearance
E1	Upto 2 hrs	Slightly pink
E2	4 – 6 hrs	Red
E3	1 – 4 hrs	Red, fiery, painful
E4	Same	Blister

Progression of Doses

Once the treatment is started, the doses are progressed as follows:

Suberythemal dose	-Previous + 12.5% of that dose
E1 dose	-Previous + 25% of that dose
E2 dose	-Previous + 50% of that dose
E3 dose	-Previous + 75% of that dose
E4 dose	-Previous + 100% of that dose

FACTORS DETERMINING THE DEGREE OF ERYTHEMA

1. Individual patient sensitivity
2. Intensity of radiation source
3. Distance of lamp to target
4. Angle of incidence of radiation at skin

5. Duration of exposure
6. Skin: Flexor surfaces are more sensitive than extensor surfaces; blondes and redheaded are more sensitive; and children receive half-dosages.

CONTRA-INDICATIONS

1. **Dermatological conditions:** Certain conditions, such as acute eczema, erythematoses, and herpes simplex may be exacerbated by UVR.
2. **Hypersensitivity to sunlight:** Patients, who are known to react adversely to even minimal exposure to sunlight, should not be treated by UVR.
3. **Febrile disorder:** UV radiation should not be applied to large body areas if the patient has raised temperature, as a further increase in temperature may result.
4. **Deep X-ray therapy:** If the area to be treated with UVR has received deep X-ray therapy within the preceding three months, it may be hypersensitive to the effects of the ultraviolet rays.
5. **Infrared therapy:** If infrared therapy has been given recently to the area to be treated, and the erythema produced is still present, there will be increased absorption of the ultraviolet rays, with a resultant increase in their effects.
6. **Photo allergy:** If the patient is known to develop a rash after exposure to sunlight, treatment with ultraviolet rays should be avoided.
7. **Tuberculosis or Tumors:** In the area to be treated may be exacerbated by the effects of the UVR.
8. Recent skin grafts.

DANGERS

1. **Damage to eyes:** Eyes should be protected, both of the patient and the therapist. Eyes can be protected by wearing goggles. Patient should wear the goggles even when not facing the source of radiation. The absorption of UVR from eyes can lead to the formation of cataract.
2. **Over dosage:** Common mistakes which can lead to over dosage are:

   a. Too long exposure
   b. Too close to lamp
   c. Previously protected skin being irradiated at subsequent treatment
   d. Change of sensitizer drug
   e. Change of lamp
   f. A poor timing technique.

RECORDS OF ULTRAVIOLET TREATMENT

It is important to keep adequate records of all treatments but for ultraviolet treatment, the information must be precise and complete, both for safety and in order to give adequate treatment. For all ultraviolet treatments, the following should always be recorded:

1. **Date:** It is essential to know the exact date of a given treatment for calculating progression etc.
2. **Lamp used:** The particular lamp should be clearly identified.
3. **Distance** at which the treatment is applied; this must be unequivocal.
4. **Exact area treated:** and precisely where and how untreated regions were screened. The position of the patient should be noted in the case of the theraktin.
5. Time for which treatment was applied.
6. **Reaction obtained:** this should be recorded at the subsequent attendance.

HELIOTHERAPY

Heliotherapy is treatment by natural sunlight and has been used since Greek and Roman times. Early in this century, heliotherapy was widely used for treatment of tuberculosis, both pulmonary and other. This can only be effectively applied if there is a reasonable expectation of sufficient sunshine, so that many sanatour developed in mountainous regions, notably the Swiss Alps, where the proportion of ultraviolet compared to infrared radiation is greater due to the attitude. The technique used was to expose the whole body to gradually increasing doses by graded increases of both time and area.

A more recent form of heliotherapy involves the treatment of psoriasis at the Dead Sea in Israel. It is considered that the lower UVB spectrum of the sun in this region, which is well below the sea level, may allow patients to receive more ultraviolet without burning; that is, the spectrum contains relatively more UVA.

Some local minerals are also considered to contribute. There are claims that this is a highly effective treatment for psoriasis.

It is well known that sunburn—due to solar UVB—is only likely to occur in the summer in temperate zones. The UVB component of solar radiation is particularly dependent on the angle of the sun to the surface of the earth, thus although visible and UVA radiations increase in summer, the UVB increases proportionally much more. In fact, the UVB is about 100 times more intense in summer than in winter. This large change occurs very slowly and it is reasonable to presume that human skin is biologically adapted to adjust to this slow change.

CHROMOTHERAPY—USE OF COLOURS OF THE SUN

The sun is the greatest source of energy, and the Vedas speak volumes about its healing and curing effect. Our cosmos exists just because of the sun, and its energy is abundant and unlimited.

The sunlight is white but its consists of seven colours – Violet, Indigo, Blue, Green, Yellow, Orange and Red.

The first three create a cooling effect on the body and are also antiseptic. The last three colours have a heating effect; GREEN is neutral.

Therapeutic effect of different colours on different diseases:

Violet:

- Bone and Bone marrow diseases
- Tumours
- Baldness
- Cataract
- Blindness

Indigo:

- Eyes-Nose-Throat problems
- Facial paralysis
- Respiratory diseases
- Asthma
- Tuberculosis
- Digestive problems
- Neurological diseases
- Convulsions
- Madness

Blue:

- Whooping cough
- Fever
- Typhoid
- Small-pox
- Measles
- Mouth ulcers
- Cholera
- Brain oedema
- Insomnia
- Depression
- Burns
- Problems of semen discharge

Blue colour is the world's best antiseptic.

Green:

- Heart problems
- Hypotension/Hypertension
- Skin diseases
- Cancer
- Influenza
- Syphilis

Yellow:

- Digestive problems
- Spleen and liver diseases
- Diabetes
- Leprosy

Orange:

- Chronic asthma
- Bronchitis
- Gout
- Kidney problems
- Mental nervousness
- Epilepsy

How to take these rays?

The sunlight suitable for this purpose is 90 minutes from sunrise and 60 minutes before sunset. The glass of the desired colour is kept in sunlight in such a way that the rays fall on the affected part. Care should be taken that during this time, the patient is not exposed to strong direct wind.

Alternatively, a coloured bulb (of desired colour) of 60 to 100 watts; or a plain bulb covered with coloured gelatin paper can be used. The bulb is switched ON and the affected part is kept 18–20 inches away. The light is taken for 5–10 minutes twice a day.

How to take colours through water?

A glass bottle of the desired colour, or a plain glass bottle covered with coloured gelatin paper is used. It is filled to three-quarters and kept on a wooden plank for at least three hours in bright sunlight. Care should be taken that this colour-medicated water is not exposed to other colours.

Now the colour-medicated water is given to the patient at an interval of 15 minutes to 120 minutes, depending on the intensity of disease.

If water of other colours is also a part of treatment, it can be given alternatively.

This is a therapy of nature and can be effectively used with other therapies.

CHAPTER 5

INFRARED RADIATION

- Introduction
- Production of Infrared
- Sources of Infrared
- Dosage
- Absorption and Penetration of Infrared Radiation
- Dangers with Infrared Treatment
- Effects of IR Rays
- Indications
- Contra-indications
- Method of Application

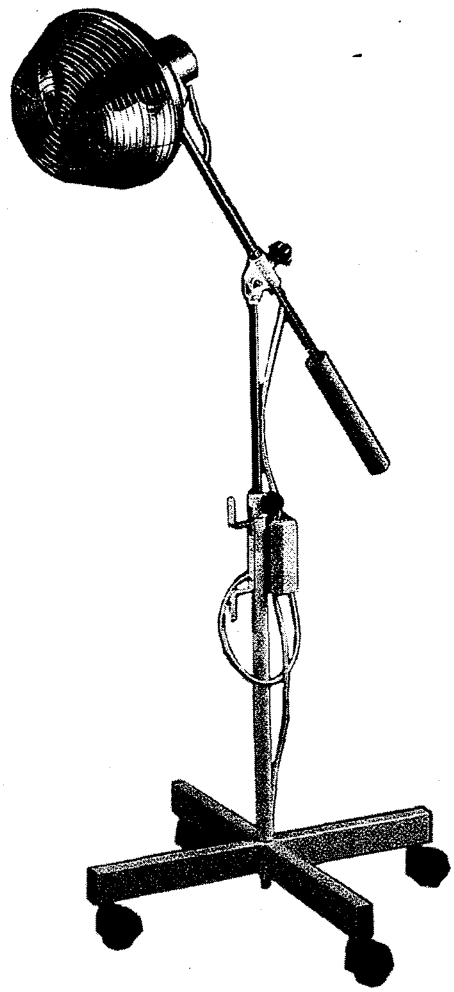

Fig. 5.1 (a) *Infrared radiation lamp*

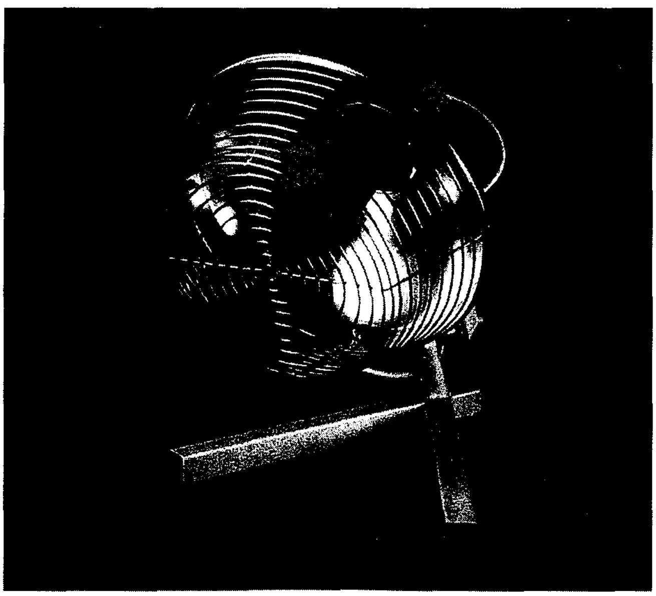

Fig. 5.1 (b) *Portable Infrared lamp*

INTRODUCTION

Infrared rays have been used for various therapeutic effects. Infrared rays lie in that part of electromagnetic radiation which falls between visible light and microwave on the spectrum. They have wavelengths in the range of 750–400000 nm. Any hot body emits infrared rays *e.g.* the sun, coal fires, gas fires, etc.

Infrared radiations are produced by various kinds of molecular vibration. When atoms move further apart or closer together without breaking free from one another, the molecules formed by them alter shape and infrared radiations are emitted.

Table 5.1 Classification of infrared (IR) radiation

Type	Wavelengths	Former classification	Wavelengths	
IR A	760–1400 nm	Near IR	760–1500 nm	used in therapy
IR B	1400–3000 nm	Far IR	1500–15000 nm	
IR C	3000 nm–1 mm			

PRODUCTION OF INFRARED

Any heated material will produce infrared radiations, the wavelength being determined by the temperature. If short infrared is to be produced efficiently, the material must not be burnt by the higher temperature used. Most convenient method is to heat a resistance wire by passing an electric current through it. An ordinary household electric fire can be made of a coil of suitable resistance wire, such as nickel-chrome alloy, wound on a ceramic insulator.

SOURCES OF INFRARED

The most natural source of infrared is the sun. The artificial sources may be divided into luminous or non-luminous generators.

Luminous Generators

Luminous generators consist of a tungsten filament within a glass bulb which contains an inert gas at low pressure. They emit both infrared and visible radiations with a peak wavelength of 1 μm. The exclusion of air prevents oxidation of the filament, which could cause an opaque deposit to form inside of the bulb. Filters may be used to limit the output to particular wave bands.

Non-luminous Generators

Non-luminous generators consist of a coiled resistance wire which is either wound around or embedded within a ceramic insulating material like fireclay. The heated wiring maybe placed behind or within a metal shield or tube. Infrared radiation will be emitted by both the wire and the heated materials surrounding it, resulting in the emission of radiations of different frequencies. Non-luminous generators produce radiations which peak at a wavelength of 4 µm. All non-luminous elements require some time to heat up before the emission of rays reaches maximum intensity.

DOSAGE

The degree of heating produced in the tissues of a patient by IR may be calculated mathematically or may be recorded by the use of heat sensors of varying types. The amount of energy received by the patient is governed by the intensity of the output of the lamp, the distance of the lamp from the patient and the duration of the treatment.

ABSORPTION AND PENETRATION OF INFRARED RADIATION

The depth of penetration of electromagnetic radiation depends on the wavelength and the nature of the material. The human skin allows the penetration of infrared and its approximate depth is 1200 nm. The maximal penetration of the short infrared rays is about 3 mm.

All radiant energy, when it strikes the body, must be reflected, absorbed or transmitted. The absorption of infrared and the maximal penetration of the rays will depend upon the following variables:

1. Frequency or wavelength of the rays
2. Thermal conductivity of the tissue
3. Angle of incidence of the rays
4. Density of each tissue
5. Distance from the source of infrared
6. Patency of the circulation
7. Source of the infrared.

DANGERS WITH INFRARED TREATMENT

Burns

The most obvious danger is of a heat burn which occurs if the patient is unaware of the heat by reason of defective sensation or reduced consciousness. Rarely, a mentally abnormal or perhaps masochistic patient may stoically tolerate painful and damaging levels of heat. Occasionally, patients accidentally touch the hot element if there is no protective guard. These dangers can be avoided by careful application, adequate warnings to the patient and checking the effects on the skin (which is easily visible with this treatment) several times during the application. The patient could be burnt if he or she falls asleep during treatment.

Burns can, of course, arise if the infrared lamp sets fire to some combustible material. Highly inflammable materials should not be in the region. Poor positioning of the lamp can lead to blankets or pillows being charred, but these should be of low flammability and thus relatively safe.

This will only be a danger if the metal itself becomes heated to the point at which contact with it is injurious. This is unlikely with the intensity and duration of most infrared treatment but it is a precautionary measure to remove surface metals from the area being irradiated. Additionally, metal will reflect radiations and for that reason, will lead to irregular application of infrared.

Skin Irritation

Most acute inflammatory skin conditions are made worse by heating. Some chemical irritants on the skin have their effects increased by heating, sometimes to the point of irritation or inflammation. For this reason, liniments, which cause mild erythema, should be removed prior to treatment.

Lowered Blood Pressure

As infrared treatment causes marked cutaneous vasodilatation, it may lead to temporary lowering of blood pressure, particularly in elderly people who have less effective vasomotor control. This may lead to faintness, especially on standing up, immediately after treatment. It may also cause headache.

Areas of Defective Arterial Blood Flow

Areas in which the arteries and arterioles cannot respond by adequate vasodilatation to the demands of additional heating should not be treated. Such areas would be those affected by arterial disease such as atherosclerosis, arterial injury or after skin grafting. The possible result of heating such tissue would be tissue necrosis (gangrene).

Eye Damage

Prolonged and extensive exposure to infrared, such as occurs in furnacemen, has been associated with eye damage. Long-term irradiation can cause corneal burns from far infrared, and retinal and lenticular damage from near infrared. However, infrared applied to the eyes causes surface drying, hence irritation, and should be avoided.

Dehydration

Prolonged and intensive treatment to large body areas could cause sweating, sufficient to provoke dehydration if the water is not replaced.

EFFECTS OF IR RAYS

Physiological Effect

Infrared treatment produces heating effect in the superficial epidermis, resulting in vasodilatation which increases blood circulation in that area. This will lead to more oxygen supply and nutrient supply in that area leading to drainage of waste products, resulting in the relief of pain. The sedative effect on nerve endings lead to reduction in the muscle spasm.

Therapeutic Effects

IR radiation produces heating effects on the superficial epidermis. This results in the increase in blood circulation, as superficial wounds require good blood supply for healing. Therefore, IR radiation can be used in superficial wounds, IR radiation can also be used in treating pain.

Neurological Effects

IR radiations are used for muscle relaxation, thus helping in treatment of inflammation. IR radiation due to sedative effects on the nerve endings helps in relieving pain, muscle spasm and neuralgia.

Metabolic Changes

Due to heating, there is vasodilatation, resulting in more blood circulation (supply) and more nutrition. Due to this, there is removal of waste products.

The primary effects of superficial heating are:

1. Local increase in tissue temperature
2. Increase in metabolism
3. Vasodilatation
4. Increased blood flow
5. Increased capillary permeability
6. Increased lymphatic and venous drainage
7. Secondary axonal reflex activity
8. Increased elasticity of connective tissue
9. Decreased formation of oedema
10. Decreased muscle tone
11. Decrease in muscle spasm
12. Analgesia.

INDICATIONS

Infrared radiation is used for the following purpose:

1. To reduce pain
2. To reduce muscular spasm
3. To reduce joint stiffness
4. To accelerate the healing process
5. To improve the local circulation
6. To reduce oedema
7. To promote sweating
8. To increase the elasticity of connective tissue.

CONTRA-INDICATIONS

Impaired Sensation

Patients with impaired sensation in the area to be treated will not be able to determine if excessive heating is occurring. As there are no meters to register the intensity delivered to the patient, it is essential to assess sensation prior to treatment. Large areas of scar tissue with impaired sensation will also be a contra-indication.

Impaired Circulation

When there is a history of defective circulation from any circulatory disease, such as atherosclerosis, deep vein thrombosis, and Buerger's disease, care must be taken not to administer heat over the areas with impaired circulation. The function of skin circulation is to dissipate heat, and if this heat-regulating mechanism is defective, then it would be quite easy to cause a burn. Heating of thrombi will also cause dislodgement of the thrombi with severe onsequences.

Dermatological Conditions

Heat must not be given over any dermatological condition. Skin lesions such as fungal infection, dermatitis and eczema are some of the lesions to look for. Heat tends to irritate skin lesions.

Metal

There should be no metal in the area that is irradiated with radiant heat. Metal retains the heat and will cause a burn to the underlying tissue. Metal implants are not a contra-indication. Superficially placed implants can be irradiated, provided the circulation is intact and functioning normally.

Eyes

It is important that the eyes are protected from the infrared rays, as it is thought that the radiations can cause radiation cataracts. It can also cause iritis.

Age

Elderly patients generally have impairment of sensation and circulation. In addition, lack of normal cardiovascular and respiratory reserves may lessen the tolerance of thermal stress of a mild degree. It is important not to give radiant heat if the room is hot and humid. Large areas must not be irradiated in elderly patients. Additional dangers in elderly patients include unreliable reporting of the intensity of the heat, and the tendency to fall asleep.

Analgesic and Narcotic Drugs

If patients have had strong analgesic or narcotic drugs just prior to treatment, infrared radiations must not be given. These drugs will raise the pain threshold and the patient will not be able to determine whether the infra-red rays are of too great an intensity.

Deep X-ray Therapy

Patients, who are on deep X-ray therapy or who have had it in the past three months, must not be given infrared, as deep X-ray therapy reduces sensory appreciation.

Topical Creams and Oils

All topical applications must be removed before giving infrared rays or the creams and oil will cause a burn.

Skin Tumours

Patients with skin tumours or melanomas must not receive infrared, as tumour growth may be increased.

Acute Infection

All acute infections are a contra-indication to infrared rays, as the increase in temperature is likely to exacerbate the infective process.

Blood Pressure Abnormalities

Infrared radiation should not be given to large areas for a prolonged time, as the patient may be unable to tolerate the change in blood pressure which may be produced.

Severe Cardiac Conditions

Heating a large area will cause an increase in cardiac output which may not be tolerated by patients with severe cardiac conditions.

METHOD OF APPLICATION

1. Patient should be positioned in a suitable posture so that he is supported and comfortable.
2. The treatment part should be uncovered and skin should be examined for any lesion, rashes, erythroderma etc.
3. The skin should be clear and dry.
4. Patient should be explained about the treatment and its effects.
5. Lamp is positioned in a way that radiation is at right angle to the skin.
6. Lamp is set at a distance of 50–75 cm from the body surface.
7. Switch ON the lamp for 10 min–20 min depending on surface area and vascularity of the part under treatment.

SECTION III

- Short Wave Diathermy
- Pulsed Short Wave Diathermy
- Microwave Diathermy
- Pulsed Microwave Diathermy
- Ultrasound
- Phonophoresis

CHAPTER 6

SHORT WAVE DIATHERMY

- Introduction
- Components of Short Wave Diathermy
- Mechanism
- Production of Heat in Cell
- Methods of Application
- Method of Controlling the Dose
- Physiological and Therapeutic Effects
- Indications
- Contra-indications
- Dangers and Precautions in Short Wave Diathermy
- Preparing the Patient and Device for Treatment
- Treatment of Some Important Conditions by SWD

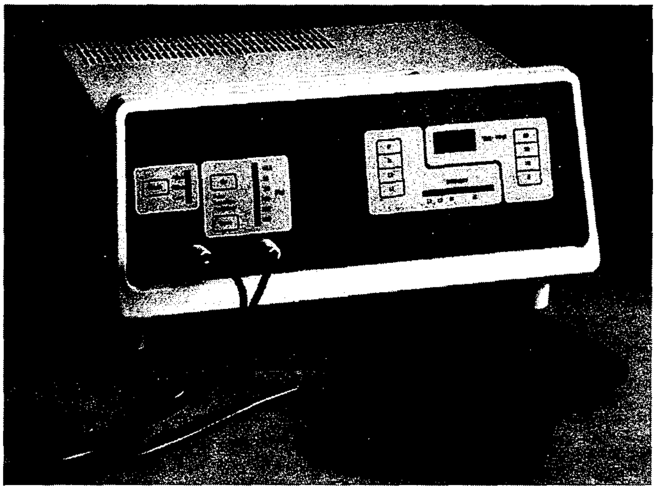

Fig. 6.1 (a) *Short wave diathermy portable unit*

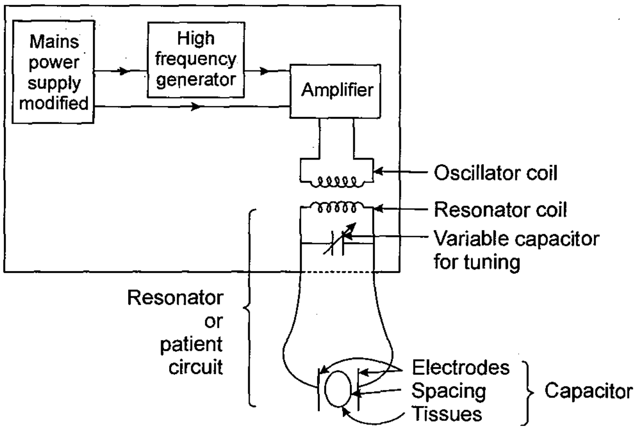

Fig. 6.2 *Block diagram to show short wave diathermy*

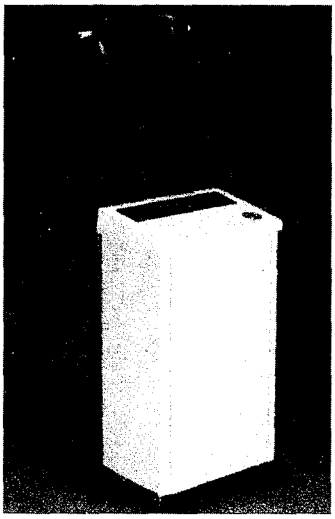

Fig. 6.1 (b) *SWD Unit disc electrode*

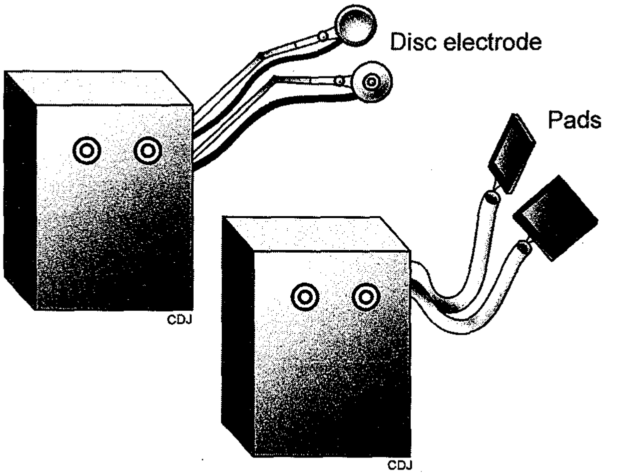

Fig. 6.3 *Condenser field applicator uses two separate pads or disc electrode with air space between them*

INTRODUCTION

The term 'diathermy' means to heat through. Diathermy is applied using electromagnetic waves that produce heat, but are non-ionizing.

Radio waves in the short wave band have frequency in the range 10 MHz–100 MHz. The short wave diathermy used widely utilise the frequency of 27.12 MHz and wavelength greater than 11m.

There are two main circuits:

COMPONENTS OF SHORT WAVE DIATHERMY

There are two main circuits of short wave diathermy and both are coupled to get proper effect.

a. **Machine Circuit / Oscillator Circuit:** It produces high frequency current and amplifies its intensity.
b. **Patient Circuit / Resonator Circuit:** It transfers the electrical energy to the patient, when coupled to the machine circuit by inductors. The energy is transferred in the form of electrostatic or electromagnetic field.

Oscillator Circuit

It is also called as the generator or machine circuit. The main function is to give an amplified AC that has a very high frequency of 27.12 MHz and wavelengths of 11.06 m to the resonator circuit.

It consists of:

1. Main supply
2. Transformer

3. Triode valve
4. Grid leak circuit
5. Oscillator.

Main Supply: It is connected with AC mains that gives current of 220 to 240 volts and frequency of 50 cycles/sec.

Transformer: There are two types of transformer which are used in the construction.

1. Step-down transformer—The secondary coil of this transformer is directly connected to the filament of the triode valve.
2. Step-up transformer—The secondary coil of this transformer is connected to the oscillator and the anode plate of the triode valve.

Triode Valve: This is the thermionic valve which allows electrons to flow in one direction. When a current heats the filament, the electrons are emitted from the cathode. The electrons move to the anode in the form of current. The filament of the triode valve is connected to the step-down transformer. The anode plate is connected to the step-up transformer. This triode valve has a third electrode or grid, which is introduced between the cathode and the anode. This grid is connected to the grid leak circuit. The function of the grid is to control the flow of electrons from the cathode. The grid is an open mesh of wire which surrounds the cathode but is separated from it. The neutral grid will not affect electron flow across the valve. If positive charge is given to the grid, it will attract the electrons emitted by the cathode, thus increasing the current. If negative charge is given to the grid, it will repel the electrons and the current will in turn reduce or stop. The valve here acts as a regulator.

Grid Leak Circuit: It consists of a variable condenser and a resistance connected to the grid of the triode valve.

Oscillator: It consists of stable condenser and an oscillator coil which gives high magnitude, high frequency oscillating current to the resonator circuit.

Resonator Circuit

Resonator circuit or patient circuit lies parallel to the oscillator circuit. It consists of a variable condenser and an inductance coil. The resonator circuit consists of:

1. Resonator coil
2. Resonator condenser
3. Electrode
4. Ammeter
5. Tissues.

Resonator Coil: The high frequency and high magnitude current from the oscillator flows in the resonator coil by electromagnetic induction.

Resonator Condenser: It is a variable condenser. It is used for tuning the machine and patient circuit to obtain maximum heating of the tissues. It is a device for storing the electric charge. It consists of two metal plates separated by an insulator called as dielectric as shown in fig. 6.4. If the plates are given opposite static charges, the lines of forces concentrate between the plates. Thus an electric field is created. The electric field formed effects the atom of the dielectric such that their electron orbits are distorted and they are attracted towards the plates. Atoms remain in the state of tension until the potential difference is removed and energy is released.

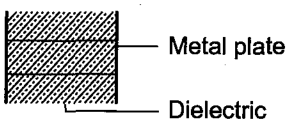

Fig. 6.4

Electrodes: The output of SWD machine is connected to the electrodes which are positioned on the body tissues to be treated. They are of two types:

1. Pad electrode
2. Disc electrode.

Pad Electrode: They are not kept in direct contact with the skin. Usually layers of towels are kept between the pads and the surface of the body. The pads are placed in such a manner so that the body part to be treated is sandwiched (See Fig. 6.3).

Disc Electrode: These are fixed with multipositioned arms. It is very easy to adjust the electrode to the area to be treated on the body. The angle of the arm and the height can be adjusted. This is used when the treatment requires no touching to the skin. A small air gap is given between the body and the electrode. The electromagnetic waves penetrate the patient's body through air (See Fig. 6.3).

Ammeter: This shows maximum reading when the oscillator circuit and resonator circuit resonate.

Tissues: The two electrodes are kept on the skin. Through these electrodes, induced electromagnetic short waves penetrate into the body and production of heat is obtained. This results in the relief of pain and swelling.

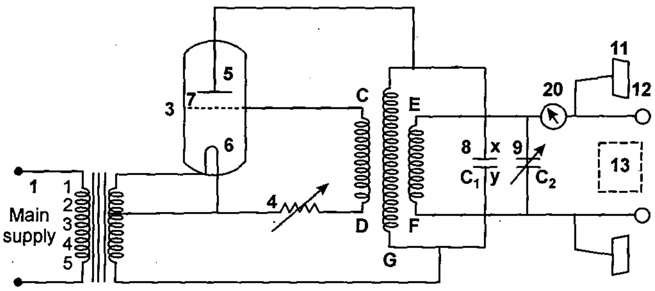

Fig. 6.5

MECHANISM

Oscillator Circuit

The main supply gives an alternating current to the primary coil of the transformer from which the e.m.f. is induced in the secondary coil. The secondary coil of the step-down transformer induces e.m.f. of 20–25 volts which produces current in the filament of the triode valve. Due to this, the filament becomes negatively charged and acts as a cathode.

The secondary coil of the step-up transformer induces an e.m.f. of 4000 volts producing a positive charge at the anode of the triode valve. Now the current from the cathode flows towards the anode. This current flows in the oscillator coil AB in the direction from A to B, producing an induced e.m.f. In the nearby coil CD, the electron will flow from D to C. The current finally passes through the grid coil of the valve producing a negative charge at the grid. The negative charge repels the cathodic electron and causes the stoppage of the flow of current.

Hence the intensity of the oscillator coil decreases resulting a self induced e.m.f. produced in it which charges the condenser XY in which X is positively charged and Y is negatively charged. As the induced e.m.f. dies off, the condenser gets discharged and the current flows from B to A. This is the first wave of oscillating current. This recharges the condenser with negative charge at X and positive charge at Y. When the current flows from B to A, it induces e.m.f. in the coil CD so that the electrons start moving from C to D. The grid loses its negative charge and again the current starts flowing in the anode circuit from A to B. This cycle is repeated again and again and in this way oscillating current is produced in the oscillator circuit.

Resonator or Patient Circuit

The resonator circuit is coupled to the machine circuit by inductors and a high frequency current is produced in it by electromagnetic induction.

When the oscillator circuit and resonator circuit are in resonance, then the maximum current will flow in the resonator circuit and for this the product of conductance and inductance must be same for both circuits. When the machine and patient circuit are in resonance with each other, there is maximum power transferred to the patient circuit.

The SWD current is obtained by discharging a condenser through an inductance of low ohmic resistance.

Applying a potential difference across the main supply or battery, charges the capacitor. A capacitor discharges when the accumulated charges are allowed to flow-off the plates to produce the high frequency current. A condenser is made to charge and discharge regularly.

Indication for circuits in tune:

1. Indication light on the equipment glow when switch is "ON".
2. An ammeter wired into the circuit shows maximum reading that is diminished by turning the knob.
3. A tube containing a small amount of neon gas placed within the electric field between the electrodes will glow at maximum intensity when the circuits are in resonance.

PRODUCTION OF HEAT IN CELL

An atom consists of:

1. Electrons
2. Protons
3. Neutrons.

The electrons are negatively charged particles. They are arranged in definite energy shells or orbits around the nucleus (as shown in fig. 6.6).

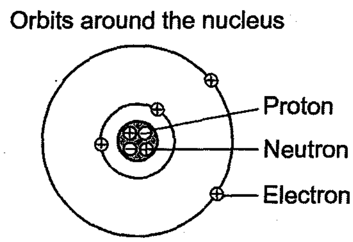

Fig. 6.6

The protons are positively charged particles.

The neutrons are electrically neutral.

Electrons are arranged in various orbits according to $2n^2$ where n = number of orbit.

E.g.: (i) Number of electrons in the first orbit,

$$n = 1$$
$$2 \times (1)^2 = 2$$

Now if an orbit is not complete, for example if an orbit has 17 electrons instead of having 18 electrons, it means the orbit is unsaturated.

The substance having free electrons is called a good conductor and the substance that does not have free electrons is called a bad conductor.

These free electrons travel from negative side to positive side and they have some kinetic energy. They collide with many other electrons and lose their kinetic energy. When these electrons reach the positive side, they leave their negative charge and return back towards the negative side for charging negatively. In this way they lose their kinetic energy that results in production of heat.

Production of Heat by High Frequency Currents

There are three methods:

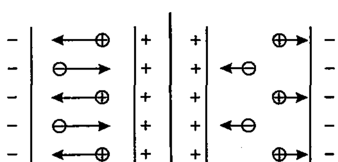

Fig. 6.7

1. **To and Fro/Ionization:** In the living tissue, there are a number of charged molecules, mainly ions and certain protons. In response to the forces of repulsion and attraction which is present between charged molecules as shown in fig. 6.7 exposured to SWD field, there will be acceleration of charged molecules along the lines of electric force.
   The high frequency field induces the charged molecules to oscillate and kinetic energy is converted into heat.
2. **Dipole Method:**

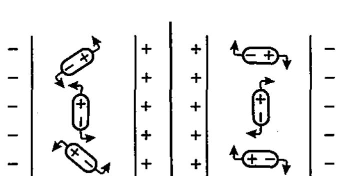

Fig. 6.8

In living tissues, water and other proteins are dipolar molecules. They are affected by electric fields. The positive pole of molecule moves towards the negative pole of the electric field and vice-versa (fig. 6.9) and so the alternating SWD field causes rotation of these molecules as the charge of the plates alters rapidly.

3. **Non-Polar Molecules:**

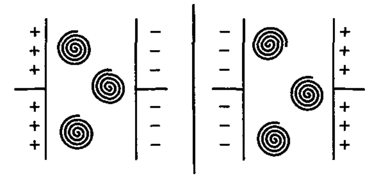

Fig. 6.9

Fat cells are the example of non-polar molecules. In insulator, electrons are firmly held to nucleus and are not easily displaced. In such a substance, the varying electric field causes molecular distortion.

In body tissues, fluids are the electrolyte. When tissue containing a good quantity of fluid is lying in the electric field, vibration of ions and rotation of dipoles take place within them (fig. 6.10).

Other tissues such as fats are insulators, so electric field produces molecular distortion in these. All these processes constitute current and produce heat in accordance with the Joule's Law *i.e.* $Q = I^2RT$.

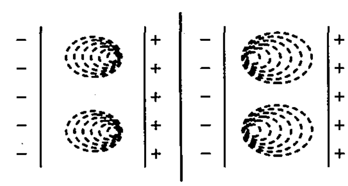

Fig. 6.10

The heating effect of an electric current (I) flowing through a conductor of resistance (R) for time (T) is proportional to Joule's Law.

Non-polar molecules do not have free ions or charged poles, they still respond to the influence of the SWD field. During exposure to SWD, the electron cloud becomes distorted and heat is produced.

Heat production is the primary effect of SWD but it differs from other treatments in regard of heat that depends on distribution of electric field.

One electrode is placed on sole of foot and other above the flexed knee. The density of field is greatest in ankle, so heating is more in ankle.

METHODS OF APPLICATION

There are two methods of application:

1. Capacitor field method.
2. Cable method or Inductothermy.

Capacitor Field Method: In this method, electrodes are placed on each side of the part to be treated. The electrodes are separated from the skin by an insulating material. The electrodes act as the plates of the condenser. The patient tissue with the insulating material forms the dielectric. When the current is applied, rapidly alternating charges are set up on the electrodes and give rise to a rapidly alternating electric field between the electrodes or the plates. The electric field influences the material that lies between the plates. This causes the oscillation of the ions, rotation of the dipoles and the distortion of the insulating material. This agitation causes the production of heat that is primarily the effect of SWD.

In the body the tissue fluids are electrolytes. Application of SWD causes the ions present to vibrate as well as the dipoles to rotate, whereas the fats are insulators. An application of SWD causes the molecules to distort. All this process constitute electric current and produces heat in accordance to Joule's Law

$$Q = I^2RT$$

Arrangement of Pads:

The arrangement of tissues in the pathway of electric field affects the distribution of force and hence affects the heating. When different body tissues lie parallel to the electric field, the density of field is greatest in tissues of low impedance.

E.g.: When field is passed longitudinally through a limb, blood is heated more because of its low impedance.

If tissues lie transversely across the electric field, density of lines of force is same throughout and tissues with highest impedance are heated more resulting maximum heat production in fat tissues which has high impedance and lie in series with other tissues, so appreciable amount of heat is generated in this region. The production of heat results in rise of temperature. Rise in temperature induces relaxation of muscles and increases the efficiency of their action. This increases blood supply for muscle contraction.

The dielectric constants of various tissues differ. Tissues of low impedance such as blood and muscles have higher dielectric constant. Tissues of high impedance such as fibrous tissue and fat have lower dielectric constant.

Differential Heating of Tissues

It depends on:

1. Size of the pads of electrodes
2. Spacing of the pads of electrodes
3. Positioning of the pads of electrodes.

1. **Size of the Electrodes:** The two electrodes must be of the same size. If they are of the different size then different magnitude of current is required to charge them. As per general rule, electrodes should be larger than the part that is to be treated because the electric field tends to spread, particularly at the edges. Therefore, the structure should be at the centre of the field.

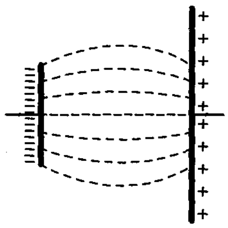

Fig. 6.11

If one electrode is larger than the other, the field tends to concentrate on one side and remains dispersed on the other side (fig. 6.11).

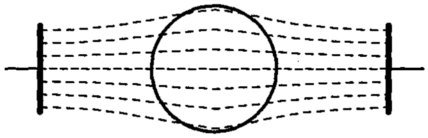

Fig. 6.12

If the two electrodes are small then the superficial structures will receive more heat than the deep tissues (fig. 6.12).

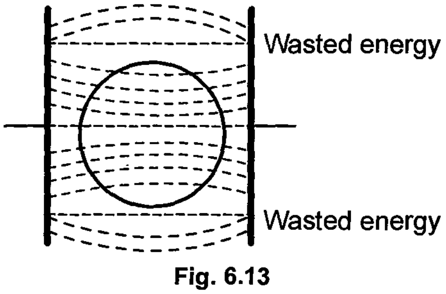

Fig. 6.13

If the electrodes are too large then the heat energy will be wasted (fig. 6.13).

2. **Spacing of Electrodes:** The widest possible spacing tends to lead the most uniform field in the tissues but should be in limits.
   While giving SWD, the pads should be placed properly and space between two pads should be maintained.
   If the distance between two electrodes is less than the width of two pads, the lines of force will travel through pads only and do not produce heat in the body tissues (fig. 6.14).

Fig. 6.14

If the electrodes are at unequal distances from the body, the electrode closer to the body will produce more heat to the same side (fig. 6.15).

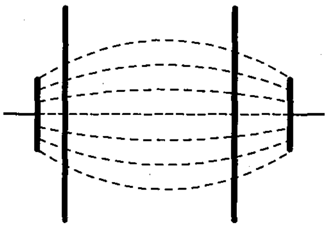

Fig. 6.15

It has been suggested that at the most, spacing of about 4 cms is the maximum that will give the greatest absolute heating of the deep tissues. Conversely, the minimum difference between the skin and the electrode should be 2 cm (fig. 6.16).

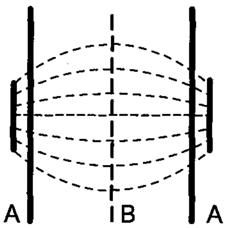

Fig. 6.16

3. **Positioning of the electrodes:** The electric field tends to spread between the tissues and this depends upon the arrangement of the tissues to the electrode. When the tissues lie parallel to the electric field, then the density of the field is greatest in the tissue of low impedance, *e.g.*, when field is applied longitudinally through a limb, blood is heated more because of the low impedance. One electrode is placed at the sole and the other is placed above the flexed knee. The density of the lines will be more at the ankle, thus heating will be more in ankle (fig. 6.17).

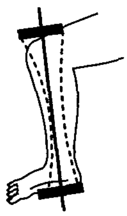

Fig. 6.17

If the tissues are placed transversely across the electric field, the densities of the lines of forces are constant throughout and the tissues of high impedance are heated more, *e.g.* when we apply the electrode transversely (contra-planar) through the joint, the tissues lie in series with relation to the field and the tissues with high impedance such as fat, bone, fascia are heated.

There are three methods of placing the electrodes:

1. **Co-planar:** It is also called as the parallel method. The electrodes are placed side by side (fig. 6.18).

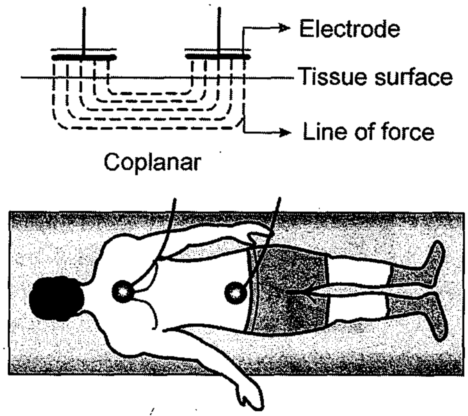

Fig. 6.18

2. **Contra-planar:** It is also called as through and through method. Pads are placed on either side of the joints (fig. 6.19). In this method, deeper tissues are heated.

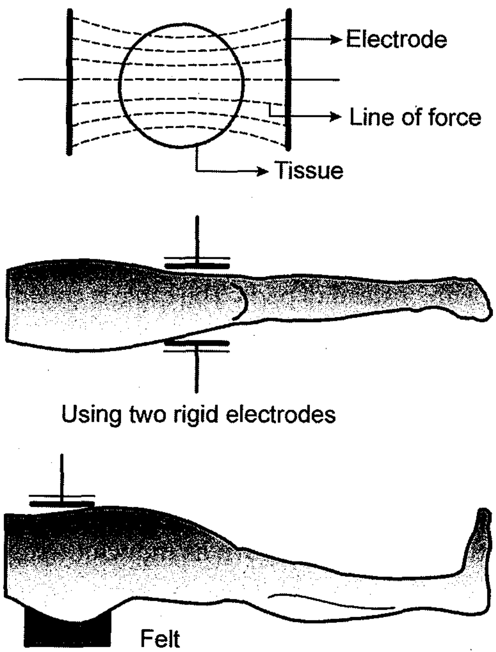

Fig. 6.19

3. **Crossfire Method:** First pads are kept in the position of through and after half time of the treatment, above pads are changed to crossfire method as in fig. 6.20 (a) and (b).

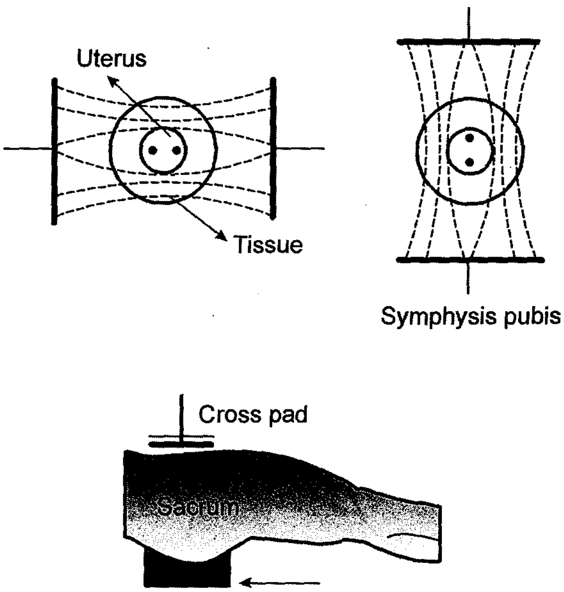

Fig. 6.20 (a) *Anterior posterior field*

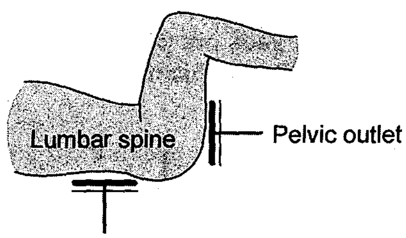

Fig. 6.20 (b) *Superior inferior field*

Cable Method of Inductothermy

The output of diathermy machine is connected to a flexible wire instead of pads. The cable is coiled around the patient's body where pad electrodes are inconvenient to use. When high frequency current is passed through such a cable, an electrostatic field is created between its ends and a magnetic field is created around its centre. Deep heating results due to the electrostatic field, whereas heating of superficial tissues is caused by eddy currents that are set up by the magnetic field. This is known as Inductothermy.

1. **Electrostatic field:** The electrostatic field will be produced in the end of the coil similar to the field in condenser field method. The distribution of field follows the same principle. In this the heat tends to be maximum in the superficial tissues.
2. **Magnetic field:** The magnetic field varies as the current oscillates and e.m.f. is produced by the electromagnetic induction in any conductor that is cut by the magnetic lines of force. If the conductor is a solid piece of conducting material, the e.m.f. gives rise to eddy current. These eddy currents are capable of producing heat in low impedance tissues that lie close to the cable. As with other methods, some heat is transferred to adjacent tissues by conduction and the circulation of blood but the heating is primarily on the superficial tissues of low impedance.

The Effect of the Two Fields

It has been shown experimentally that if the cable is coiled round the material of high impedance, the electric field predominates. When the cable is coiled around the material of low impedance, the electromagnetic field (eddy currents) predominates. When treating a high impedance structure *e.g.* bone, the arrangement should be such that the ends of the cable lie in that area. If structures of low impedance are to be treated *e.g.* blood, then arrangement of the cable should be such that the structure lies towards the centre of the cable. If we want to treat both the tissues, we should use both electrostatic and magnetic field such as the whole cable is arranged in relationship to the patient's tissues, as electrostatic field is setup between its ends and eddy currents in its centre.

Technique of applications in Inductothermy.

The cable can be arranged as:

- A coil is wound around the circumference of the limb. According to the part to be treated, the centre of the cable or its centre can be used.

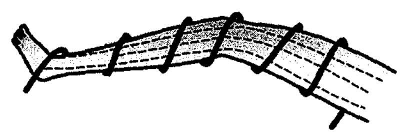

Fig. 6.21 (a) *Whole cable applied to the lower limb*

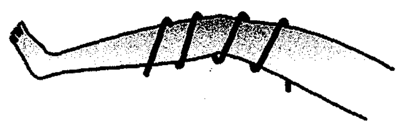

Fig. 6.21 (b) *Ends of the cable applied to the knee*

- A helix is required to treat large and flat areas like back.
- The cable is pre-coiled and encased in insulated drums. This drum is placed close to the area to be treated so that the coil is parallel to the skin surface. This method is known as circuplode. When the current passes the magnetic field associated with this, current is set up at right angles, this will cause the production of eddy currents that will in turn heat superficial tissues.

METHOD OF CONTROLLING THE DOSE

The dose of SWD is measured in Watts. The dose is controlled by the following factors:

1. **Duration of treatment:** More the treatment time, higher is the dose and vice versa.
2. **Milli-amperage indicated by meter:** More the wattage, higher is the dose, and vice versa.
3. **Distance between pads:** Nearer the pads, higher is the dose.

The dose is the product of the watts applied and the duration in minutes. The range of watt selection also depends on the musculature and the depth of pain. If the warmth felt by the patient is intolerable, watts should immediately be decreased, and vice versa. The dose parameters may be changed also depending on the intensity of pain, duration of onset and the nature of pain.

In Chronic Condition

Intensity — Comfortable warmth
Duration — 20 minutes
Frequency — Daily.

In Acute Condition

Intensity — Below sensation of warmth
Duration — 10 minutes
Frequency — Twice a day.

PHYSIOLOGICAL AND THERAPEUTIC EFFECTS

Physiological Effects

The principle effect of SWD on the body is production of heat in the tissues. Maximum heat is produced in the fat tissues, which results in the rise of temperature. Rise of temperature causes relaxation of muscles and increases the efficiency of their action. This increases blood supply ensuring the optimum condition for the muscle contraction.

The amount of distribution of heat depends on arrangements of electric field. If the electric field is applied in parallel to tissues, low impedance tissues are heated more like blood, muscles.

The therapeutic effects of short wave diathermy are used for the treatment of both deep and superficial structures.

1. **Muscle spasm:** It is reduced by short wave diathermy. This is helpful for pain relief.
2. **Inflammation:** Chronic inflammation is resolved as a result of increase in blood circulation, and aids the resorption of oedema exudates.
3. **Infection:** It increases the number of white blood cells and antibodies to fight the infective organism, thereby enabling the control of chronic infection.
4. **Delayed healing:** To promote the healing of open skin areas, there's an increase in the cutaneous circulation.
5. **Fibrosis:** Heat increases the extensibility of fibrous tissues like tendons, joint capsules and scars. This effect is produced by temperature increase within the therapeutic range.

INDICATIONS

Short wave diathermy is indicated for the treatment of:

1. Disorders of the musculo-skeletal system
2. Sprains
3. Strains
4. Capsule lesions
5. Muscle and tendon tears
6. Chronic rheumatoid arthritis
7. Degenerative joint disease
8. Joint stiffness
9. Haematoma
10. Chronic inflammatory/infective conditions
11. Tenosynovitis
12. Synovitis
13. Bursitis
14. Sinusitis
15. Carbuncles
16. Abscesses
17. Infected surgical incisions
18. Dysmenorrhoea
19. Frozen shoulder
20. Cervical spondylosis
21. Lumbar spondylosis.

CONTRA-INDICATIONS

SWD is contra-indicated in the following conditions:

1. **Over Metallic Implants:** If there's any metallic implant of the body in the field of short wave diathermy, it will cause concentration of the field and will result in destruction of adjacent tissues.
2. **Haemorrhagic Areas:** The increase in circulation can precipitate haemorrhage *e.g.* in haemophilia.
3. **Over Ischaemic Tissues:** In ischaemia, the circulation is unable to disperse the heat that could lead to burns or even gangrene.
4. **Over Malignant Tissues:** The increase in temperature causes increase in metabolism, which could accelerate neoplastic growth or even lead to metastasis of malignancy.
5. **Tuberculous Joints:** It may cause spread of infection, thereby leading to joint damage.
6. **Impaired Thermal Sensation:** Application of a safe level of intensity requires patient's sensitivity to heat. Disturbed or impaired thermal sensation could result in high intensities being applied with consequent tissue destruction.
7. **Unreliable Patients:** In very old or very young patients, the cooperation in monitoring the administration of the level of intensity cannot be guaranteed.
8. **Excessive Oedema:** Non-inflammatory oedema is likely to be aggravated by the administration of any form of heat.
9. **Recent Radiotherapy:** For a period up to 3 months following therapeutic doses of radiotherapy, skin sensation and circulation is diminished.
10. **Hypersensitivity to Heat:** When liniment is applied, the circulation increases and if heat is then applied, further increase in circulation may not be possible to disperse the heat.
11. **Acute Infection:** There may be exacerbation of infection by heat *e.g.* in case of acute osteomyelitis.
12. **Cardiac Pacemakers:** The high frequency of SWD interferes with the functioning of pacemakers.
13. **Over Wet Dressings and Adhesive Tape:** The heat is more readily absorbed and the field is concentrated on that area. A burn or scald could result.
14. **Intra-Uterine Contraceptive Devices (IUCD):** Those women using IUCD for contraception should not take diathermy over pelvic region since these are metallic and the field may concentrate, thereby causing tissue damage of adjacent areas.
15. **Over Pregnant Uterus:** SWD may be harmful to the developing foetus.
16. **Venous Thrombosis or Phlebitis:** Heat applied to the affected area may result in formation of embolus.

DANGERS AND PRECAUTIONS IN SHORT WAVE DIATHERMY

Burns: The greatest potential danger associated with the application of short wave diathermy is that of producing a burn. Therefore, the following precautions must be taken in order to avoid such an occurrence:

a. Thoroughly check all **contra-indications** by examining the patient's case history, the area to be treated, and by questioning the patient.
b. A test of **thermal skin sensation** must always be performed.
c. Care must be taken if short wave is to be given over **bony prominences**, as heating will be greater due to the reduced depth of tissue and the heat will be less quickly dispersed as blood flow over bony prominences tends to be less than over muscle tissue. Therefore, if possible, bony prominences should be avoided, or the electrode should be positioned at a greater distance from the skin.
d. **Never** apply short wave over **clothing**, as it will inhibit heat loss from the skin, resulting in excessive heating. In particular, nylon will retain perspiration, resulting in a scald.
e. Ensure that the skin is **dry**. If space plates are being used, watch for any sweat production during treatment. With flexible pad applications, the towelling or felt spacing will absorb any sweat produced.
f. If two skin surfaces are in **contact within the area** which will be affected by the application, they must be separated by a layer of absorbent material, such as towel or cotton wool, to absorb any perspiration produced, or a scald may result.
g. Care must be taken to ensure that the leads from the machine to the electrodes are not **touching, or within 25 mm** of any part of the patient, the machine or any other conducting material such as metal. An electromagnetic field is produced around the leads which would result in a burn if near the patient, or breakdown of the insulation and a short circuit if near the machine or any other conductor.
h. Always apply the electrodes in such a way as to make sure that an **even pattern of heating** will occur.
i. Ensure that there is **adequate spacing** between the electrodes and the skin, and fix the electrodes

firmly to avoid the risk to electrode contact with the skin.

j. Care must be taken to allow **2 to 3 minutes** on each intensity setting so that maximum heat production for that setting is obtained before increasing to the next intensity setting.
k. Never resonate the machine on any setting other than the minimum intensity setting.

Shock: The danger of electrical shock is present in the use of short wave diathermy. In this case, both the patient and the therapist are potentially at risk. The following precautions must be taken to prevent this occurrence:

a. **Do not increase the intensity** unless the leads and electrodes are correctly connected to the machine.
b. Ensure that the machine is **correctly earthed**.
c. **Do not touch**, or allow the patient to touch, the machine if you are earthed, for example, by also touching another machine which is switched on, or touching a water pipe.

Other precautions which must be taken include:

a. Ensure that there is **no metal** within a range of 300 mm of the application as this will distract the field.
b. If the patient is wearing **a hearing aid**, it should be switched off, as the high frequency of short wave diathermy produces marked interference.

PREPARING THE PATIENT AND DEVICE FOR TREATMENT

Prior to treatment, the therapist should evaluate the patient and carry out the necessary operating and safety checks of the SWD device as follows:

1. Test and record the patient's thermal sensation of the body part to be treated.
2. For determining adequacy of blood flow to an extremity, check arterial pulses in the distal part of the limb; also check results of other vascular laboratory tests.
3. Inspect the body part to be treated for any metal on or near the patient. Ask the patient, or refer to medical records to determine, whether there is any metal (shrapnel, sutures, prosthetic implants, metal intra-uterine device) within his or her body.
4. Remove all metal objects, clothing, or other synthetic materials and electronic devices from the body part to be treated. Watches and hearing aids may be demagnetized if exposed to the EM field, if within 1 m of the operating CSWD device.
5. Ask the patient, or refer to medical records to determine, if other electronic devices are present within the patient's body (for example, cardiac pacer, bladder stimulator, spinal cord stimulator, electrodes for a myoelectric prosthesis).
6. Dry any damp skin area that will be exposed to the CSWD applicator. Do not treat over-moist wound dressings.
7. Place the patient in a comfortable, relaxing prone, supine, sitting, or side-lying position so she or he does not have to move during treatment; when treating to increase extensibility of contracted soft tissues, position the patient and the body part to encourage a gentle stretch of the tight tissues.
8. Do not place the patient on a metal surface, in a metal wheelchair, or on a mattress containing metal springs when giving a CSWD treatment because the EM field may selectively heat the metal, which could burn the patient.
9. Select an appropriate CSWD treatment applicator (capacitive or inductive field). Apply capacitive applicators using contra-planar or co-planar method.
10. Expose and cover the body part to be treated with one layer of terry cloth if using capacitive applicator (for moisture absorption) or two to four layers if using inductive applicator for additional spacing and moisture absorption.
11. Explain to the patient what the treatment consists of and why it is being done.
12. Position the treatment applicator appropriately with sufficient spacing; if the CSWD device is older and has non-shielded cables connecting the device console to the applicator(s), make sure the cables are no closer than the terminals they plug into on the device.
13. Tell the patient about how much heat sensation to expect. Advise the patient that she or he should only experience "comfortable warmth" and that if it is hotter than comfortable, she or he should either notify the therapist or pull the emergency off switch.
14. To avoid possible shock, instruct the patient not to touch any part of the CSWD device and not to touch any object that may be grounded (such as water pipe, electrical outlet, radiator, metal sink).
15. Switch on the CSWD device; tune and adjust the heat output to comfortable warmth based on patient feedback.
16. If the patient complains of any pain or discomfort during treatment, immediately reduce the output to zero. Determine if the pain was caused by excessive heating or uncomfortable positioning

and make the necessary corrections before treatment is re-initiated.

17. Immediately after treatment, assess the patient's skin for normal erythema by observation and palpation.

TREATMENT OF SOME IMPORTANT CONDITIONS BY SWD

Sinusitis

Treatment time: 10 minutes

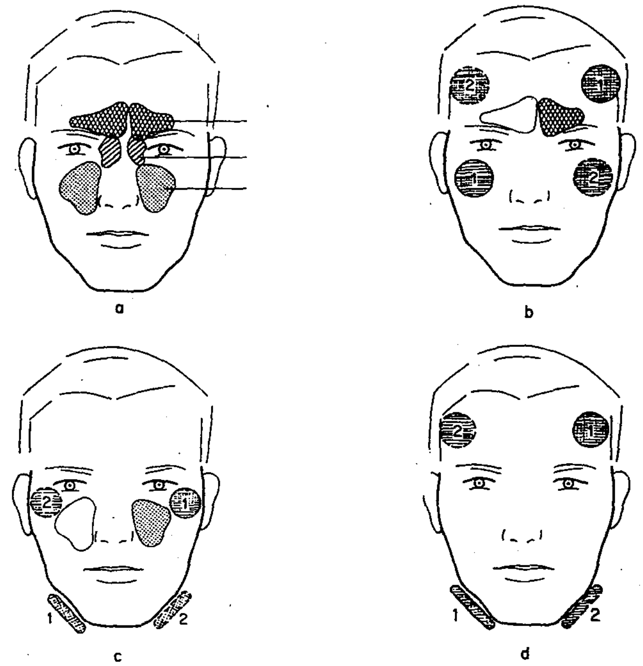

Fig. 6.22 *Cross-fire treatment of the sinuses. The spacing on the affected side (approx. 2 cm) should be less than that on the unaffected side (approx. 3 cm).*

(a) The location of the sinuses.

(b) Treatment of the frontal sinuses with one 8 cm electrode placed on the lateral part of the forehead and another on the other side of the face, high on the cheek (1). For the second half of the treatment, the electrodes are moved to position 2.

(c) Treatment of the maxillary sinuses with one 8 cm electrode placed on the lateral part of the cheek and another on the opposite side of the face below the angle of the jaw (1). For the second half of the treatment, the electrodes are moved to position 2.

(d) Treatment of all the sinuses (including the ethmoidal) with electrodes, one on the lateral part of the forehead, the other on the opposite side of the face, below the angle of the jaw.

Otitis Media

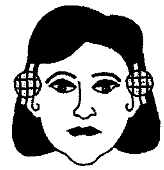

Fig. 6.23

Position of patient: Supine or side lying

Position of electrode: Place the drum electrode over the ear that is affected, place towel between the ear and electrode. Place the other electrode on the other side.

Treatment time: 10 min.

Low Back Pain

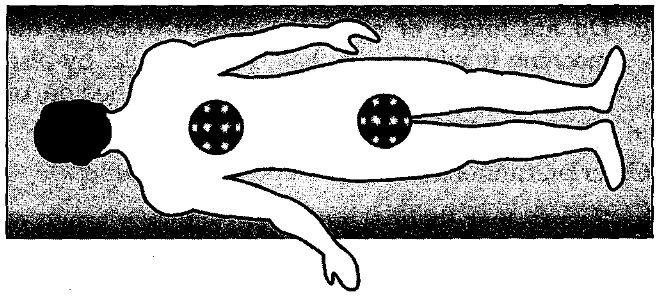

Fig. 6.24

Position of the patient: Prone.

Position of electrode: Place one electrode over the patient's lumber spine. Place towel between electrode and the region to be treated.

Treatment time: 15–20 min.

Osteoarthritis of the Knee

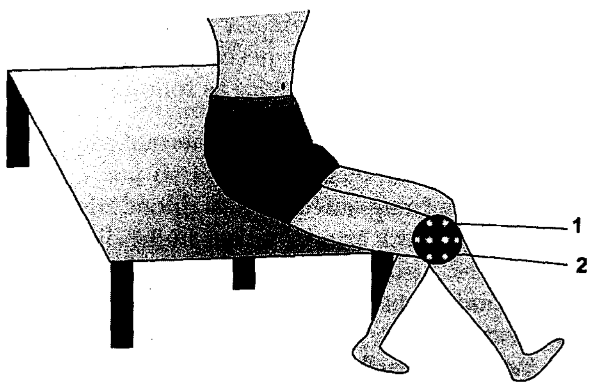

Fig. 6.25

Position of the patient: Supine lying/side lying.

Position of electrode: Place electrode on either side of the knee on medial and lateral side. Place towel as insulator.

Second position: Place electrode on anterior and posterior side.

Treatment time: 10 min. for each position.

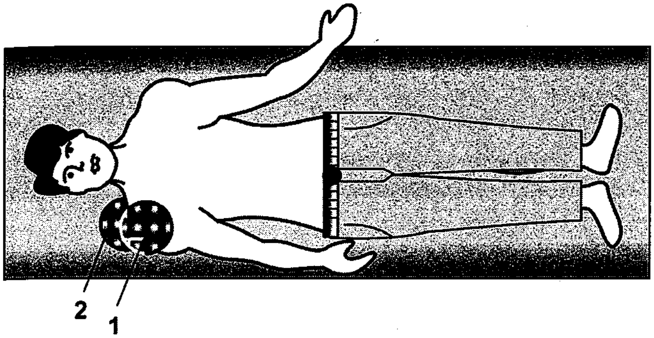

Fig. 6.26

Periarthritis of the Shoulder

Position of the patient: Supine lying.

Position of electrode: Place electrode on the anterior and posterior surface of the shoulder.

Treatment time: 15–20 min.

Pelvic Inflammatory Disease (Cross Fire Method)

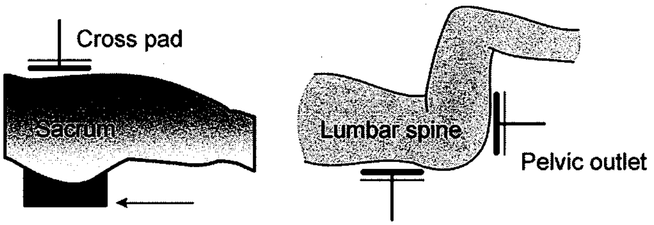

Fig. 6.27

Position of the patient: Supine lying with knee and hip flexed.

Position of the electrode: Place one electrode over the abdomen and one over the anterior superior iliac spine. Place the towel between the electrodes and the region to be treated. After 10 minutes change the upper pad and place it in the region of pelvic outlet.

Treatment time: 10 min. in each position.

CHAPTER

7

PULSED SHORT WAVE DIATHERMY

- Introduction
- Production
- Biological Effects
- Indications
- Contra-Indications
- Dosages
- Application of Pulsed Short Wave Diathermy

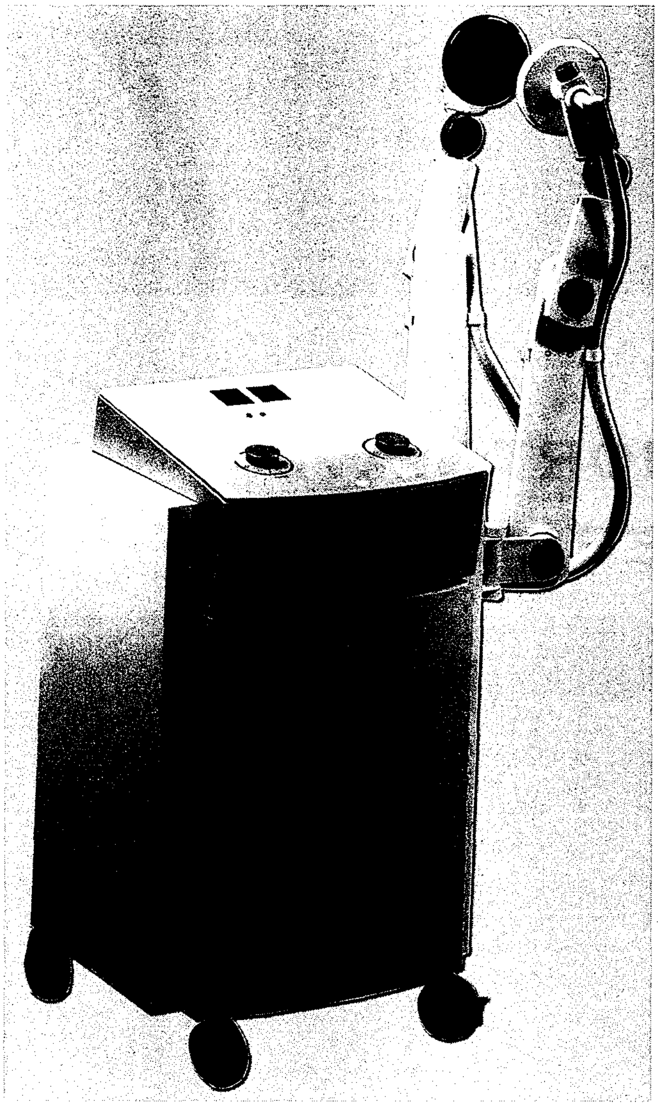

Fig. 7.1 *Pulsed short wave diathermy unit*

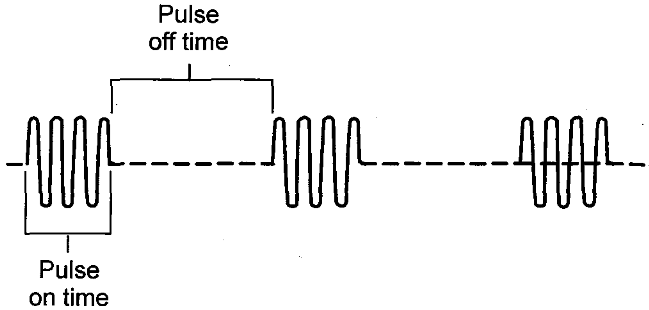

Fig. 7.2 *Pulse radio frequency are created by interrupting the 27 MHz wave output at regular intervals to deliver pulse trains or bursts of energy during successive 'on times' separated by longer lasting 'off times'*

INTRODUCTION

Pulsed short wave diathermy is short wave at the frequency of 27.12 MHz, which is pulsed at a rate selected by the therapist. The pulse frequency range is from 15 Hz to 200 Hz. The maximum intensity produced by the machine is 1000 watts. The pulse duration is constant at 0.4 ms and square pulses are used.

By pulsing the output of the machine, the thermal effect produced by one pulse is of very short duration as it is dissipated by the circulation before the next pulse occurs. Thus there are no cumulative thermal effects.

PRODUCTION

Bursts of pulse trains containing a series of high frequency sine wave oscillations are emitted from the PSWD (Pulsed Short Wave Diathermy) treatment applicator. Each pulse train has a preset duration, or "on time", and is separated from successive pulse trains by an "off time" (Fig. 7.2) that is determined by the pulse repetition rate or frequency depending on the PRFR (Pulsed Radio Frequency Radiation) device. The pulse frequency can be varied from 1 to 7000 pulses per second and is selected with a pulse frequency control on the equipment operation panel. The desired effect is production of PRFR that, like CSWD (Continuous Short Wave Diathermy), has the ability to raise tissue temperature. The variation of diathermy is called Pulsed Short Wave Diathermy (PSWD). Whether PRFR induces heat in tissues depends on three parameters that in combination give a mean power output that ranges between 38 and 665 W. The three parameters are: (1) peak pulse power, (2) pulse frequency, and (3) pulse duration. The measure of heat production with PSWD devices is the mean power (Fig. 7.3). Gradual increase in tissue heating above 37°C, that results in increased vascular perfusion with PSWD, begin to occur at a mean power of 38W. For most PRFR devices, the peak pulse power (the power in watts delivered during a pulse) ranges between 100 and 1000 W.

If the pulse duration is 400 µs (0.4 ms) and the peak power and pulse frequency are known, the mean power may be easily calculated. For example, at a peak pulse power of 800 W, if the pulse frequency is 200 pps, then the pulse period (the pulse on time plus the pulse off time) may be calculated as the pulse period (ms) ÷ pulse frequency or in this case 1000 ÷ 200 = 5.0 ms (see Fig. 7.3).

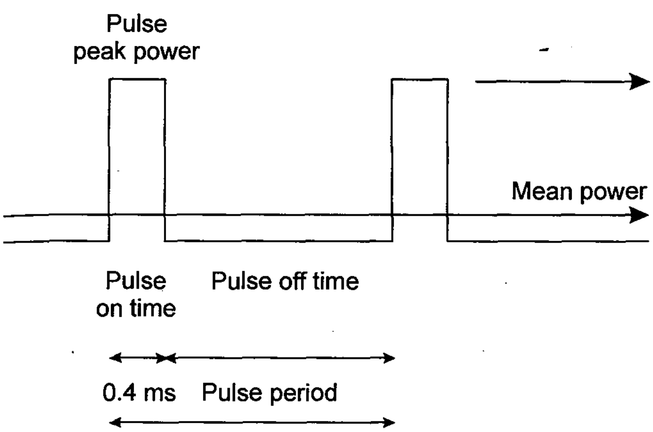

Fig. 7.3 *A subjective measure of heat production with pulsed short wave is the mean power. The highest mean power produced by pulsed short wave devices is always lower than the power produced by most continuous short wave devices*

In this example, the percentage of time during which the pulsed short wave diathermy is delivered is 0.4 ÷ 5.0 = 8 percent. Consequently, the mean power is 8 percent of 800 W or 64 W. As shown in the table, this and other mean wattage values greater than 38 W produce a significant tissue heating effect that elicits expected physiologic responses from accumulated thermal energy. PSWD devices produce heat in tissues. In the same way heat is produced in tissues by CSWD, that is, by increasing random motion and kinetic energy between atoms, ions, and molecules. Generally with most PSWD devices, the highest mean power output can be delivered which is always lower than the power delivered (80 to 120 W) during most CSWD treatments.

BIOLOGICAL EFFECTS

The effects of pulsed short wave diathermy are the same as those produced by non-pulsed short wave diathermy with the exception of the increase in temperature in the tissues. The effects are summarized as follows:

i. Relief of pain
ii. Relaxes muscle spasm
iii. Increases metabolism by 2 to 3 times
iv. Stimulates the peripheral circulation
v. Stimulates the early closure of wounds.

INDICATIONS

Pulsed short wave diathermy is used to treat acute post-traumatic and infective conditions for which non-pulsed short wave would be contra-indicated due to its thermal effects. Such conditions include:

- Sprains
- Contusions
- Ruptures
- Haematoma
- Bursitis
- Sinusitis.

CONTRA-INDICATIONS

Very few contra-indications apply to pulsed short wave diathermy. These are listed below:

Pacemakers: The passage of high frequency current may interfere with the functioning of some pacemakers.

High fever: The effects of increasing the metabolism may not be tolerated in the presence of an increased body temperature when metabolism will already be increased.

Tumours: The increase in metabolism may result in increased growth and metastasis of the tumour.

Metal: Metal is not an absolute contra-indication.

DOSAGES

The patient should not feel any heat. The dose is selected as a combination of pulse frequency and pulse power (intensity). In general, the pulse power should be as high as possible (up to 1000 watts) though lower for initial treatments and acute conditions.

The pulse frequency should be determined by questioning the patient as to the development of any heat.

	1	2	3	4	5	6	7	8	9	10	Position of intensity control
Pulse repetition frequency	100 W	200 W	300 W	400 W	500 W	600 W	700 W	800 W	900 W	1000 W	Maximum pulse power
15 Hz	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	
20 Hz	0.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	
26 Hz	1.0	2.1	3.2	4.2	5.3	6.4	7.4	8.5	9.5	10.6	
35 Hz	1.4	2.8	4.2	5.6	[illegible]	8.4	9.8	11.2	12.6	14	Mean
46 Hz	1.9	3.8	5.6	7.5	9.4	11.3	13.2	15.1	17	18.8	power in
62 Hz	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	watts
82 Hz	3.3	6.6	10	13.3	16.6	20	23.2	26.5	29.9	33.2	
110 Hz	4.4	8.8	13.2	17.7	22	26.5	30.9	35.3	39.7	44.1	
150 Hz	5.9	11.7	17.6	28.5	29.4	35.2	41.1	47	52.8	58.7	
200 Hz	7.8	15.6	23.4	31.2	39	48.9	54.7	52.5	70.3	78.1	

A mean power of 25 watts is experienced as imperceptible by a patient with normal sensation. Combination of pulse repetition and pulse power above the line on the table should produce thermal effects.

APPLICATION OF PULSED SHORT WAVE DIATHERMY

Pulsed short wave can be applied to the body tissues in the same way as conventional short wave but several machines, *e.g.*, Diapulse and Megapulse, limit the method of application to a drum type electrode consisting of a flat helical metal coil contained in a plastic casing. The pattern of effects in the tissues would be same as described for heating the tissues with continuous short wave. Thus one would expect the drum type electrode to cause effects principally in the skin and superficial muscle tissues, having weaker effects as it spreads further into the tissues.

The patient is placed in a comfortable, supported position and the nature of the treatment explained. The drum type electrode is placed close to, or just touching the skin over the area to be treated. The parameters of treatment, which can be adjusted, are selected and set and the machine is tuned either manually or automatically.

CHAPTER

8

MICROWAVE DIATHERMY

- Introduction
- Production of Microwave Radiation
- Therapeutic Effects of Microwave Diathermy
- Biophysical and Biochemical Effects of Microwave Diathermy
- Methods of Application
- Indications
- Contra-indications
- Dangers and Precautions in Microwave Diathermy

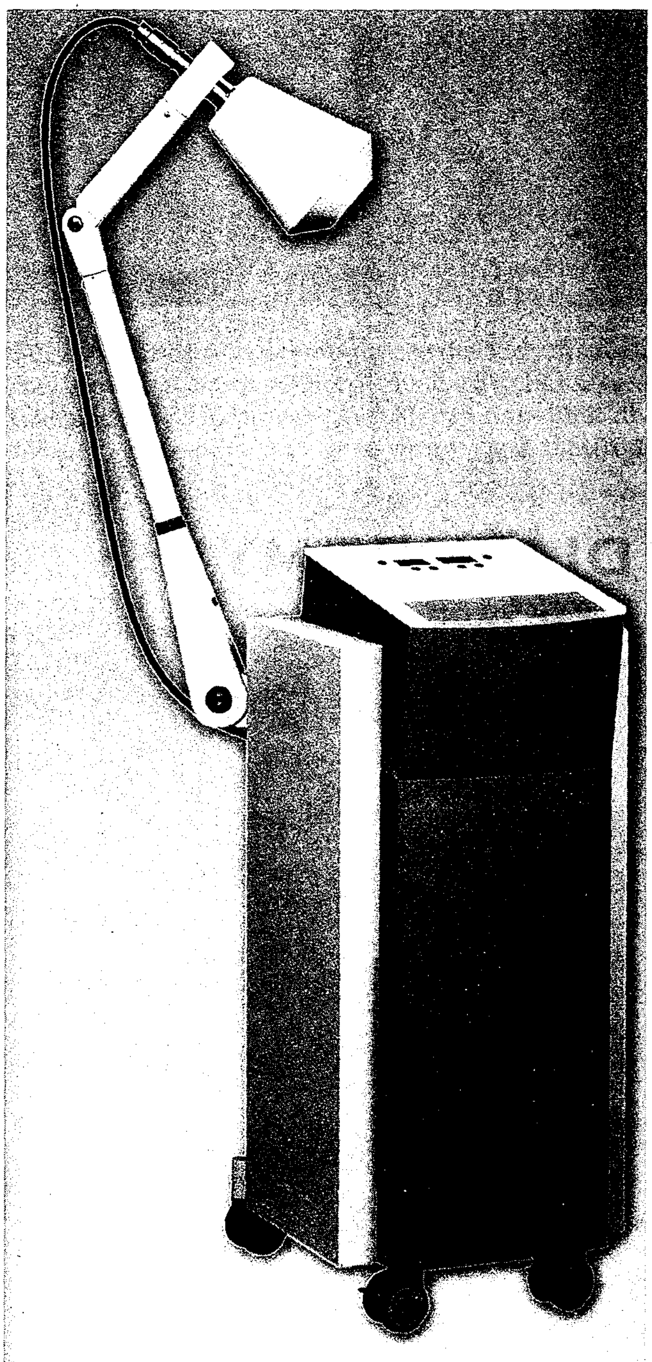

Fig. 8.1 *Microwave diathermy unit*

The frequencies and wavelength of microwaves used in medicine

Frequency (MHz)	Wavelength (cm)
2450	12.245
915	32.79
433.9	69.14

INTRODUCTION

Microwave Diathermy

Microwaves are a form of electromagnetic radiation. They lie between short waves and infrared waves in the electromagnetic spectrum. The frequencies lie in the range of 300–30000 MHz and wavelengths of 10 mm–1 metre.

The most widely used therapeutic frequency and wavelength is 2450 MHz and 12.245 cm respectively.

Microwaves, like other electromagnetic radiation, travel at the speed of light and are governed by laws of reflection, refraction, absorption and inverse square law. The microwave diathermy works on the principle of thermionic emission.

PRODUCTION OF MICROWAVE RADIATION

The magnetron (a diode valve) produces a high frequency alternating current, carried by a coaxial cable to the transducer (or director).

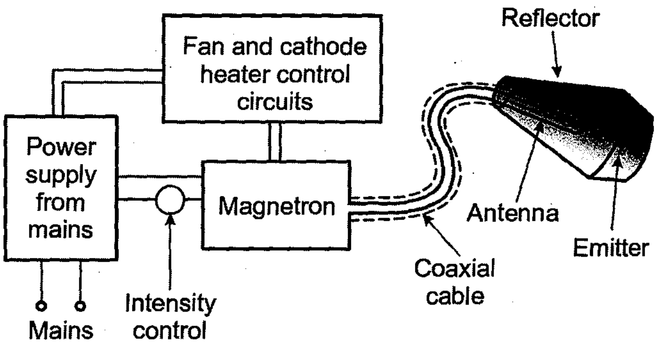

Fig. 8.2 *Production of microwaves: Block diagram of microwave diathermy generator*

The transducer contains an antenna and a reflector. The high frequency current passes through the antenna. This results in transformation of electrical energy into electromagnetic energy. This energy is then focused by reflector and then beamed to the tissues.

The intensity can be varied by changing the amount of power supplied to the magnetron.

THERAPEUTIC EFFECTS OF MICROWAVE DIATHERMY

The therapeutic effects of microwave diathermy are similar to those of short wave diathermy, but since the penetration of microwave is only superficial, it is only likely to be effective in the treatment of superficial structures. It is more suitable for the treatment of localised rather than widespread conditions.

Pain: The relief of pain by microwave diathermy is useful in the treatment of traumatic and rheumatic conditions affecting superficial muscles, ligaments, and small superficial joints.

Muscle spasm: May be reduced directly by microwave diathermy, or may be reduced by relieving the pain, which is contributing to it.

Inflammation: Resolution of chronic inflammation may be accelerated by treatment with microwave diathermy as a result of the increase in blood supply and aids the resorption of the oedema exudate.

Delayed healing: To promote the healing of open skin areas, an increase in the cutaneous circulation may be of assistance, provided the vascular responses to heat are normal. If the arteriolar and capillary dilatation does not allow sufficient increase in blood flow, heat should not be applied directly but may be applied proximally to an area with a good blood supply.

Infection: Treatment with microwave diathermy may assist in the control of chronic infection by increasing the circulation, by an increase in the number of white blood cells and antibodies brought to the area.

Fibrosis: Heat has been found to increase the extensibility of fibrous tissues, such as tendons, joint capsules, and scars. The effect is produced by temperature increases within the therapeutic range.

BIOPHYSICAL AND BIOCHEMICAL EFFECTS OF MICROWAVE DIATHERMY

The basic events, which take place when microwave diathermy is applied to tissues, are:

Penetration: The depth of penetration depends on the frequency of the wave and the properties of the medium, which it is penetrating. In general, the wave energy decreases exponentially with distance travelled, and decreases as the wave frequency increases. Tissues of low water content are penetrated to a greater depth than tissues of high water content. The effective penetration of 2450 MHz microwave is said to be approximately 30 mm.

Absorption: The electromagnetic energy is transformed into heat energy as it interacts with the molecules of different tissues. The non-polar molecules will distort towards the alternating charge in the field; dipolar molecules will rotate back and forth; ions will vibrate in the field direction. The resultant energy losses are converted into heat energy. The differing electrical properties of different tissues determine the amount of absorption which will occur. For example, muscle and other tissues of high fluid content will absorb more electromagnetic energy than tissues such as fat or bone.

Reflection: The proportion of waves reaching the deeper tissues is also dependent upon the amount of energy which is reflected at the air-skin, skin-fat and the fat-muscle interfaces back into the air, the skin, and the subcutaneous fatty layer respectively. The relative amount of energy reflected is determined by the electrical properties of the tissues. At frequencies below 1000 MHz, most of the energy reaches the deeper tissues, while for frequencies of 2450 MHz, the distribution of the energy depends critically on the thickness of the skin and the subcutaneous fat. As much as 50% of the energy may be reflected at the air-skin interface.

Heat conduction: Once the microwave energy has been converted into heat energy, heat exchange will occur with other areas of lower temperature, until a 'steady state' is achieved.

Physiological responses to irradiation with microwave diathermy depend upon the reactions of the tissues to temperature rise and the amount of energy absorbed. Temperature regulation is a function of cardiovascular, hormonal, and nervous control.

Heat applied to the skin (in a restricted area) results in an increased blood flow in the skin, which helps to distribute the heat to other areas. This increase in circulation is accompanied by vasodilatation. The mechanism of these changes is the same as for short wave diathermy.

Mild heat produces reflex reduction of increased muscle tone. It is suggested that increased muscle blood flow plays some part in this mechanism, along with removal of the trigger irritation. Muscle spasm is probably an increased proprioceptor reflex mechanism, and the muscle spindles are the receptor endorgans for this reflex. As it has been shown that temperature increase at the muscle spindle decreases and in some cases, inhibits the firing of the spindles, this may also contribute to the decrease in muscle spasm produced.

METHODS OF APPLICATION

Therapeutically, there are two ways by which microwave can reach a patient:

Radiating Emitter

Here the emitter is kept at some distance from the patient's body so that the microwave passes through the intervening air to reach the patient's tissues.

Frequency of 2450 MHz is used.

They are of 2 types:

a. **Circular emitter:** It emits the microwave of circular cross-section. The density of radiation is more at the periphery than at the centre.

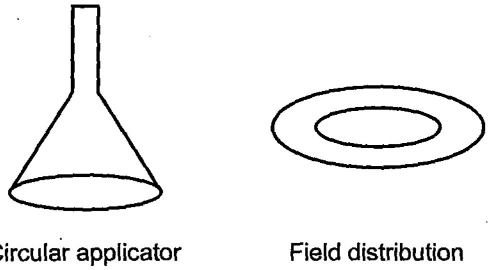

Fig. 8.3

b. **Rectangular emitter:** This type of emitter is rectangular in shape. It emits a beam of oval cross-section whose density is more at the centre.

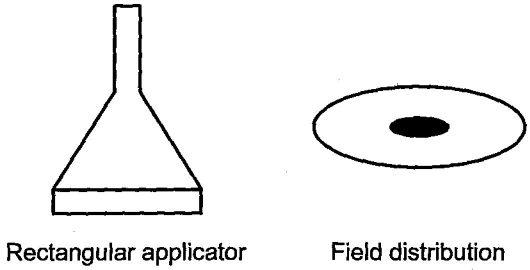

Fig. 8.4

The density of the beam reaching the target tissue depends on the distance of separation between the emitter and the target. For each treatment, the distance to be kept from the skin depends on:

a. Type of emitter
b. Operation of generator
c. Structure to be treated.

The diameter of the beam is limited to 10–20 cm. The treatment of a large area requires greater distance of separation, according to inverse square law, which in turn leads to greater output from generator.

Direct Contact Emitter

These are in direct contact with the surface of the body part. They use the frequency of 915 MHz and 433.9 MHz.

It is useful for treating cavities and has a deeper effect than radiating emitters.

INDICATIONS

MWD is indicated for the treatment of superficial structures. However, lower frequency microwave allows deeper heating if there's only a thin subcutaneous fat layer. It is used in the treatment of:

1. Disorders of musculo-skeletal system
2. Sprains
3. Strains
4. Capsular lesions
5. Muscle and tendon tears
6. Synovitis
7. Bursitis
8. Tenosynovitis
9. Haematoma
10. Joint stiffness (superficial joints)
11. Degenerative joint disease
12. Chronic Rheumatoid Arthritis
13. Superficial inflammatory/ infective conditions
14. Infected surgical incisions
15. Carbuncles
16. Abscesses.

CONTRA-INDICATIONS

The contra-indications, as distinct from precautions, for microwave diathermy are specified as follows:

Over malignant tissues: The increase in metabolism resulting from the increase in temperature would accelerate the rate of growth and metastasis of the malignancy.

Over ischaemic tissues: The inability of the circulation to disperse the heat could result in temperature elevation to a level, which would produce tissue destruction (a burn). Also the inability of the circulation to provide the increased oxygen required by the resultant increase in metabolism could result in the development of gangrene.

Moderate and excessive oedema: Particularly non-inflammatory oedema is likely to be aggravated by the administration of any form of heat.

Over wet dressings and adhesive tape: Microwave will be more readily absorbed, and a burn or scald could result.

Metallic implants: Any metal within the range of penetration of microwave will concentrate the microwave and result in the production of temperatures in the destructive range in adjacent tissues.

Pacemakers: The high frequency of microwave has been demonstrated to interfere with or even inhibit the function of some pacemakers. Therefore, it is advisable not to use microwave in the presence of any pacemaker, because the type is not always known.

Over growing bone: High doses of microwave have been shown to limit bone growth.

Male gonads: Repeated irradiation with microwave is said to produce sterility. If an area near the gonads is to be treated, for example the hip, the gonads may be shielded by fine wire mesh.

Haemorrhagic areas: The increase in circulation will increase the degree of haemorrhage or precipitate haemorrhage in unstable situations, for example, haemophilia.

Tuberculous joints: The increase in temperature will increase the rate of development of the infection, and therefore increase the possibility of joint damage.

Impaired thermal sensation: As the application of a safe level of intensity requires that the patient reports the degree of heat felt, any disturbance in, or loss of thermal sensation could result in high intensities being applied and consequent tissue destruction.

Unreliable patients: For example, very old or very young patients, whose cooperation in monitoring the administration of the level of intensity cannot be guaranteed?

The eyes: The development of lenticular opacities (cataracts) has been demonstrated in subjects exposed to microwaves at comparatively low dosages, and these may or may not result in visual disturbance.

Recent radiotherapy: For a period of up to three months following therapeutic doses of radiotherapy, skin sensation and circulation may be diminished.

Hypersensitivity to heat: Particularly where liniment has been applied, the circulation is already increased by the action of the liniment and may be unable to increase enough to disperse heat applied.

Acute infection or inflammation: The process is likely to be exacerbated by the application of heat.

Obesity: Particularly with 2450 MHz microwave. There is a danger of producing an excessive level of heat in the subcutaneous fat layer.

Analgesic therapy: If the patient has recently (within the last few hours) taken any analgesic drugs, the thermal sensation may be diminished.

Venous thrombosis or phlebitis: Heat applied to the affected area may result in embolus formation.

DANGERS AND PRECAUTIONS IN MICROWAVE DIATHERMY

Burns: The greatest potential danger associated with the application of microwave diathermy is that of producing a burn. Therefore, the following precautions must be taken in order to avoid such an occurrence:

a. Thoroughly check all contra-indications by examining the patient's case history, the area to be treated, and by questioning the patient.
b. A test of **thermal skin sensation** must always be performed.
c. Care must be taken if microwave is to be given over **bony prominences**, as heating will be greater due to the reduced depth of tissue and the reflection of the microwave by the bone, giving a double heating effect. Heat will be less quickly dispersed as blood-flow over bony prominences tends to be less than over muscle tissues. Therefore, if possible, bony prominences should be avoided, or the director should be positioned at a greater distance from the skin.
d. Care must be taken when applying microwave over areas where the **subcutaneous fat layer is thicker,** as 'hot spots' may occur.
e. Ensure that the skin is dry, and watch for any sweat formation during treatment.
f. Never apply microwave over clothing, as it will inhibit heat loss from the skin, resulting in excessive heating. In particular, nylon will retain perspiration, resulting in a scald.
g. Always align the director accurately to ensure an even pattern of heating.

Shock: The danger of electrical shock is present in the use of microwave diathermy. In this case, both the patient and the therapist are potentially at risk.

The following precautions must be taken to prevent this occurrence:

a. Do not increase the intensity unless the coaxial cable is correctly connected, both to the machine and to the director.
b. Ensure that the machine is **correctly earthed.**
c. Do not touch, or allow the patient to touch the machine if you are earthed, for example by also

touching another machine, which is switched on, or touching a water pipe.

Other precautions, to be taken, include:

a. Do not position the director in such a way that **eyes** could receive radiation. Mesh goggles are available to protect the eyes.
b. Avoid irradiating the male gonads.
c. Do not position the director over any **metal surfaces** otherwise reflection may result in damage to the magnetron.
d. If the patient is wearing a **hearing aid**, it should be switched off, as the high frequency of microwave produces marked interference.

CHAPTER 9

PULSED MICROWAVE DIATHERMY

- Introduction
- Effective Uses of Pulsed Microwave Therapy

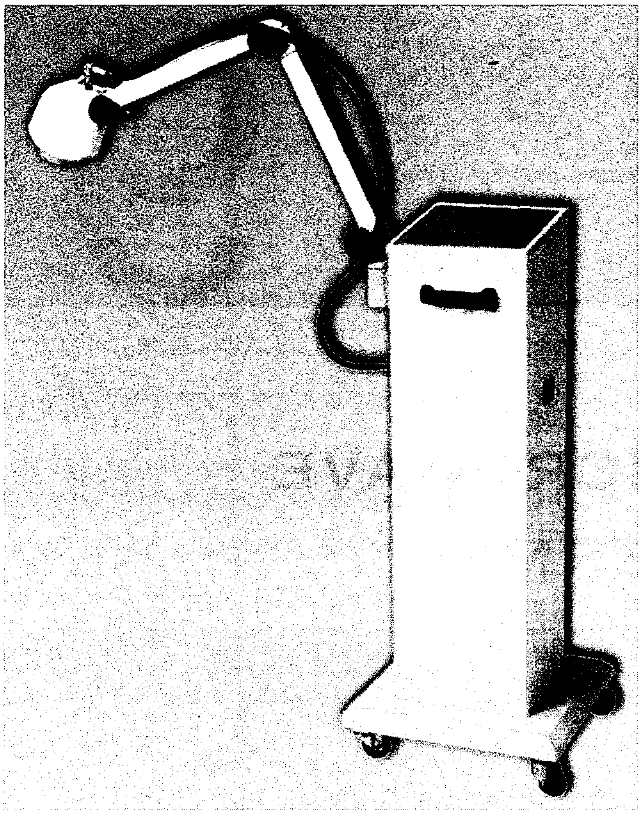

Fig. 9.1 *Pulsed microwave diathermy*

INTRODUCTION

Pulsed Microwave Diathermy

In recent years, some manufacturers have realized that the principles of pulsed short wave diathermy could also apply to microwave, and machines have been developed which produce pulsed microwave diathermy. The effects of pulsed microwave are the same as those of non-pulsed microwave with the exception of the production of a rise in temperature in the tissues. Thus many of the conditions, which contra-indicate treatment with microwave diathermy, can be effectively treated by pulsed microwave. However, as with non-pulsed microwave, the depth of penetration is comparatively superficial and only one aspect of the part can be treated at a time.

Pulsed microwave machines are not seen as frequently as pulsed short wave machines. They are expensive and the purchase of the short wave machine allows a wider range of usage because of the greater versatility of short wave diathermy.

Kinds of Electrical Energy and their Biological Effects

Microwave therapy is electrophysical therapy. Physical therapy units differ in their energy source, energy absorption, depth of penetration, and physiological effects on the living body.

These relationships are outlined below.

EFFECTIVE USES OF PULSED MICROWAVE THERAPY

Healing is the goal of therapy. This goal is achieved only when pain or functional disorders are eliminated. When pain is felt at the lesion, therapy must be directed both at the pain & at the underlying lesion.

Types of energy	Biological effect	Clinical effect	Depth of penetration	Handling ease
Ultrasonic	Thermal (joule heat):	Healing +	Deep	Complicated
	Promotion of metabolism	analgesic effect		
	Sound pressure:			
	Stimulation of nerve fibres			
Microwave	Thermal (joule heat):	Healing +	Shallow	Simple
(pulsed mode)	Promotion of metabolism	analgesic effect		
	Stimulation of nerve fibres			
Microwave	Thermal (joule heat):	Healing	Shallow	Simple
(continuous)	Promotion of metabolism			
Short wave	Thermal (molecular		Deep	
(continuous)	vibration)			

Sedation, if not applied soon, can adversely affect healing. Pulsed microwave therapy simultaneously provides healing and sedation, similar to ultrasound. This is one advantage of pulsed microwave therapy over electric current or laser therapy equipment.

Healing

Dead or injured cells must be removed for healing to occur. For this to happen, new materials need to be brought in and cell debris extruded. Blood and lymph carry out these functions. Microwave radiation promotes the circulation of blood and lymph.

When tissues are destroyed, bradykinin or a similar substance is released, stimulating the nerve terminals that signal pain. Prostaglandins emphasize the perception of pain, while prostaglandin inhibitors, like common analgesics, diminish the effect and act to alleviate pain. This, however, does not heal the lesion. Exogenous morphine has a sedative effect on the central nervous system, while the body's own endorphins act to counter pain.

The purpose of microwave radiation is to remove the bradykinin released by the lesion and extrude it through the blood or lymph circulation. Microwave radiation aims to halt the generation of pain-causing substances by healing the lesion.

Sedation

It takes time for a lesion to heal. During the process of healing, pain continues as pain-causing substances are constantly being generated. Pain is necessary for the living body as it signals a disruption of homeostasis. However, intense; long-term sensations of pain cause reflex muscle contractions that can reduce the supply of blood to the lesion, causing an oxygen deficit. The lesion then releases bradykinin or a similar substance, causing a vicious cycle of pain.

Pulsed microwave therapy has been developed to deliver healing energy to the deep tissues of the body. This method of healing promotes metabolism and provides an analgesic effect. The amount of surface heat generated is substantially lower than that of conventional continuous radiation. This is because pulsed mode does not raise the skin's temperature to dangerous levels. Further, its thermal effect lasts much longer than that of continuous radiation. It increases the temperature of internal lesions by 3 to 4°C, and is perceived as a pleasant sensation of warmth.

CHAPTER

10

ULTRASOUND THERAPY

- Introduction
- Components of Ultrasound
- Production
- The Piezoelectric Effect
- Types of Waves
- Ultrasound Modes
- Parameters
- Ultrasound Dose Range
- Treatment Time
- Coupling Medium
- Penetration
- Physiological Effects of Ultrasound Therapy
- Cavitation
- Method of Application
- Indications
- Contra-Indications
- Treatment Table
- Precautions
- Techniques of Application
- Method of applying Ultrasound in Specific Conditions

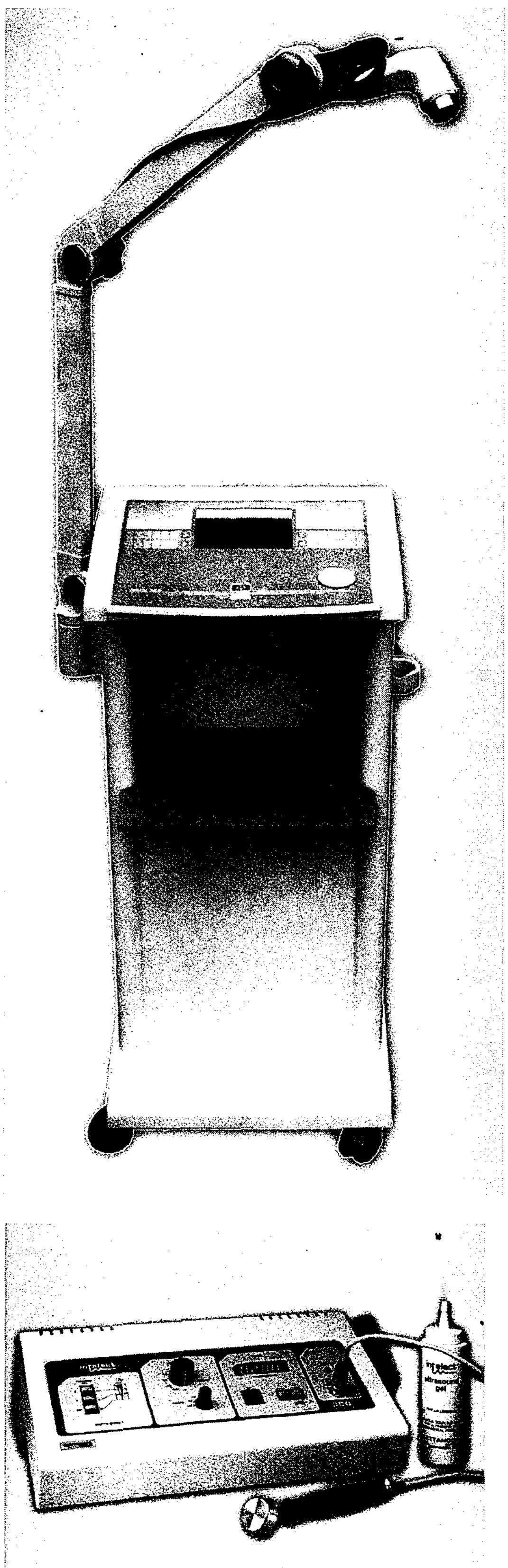

Fig. 10.1 *Ultrasound therapy unit*

INTRODUCTION

Ultrasound Therapy

In ultrasound therapy, ultrasound energy is used to treat human tissue. The energy is applied through a transducer head which consists of a crystal, which vibrates to produce energy. Ultrasound is a form of acoustic vibration propagated in the form of longitudinal compression waves at frequencies too high to be heard by the human ear.

COMPONENTS OF ULTRASOUND

Components used in ultrasonic instrument are:

Main Supply: This is the A.C., normally of 220 volt having the frequency of 50 Hz.

Transformer: In this, a step-up transformer is used to increase the voltage of the current. The current now flows from transformer to rectifier.

Rectifier: The current is converted from A.C. to D.C. The current then flows to the amplifier.

Oscillator: The purpose of oscillator is to give high frequency oscillating current to the output circuit which then flows to the amplifier.

Amplifier: The purpose of increasing the magnitude of current is called amplification. The current then flows to the coaxial cable.

Co-axial Cable: It is a simple wire covered by a metallic plate, which runs parallel to the wire and separated by insulating material. It takes the current to the transducer.

PRODUCTION

Ultrasound waves are the sound waves which cannot be heard (above 1 Mega Hertz) and the sound waves,

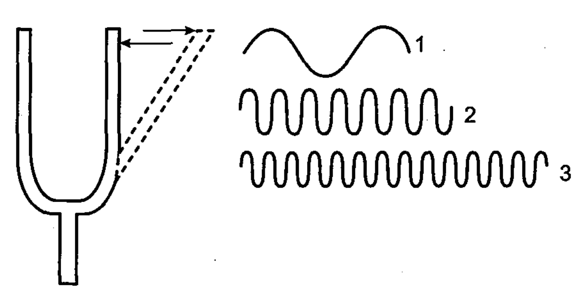

Fig. 10.2 *Sound is always produced by oscillation, frequency decides the audibility*

which can be heard by human ears, are called audio waves (about 16 to 20 kilo Hertz), while the vibration below 16 Kilo Hertz are called Infrasonic or Infrasound. The meaning of word 'sound' & 'sonic' are same.

1. Infrasound waves
2. Audible waves
3. Ultrasound waves. Arrows indicate direction of oscillation.

When the electrical potential is applied on the Quartz or Barium titanate or Zirconate titanate crystal of a specific size, it starts vibrating and produces sound. If the potential is increased, the sound cannot be heard and thus ultrasound is produced. This is called Piezoelectric phenomena. This phenomena is used in both diagnostic and therapeutic ultrasound machines.

The probe or head through which ultrasound are subjected into the body is called Transducer. In diagnostic ultrasound (Sonology), the transducer has an array of sonar detectors which send the signal to microprocessor based circuit of machine where the sound is converted into digital picture of the area scanned. This detector array is not present in case of therapeutic ultrasound machines. Diagnostic ultrasound is used to visualise internal abdominal organs, system, blood flow through any vessel etc.

Ultrasound therapy is associated with the transference of sound waves into the body by a machine called Therapeutic ultrasound machine. These waves are beyond the acoustical range (one Megahertz onwards). The region, where the irregular pattern of ultrasound is present near the transducer or head, is called Near Field or Fresnel Zone, while the region beyond this zone is called Far Field or Fraunhofer Zone. The depth of near field is directly proportional to the square of transducer radius and it is inversely proportional to the wavelength of the ultrasound waves produced by transducer.

In physiotherapy, when we treat a disease or condition using ultrasound, it is the near field used therapeutically which has more average energy.

THE PIEZOELECTRIC EFFECT

There are two forms of the piezoelectric effect—direct and reverse (indirect). The direct piezoelectric effect is the generation of an electric voltage across a crystal when the crystal is compressed. If the crystal is expanded instead of compressed, a voltage of opposite polarity is induced. A sound wave impinging on a piezoelectric crystal will cause the crystal to expand and contract at the same frequency as the sound wave, and in turn induce an oscillating voltage across the crystal face. The direct piezoelectric effect is utilized for converting ultrasound into an electrical signal that replicates the sound pattern and can be conveniently and accurately processed and analyzed.

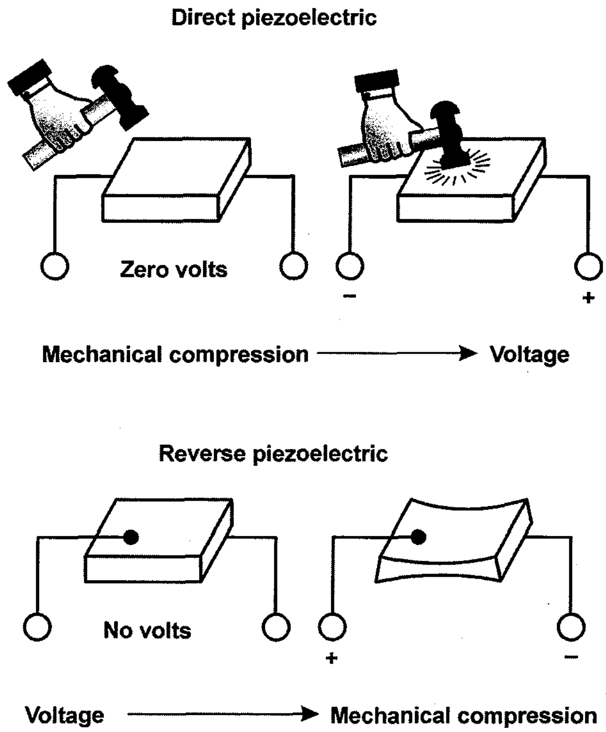

Fig. 10.3 *The direct and indirect (reverse) piezoelectric effects*

The reverse piezoelectric effect is the contraction or expansion of a crystal in response to a voltage applied across its face. A change in the polarity of the applied voltage cause a contracted crystal to expand, and vice versa. An alternating voltage makes the crystal vibrate at the frequency of the electrical oscillation. In this manner, a piezoelectric crystal can be used to generate ultrasound at any desired frequency.

TYPES OF WAVES

Sound waves are classified as longitudinal or transverse, according to the direction of motion of the molecules of the medium through which they travel. A longitudinal wave is one in which the direction of motion of the molecules is parallel to the direction of wave propagation in a transverse wave. The direction of molecular motion is perpendicular to the direction of wave propagation.

Because gases and liquids are not able to sustain transverse vibrations, transverse sound waves do not occur in these substances. In solids, both longitudinal and transverse waves occur. With the exception of compact bone, the tissues of the body behave acoustically as though they were liquids and support only longitudinal waves. Within the body, therefore, transverse waves are found only in bone.

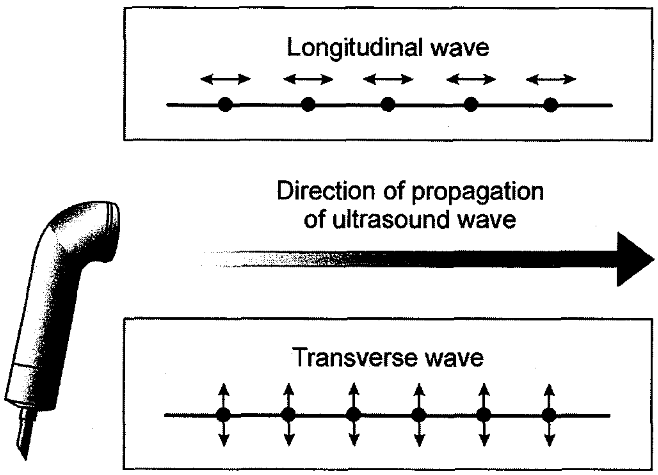

Fig. 10.4

Sound waves can be produced as continuous wave or pulsed wave. A continuous wave is one in which the sound intensity remains constant whereas a pulsed wave is intermittently interrupted. Pulsed waves are further characterized by specifying what fraction of time the sound is present over one pulse period. This fraction is called the duty cycle and is calculated using the following equation:

$$\text{Duty Cycle} = \frac{\text{Duration of pulse (time on)}}{\text{Pulse period (time on + time off)}}$$

ULTRASOUND MODES

Ultrasound may be used in a continuous mode where the treatment head continuously produces ultrasonic energy, or pulsed where the period of ultrasound are separated by period of silence.

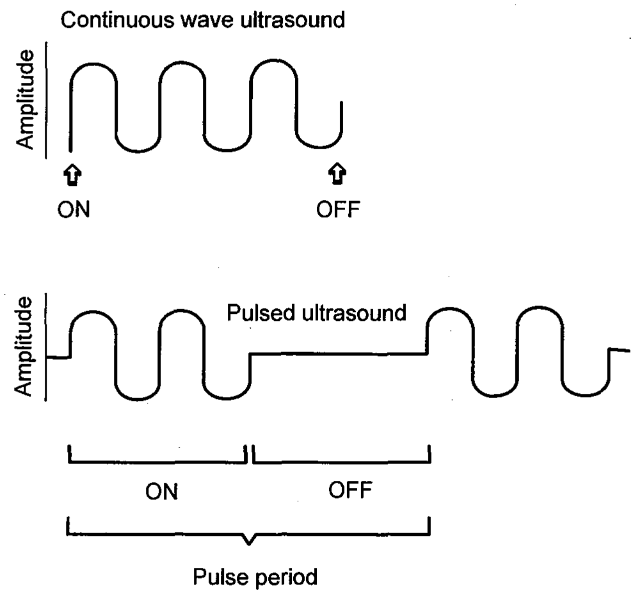

Fig. 10.5 *Continuous wave and pulsed wave ultrasound*

PARAMETERS

Intensity

The intensity of the ultrasound should be pre-determined, based on both the condition of the patient (acute, sub-acute, chronic) and the thickness of the body part to be treated.

The following guidelines are suggested:

- **Acute condition (thin skin):** Such as forearm or ankle, 0.5 to 1.0 w/cm^2 (watts per square centimetre).
- **Acute condition (thick skin):** Such as the thigh or buttocks, 1.0 to 1.5 w/cm^2.
- **Chronic condition (thin skin):** 1.0 to 1.5 w/cm^2.
- **Chronic condition (thick skin):** 1.5 to 2.0 w/cm^2.

When ultrasound is applied using an underwater technique, it is suggested that approximately 0.5 w/cm^2 be added to the above parameters.

ULTRASOUND DOSE RANGE

Low intensity	0.1 to 0.8 w/cm^2
Medium intensity	0.8 to 1.5 w/cm^2
High intensity	1.5 to 3.0 w/cm^2

TREATMENT TIME

The amount of time that is required for the application of therapeutic ultrasound has a great deal of variation.

By convention, many therapists use time of 10 to 15 minutes. It is generally agreed, however, that much of the benefit derived from the application of this modality occurs in the first few minutes and, although not harmful, applications in excess of 7 or 8 minutes probably are unnecessary.

The following guidelines are suggested as reasonable parameters:

- Acute condition — 4 to 6 minutes
- Chronic condition — 6 to 8 minutes.

NOTE: It is suggested that the applications of 0.5 to 1.0 w/cm^2 and 2 to 3 minutes may be adequate for many conditions and that greater intensities or longer treatment times are unnecessary.

DIFFERENT KINDS OF ENERGY AND THEIR PHYSIOLOGICAL EFFECTS

Physical therapy units differ in their energy source, energy absorption, depth of penetration, and physiological effect on the living body.

These relationships are outlined below:

COUPLING MEDIUM

To make a firm contact between skin of patient and transducer, jelly or olive oil, or liquid paraffin is used.

These are called coupling medium or coupling agents.

A coupling medium should have following properties:

1. Gel like viscosity for the ease of use
2. Non-allergic
3. Chemically inert
4. Transparent
5. Inexpensive.

PENETRATION

Ultrasound waves are generally thought to penetrate as deep as 4 to 6 cm into the tissues.

The tissues, with a high fluid content such as blood and muscle, transmit sound waves much better than less hydrated tissues.

The energy is best absorbed in tissues that are highly organized, particularly the ligaments and tendons, which make the ultrasound very beneficial in treating injuries to these areas.

Type of energy	Biological effect	Clinical effect	Depth of penetration	Handling ease
Ultrasonic	Thermal (joule heat) Promotion of metabolism Sound pressure Stimulation of nerve fibres	Healing+ analgesic effect	Deep	Complicated
Microwave (pulsed mode)	Thermal (joule heat) Promotion of metabolism Stimulation of nerve fibres	Healing+ analgesic effect	Shallow	Simple
Microwave (continuous) Shortwave (continuous)	Thermal (joule heat) Promotion of metabolism Thermal (molecular vibration)	Healing	Shallow Deep	Simple
Electric current (interference, low-frequency, microampere, etc.) Laser	Stimulation: Stimulation of nerve fibres (Excitation)	Analgesic effect	Shallow	Complicated

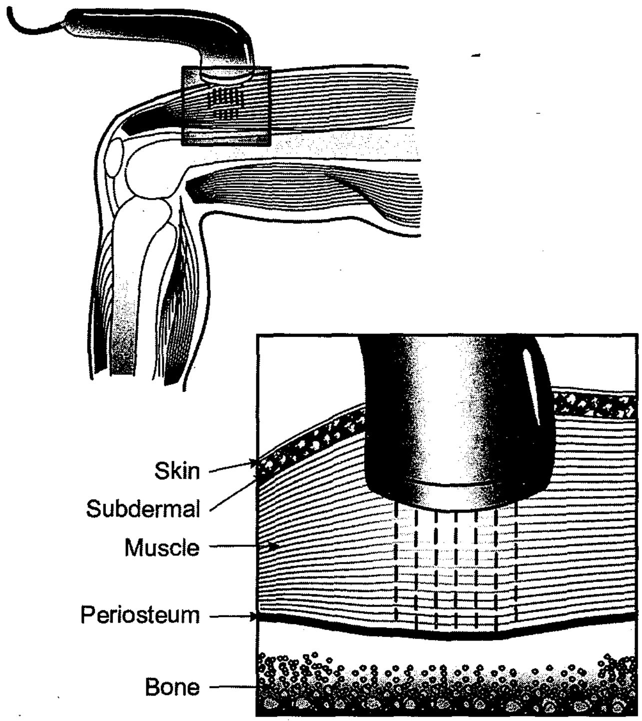

Fig. 10.6 *Ultrasound wave penetration is beneficial in treating injuries to the deeper tissues*

PHYSIOLOGICAL EFFECTS OF ULTRASOUND THERAPY

Therapeutic ultrasound is generally considered to be a form of deep heat. As such, the reaction of tissue to sonation is similar to that for any other form of deep-heating modality.
These effects include:

- An increase in tissue temperature and in local metabolism.
- Softening of tissues.
- An increase in local circulation.

However, in addition to its known heating effects, ultrasound also produces several non-thermal effects, such as:

1. **Chemical reactions:** Ultrasound vibrations stimulate the rate of chemical activity in the tissues, much like shaking a test tube in a laboratory.
2. **Biological reactions:** Ultrasound alters the permeability of the cell membrane, thereby enhancing the transfer of fluids and nutrients to the cells.
   There is some evidence that ultrasound may increase the rate of healing of certain injuries, which, it is postulated, may occur through this biologic response.
3. **Mechanical reactions:** The high-frequency vibration of ultrasound deforms the molecular structure of the tissues. If the intensity of the sound waves is great enough, the tissues may actually be irreparably damaged, a process known as cavitation. Therapeutically, this reaction is useful for its sclerolytic effects.
   Ultrasound has been shown to reduce spasm, to increase range of motion that has been lessened by adhesions and fibrosis, and to break up calcific deposits. It has also been shown to increase the extensibility of tendons.
4. **Acoustic streaming:** It is a unidirectional movement in the tissues that pulsed ultrasound produces, which is particularly marked at the boundaries of the cells & organelles.

It has been observed that streaming induces changes in diffusion rates and in membrane permeability, both of which could alter the rates of protein synthesis & affect tissue repair.

CAVITATION

When ultrasound is applied on the body after 30 to 60 seconds, small bubbles are formed inside the tissue due to the vibration, this phenomena is called cavitation. These bubbles are about one micron in diameter.

The cavitation is of two types:

- Stable
- Transient

1. **Stable cavitation:** It is of therapeutic importance. When the cavitation occurs and the bubbles formed oscillate forward & backward but they are still intact to each other, it is called stable cavitation.
2. **Transient cavitation:** When the cavitation results into the formation of bubbles of the increasing diameter, which after few seconds implode and damaging to the tissue, it is called transient cavitation, which generally occurs at high intensity.

METHOD OF APPLICATION

1. The area to be treated should be free from any cut, wound, rashes or any skin disease. If so, ultrasound treatment will not be given on this area.

2. Clean the skin by tissue paper or cotton, preferably wet cotton.
3. The patient is positioned in such a way so that the application area is well visualised and patient can sit or lay down still during the treatment. The patient should be in a comfortable position.
4. Bring the machine near the patient's bed or chair.
5. In easy language, brief the patient about the treatment and what you are going to do by the machine. Technical and medical terms should be avoided while briefing.
6. Good quantity of coupling medium should be placed on the application area.
7. Activate the machine and set timer and intensity after keeping the transducer on the skin of patient.
8. Ultrasound are being delivered into tissue now keeping the head of transducer at 90° to the patient's skin and make small circular movement throughout the treatment. The most painful area should be focused.
9. The head should be in well contact with skin and sufficient quantity of coupling medium should be there.
   If more coupling medium is needed, turn OFF the machine and then pour the coupling medium, and then turn ON the machine.

INDICATIONS

1. Most acute or chronic musculoskeletal conditions, such as
   - Myositis
   - Fibrositis
   - Capsulitis
   - Bursitis
   - Tendinitis
   - Tenosynovitis
   - Sprains & strains
2. Myofascial trigger points
3. Muscle spasms
4. Carpal tunnel syndrome
5. Neuralgia
6. Neuromas
7. Calcific deposits
8. Scar tissue
9. Chronic indurated oedema
10. Osteoarthritis
11. Radiculitis
12. Joint contractures.

Ultrasound energy is the only type of diathermy, which can be used with metal implants in the treatment field.

CONTRA-INDICATIONS

1. Infection
2. Peripheral vascular disorders; such as thrombophelibitis.
3. Peripheral neuropathies
4. Malignancies
5. In actively haemorrhaged contusion
6. Recent grafts
7. Over metal implants
8. Fertile epiphysis of children
9. Directly at abdomen of pregnant ladies, as it may lead to deafness of foetus
10. For patients on blood thinning medication
11. Near a pacemaker
12. Tuberculosis of bone
13. Over nerve plexuses
14. Over the eyes, heart, reproductive organs, or brain
15. Reproductive organs or abdominal organs.

PRECAUTIONS

1. Transducer should be continually moved in circular fashion to prevent accumulation of waves at one site which may cause burns if applied for longer period.
2. There should be no gap between transducer head and skin. Use good amount of coupling medium.
3. When applying coupling medium in the middle of treatment, turn OFF the machine.
4. Transducer should be kept perpendicular to the skin.
5. Don't apply ultrasound on the shoulder of the patient with pacemaker implanted.
6. Avoid using ultrasound over the carotid bodies or the anterior portion of the neck.
7. Avoid using ultrasound where the internal fixtures are present for orthopedic purpose.
8. Avoid using ultrasound directly on the abdomen in the pregnant ladies.
9. Don't use ultrasound on the abdomen of females with metallic intra-uterine contraceptive devices, like copper-T etc.
10. Avoid using ultrasound over the nerve plexuses or superficial nerves, such as the ulnar nerve.

TECHNIQUES OF APPLICATION

Direct Contact

On a regular skin surface, a coupling medium is applied to eliminate air between skin and the transducer and transmit the ultrasound beam to the tissues. The transducer head is moved in small concentric circles over the skin, keeping the metal front plate in full contact with the surface. This is suitable for areas nearly there times the size of the transducer head. The machine is turned on and off while in contact with the patient.

Direct contact method based on 3 different techniques:

- Small concentric circles
- Parallel method
- Figure of '8' method.

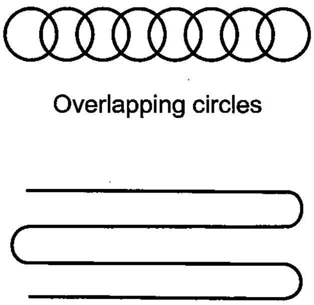

Fig. 10.7

Underwater Bath

A water bath is filled with de-gassed water if possible. Ordinary water presents a problem that gas bubbles dissociate out from water. These bubbles accumulate on the skin and transducer head, and so reflect the ultrasound beam. Then these bubbles must be wiped from these surfaces regularly.

The transducer head is held one cm from the skin and moved in concentric circles, keeping the front plate parallel to the skin to minimize reflection.

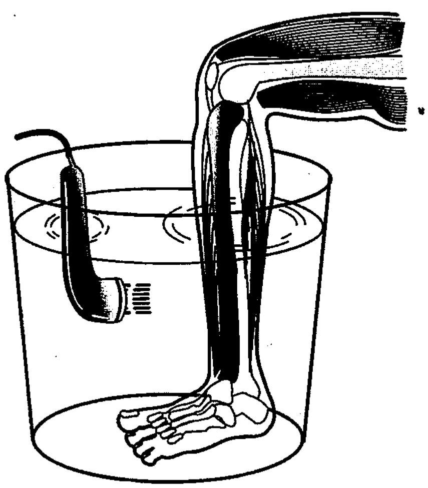

Fig. 10.8 *Underwater ultrasound technique*

Water Bag

On irregular bony surfaces, a rubber bag filled with de-gassed water is used. A coupling medium is placed between rubber bag and the skin, and between rubber bag and transducer head. The treatment head is moved over this rubber bag. The only disadvantage is of attenuation of ultrasound, as it has to cross many interfaces.

This method also can also be used in grade '4' type tenderness when patient does not allow touching the part by the direct method of application of ultrasound.

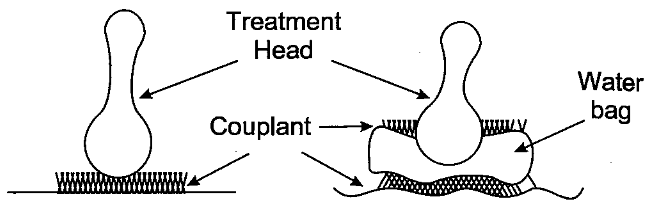

Fig. 10.9 *Water bag technique*

Combined Ultrasound Electrical Stimulation

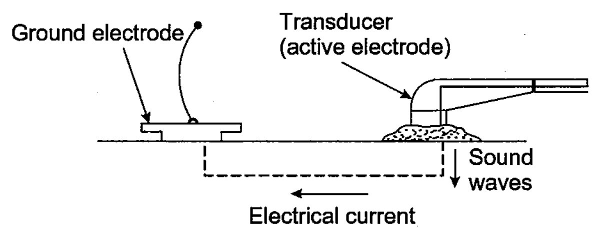

Fig. 10.10 *Ultrasound often is used in combination with electrical stimulation*

One of the more frequently used and useful modifications of therapeutic ultrasound involves combining it with electrical stimulation. This is accomplished by simultaneously directing both sound waves and electrical current through the transducer head. In addition to emitting acoustic energy, the sound head becomes the active electrode in an electrical stimulator.

The combined effect of these two modalities allows the therapist to warm the deeper tissues, to improve cellular transport mechanisms, to soften connective tissues, and generally to improve circulation with the ultrasound. At the same time, the electrical stimulation reduces pain by closing the pain gate and it improves muscle tone, function, and circulation by producing muscle contraction. This has dramatic effect on many chronic conditions such as myofascial trigger points and has the added advantage of significant patient awareness.

Application Technique of Combined Ultrasound Electrical Stimulation

During the course of the ultrasound application, the therapist should keep the sound head in firm contact with the patient. Failure to do so can damage the crystal and shorten the life of the transducer. The sound head should be continually moved slowly over the target tissue in overlapping concentric circles or longitudinal strokes during the course of treatment. It should not be allowed to remain in one place, as this may focus the energy in a small area and increase the risk of periosteal burns.

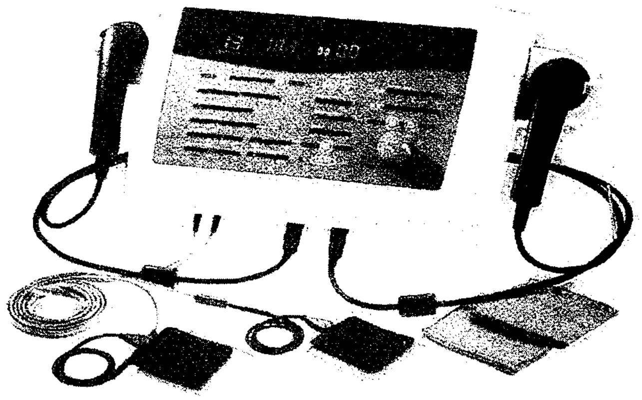

Fig. 10.11 *Combination of ultrasound electric stimulation equipments*

TREATMENT TABLE

Affections treated by ultrasonics	Power W/Sq. cm	Pulsed or continuous treatment	Treatment time (Min)	Efficiency
Post herpes pain (Except Ophthalmic)	1.5–2	Continuous	5–6	Good
Neurinoma	1.5	Continuous	5–6	Excellent
Causalgia	2	Pulsed	5–8	Good
Talalgia	2	Continuous	10	Very good
Reflex algodystrophia	2.5	Continuous	3–6	Good
Amputation pain	1.5–2	Pulsed	5–8	Very Good
Lumbago	2	Continuous	10	Good
Circulation problems	1	Continuous	3–6	Good
Dysmenorrhea (before periods)	1.5	Pulsed	4–5	Average
Neuralgia (except facial)	1.8	Pulsed or Continuous	10	Average
Arthrosis of minor joints	2–2.5	Continuous	10	Very Good
Vertebral arthrosis	2–2.5	Continuous	6–10	Good
Sacro-iliac arthrosis	2	Continuous	10	Good
Radial epicondylitis/styloiditis	1	Continuous	5–8	Very Good
Teno-synovitis/tendinitis/bursitis	1–1.5	Continuous	5–8	Very Good
Osseous/mascara	2–2.5	Continuous	7–8	Very Good
Dupuytren's disease	1.5	Continuous	10	Good
Ledderhose disease	2.5	Continuous	5–6	Average
Scars	1.5	Continuous	5–6	Good
Atonic wound	1–1.5	Continuous	5–6	Good
Varicose ulcers	0.5–1	Continuous	10	Good
Pulmonary infections (asthma)	5–1	Continuous or pulsed	5–10	Good
Plantar verrucas	0.5–1.5	Continuous	15	Good
Arteritis of lower limbs	0.5	Continuous	2–3	Average
Meniere's vertigo (buzzing in the ears)	0.5–1	Pulsed	3–4	Good
Gallstones	1	Pulsed	7–10	Average
Cellulitis	0.5–1	Continuous	10–15	Good

Clinical Application: As stated, it is helpful to explain the treatment to the patient prior to any application. Although patients do not feel ultrasound, they do feel a tingling sensation or "pins and needles" that result from the electrical current. In addition, if the intensity of the electrical stimulation is adequate, they will experience muscle twitching. Some patients respond better to ultrasound when they "feel" some sensation.

Note: Some patients, who have been treated previously with this combination of ultrasound and electrical stimulation, and who were not adequately informed about the effects of the modalities, may associate the tingling sensation with the ultrasound.

Patient Preparation: The patient should be prepared as for the application of therapeutic ultrasound described above. In addition, the application of electrical stimulation requires the use of at least two electrodes. As previously described, the transducer head of the ultrasound becomes the active electrode of the electrical stimulating device. A second electrode, the dispersive or ground electrode, must also be connected to the patient. This second electrode often consists of a large 8x10 inch pad, but smaller pads may be more convenient to use. The dispersive electrode should be placed on the patient in some convenient location, such as the lower back or under the thigh. Some type of moist barrier, either a moistened sponge or an electrical gel must be placed between the electrode and the skin.

METHOD OF APPLYING ULTRASOUND IN SPECIFIC CONDITIONS

Fig. 10.12 *Ultrasound applied to the insertion of the supraspinatus tendon. Position of the arm in internal rotation*

Fig. 10.13 *Ultrasound applied to the anterior aspect of the shoulder for treatment of adhesive capsulitis*

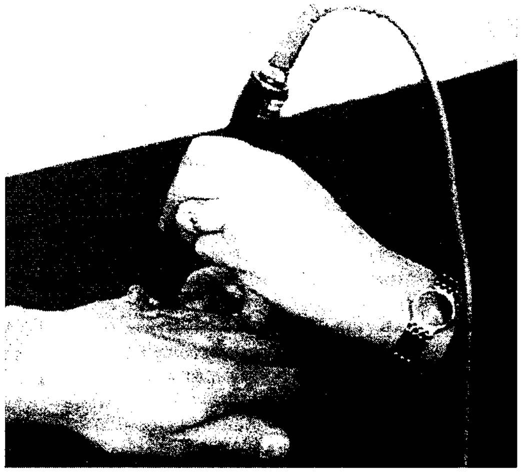

Fig. 10.14 *Ultrasound applied to the dorsum of the hand over the metacarpophalangeal joints of digits 4 and 5*

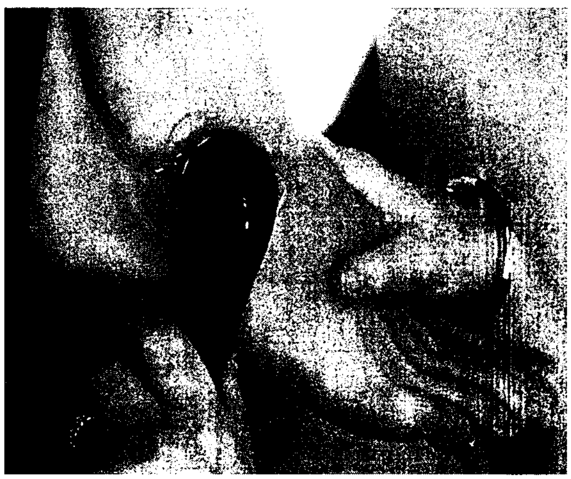

Fig. 10.15 *Ultrasound applied to the lateral ankle with a direct coupling technique*

Fig. 10.16 *Ultrasound administered for adhesive capsulitis of the shoulder*

Fig. 10.17 *Ultrasound with or without phonophoresis for chronic osteoarthritis of knee*

Fig. 10.18 *Ultrasound focused on the medial calcaneal tubercle and medial longitudinal arch in the management of plantar fasciitis*

Fig. 10.19 *Ultrasound applied to abdominal surgical scars*

Fig. 10.20 *Ultrasound applied to temporomandibular joint*

CHAPTER 11

PHONOPHORESIS

- Introduction
- Method of Treatment
- Indications
- Contra-indications
- Precautions

INTRODUCTION

The introduction of substances into the body by ultrasonic energy is called **phonophoresis**. This non-invasive procedure has been improperly compared with iontophoresis. Iontophoresis involves the transfer of ions into the tissues, whereas phonophoresis transmits molecules—a different process, although based on a similar concept.

Molecules introduced into the target must be broken into component elements and radicals by natural chemical processes and recombined with existing bloodstream radicals.

METHOD OF TREATMENT

Fig. 11.1 *Ultrasound used with zinc oxide phonophoresis over an open lesion*

Fig. 11.2 *Phonophoresis with iodine to the lipoma*

The technique for phonophoresis is the same as that for standard ultrasound administration. The ointments massaged into the target area prior to sounding differ, however (Fig. 11.1). Solutions are not used for phonophoresis. The dissipation of the substances in solutions minimizes molecular transfer, as does the reduction of the soundwave energy when it enters the water.

Molecular Substances

The selection of molecular substances depends on the requirements of the condition—not the disease by name, but the physiologic need of the patient. Chemicals available for phonophoresis are listed below:

Hydrocortisone

1. An excellent anti-inflammatory agent, hydrocortisone also provides analgesia in many instances.
2. Hydrocortisone is available over the counter as a 1 percent ointment.
3. Some practitioners prefer the 10 percent ointment.

Mecholyl

1. Mecholyl can be obtained as an ointment with 0.025 percent methacholine and 10 percent salicylate in a suitable base for either iontophoresis or phonophoresis.
2. Mecholyl is an effective vasodilator and is recommended in vascular conditions, neurovascular deficits, and as a mild analgesic.

Lidocaine

1. Lidocaine is available as a 5 percent ointment.
2. Lidocaine is used primarily as an analgesic/anesthetic is acute conditions or when decreased sensitivity is desired.

Iodine

1. Available in ointment form, iodine is combined with methyl salicylate as an over the counter product at local pharmacies. *E.g.*: 4.8 percent methyl salicylate, with 4.7 percent iodine in a petroleum base.
2. Iodine is used as a vasodilating agent, an anti-inflammatory agent, and as a sclerolytic agent in cases involving scar tissue, adhesions, calcific deposits, and adhesive joints (*e.g.*, frozen shoulder).

Salicylate

1. Salicylate is available as a 10 percent ointment over the counter.

2. A basic anti-inflammatory agent, salicylate is also used as a decongestant, as is chemically related aspirin.

Zinc

1. Zinc is available over the counter as a 20 percent zinc oxide ointment.
2. Zinc is a trace element noted for contributing to the healing process.
3. Zinc is indicated in the treatment of open wounds and lesions.

Mecholyl, Lidocaine, Iodine and Salicylate do not transmit the ultrasound wave readily. It is highly recommended that these ointments be massaged onto the target tissue thoroughly before applying transmission gel and sounding.

INDICATIONS

1. Bursitis
2. Tendinitis
3. Sprain and strain
4. Pain
5. Inflammatory conditions.

CONTRA-INDICATIONS

Skin and systemic reactions with phonophoresis are rare, but practitioners must be aware of the possibilities and be prepared with antidotes, should any of the chemicals listed above present unfavorable reactions in individuals. Keep in mind that allergies and sensitivities to the substance contra-indicate its use on the skin as well. For example:

1. Those patients who cannot eat sea food should not be treated with iodine. Should skin irritation and itching be reported, the usual antidote is an antihistamine. An alternative chemical should be selected in future treatments.
2. Those patients sensitive to metals should not be treated with zinc. These patients usually cannot wear metallic watchbands, jewellery, etc., without having skin and, at times, systemic reactions. Dermatologic consultation should be sought for specific antidotes for the offending metals. Non-metallic substances should be substituted.
3. If a patient has a reaction to mecholyl with vasomotor shifting, administer a simple stimulant, such as black coffee. Vertigo from orthostatic adjustment is usually momentary.
4. Reactions to hydrocortisone are not as common.
5. Do not treat patients who are sensitive to aspirin with salicylates. Seek medical consultation for the specific treatment of symptoms.

PRECAUTIONS

- Check the patient for sensitivity or allergies to the agents used.
- Keep the sound head moving continuously on the skin throughout the treatment or burning may occur through overheating of tissue.
- Maintain uniform contact between the ultrasound head and the area being treated, or burns may occur.
- When the unit is on, do not hold the sound head in the air or break treatment contact, as this could damage the sound head crystal.
- A complaint of sharp pain by the patient indicates the intensity needs to be reduced, more coupling medium needs to be added, and/or move the sound head a little faster.
- Do not treat over bony prominences to eliminate the possibility of concentrated energy causing localized heating.
- Do not treat over or near the heart.

SECTION IV

- Electric Current
- Faradic Current
- Galvanic Current
- Iontophoresis
- Electromyography and Biofeedback
- Electro Diagnosis
- TENS
- HVPC (High Voltage Pulsed Current)

CHAPTER

12

ELECTRIC CURRENT

INTRODUCTION

Electricity is defined as one of the fundamental forms of energy. Electric current consists of the flow of electrons along some type of conducting medium. The electrons, that make up the current, are particles of matter possessing a negative charge. The total amount of electric current is determined by the number of electrons and is measured in Amperes. The currents used in therapeutic electrical stimulators are described in milliampere (mA). Each milliampere is one thousandth of an Ampere.

TYPE OF ELECTRIC CURRENTS

Although there are a number of ways to classify electric current, there are only two principal types of current:

Direct Current (DC)

Electric current that flows in one direction for about 1 sec or longer can be defined as direct current (DC). A direct current that flows unidirectionally for less than 1 sec, especially a few milliseconds or less, is no longer a DC current but rather a pulsed or AC current.

The flow of a DC can be modulated for clinical purposes. The three most common modulations are:

1. Reversed DC
2. Interrupted DC
3. Surged DC

In reversed DC, the direction of current flow is reversed. Since, by definition, DC should flow for about 1 sec or longer, reversal also occurs after about 1 sec or longer. Reversal of the current can be accomplished by using a hand switch or an automatic switch inside the unit. Continuous DC and reversed DC are illustrated in Figure 12.1.

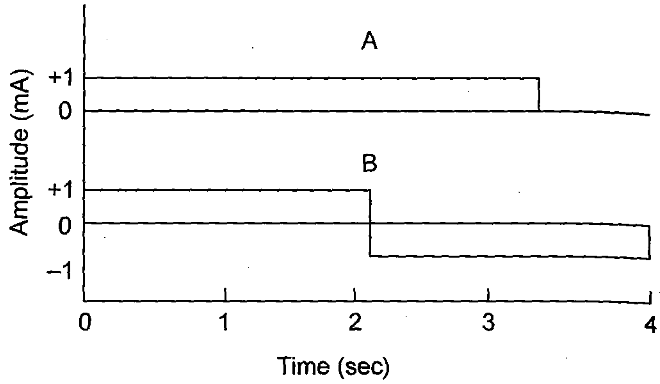

Fig. 12.1 *Direct current (DC): (a) Continuous DC, (b) Reversed DC*

Interruption of current flow occurs when the current ceases to flow for about 1 sec or longer, usually up to 50 to 60 sec, and then flow again for about 1 sec or longer. Interruption is usually accomplished by a switch on the hand probe or by an automatic switch inside the stimulator. The most common classical purpose of interrupted DC is to cause twitch contraction of denervated muscles during electrodiagnosis or treatment (TMS). When the switch is closed, an ON current flow prevails. Switching OFF stops current flow. Switching ON and OFF occur abruptly. If one wishes to grade the ON and OFF so that current amplitude will increase and decrease gradually, a modulation termed "ramp" can be added. Classically, ramp-up and ramp-down were termed surge-up and surge-down, respectively. Ramping usually occurs over a period of time lasting from 0.5 sec to several seconds. Interruption without ramp, with ramp, and the combination of interruption coupled with reversed DC and ramp are illustrated in Figure 12.2.

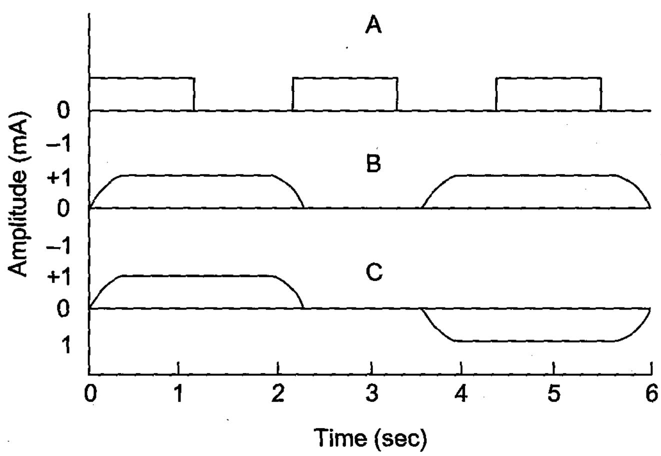

Fig. 12.2 *Direct current modulation: (a) Interrupted DC, (b) Ramped, interrupted DC, (c) Ramped, reversed, interrupted DC*

Ramping takes place inside the stimulator, but the therapist determines the time of ramping by a switch on the unit panel. With modern clinical methods, interrupted DC is only used for treating denervated muscles. In fact, most applications of electrical stimulation over the last decade have been used to treat intact peripheral nerves and mostly pulsed currents and to some extent, alternating current (AC) have been used.

Alternating Current (AC)

Alternating current (AC) is a current that changes the direction of flow, with reference to the zero baseline, at least once every second. Continuous AC indicates no modulation, and no intervals between pulses. The typical AC is symmetrical and can be delivered in various shapes including sinusoidal, rectangular, trapezoidal and triangular. Atypical AC can be non-symmetrical and of various shapes (Fig. 12.3).

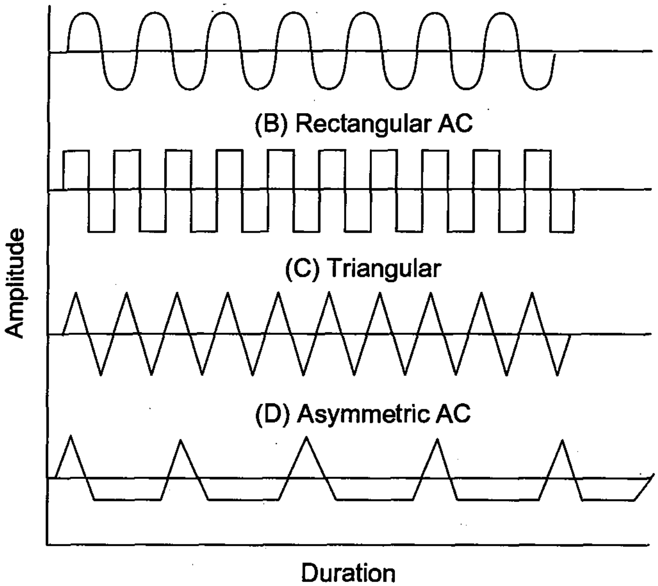

Fig. 12.3 *Different shapes of continuous (non-modulated) alternating current (AC)*

Typical to AC are the inverse relations between frequency, pulse and phase durations. Inherent in this relationship is the phenomenon that as the frequency of AC is increased, phase and pulse durations are automatically decreased. The opposite occurs if the pulse frequency decreases (Fig. 12.4). It follows that phase and pulse duration can be calculated as the reciprocal of frequency.

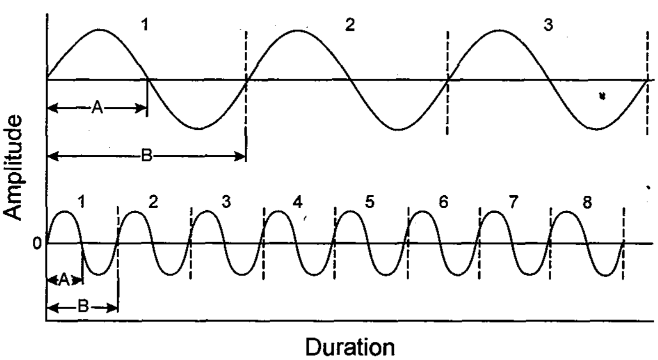

Fig. 12.4 *Frequency-pulse end-phase duration relationships of continuous sine waves. (a) Phase duration. (b) Pulse duration. Note how phase and pulse are shortened as frequency increases*

The most common use in continuous unmodulated AC is of a 60,000 Hz sine wave with a 5 to 10 volts peak-to-peak (P-P) amplitude. Such AC is not designed to excite peripheral nerves and is aimed at promoting soft and osseous tissue regeneration.

PHYSIOLOGIC RESPONSE

The application of electricity to the body involves a variety of physiologic responses. These effects can be summarized in three basic areas:

Thermal Effects

The movement of an electric current through a conductive medium produces a vibration of molecules. This vibration produces friction that leads to an increase in temperature. Added to this vibration is natural skin impedance, which also leads to the production of heat. Although the thermal effects are minimal with most therapeutic currents, they must be taken into consideration. Strong polarizing currents, such as galvanic, may cause serious burns if not used cautiously.

Chemical Effects

Electric current produces the formation of new chemical compounds. The reaction to electrical current varies with the polarity of the electrode and, with some currents (*e.g.*, galvanic), this reaction can be significant. The production of potassium and sodium hydroxide under the electrodes of a galvanic current may lead to serious skin burns.

Physical Effects

In the clinical setting, electric current typically is used for its physical effects. These physical effects can be divided into two areas:

Excitatory Effects: The most common application of electrical stimulation involves the effects that such currents have on the excitable tissues, particularly the peripheral nerve fibres. When an adequate stimulus (*i.e.*, a current that has sufficient intensity and duration) is applied to the tissues, the nerve is depolarized and an action potential is elicited (Figure 12.5). The resulting depolarization leads to sensory and motor responses that have predictable clinical uses. In fact, the vast majority of clinical applications involve the depolarization of sensory and motor nerves. Under certain circumstances, muscle fibres themselves may be excited by the electrical current. It should also be noted that the autonomic nerves are also affected by electrical current. This has effects on the body in ways that are not as well understood or as often utilized therapeutically.

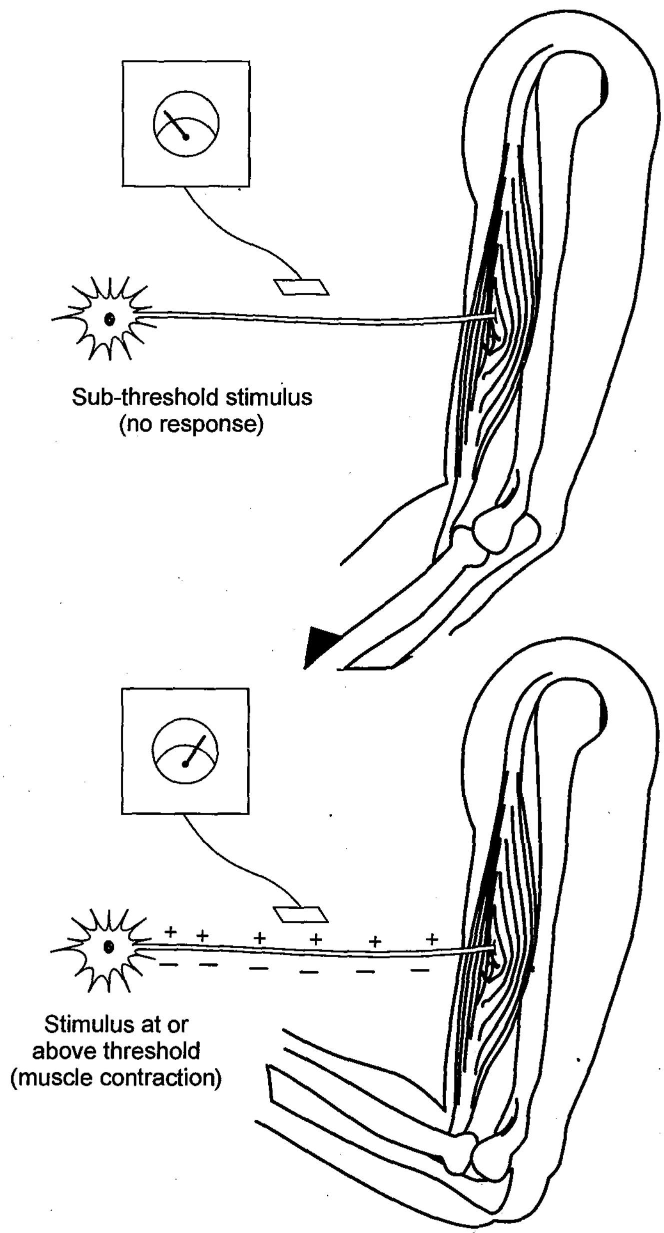

Fig. 12.5 *Depolarization of nerves occurs when an adequate stimulus is applied to the tissues*

Non-excitatory Effects: As the electrical current passes through the body, an alteration in physiologic processes is seen. This alteration differs from tissue to tissue. Although all tissues are affected by the current, not all are excited. The effects, however, may be seen at several different levels – cellular, tissue, segmental, and systemic. These effects can be direct (*e.g.*, changes of cell membrane permeability) or indirect (*e.g.*, changes in blood flow). There is some evidence that electrical current may promote protein synthesis and stimulate tissue growth and repair. For example, electrical stimulation is often used to stimulate bone growth following spinal surgery. In addition, electrical stimulation is thought to affect both the ion-sensitive and voltage-sensitive channels in the cell membrane, thus enhancing intracellular transport mechanisms.

PULSED CURRENTS – PULSE PARAMETERS

Electricity is a form of electromagnetic energy. Most electrical currents consist of a series of pulsations or pulses. With the exception of the true galvanic form of current, all of the electrical stimulators currently in use utilize a pulsed or pulsatile form of current. By altering the various parameters of the pulse, a number of different physiologic responses can be invoked. It is possible to modify the following parameters:

- Shape of the pulse
- Intensity of the pulse
- Frequency of the pulse
- Duration or width of the pulse
- Mode of delivery of the current
- Polarity
- Pulse charge.

For effective administration, it is necessary to understand the effect each of these pulse parameters may have.

PULSE SHAPE

Each pulse of current has a particular shape or **waveform**. There are some unique waveforms that are used with specific types of electrical stimulators. For example, a high voltage generator uses a double spike waveform that has a twin peak, whereas an interferential stimulator uses a combination of sinusoidal waveforms. Great emphasis is often placed on the unique characteristics of particular pulse shapes. Although the manufacturers of electrical stimulation devices sometimes claim that a particular stimulator is unique and different because of the dynamics of the pulse shape, from a practical point of view the pulse shape is probably the least important parameter.

The pulse shape is important when considering patient comfort. Pulses with a gradual slope, such as the sinusoidal pulse, are more comfortable than those with abrupt rises in current as seen with the square or rectangular wave. In addition, there may be instances when pulse shape is important from a physiologic perspective. The manufacturers of microcurrent stimulation devices claim that pulse shape is crucial at the cellular level; however, many of these claims have yet to be substantiated.

The pulse shape (Fig. 12.6) may be varied in any of the following ways:

- Sine wave (sinusoidal)
- Square wave
- Twin-peaked wave
- Asymmetric wave.

PULSE INTENSITY

Intensity is a measure of the amount of electrical current available. Intensity is also called "amplitude" or "output" and is measured in milliamperes (mA). Some of the newer electrical stimulation devices utilize a microamperage that is incapable of eliciting a neurologic response. These device are thought to function by stimulating the cell membrane rather than the peripheral nerve.

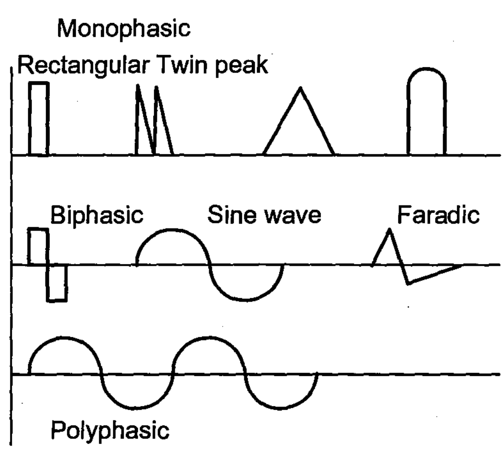

Fig. 12.6 *Electrical stimulation devices utilize a wide range of pulse shapes*

Regardless of the type of electrical stimulation device used, as the intensity of the current is raised, the body responds in a predictable manner as follows:

- At a level below 1 mA, there is not enough current to depolarize the nerve fibres and elicit any form of neurologic response. However, there does appear to be some evidence that such a sub-threshold stimulus can produce a physiologic response. It is theorized that these low amplitude microcurrents affect the cell membrane permeability and may also affect cellular activity and growth. These small sub-threshold currents are used by the microcurrent stimulators (microamperage stimulation devices [MAS]). Although many questions remain about the effectiveness of these devices, microamperage stimulation may be one of the most promising areas for future research in applying electrical stimulation.
- As the current intensity is increased, the threshold for depolarization of the large superficial sensory nerves is reached. This is perceived as a fine, tingling sensation by the patient that is similar to "pins and needles." It is referred to as a "sensory level stimulus" (SLS). This stimulation level is used for many pain control techniques, such as the classic TENS that target the superficial sensory nerves.
- As the current intensity is increased further, a stronger sensory stimulus is achieved. When the current reaches sufficient intensity to overcome the threshold of the motor nerves, these nerves also respond and a muscle contraction is experienced. This is referred to as a "motor level stimulus" (MLS). It should be emphasized that this motor level response does not replace any sensory effect that is achieved by stimulating the sensory nerves. Rather, it is a second response that is added to the first. The greater the amount of current at a motor level, the stronger the muscle contraction will become.
- Eventually, as the current intensity increases even further, the smaller, deeper C-fibres are stimulated. At this point the patient will experience a burning or aching type of pain that is referred to as a "noxious level stimulus" (NLS) or a tolerable pain. This uncomfortable stimulation level is used in several pain control techniques that may be helpful for chronic or resistant pain when other, less invasive methods have failed.
- Further increase in current intensity lead to an "intolerable pain" and eventually to tissue damage and necrosis.

METHOD (MODE)

The mode or method of delivery of current is one of the important parameters to be considered (Fig. 12.7). Altering the mode enables the doctor to accomplish a variety of different therapeutic objectives. The current can be delivered in the following ways: (1) a continuous current is delivered in a steady, uninterrupted manner for the duration of the treatment (continuous currents are used for many pain control techniques, for decreasing edema, and to fatigue or relax tight muscles), and (2) an interrupted current is repeatedly turned ON and OFF at pre-determined intervals throughout the course of the treatment. This interrupted current is sometimes referred to as a "surged" or a "pulsed" current. Two separate interrupted currents can be combined by connecting electrodes to antagonist muscles and alternating the ON and OFF cycles between the two currents. This is referred to as an "alternating" or "reciprocating" mode. These interrupted modes of delivering current are useful in creating intermittent muscle contractions to reduce edema, increase range of motion, and so forth. They may also help to reduce patient accommodation or adaptation to treatment.

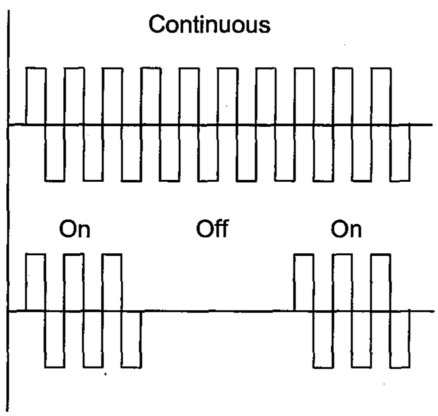

Fig. 12.7 *Current can be delivered either continuously or surged*

The ratio of ON time to OFF time is dependent on the nature of the condition and may be varied as follows:

- During the acute phase of care, the ON : OFF time should be relatively short, with a 1 : 1 ratio (*e.g.*, 5 seconds ON and 5 seconds OFF);
- As treatment progresses to the sub-acute phase, the ON : OFF time should be lengthened but the ratio remains the same 1:1 (*e.g.*, 10 seconds ON and 10 seconds OFF);
- During the later phases of treatment, the OFF time should be lengthened and the ratio of ON : OFF time should be either 1 : 4 or 1 : 5 (*e.g.*, 10 seconds ON and 50 seconds OFF); during the OFF time, the patient may be instructed to actively move or exercise the area being treated.

When an interrupted current is used, the intensity of the current is established at the beginning of the course of treatment. With each current interruption, the current is "ramped" when it comes ON again to allow for a gradual re-establishment of current (Fig. 12.8). This current ramping makes the re-introduction of the interrupted current much more comfortable and tolerable to the patient and prevents any shocking or jolting that might otherwise occur. Many electrical stimulators have a preset current ramp that is automatically activated whenever an interrupted current is used. Some machines allow the clinician to control the ramp (both the rate of rise [ON] and the rate of decline [OFF]). For optimal effectiveness, the amount of time of the current ramp should not exceed one-third of the total ON time of the current.

POLARITY

When tissue is exposed to electric current, the ions in the tissue are aligned or polarized according to the direction of current flow. Under certain circumstances, such as that seen with galvanic current, this polarizing effect may be significant and may account for part or all of the physiologic response (*e.g.*, iontophoresis). However, the pulsed nature of most therapeutic electrical currents reduces the impact of any polarizing effect that might otherwise occur. For all practical purposes, with the exception of the low-voltage galvanic current, the polarity of commonly used pulsatile currents is not significant. The direction of current flow in an alternating current (AC) is continually reversing, so there is no polarizing effect in alternating current stimulators.

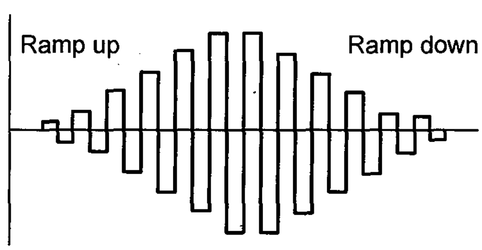

Fig. 12.8 *With each current interruption, the current is ramped when it comes ON again*

Pulse Charge

The pulse charge represents the accumulation of current in the tissues. The pulse charge is represented by the area under the pulse and is measured in microcoulombs. Alternating current has both a positive and a negative phase that effectively eliminates each other; consequently the pulse charge is zero. The pulse charge is perhaps most important when considering the effects electric current has on the non-excitable tissues of the body, such as blood, bone, and cartilage. Pulse charge is related to the width of the pulse in the following way: the wider the pulse width, the greater the pulse charge (Fig. 12.9).

ELECTRODES

Current must be introduced into the body to exert any effect on the tissues. With rare exception, the electrical stimulators used to employ some type of surface electrode that is known as a "transcutaneous" electrode. Because it is the interface between the patient and the machine, the electrode represents one of the most important parts of the electrical stimulation apparatus. Many problems that develop with electrical stimulation, including failure to arrive at the desired effect, can be traced to problems with the electrode.

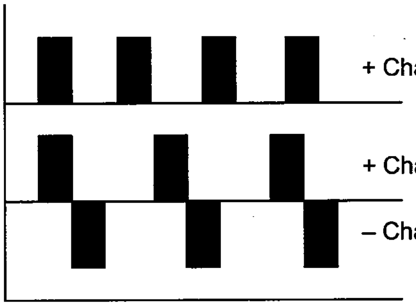

Fig. 12.9 *Pulse charge is a measure of the accumulation of current in the tissues*

Electrode Type

Currently, there are a number of different electrodes that are used in the clinical setting. Each type has certain advantages and disadvantages. Often, the type of electrode used is based more on habit than on any particular rationale. A variety of electrodes, that are commonly used, include:

Carbon-filled Silicone Electrodes (Rubber): These are probably the most commonly found electrodes. They come in a variety of sizes and are usually black and red (Fig. 12.10). These electrodes must have some moist material such as a moistened sponge placed between them and the patient's skin. Some clinicians prefer to use an electrolytic gel or spray on the electrodes. As with other types of electrodes, the rubber electrodes must be held in firm contact with the skin. This is usually accomplished by the use of elastic straps. The advantages of this type of electrode include ease of use, pliability, and availability. Disadvantages include that they tend to get dirty and become less pliable with age, especially when gels or sprays are used as a contact medium. When sponges are used with these electrodes, they should be disinfected between each patient application.

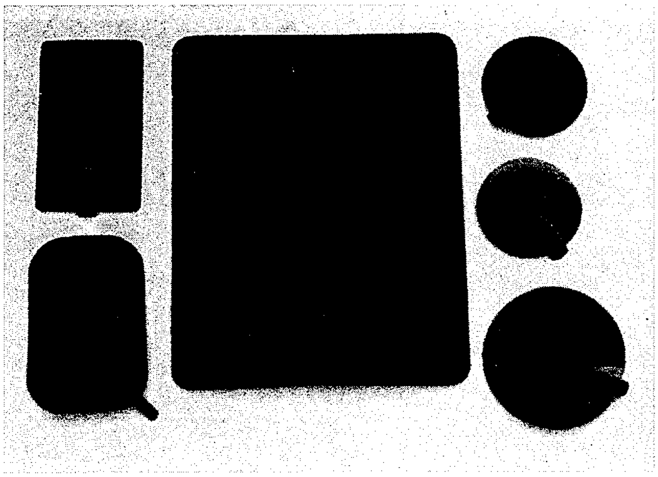

Fig. 12.10 *Carbon-filled silicone electrodes (rubber)*

Metal Electrodes covered by a Moistened Sponge: This type of electrode was commonly used in the past, but less frequently these days. These electrodes may still be found with electrical stimulators provided by some manufacturers (Fig. 12.11). As with rubber electrodes, metal electrodes must be held in place with some type of strap. There are no particular advantages to this type of electrode. Disadvantages are much the same as those for the rubber electrode.

Vacuum Electrodes (usually found with Interferential Current): This type of electrode consists of a rubber cup that is designed to be held in place by a vacuum apparatus. Inside the rubber cup is a metal plate that is covered with a moistened sponge (Fig. 12.12). The lead connecting the electrode to the stimulator consists of a hollow metal ring. When the vacuum apparatus is turned on, the resulting suction holds the electrode in place. These electrodes were designed to maximize the contact between patient and stimulator and to allow good electrode contact in areas, such as the shoulder, that might otherwise be difficult to accomplish. The primary advantage of these electrodes is the ability to apply them in rough or uneven areas of the body. Disadvantages include the creation of a welt under the electrode and the added expense of the vacuum apparatus.

Self-adhesive Electrodes made of Karya Gum (often used with TENS units): One of the more recent innovations in the field of electrical stimulation is the self-adhesive electrode (Fig. 12.13). Although these electrodes have been available for several years, recent improvements have made them an essential part of electrical stimulation. The only disadvantage is that they tend to wear out after repeated use.

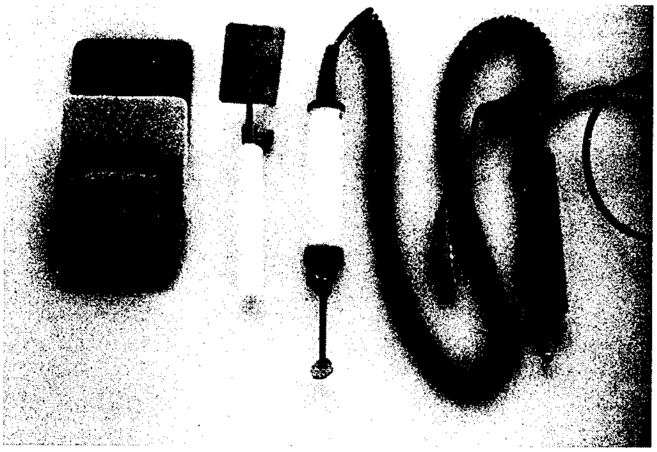

Fig. 12.11 *Metal electrodes covered by a moistened sponge*

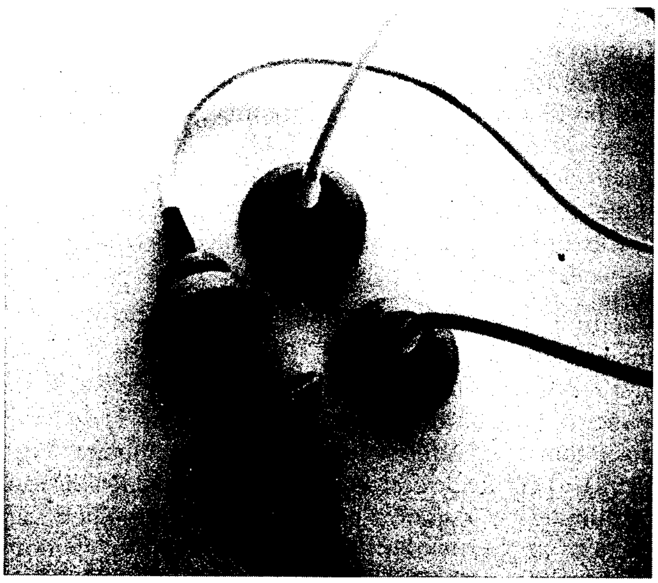

Fig. 12.12 *Vacuum electrodes usually found with interferential current stimulators*

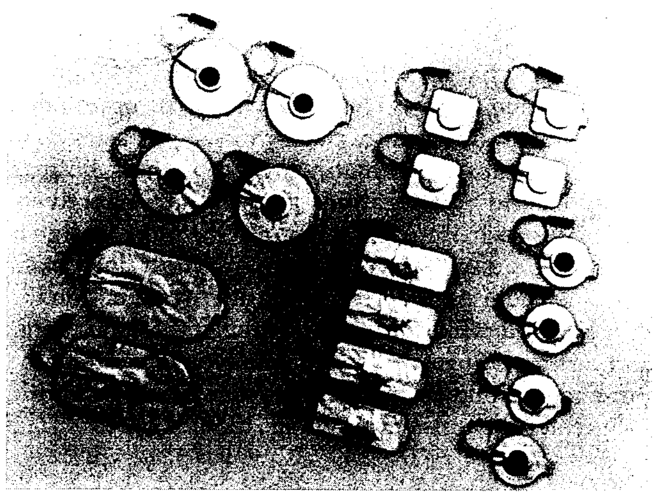

Fig. 12.13 *Self-adhesive electrodes oftenly used with TENS units*

ELECTRICAL PULSE GENERATOR

A pulse generator has four functional parts:

1. A power source; this may be from the mains supply or a battery.
2. An oscillating circuit to provide a train of pulses.
3. A modulating circuit to alter the train of pulses, perhaps splitting it up into short bursts or surging it.
4. An amplifying circuit to increase the output voltage appropriately.

When power is drawn from the mains, it has to be modified. The voltage will have to be reduced to an appropriate level for the subsequent circuits and output. This is done with a transformer and rectified by means of a diode (semiconductor diodes are usually

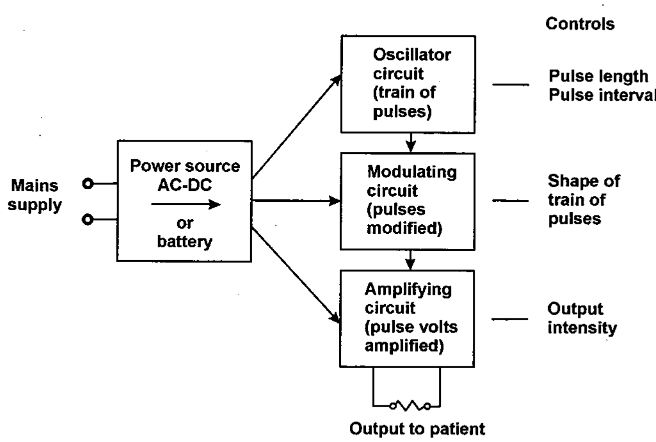

Fig. 12.14 *Diagram to illustrate electrical pulse generators*

used). With a suitable controlling circuit, these could be applied as diadynamic current to a patient. If the voltage-reduced rectified mains current is applied to a 'smoothing' circuit (a capacitor in parallel and a series inductance), it becomes an unvarying direct current and, if regulated with a potential divider, could be applied to a patient.

Modern pulse generators go through the above steps to produce a smooth unidirectional current that can be applied to an oscillator to generate any type of current. For low-intensity TENS currents (used for patient-controlled pain modulation), the smooth DC can be supplied by a small battery. There is a light provided to indicate that the power circuit is on.

The oscillator to generate a train of pulses works, in principle, as a multivibrator. Such circuits are usually manufactured all in one piece as an integrated circuit, which can be fitted to appropriate resistors to give the desired pulse lengths and intervals. Where these are to be varied, a switch on the panel of the machine connects the necessary resistance to give the pulse length required.

The train of pulses may then be modified, surged for example, by another integrated circuit, which may also be controlled by a switch on the machine. A circuit may also make the DC pulses biphasic. Finally the output is amplified and applied to a potential divider to regulate the output to the patient. This is illustrated in Figure. 12.14.

CHAPTER

13

FARADIC CURRENT

INTRODUCTION

Faradic Current (F.C.) is a short frequency therapeutic current. The term 'Faradism' is applied to the current as it is produced by faradic coil. This current stimulates motor nerves and causes contraction of muscles to which they supply. Faradic current is named after the scientist 'M. Faraday'. It is an alternating therapeutic current which changes its polarity 50 times in one second. This current is very useful to stimulate the muscles in comparison of galvanic current.

Faradic current is not painful to the patient. No form of the Faradic current is used on completely denervated muscles.

TYPES

Therapeutic Faradic current can be classified into 2 types:

1. Plain: This includes single stimulation with no interruption *i.e.* it is continuous current.
2. Surged Faradic: It is interrupted therapeutic current and it is also called "Modified Faradic Current".

Usually the impulses, which rise and fall gradually, are better than pain because they produce less sensory irritation.

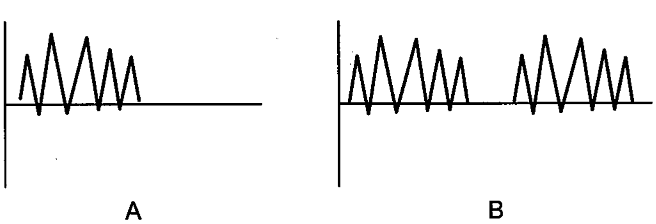

Fig. 13.1 *Faradic currents on the basis of pulse gap (A-plain, B-modified)*

EFFECT OF FREQUENCY ON STIMULATION

When single stimulus is given to a muscle, there is one complete contraction followed by complete relaxation. This is called 'Twitch or Contraction'.

If the frequency is upto 20 Hz, there is a good time to relax. As the frequency increases beyond 20 Hz, the relaxation time decreases.

When the frequency is reached upto 80 Hz, there is no time for relaxation and the current physiologically flows continuously and it is called 'Tetanic current'.

PHYSIOLOGICAL EFFECTS OF FARADIC CURRENT

The body tissues are capable of transmitting electrical current due to ionic nature of most of the body fluids.

The muscles and the blood are considered as good conductors for electric current.

Thus if we want better therapeutic results, impedance of skin should be reduced. The skin should be well moistened and washed before application of therapeutic current. Application of faradic current causes a pricking sensation felt by patient due to its frequency. It causes reflex vasodilatation and erythema in the superficial tissues.

When muscle contracts due to applied stimulation, the changes occurring in muscle are same as due to voluntary contraction. There is increased demand for nutrients, which as a result increases output of waste products. The increase in rate of metabolism also causes dilatation of capillaries and arterioles, ultimately resulting in increased blood supply to the muscle.

When muscles are contracting and relaxing, they produce a sort of pumping action on veins and lymphatic, thus improving lymphatic drainage and venous return.

INDICATIONS

1. **Facilitation to Muscle Contraction:** When patient is unable to perform voluntary action, electric stimulation is given to assist the muscular contraction.
2. **Re-education of Muscle:** As a result of long illness, if a muscle doesn't perform its function or forgets its function, then the electric stimulation is given to act so that it can resume its function and the phenomenon is called 'muscular re-education'. During muscular re-education, when the stimulation is given, patient is asked to perform the contraction himself too.
3. **Neuropraxia of Motor Nerves:** Injury to a nerve is called neuropraxia, and the impulse originating from brain is unable to pass across the site of lesion and thus unable to reach the muscle which results in reduced muscular contraction.

The innervation status should be verified by plotting S.D. curve or N.C.V. test.

a. If there is slight response to the Faradic current, it means there is partial injury to the nerve, and is called 'partial Reaction of Degeneration'.

b. If there is not even slightest response to the Faradic stimulation, it means there is complete injury in the nerve, and is called 'complete reaction of degeneration' (but response to the Galvanic current is present).
c. If muscle is cut along with its nerve, there will be no response even to the Galvanic current, and it is called 'Absolute Reaction of Degeneration'.
d. If the muscle is responding to Faradic as well as Galvanic stimulation, then the muscle is well innervated.

4. **Pumping Action:** The alternating contraction and relaxation results in the pumping action which results in increased venous and lymphatic return.

Facilitation of muscle contraction when inhibited by pain: Controlled muscle contraction results from a sequence of events involving at least 3 neurons: excitation of the small efferent fibres which merely causes contraction of the intrafusal fibres; stretching of muscle spindle which sends information to the anterior horn neurons where recruitment of motor units is followed by the contraction of muscle, and from the internuncial neurons, there is inhibition of anterior horn cell supplying the antagonistic groups. If this servo-mechanism works efficiently, there is no need to stimulate the muscles electrically.

CRITERIA FOR SELECTION

Criteria for the selection of Faradic type currents to produce a muscle contraction:

a. A muscle contraction that is inhibited by pain.
b. The patient should not have any capsular contractures or adhesions in the muscles around the joint.
c. There should be no gross effusion as it will cause difficulty in obtaining the motor points of the muscle.
d. The presence of muscle atrophy and diminished muscle tone.

Some conditions successfully treated with faradism for the problem of inhibition of quadriceps contraction by pain include:

- Meniscectomy
- Chondromalacia patellae
- Chronic effusion of the knee joint
- Rheumatoid arthritis
- Recurrent subluxation of the patella.

CONTRA-INDICATIONS

- **Skin Lesions:** Any large open area, which is in direct pathway of current, particularly under the electrodes, will cause intense discomfort and pain, as current tends to collect at that point or on raised areas. Small skin lesions can be insulated with vaseline.

Certain dermatological entities, such as eczema, tinea, ringworm, psoriasis, fungus growths and similar conditions should not be in the pathway of the current.

Low frequency currents tend to exacerbate the condition, and if it is infectious, it will spread the infection further in the patient himself or to other patients using the same apparatus.

Particularly in hot humid climates, care must be taken to inspect the part.

Oedematous areas with a fine paper-like skin must be avoided.

- **Infections:** An infection must not be treated with low frequency currents because of the danger of spreading the infection or exacerbating the condition.
- **Inflammation:** Any acute inflammation with an underlying danger of infection or with thrombosis as a complication is a contra-indication.
- **Thrombosis:** Patients with deep vein thrombosis or with artheroselecrosis of the arterial vessels must not be treated with Faradic-like currents because of the danger of causing an embolus.
- **Marked Loss of Skin Sensation:** If there is total loss of sensation in the limb being treated, a low frequency current must not be given for a long period of time. Even with short duration pulses, a chemical burn is possible if the treatment is given for over 20 minutes with a high intensity.
- **Active Tuberculosis or Cancer** in the area may be exacerbated.
- **Cardiac Pacemakers:** It is not advisable to apply a low frequency current in the region of the thorax or the pacemaker control unit (shoulder or abdomen), as it may interfere with the function of the pacemaker.
- **Thrombophlebitis:** The dislodgement of small thrombus may result.
- **Unreliable Patients:** Patients who cannot co-operate or understand the dangers of the treatment. For example, very old or very young patients.
- **Superficial Metal:** Metal in the pathway of the current will concentrate it and may cause a burn.

SELECTION OF APPARATUS

Essential features of low voltage stimulators necessary for the selection of suitable Faradic-type currents include:

a. A range of pulse duration from 0.01 to 1ms, or a standard Faradic current with a 1ms pulse duration and a frequency of 50 Hz.
b. Controls for intensity/dose: The controls should read zero at the OFF position.
c. A meter for reading intensity: This is generally expressed in voltage unless it is a constant current circuitry where there is current control, as in the Siemens Neurotron.
d. Optional frequency and rest period control: Some machines have a frequency control which requires the therapist to select the correct frequency with the pulse duration, making sure that the rest between pulses is at least twice the pulse duration.
e. There should be adequate continuous control of the speed of surges/currents; there is generally a range of from 6 to 30 surges per minute.
f. Clearly marked patient terminals indicating both a cathode and anode pole, in the tetanic alternating currents, as in the smart-Bristow coil, there is no need for polarity markings.
g. A polarity reversal switch is incorporated in most electronic equipment, thus facilitating selection of polarity.
h. A clearly marked mains ON/OFF switch.
i. The ability to select the shape of the pulse – rectangular, triangular, trapezoidal.
j. A safety mains plug, which have an earth socker.

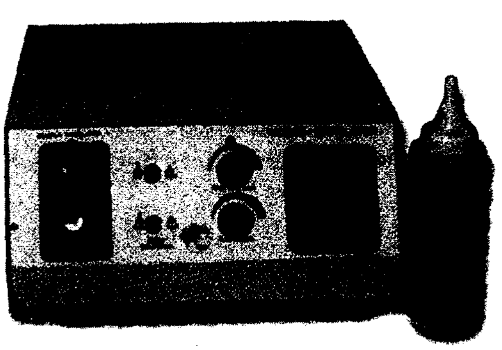

Fig. 13.2 *Example of machine producing Faradic type current*

FARADISM FOR INNERVATED MUSCLES

Faradism can be used to obtain either a group action or the contraction of an individual muscle.

- Equipment required
- A smart-Bristow coil (Faradism) or a low frequency electronic stimulators
- Two leads
- Two suitably sized metal electrodes
- Two moist pad electrodes, 5 mm thickness compressed when using smart-Bristow coil or 10 mm thickness compressed when using electronic stimulators
- Two pieces of plastic to cover the pads
- A sandbag
- A bandage
- Two small basins of warm water
- Towels
- Soap
- Insulating cream (petroleum jelly, vaseline, or lanolin)
- Spatula.

Position the patient comfortably with a plastic sheet and towel under the limb. Support the muscle in the pain-free position with the area to be treated adequately exposed. The knee should be flexed slightly over a rolled up towel, and the ankle stabilized to prevent hyperextension if the quadriceps muscle is being treated.
Advise the patient as to:

a. The rationale for treatment
b. The sensation to be experienced – when the current is turned on, a prickling sensation is felt; as the intensity is increased, the muscle will contract, and relax as intensity decreases.

Check that there are no contra-indications to treatment. Examine the area to be treated. Note any cuts, skin lesions and inflammation.

Small cuts and abrasions need to be insulated with sterile vaseline. Inflammation impedes the penetration of current. Large open areas and extensive inflammation may contra-indicate treatment. Measure the girth of the muscle for wasting.

Test the ability of the muscle to contract fully isometrically. Note the patient's particular problems in doing so. No skin test for sharp-blunt discrimination is necessary when using the smart-Bristow coil as there are no chemical effects with the Faradic current, but the test must be carried out when an electronic low frequency stimulator is used.

With soap and water, wash the patient's skin where both the electrodes are to be placed to remove any grease. Rinse with clean water.

Place a warm, moist pad over these areas to decrease skin resistance.

Connect the leads firmly to the machine.

Check that all the controls on the machine are in the correct position.

Plug into the mains power supply and switch on, if applicable.

Select the setting for Faradic type current, if applicable.

- Soak the pads in water.
- Connect the leads firmly to the metal electrodes.
- Cover the metal electrodes with the pads and test the application on yourself by placing the flexor surface of the forearm on one pad electrode and holding the other in the hand. Describe to the patient the sensation he will feel and make sure the patient can see the muscle contraction produced.

Remove the hot soak and if there are any breaks in the patient's skin, insulate these with a small amount of vaseline, using the spatula.

Moisten the skin where both the electrodes will be placed.

The group action is obtained by placing one electrode over the nerve trunk.

Electrode is covered with plastic and held firmly in position with a sandbag. If this is not possible, this electrode can be placed over the nerve roots at the spine. The other electrode, also covered with plastic, is placed across the motor points and held in position by the therapist or bandaged on firmly. The principle is that, wherever possible, the impulse is passed via the nerve, therefore, one electrode is positioned on a suitable superficial nerve trunk and the other electrode over the motor point.

Warn the patient:

a. That there should be no sustained intense pricking or burning sensation under entire area of either electrode or in one spot, when using an electrode.
b. Not to touch any of the equipment, if power from the mains supply is being used.
c. Not to move.
d. That a mild, pricking sensation will be felt, increasing as the intensity increases, and accompanied by muscle contraction.

The therapist should be seated facing the patient, and with the machine placed conveniently for manipulating the controls. Where the surge is controlled manually, the therapist's forearm should be supported with the shoulder relaxed.

Check that all the controls on the machine are in the correct position.

Give a few gentle contractions until the patient becomes accustomed to the current. Then increase the intensity gradually until he sees and feels quite a strong contraction. This enhances the patient's confidence as he realizes that the muscle will contract painlessly.

Keep repeating the electrical stimulation while instructing and encouraging the patient to contract voluntarily with the current. As he feels the current increasing in intensity, instruct him to tighten up his muscle and to relax the contraction as the current intensity decreases, until gradually he superimposes his voluntary contraction over the electrically produced one.

The patient then progresses to contract the muscle strongly as the current intensity increases and to hold the muscle in its contracted position against the decreasing intensity of current. Allow a relaxation phase between each contraction.

Finally test if the patient can voluntarily initiate, hold and relax the contraction. Once this is achieved, discontinue the electrical stimulation.

The entire emphasis of the treatment is on the active participation of the patient.

If it is necessary to stimulate muscles individually, for example the vastus medialis to overcome a quadriceps lag, place one metal electrode with a pad over the nerve as above. Using a suitably sized button electrode (large in this instance), covered with 5 mm thickness of absorbent material and secured with a rubber band, locate the motor point and give the necessary number of contractions.

At the conclusion of treatment, remove the electrodes, wash the skin thoroughly and check for any excessive erythema, which could indicate a chemical burn.

FARADISM WITH COMPRESSION FOR CHRONIC SYNOVITIS

Cases of painful and chronic effusion of the knee with a quadriceps lag have been treated successfully by stimulating the quadriceps group in elevation with a pressure bandage around the knee and quadriceps muscle. The treatment is carried out with the patient's knee held flexed to 5° with a restraining strap placed over the ankle to prevent hyperextension of the knee joint. No other exercises are given.

SEQUENTIAL FARADISM IN QUADRICEPS REHABILITATION

This method of Faradism uses simultaneously an electronic low voltage stimulator and an induction coil to obtain maximal contractions of the total quadriceps mechanism.

The problem of reduced proprioception with inability of the vastus medialis to coordinate with the rest of quadriceps group to maintain the leg in full extension may be treated by this method.

Position the patient in long sitting with a pillow or block under the heel. The other leg rests on the floor or stool over the edge of the bed.

Attach the indifferent electrode (120 mm × 80 mm) of the electronic stimulation over the femoral nerve trunk in the groin. The active electrode is placed over the common motor points approximately two-thirds of the way down the thigh.

Attach the induction coil apparatus (smart-Bristow coil) or a second surge controllable electronic stimulator to the patient by placing an indifferent electrode under the thigh (120 mm × 80 mm). The active electrode (50 mm × 50 mm) is placed on the motor point of vastus medialis. The electronic stimulator is positioned to obtain the longest hold of the current obtaining a good maximum tetanic-like contraction with a reasonable rest period between each contraction.

The rest periods are reduced to a reasonable minimum, allowing the muscle time to relax. Before commencing treatment, make sure that the electrode positions enable the quadriceps muscle to contract fully with no fibrillations and discomfort.

The main bulk of the quadriceps is stimulated with the electronic stimulator, initially for about 10 to 20 contractions.

Fig. 13.3 *Faradic current for quadriceps rehabilitation*

The patient is then instructed to work the induction coil using the surger. The vastus medialis, which is connected to the induction coil, is made to contract just before the main bulk of the quadriceps contraction starts. The surger in the induction coil is kept in, maintaining the contraction of vastus medialis, until the main quadriceps contraction is completed. It is then withdrawn, ready for the next sequential set of contractions.

The sequential group of contractions are given in sets of 10 with a rest in between.

The treatment lasts about 20 minutes. The patient is encouraged to contract the vastus medialis voluntarily, in time with the electronic stimulation as he feels and controls the contraction. Thus proprioception is re-educated, pain of muscle contraction is inhibited and the patient obtains a more satisfactory voluntary contraction of the total muscle bulk. The strength of contraction should be as maximal and comfortable as possible. A course of daily treatments for 2 to 3 weeks is given.

FARADIC FOOT BATH

The small muscles of the foot can be re-educated and facilitated by Faradic electric stimulation under saline water. The saline water bath for this purpose is called 'Faradic Foot Bath'. It needs a deep and long plastic bag, Faradic stimulator with rectangular rod type electrodes.

Equipment required:

- A smart-Bristow coil or a low frequency electronic stimulator with Faradic-like duration and frequency
- Two metal electrodes (100 mm × 30 mm)
- Two leads
- A small table and trolley for the machine
- A stool covered with plastic and a towel for the bath
- Two baths with warm water
- Towels
- Vaseline
- A wooden spatula
- A chair or stool for the operator.

Preparation of Patient

Position the patient comfortably in high sitting on a plinth with the back well supported with pillows, and the feet on a stool covered with plastic and towel.

Patient should be explained the rationale for treatment and sensation to be experienced.

Check that there are no contra-indications to treatment with faradism.

Examine the area to be treated. Note any cuts, skin lesions, inflammation or swelling. Small cuts and obtrusions to be insulated with sterile vaseline. Inflammation and oedema impede the penetration of the current.

No skin test for sharp-blunt discrimination is necessary when using the smart-Bristow coil as there are no chemical effects with the Faradic current, but the test must be carried out when a low Frequency electronic stimulator is used.

Place the patient's foot in a bath of warm water to decrease the skin resistance. Connect the leads firmly to the machine.

1. The foot is immersed in tap water in a plastic tray till the water level touches mild of navicular bone or medial malleolus of foot.
2. Add few pinch of sodium chloride to make the water good conductor. Patient should sit comfortably on a chair or stool, preferably plastic or wooden. Wait for 2 to 3 minutes so that the foot skin is well moistened, thus reduced skin impedance is obtained.
3. Put one electrode near the toe and other near the heel. About one inch electrode should be submerged into the water.
4. Turn ON the stimulator and increase the intensity till patient feels tingling sensation in foot.
5. Fix the knob for the period of 5 to 10 minutes. Ask how the patient feels.
6. When the time is over, slowly decrease intensity and turn OFF of the stimulator.
7. Remove patient's foot from the bath and dry with a towel.

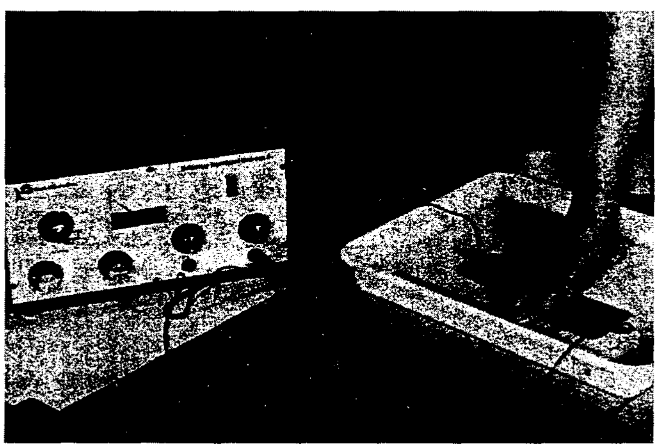

Fig. 13.4 *Stimulation of lumbrical muscle with Faradic current*

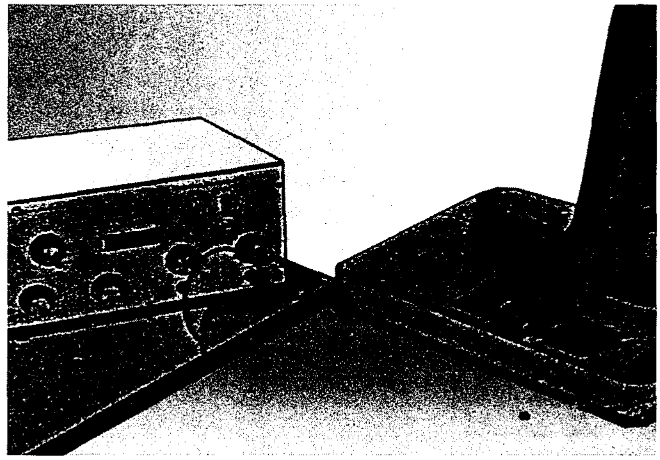

Fig. 13.5 *Faradic stimulation to plantar interossei*

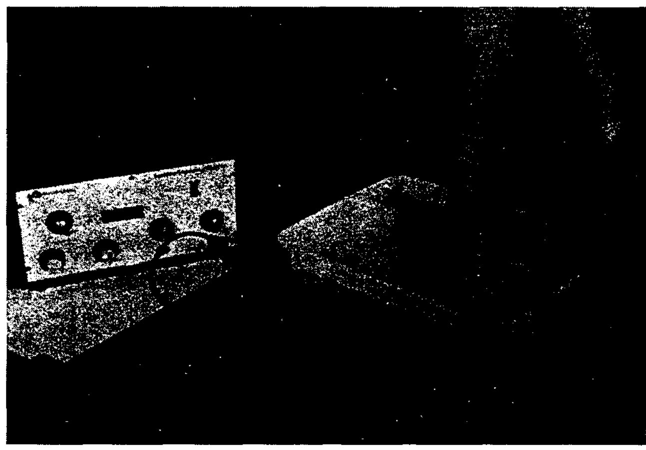

Fig. 13.6 *Stimulation of abductor hallucis with Faradic current*

Stimulation of Motor Points

This method has the advantage that each muscle performs its own individual action and that the optimum contraction of each can be obtained. It may therefore be selected when training a new muscle action or when isolation of one muscle is indicated.

The apparatus and patient should be prepared as previously described. The indifferent electrode is applied and secured in a suitable area. The active electrode may be a disc electrode, which is held between the index and middle fingers, or a small pad which is held in the palm of the hand. It is placed over the motor point of the muscle to be stimulated. Firm contact ensures a minimum of discomfort, and where possible the whole of the operator's hand should be in contact with the patient's tissues so that she can feel the strength of the contractions produced. A suitable duration and frequency of surge must be selected. The intensity of the current is gradually increased until a good muscle contraction is obtained at the maximum point of each surge, then the surging is continued to produce alternate contraction and relaxation of the muscle.

The duration of the treatment session is determined by the length of time for which the patient can concentrate on the movement and assist in its production. Muscle fatigue is indicated by weakening of the contraction, but does not occur rapidly with faradic-type stimulation.

To stimulate lumbricals, one pad is placed transversely or below the heel, the other below metatarso-phalangeal joints. To stimulate interossei, pads are placed on either side of foot. In both the above said conditions, patient is asked to perform foot and finger movements when the foot is under stimulation in water. If the large tray size is selected, you can stimulate both the feet simultaneously in the same foot bath.

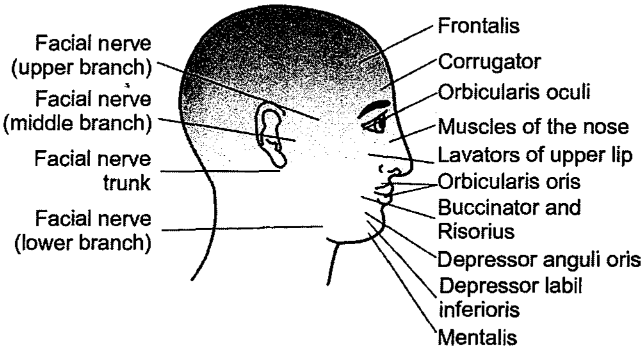

Fig. 13.7 *Motor point of some of the muscles supplied by the facial nerve*

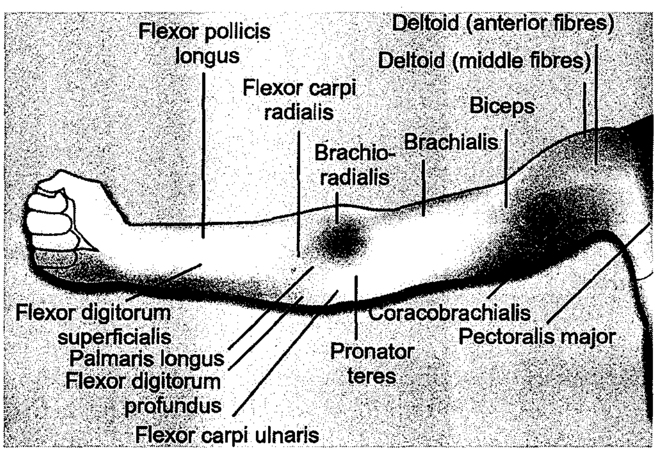

Fig. 13.8 *Approximate positions of some of the motor points on the anterior aspect of the right arm*

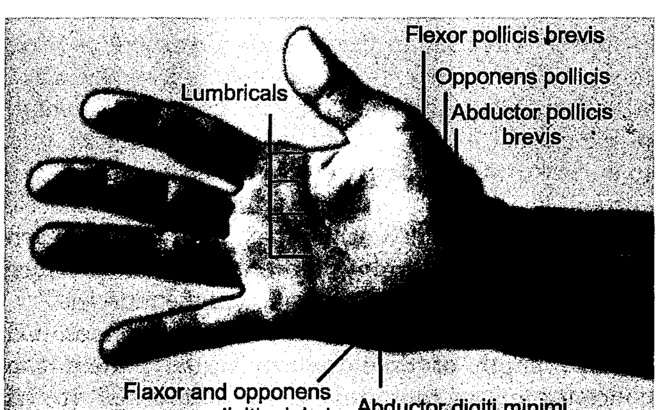

Fig. 13.9 *Approximate positions of some of the motor points on the anterior aspect of the right hand*

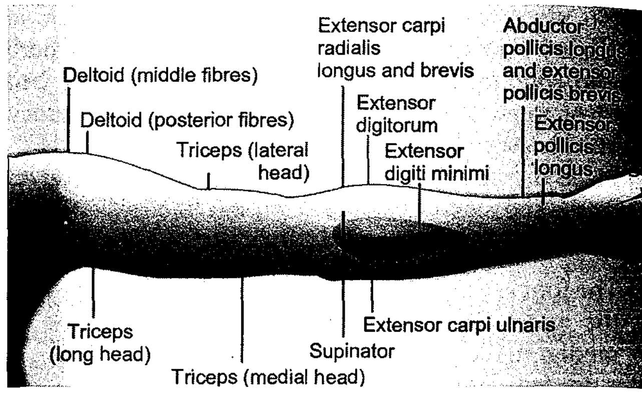

Fig. 13.10 *Approximate positions of some of the motor points on the posterior aspect of right arm*

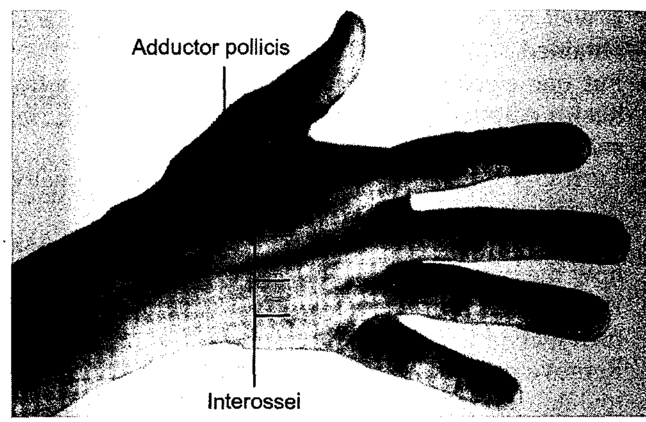

Fig. 13.11 *Approximate positions of some of the motor points on the posterior aspect of the hand*

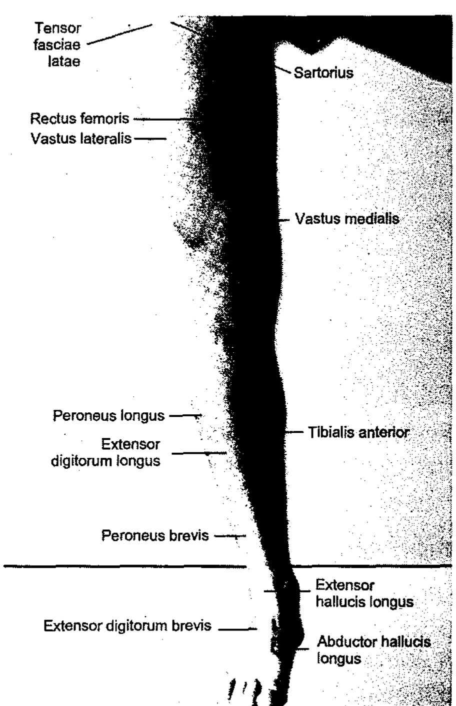

Fig. 13.12 *Approximate positions of some of the motor points on the anterior aspect of the right leg*

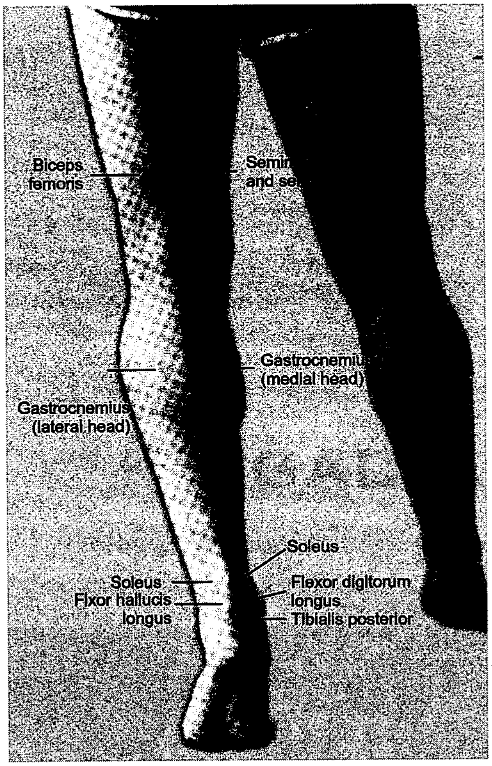

Fig. 13.13 *Motor points on the posterior aspect of the left leg*

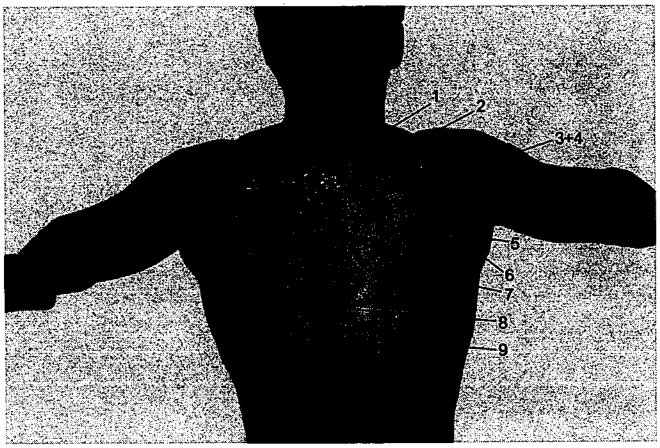

Fig. 13.14 *Approximate positions of some of the motor points of the back:*

1. *Trapezius (upper fibres)*
2. *Supraspinatus*
3. *Rhomboids*
4. *Trapezius (middle fibres)*
5. *Infraspinatus*
6. *Teres major and minor*
7. *Serratus anterior*
8. *Trapezius (lower fibres)*
9. *Latissimus dorsi.*

CHAPTER

14

GALVANIC CURRENT

- Introduction
- Types of Intermittent Galvanic Current
- Physiological Effects of Interrupted Direct Current
- Indications
- Selection of Type of Impulse
- Duration of Impulse
- Method of Application
- Difference between Faradic and Interrupted Galvanic Current

INTRODUCTION

Therapeutic Direct Current (Galvanic current)

This is a direct electric current (DC). Its direction of polarity is constant and passes continuously in one direction only. In most of the therapeutic references, it is known a Galvanic current. It is also called constant current. An Italian scientist named Wigi Galvany found that when the sky lightening is introduced in the muscles of frog's leg through a copper wire, muscles get contracted. To honour him, the name of DC is given as Galvanic current.

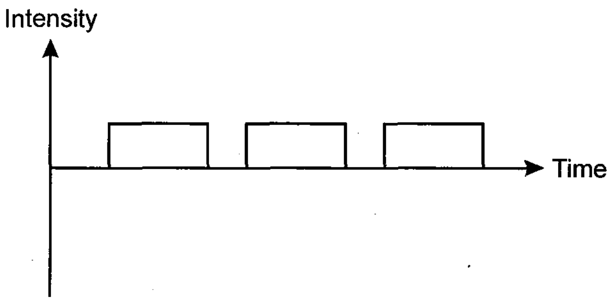

Fig. 14.1 *Interrupted direct current*

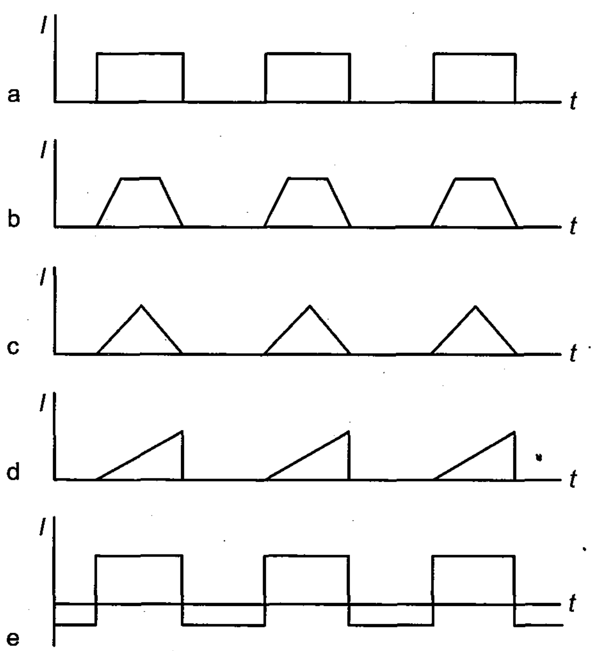

Fig. 14.2 *Types of intermitted galvanic current*

a. Rectangular
b. Trapezoidal
c. Triangular
d. Saw-tooth
e. Depolarized.

If we apply galvanic current to a muscle, it will contract and will remain in contraction till current is not brought to zero. During treatment, our purpose is to get the muscle contracted and relaxed, which is possible only when we apply the current for a shorter duration and there should be a silent period during two pulses.

This type of galvanic current is called interrupted galvanic current or intermittent galvanic current.

Some machines (stimulators) give the output of medium frequency direct current in pulse of 125 microseconds with a silent period of 5 microseconds. This type of current has no difference in effect but it is more comfortable for the patients.

TYPES OF INTERMITTENT GALVANIC CURRENT

1. **Rectangular:** When there is sudden rise, short stay at peak and sudden fall in the impulse.
2. **Triangular:** When there is sudden rise and fall of the impulse with no stay at peak.
3. **Trapezoidal:** When there is gradual rise and fall of impulse with a short stay at peak. It is also known as selective current.
4. **Saw-Tooth:** When there is very gradual rise but sudden fall of the impulse.
5. **Depolarised:** Some stimulators produce reversal polarity between the intervals, it is called depolarized current.

In all the above types of currents, pulse width of about 100 milliseconds of desired amplitude and 30 cycles per minute frequency is used. However, the duration and frequency of the current can be selected by the therapist as desired.

PHYSIOLOGICAL EFFECTS OF INTERRUPTED DIRECT CURRENT

Provided that the intensity of current and duration of impulses are adequate, a contraction of **denervated muscle** can be initiated. The contractions are sluggish, the contraction and relaxation being slower than when the motor nerve is stimulated. As denervated muscle tissue does not have the same property of accommodation as motor nerves, a current that rises fairly slowly is as effective in producing a contraction as one that rises suddenly. Moreover, the slowly rising current can produce a contraction of denervated muscle with a current that is insufficient to stimulate selectively the motor nerve. An impulse with a duration of 100 ms is the shortest that is generally considered satisfactory for the treatment of denervated muscle, but it is often necessary to lengthen this impulse in order to eliminate contractions of innervated muscles. Both of these factors should be taken into consideration before treating the patient.

When interrupted DC is applied to the body, there is **stimulation of sensory nerves**. The impulses are of fairly long duration so the effect is rather marked, giving rise to a stabbing or burning sensation. There is reflex dilatation of the superficial blood vessels and consequent erythema of the skin.

Stimulation of motor nerves with interrupted DC produces contraction of the muscles supplied. The stimuli are frequently repeated, so each one produces a brisk muscle twitch followed by immediate relaxation. There is, therefore, little beneficial effect on the muscles.

INDICATIONS

The most significant use of Galvanic current in electrotherapy is the stimulation of denervated muscles by non-continuous mode. A denervated muscle or group of denervated muscles cannot contract and relax, thus blood supply of such muscle/muscles is decreased resulting into wasting. After a long time, such muscles loose their property of contraction and get hypotrophied or atrophied.

A current of 100 millisecond is applied on such muscles to produce contraction. A current below 100 milliseconds duration will not stimulate all the muscle fibres.

SELECTION OF TYPE OF IMPULSE

If a good muscle contraction is obtained with a rectangular impulse, this may be used, but the 'selective' impulses often prove more satisfactory. The difference between the various types of impulse lies in the time taken for the intensity of current to rise to maximum. With the rectangular impulses, the rise is sudden, with the trapezoidal it is fairly slow, with the triangular even slower and with the saw-tooth slower still, provided that the impulses are of the same duration (see Fig 14.2). A slow rise in the intensity of current has the advantages that a contraction of denervated muscle is often obtained with less sensory stimulation than when rectangular impulses are used, and that denervated muscle often responds to a lower intensity of current than that required to stimulate motor nerves, so that unwanted contractions of normally innervated muscles in the region are eliminated. In long-standing denervation, a muscle contraction may be obtained with a slow-rising current when there is no longer any response to a rectangular impulse.

When various types of impulse are available, it is advisable to attempt stimulation with each in order to ascertain which produces the most satisfactory contraction. It is often found that the more long-standing the denervation, the slower the rise in intensity of current that is required.

DURATION OF IMPULSE

An impulse of at least 100 ms is necessary in order to ensure that all the denervated muscle fibres are stimulated. If shorter impulses are used, some of the muscle fibres may fail to contract. When attempting to eliminate contractions of normally innervated muscles or to stimulate a muscle which has been denervated for some time, it is necessary to increase the duration of the impulses to 300 or 600 ms.

METHOD OF APPLICATION

There are 2 ways to apply Galvanic current on the affected part of the body called Labial Technique and Stable Technique.

In Labial Method: One muscle is stimulated at a time. Anode is kept on the origin of the muscle and cathode is placed on the belly of the muscle or nerve trunk. Cathode is moved slowly in the whole muscle to get every muscle fibre stimulated, thus this method is widely used.

In Stable Method: Anode is kept at origin and cathode is kept at near the other end of muscle and pressed firmly. Then there is no need to move the cathode. It is better if the skin is moistened before applying the electrodes. In case of loss of sensation, repetitive small sittings should be given to avoid electrical skin burns. About 70 to 90 contractions to each muscle is given one sitting. At the end of the sitting, remove electrodes and apply talcum powder over the electrode area.

Preparation of Equipment: The apparatus is tested and the other equipment prepared as for the treatments previously described. Make sure that the coverings of the disc electrodes and the pads consist of at least eight layers of lint. This is because it is possible to get a chemical burn with long-duration pulse if the treatment is given at the same spot for long periods of time, particularly if the current selected is without the reverse wave of current between the impulses (*i.e.* it is not depolarized). No metal should be allowed to come into contact with the patient's tissues.

Preparation of the Patient: The skin is prepared by washing and protecting abrasions as for other electrical treatments. It is often an advantage to soak the part in warm water before the treatment to lower the resistance of the skin and to warm the muscles, although if there is extensive loss of sensation, care must be taken that the water is not too hot.

Contractions are obtained most easily if the part is supported so that the muscles to be stimulated are in a shortened position. Alternatively, the current may be applied with the muscles in a partly lengthened position. This should only be done if the contractions produced are sufficiently strong to cause shortening of the muscle and so joint movement. If this is achieved, the load opposing the muscle action should increase the beneficial effects. It is usually possible to produce movement only in the smaller joints, *e.g.* the wrist.

Application of Interrupted DC: Muscle contractions are obtained most easily if the active electrode is connected to the anode, but this is not always the case. Each patient should be tested to determine whether the anode or the cathode produces the better response, and the more effective pole used for the active electrode.

When the electrodes have been applied, the intensity of current is increased until a good muscle contraction is obtained. A large number of contractions is desirable, but any sign of fatigue, such as weakening of the contraction, is an indication for limiting the length of the treatment. Contractions are usually produced in groups, allowing rest periods in between.

DIFFERENCE BETWEEN FARADIC AND INTERRUPTED GALVANIC CURRENT

Faradic	Interrupted Galvanic
1. It is of short duration ranging from 0.01ms–1ms.	1. It is of long duration ranging from 1–300ms
2. It has a high frequency ranging from 50–100 Hz	2. It has a lower frequency than faradic.
3. It is used to stimulate innervated muscles	3. It is used to stimulate denervated muscles
4. It gives mild prickling type of sensation	4. It gives stabbing type of sensation

CHAPTER

15

IONTOPHORESIS

- Introduction
- Principle
- Apparatus for Iontophoresis
- Formula for Iontophoresis
- Ions and their Relationship with Pathologic Conditions
- Selection of Appropriate Ions–Properties and Sources
- Preparing the Electrodes
- Positioning the Patient
- Treatment—Selecting the Appropriate Technique
- Treatment Steps
- Placement of Electrodes
- Indications
- Dangers
- Contra-indications

INTRODUCTION

Iontophoresis is the transfer of the ions of drugs into the body through the skin by the use of a constant direct current.

PRINCIPLE

It is based on the fact that ions will migrate to the electrode of opposite charge under the influence of an electromotive force.

The hyperaemia, which is produced following iontophoresis, disappears after a few hours, but renders the blood vessels more sensitive to changes from thermal or mechanical stimuli, and hence vasodilatation occurs more easily in the treated area.

APPARATUS FOR IONTOPHORESIS

All modern low frequency generators provide both direct current and alternating current circuits for connecting to the patient. The DC is obtained from the mains power supply after it has been rectified by suitable rectifiers, inductors, and capacitors in the circuit.

The direct current controls in low frequency apparatus. The basic requirements for the application of DC in an apparatus are clearly indicated positive and negative terminals. Red denotes the positive terminal, or the anode. Black indicates the negative terminal, or the cathode.

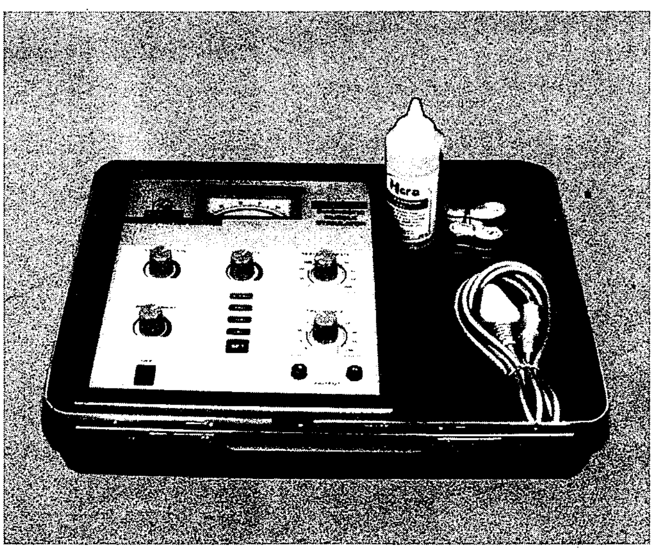

Fig. 15.1 *Low-voltage generator unit used for iontophoresis*

The power output and the milliammeter must be clearly indicated. Generally there will be two current ranges. The dial indicating the range should be clearly marked.

There should also be a polarity reversal switch, which enables to change the polarity of the terminal and also a clear ON/OFF switch connecting the machine to the mains.

It is important to select the circuit that produces a direct current only.

Accessories with the Apparatus

- The electrodes are made from aluminium foil or metal. Care must be taken that the electrodes are smooth and have rounded edges. Circular electrodes are more useful because they have no sharp edges and are easier to apply over joints.
- The pads may be made from any smooth absorbent material such as lint, gauze pads, sponge or household absorbent cleaning cloth.
- The important factor is that when compressed, the thickness of the pad should be 10 mm. The pad should be uniform in thickness.
- Conducting leads with a variety of end fittings are provided with the apparatus.

It is important to ensure that the fittings to the lead wires are firm and not broken.

FORMULA FOR IONTOPHORESIS

The basic formula for using iontophoresis is:

I × T × ECE = grams of substance introduced.

where,

I → Intensity; measured in amperes.

T → Time; measured in hours.

ECE → Electrochemical equivalency refers to standard figures for ionic transfer with known currents and time factors.

An example is magnesium, found in solution of magnesium sulphate.

I	x	T	x	ECE	=	
5 mA		30 min		0.0115	=	
0.005A		0.5 hr		0.0115	=	0.0002875 g
					=	0.2875 mg

It is much more difficult to analyze and determine the ECE for many radicals and complex substances (*e.g.*, steroids).

It may be safely assumed, however, that even fewer milligrams of these larger, more complex submolecular substances will penetrate the skin.

IONS AND THEIR RELATIONSHIP WITH PATHOLOGIC CONDITIONS

Pathology	Ion Selection
Pain	Hydrocortisone, Lidocaine, Magnesium, Salicylate
Inflammation	Hydrocortisone, Salicylate
Spasm	Calcium, Magnesium
Oedema	Mecholyl, Iodine, Magnesium, Salicylate Hyaluronidase
Ischemia	Mecholyl, Magnesium, Iodine
Calcific deposits	Acetic acid
Gouty tophi	Lithium
Fungi	Copper
Allergic shinitis	Copper
Open lesions	Zinc
Hypo/hyperirritability	Calcium
Hyperhidrosis	Tap water with alternating polarity
Scars, adhesions	Chlorine, Iodine, Salicylate

SELECTION OF APPROPRIATE IONS; PROPERTIES AND SOURCES

Hydrocortisone

1 percent ointment, various local sources, positive pole, anti-inflammatory,
avoid ointments with "paraben preservatives",
used for → arthritis, tendinitis, myositis, and bursitis.

Lidocaine

From Xylocaine 5 percent,
Positive pole,
Anaesthetic analgesic,
used for → neuritis, bursitis, and painful range of motion.

Mecholyl

Mecholyl ointment,
Positive pole,
Vasodilator, analgesic,
used for → neuritis, neurovascular deficits, sprains, and oedema.

Salicylate

From myoflex ointment, 10% salicylate preparation
Or iodex with methyl salicylate.
Negative pole,
Decongestant, analgesic,
used for → myalgia, rheumatoid arthritis.

Iodine

From iodex with methyl salicylate,
Negative pole,
Sclerolytic, antiseptic, analgesic,
used for → scar tissue, adhesions, and fibrositis.

Acetic Acid

10% stock solution, cut to 2 percent, negative pole, used for → calcific deposits, myositis ossificans, frozen joints.

Lithium

From lithium chloride or lithium carbonate, 2% solution,
Positive pole,
used for → Specifically for gouty tophi.

Hyaluronidase

From Wydase; solution to be mixed as directed on vials,
Positive pole,
Absorbent agent for oedema sprains.

Chlorine

From table salt (Nacl), 2% solution,
Negative pole,
Sclerolytic,
used for → scar tissue, adhesions.

Calcium

From calcium chloride, 2% solution,
Positive pole,
Stabilizer or irritability threshold,
used for → myospasm, frozen joints, trigger-fingers, mild tremors (non-parkinsonian).

Zinc

From zinc oxide ointment 20%,
Positive pole,
Caustic, antiseptic, enhances healing,
used for → otitis, ulcerations, dermatitis, and other open lesions.

Copper

2% solution, copper sulphate,
Positive pole,
Caustic, antiseptic, antifungal
used for → rhinitis (allergic), dermatophytosis (athelete's foot).

Magnesium

From 2% solution of magnesium sulphate,
Positive pole,
Antispasmodic, analgesic, vasodilator,
used for → osteoarthritis, myositis, and neuritis.

PREPARING THE ELECTRODES

Electrodes may be fabricated from paper towels, washcloths, or other absorbent materials over which household aluminium foil (heavy duty) is superimposed to form an electrode unit.

The aluminium foil should be of several thicknesses, folded to size, rolled flat, and trimmed to be slightly smaller than the towel to avoid metal/skin contacts. The towels (two or three) should be folded wrinkle-free and thoroughly soaked in warm water or the ionic solution.

Electrode units are secured in position on the patient with soft rubber bandages or lightweight sandbags. As commercial electrodes are not found to be advantageous with iontophoresis, the method described above provides disposable materials and proves inexpensive.

POSITIONING THE PATIENT

Patients should never lie with their full body weight on an electrode. This creates pressure and an ischemic condition that can lead to a burn since the cooling effect of the circulatory sweep is missing.

Shoulder, hand, face, neck, elbow and brachial regions are better treated with the patient in the sitting position.

Prone, supine, and side-lying positions are appropriate for trunk, lower back, thigh, anterior chest and abdominal procedures.

The knee is best treated with the patient in the sitting position.

TREATMENT—SELECTING THE APPROPRIATE TECHNIQUE

Before administering iontophoresis, the clinician must first answer the following questions:

1. What is the underlying pathology to be treated?
2. What physiologic conditions must be altered?
3. Which ion is known to be effective in this condition?
4. Are there any contra-indications to this ion?
5. Is there an alternate ion?
6. What is the most convenient source for this ion?
7. What is the polarity of this ion?
8. What are the electrochemical and electrophysiologic properties of this ion?
9. What placement of electrodes will offer optimum passage of current?
10. What is the best position for the patient and target tissue?
11. What milliamperage is suggested for the patient's skin sensitivity?
12. What should be the duration of the treatment?
13. How frequently and for how long should the patient be seen?
14. What results are sought?
15. Are supportive and/or concurrent measures required to enhance the iontophoresis?

Only when these questions have been answered, can the astute clinician properly utilize iontophoresis to the fullest advantage, avoiding the pitfalls of treatment? Physical therapist to answer these questions and establish an effective protocol for iontophoretic procedures.

TREATMENT STEPS

Once the patient is in proper position, the following list for general procedures is recommended:

1. Set all dials to zero.
2. Set selector switch to continuous galvanic current/direct current.
3. Set polarity switch to correct polarity of active electrodes (*i.e.*, same polarity as ion to be introduced).

4. Massage ionic ointment into the target zone & place two folded, warm-water soaked towels over this zone.
5. Place aluminium foil electrode pad on the towels, avoiding skin/metal contacts.
6. If an ionic solution is used, place two towels, soaked in the solution, over the target zone together with the aluminium foil pads, as above.
7. Secure electrodes in position with soft rubber bandages, not gauze, which when wet will conduct current. Lightweight sandbags are also used for larger, flatter areas of body surface. Note that sandbags, when moist from usage, will also conduct current and should not be placed across two electrodes.
8. Connect lead wires to the aluminium foil pads using "alligator" clips and bending the connecting corner away from the skin to avoid contact.
9. Turn on generator and slowly advance the control until 5mA is reached on the direct current milliammeter. The patient should feel a slight tingle, but not a burning sensation. If, the patient is uncomfortable, reduce current to 2 or 3mA.
10. Monitor the milliammeter frequently; adjust as needed to maintain at desired intensity.
11. 15 to 20 minutes of treatment is usually sufficient at 5 mA. If it is necessary to reduce the intensity to 2 or 3 mA, an additional 5 or 10 minutes is indicated unless skin irritation warrants shorter treatment time.
12. At the termination of the treatment, turn down the current slowly, disconnect electrodes, and remove all towels from the patient.
13. Apply a soothing lotion or astringent preparation to area under negative electrode.
14. Follow with other modalities or procedures with the exception of whirlpool bath.

Fig. 15.2 *Lithium chloride iontophoresis for gouty tophi (crystals). The lithium ion replaces the sodium ion in the crystals insoluble sodium urate molecule, forming lithium urate, which is soluble in the bloodstream*

The increased circulation from whirlpool bath may tend to disperse the introduced ions more than desired.

Short wave diathermy is an excellent choice, since the deeper heating tends to "draw" the ions deeper into the underlying tissues.

15. Double iontophoresis (*i.e.*, chemicals with opposite polarities under both electrodes) enables the clinician to treat two separate locations simultaneously.

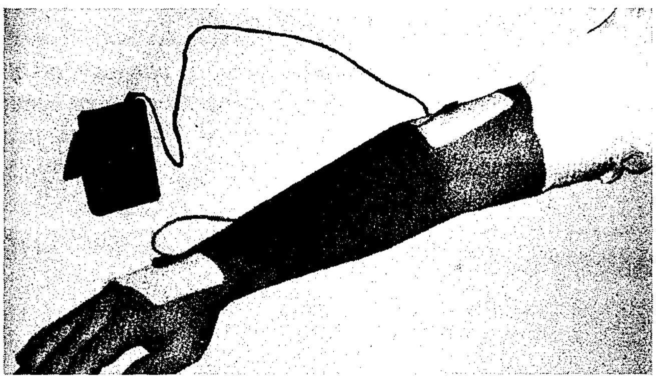

Fig. 15.3 *Special electrodes are in place*

Fig. 15.4 *In the iontophoretic approach to sciatic neuritis, the electrodes are secured by lightweight sandbags*

Fig. 15.5 *A scapular condition is treated by iontophoresis with the patient in the sitting position, leaning forward onto a pillow*

Fig. 15.6 *Double iontophoresis for a cervical/dorsal-lumbosacral condition, with ions of opposite charges under each electrode. The patient is positioned prone for comfort and convenience*

Fig. 15.7 *Lidocaine iontophoresis (or hydrocortisone) in the management of pain with a temporomandibular joint syndrome*

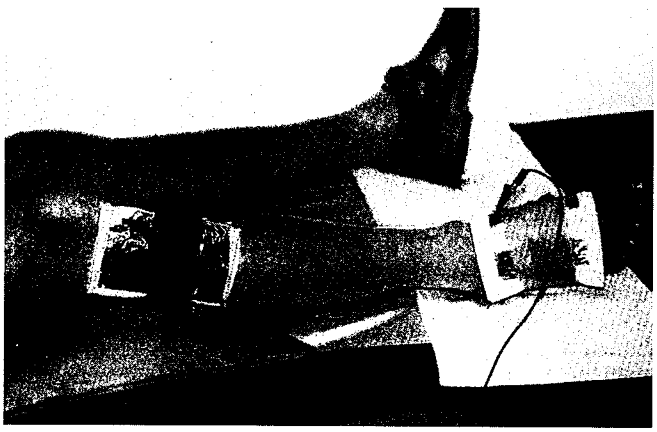

Fig. 15.8 *Mecholyl iontophoresis under the positive proximal electrode provides vasodilatation to the anterior tibial and peroneal distributions in a peripheral vascular deficit to the foot*

INDICATIONS

Relief of Pain

Cathodal galvanism: The counter irritant effect of cathodal galvanism produces a marked vasodilatation which, by helping to remove the pain factors, is responsible for the relief of pain.

Anodal galvanism: It is thought to relieve the pain by removing the increased concentration of H^+ and K^+ ions, which accumulate in ischemia or inflammation.

Adhesion

Renotin, which is a derivative of histamine, can be used in iontophoresis. Renotin sets up a marked counter-irritation by producing the triple response histamine *i.e.*:

a. A feeling of increased heat
b. Marked vasodilatation
c. Wheal.

This effects the fibrous tissues of adhesions and helps to resolve them. In cases of ligamentous and tendinous adhesions, renotin ionization may be used.

Chronic Congestion of Mucous Membrane

Transfer of zinc sulphate into congested nasal membranes has proved beneficial for patients suffering with vasomotor rhinitis (hay fever). Fairly good results have been obtained.

Calcium Deposits

Acetic acid transfer into calcium deposits has proved effective. It relieves pain by reducing the size of the calcium deposit.

Idiopathic Hyperhidrosis

Glycopyrronium bromide administered by iontophoresis has been recommended for the treatment of excessive sweating.

Local Anaesthesia

Local cutaneous anaesthesia is achieved by the iontophoresis of a suitable agent like lignocaine or procaine.

Application of Antibiotics

Antibiotics can be applied to a vascular area by iontophoresis.

Ear chondritis following burn injury has been treated. Chronic infection has been treated by metallic silver iontophoresis.

Chronic non-healing ulcers have been treated with xanthinol nicotinate; a capillary dilator.

Oedema Reduction

Oedema in acute or chronic conditions can be reduced by using hyaluronidase iontophoresis.

Hyaluronidase causes increased absorption of fluid from both the skin and subcutaneous tissues, thus reducing the oedema.

Application of Anti-inflammatory Drugs

These may be used to treat tendinitis and bursitis when delivered by iontophoresis. The advantages over conventional injection are painlessness and sterility of the treatment. The disadvantages are that there's even less certainty of their efficacy and it is time consuming and expensive.

Neurogenic Pain

Iontophoresis of vinca alkaloids is used and recommended for the treatment of intractable, chronic pain syndromes, *e.g.*, post-herpetic neuralgia and terminal cancer. The vinca alkaloids are cytotoxic drugs, which are microtubule inhibitors and are used in the treatment of malignancy.

Other Uses

For chronic wound healing → Zinc iontophoresis
To increase extensibility of scars → Iodine and chlorine
For fungal skin infections → copper iontophoresis
For relief of pain → salicylate

DANGERS

1. **Shock:** It may be because of following reasons:
   - Inadequate earthing of apparatus
   - Faulty ammeters
   - Faulty power points
   - Wet floors
   - Reversing the polarity
   - Increasing and decreasing current too quickly.
2. **Burns:** Chemical burns can occur because of following factors:
   - Contact of metal with skin
   - Over dosage
   - Skin lesions
   - Concentration of current.
3. **Skin irritation:** It is caused due to hypersensitivity to chemicals.
   It can be prevented by washing the treated part after treatment.
4. **Skin sensitivity:** It may become reduced due to anaesthetizing drugs.
5. **Systemic effects:** May occur due to iontophoresis of anti-cholinergic drugs and histamine-like drugs.

CONTRA-INDICATIONS

1. **Open skin:** Current tends to concentrate over these points. Large broken areas should be avoided.
   Small areas can be insulated by the use of vaseline.
2. **Infection:** Dangers of spreading infection by use of direct current.
3. **Bony areas:** Contra-indicated as produces burns.
4. **Loss of sensation:** It can lead to burn because of overdose.
5. **Dry scaly skin:** It increases the skin resistance.
6. **Skin lesions:** Eczema and psoriasis are made worse by direct current.
7. **Pregnancy:** It should be avoided in pelvic areas around uterus.

CHAPTER

16

ELECTROMYOGRAPHY AND BIOFEEDBACK

Part-A Electromyography

- Introduction
- Types and Physiology
- Components of Electromyography
- Clinical Examination
- The Technique of Recording the Electric Potential
- Clinical Applications
- Indications of Clinical Electromyography Test

Part-B Biofeedback

- Introduction
- Type
- Uses of Biofeedback
- Treatment Duration
- Advantages
- Disadvantages
- Summary

PART-A

INTRODUCTION

Electromyography is a technique used to diagnose the neuromuscular disease or trauma. It is also helpful in studying muscle function from kinesiologic point of view and also to study the integrity of different portions of motor unit. In electromyography, the study of the electrical activity of contracting muscle provides information concerning the structure and function of the motor units. This may make it possible to localize the site of pathology affecting either muscle or its innervation and in addition may frequently provide evidence regarding the nature of the pathological process.

The nerves that supply muscle are each, the extension of a neuron within the grey matter of the brain. They each give off terminal branches, which supply a large number of muscle fibres. The cell and the muscle fibre it supplies are defined as motor unit. Whenever a muscle fibre contracts, the surface membrane undergoes depolarization, so that an action potential recorded from fibre. When the fibres of a motor unit are activated, they contract nearly but not quite synchronously and their action potentials summate so that a relatively large complex potential, known as the motor unit action potential, can be recorded.

Diseases in which the structure and function of the motor unit is affected, the motor unit action potentials may have an abnormal configuration and the pattern of motor unit activity during voluntary contraction may be altered. Healthy muscle fibres contract only when they are activated by neurons and hence under normal conditions it is only motor unit potential that is seen. In neuromuscular disease however single muscle fibre may contract apparently spontaneously and this may be recognized by appearance of action potential derived from very small group of fibres. Electromyography is the technique by which the action potentials of contracting muscle fibre and motor units are recorded and displayed.

There are two types of Electromyography:

1. **Clinical Electromyography:** In this type, the electrical potentials are detected and recorded from skeletal muscle fibres and usually clinical electromyography deals in terms of instrumentation requirements and data analysis techniques. In this procedure, we get information regarding the muscle disease or extent of nerve injury.
2. **Kinesiologic Electromyography:** This type of electromyography is used for studying muscle activity and helps in establishing the role of different muscles for specific activity.

MUSCLE PHYSIOLOGY IN RELATION TO ELECTROMYOGRAPHY

In the true sense, we study the motor unit activity under electromyography. The motor unit is composed of:

1. One anterior horn cell
2. One axon
3. Its neuromuscular junctions
4. All the muscle fibres innervated by that axon.

The impulse is conducted by single axon to all its muscle fibres and at the same time, the depolarization occurs in the muscle fibre. The depolarization thus results in the electrical activity that is known as motor unit action potential (MUAP) and this is graphically recorded as electromyogram.

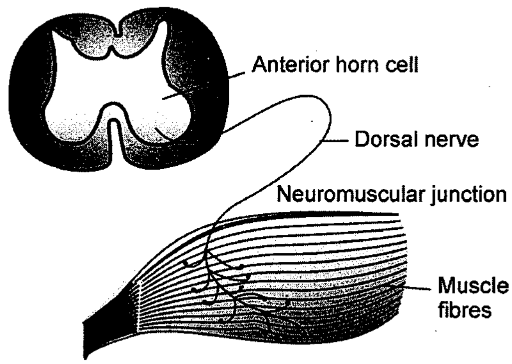

Fig. 16A.1 *The motor unit*

Motor unit action potential: The motor unit action potential (MUAP) means when the depolarization results in the electrical activity and graphically recorded by electromyogram, it represents potential derived from group of muscle fibres that are contracting nearly synchronously and are situated fairly close together and frequently activated by a single neuron. We can say that motor unit potential therefore represents a sample of activity of the fibres of motor unit and its characteristics are influenced by position of electrodes in relation to fibre of unit.

COMPONENTS OF ELECTROMYOGRAPHY

The electromyography instrument needs:

1. **Electrodes:** They are used as input phase for picking up electric potential from muscle contracting.
2. **Amplifier:** This is used in the processor phase for amplifying small electrical signals, which is thousand times amplified.

3. **A display:** This is used in output phase in which a device is used which converts the electrical signal to visual or audible signal. This is used for analyzing the data.

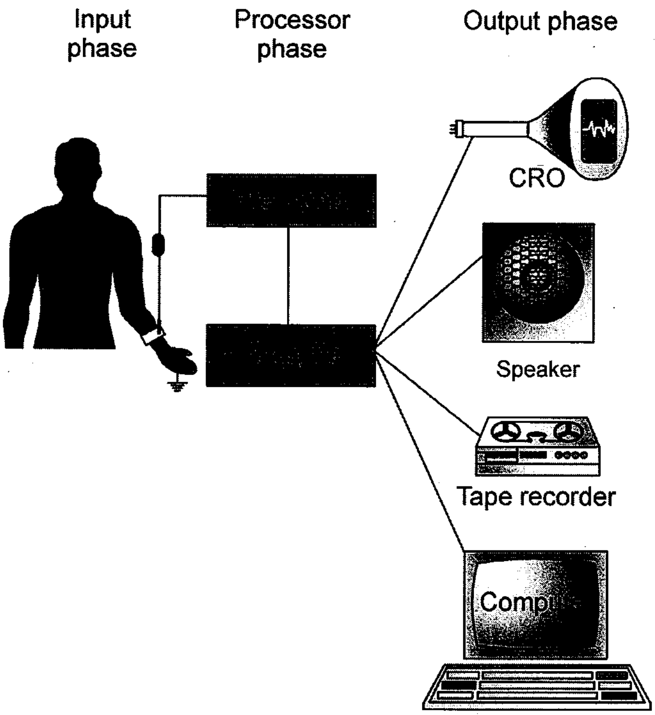

Fig. 16A.2 *The EMG recording system*

Input Phase

The main devices for this phase are electrodes as they pick up the electric signal from contracting muscle. The electrodes used in this phase are of different types :

a. **Surface electrodes:** They are used for kinesiologic investigations and testing nerve conduction velocity mentioning myoelectric signal. These type of electrodes are limited to individual motor units, specific small or deep muscles but in turn more beneficial for monitoring large superficial muscle or muscle groups.
   The surface electrodes are made up of small discs of metal, most commonly of silver and silver chloride. The electrodes are applied to the underlying muscle. The diameter of the electrodes is typically 3–5 mm. They are contained in a casing which is fixed to the skin with the tape or collar.
   If there is bipolar arrangement, then the two electrodes are placed over one muscle or muscle belly, longitudinally parallel to the direction of muscle fibre. However, to have better conduction of electrical potential, the gel is used beneath the surface electrodes.
   Skin preparations should also be done in order to reduce the skin resistance. Skin preparation includes washing of the skin and rubbing with alcohol, abrading the superficial skin to remove dead and dry cells of skin. But in latest advances, this is not required because the amplifiers and electrodes used are of such type that they may have sufficient impedance and conductivity.

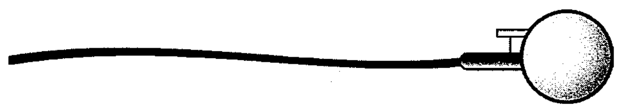

Fig. 16A.3 *Silver–Silver chloride surface electrodes*

b. **Fine wire indwelling electrodes:** These electrodes are used for the study of small and deep muscles from kinesiology point of view. It is made by using two strands of small diameter wire (100 mm) and have the coating of nylon insulation and polyurethane needle. The needle is inserted into the muscle belly and immediately withdrawn leaving the wire embedded in the muscle.
   These wires form a bipolar electrode configuration and recording is done in localized area and is capable of single motor unit potentials. Usually these electrodes are used for muscles like soleus or for small muscles like finger flexors.
c. **Needle electrodes:** They are essential parts of clinical electromyography for recording potentials of single motor unit.

   The different types of needle electrodes are:

   i. **Concentric (coaxial) needle electrode:** In this, there is a needle cannula made up of stainless steel and wire made up of platinum or silver. The cannula and wire, both act as electrodes. Both are insulated to each other except at the tips, and potential difference between them is recorded. There may be single and bipolar wire configuration.

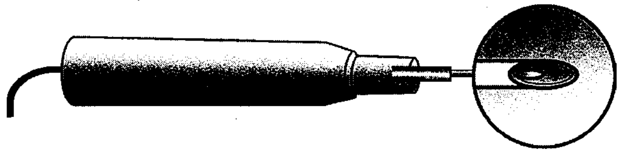

Fig. 16A.4 *Single bipolar concentric needle electrode*

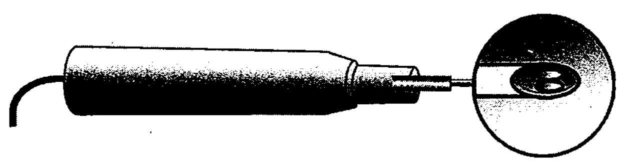

Fig. 16A.5 *Wire configuration*

ii. **Monopolar needle electrode:** It consists of single fine needle which is insulated except at the tip. Along with this, other reference electrodes are placed at the site of insertion over the underlying skin. These are less painful due to small diameter.
In addition to the surface and needle electrodes, a ground electrode is placed on the skin just near to the recording electrode. This is placed in order to cancel the efforts produced by the external environment, short wave diathermy, electrical apparatus.

iii. **Bipolar needle electrodes:** These consist of a cannula containing two installed wires with bare tips. With this electrode the potential difference between the two bare wires can be recorded. A satisfactory arrangement is to connect the two central wires to the two sides of a balanced amplifier while the outer cannula is earthed.

d. **Single fibre electrode:** This electrode consists of a stainless steel cannula of about 0.5 mm diameter which contains upto 14 insulated platinum or silver wires which emerge at a side hole 1–3 mm from the tip. This is a highly selective electrode, which gives information concerning the propagation velocity along the muscle fibres.

e. **Macro electromyographic electrode:** A concentric electrode records from only small number of muscle fibres comprising a motor unit. This method gives information concerning the whole motor unit but has not at present widely applied to the study of pathological motor units.

f. **Multilead electrodes:** These electrodes contain at least three insulated wires within a common steel cannula. In the usual from, the tips of the wire appear at intervals along the side of the cannula.

g. **Intra cellular electrodes:** If an electrode is to penetrate a single cell and register the potential changes across the membrane, it must have an exceedingly fine tip with a diameter of the order of 0.50 μm.

Myoelectric Signal: The work of transducer is done by the electrodes which convert the bioelectric signal produced due to the depolarization of the muscle or nerve to an electric potential and this electric potential is amplified by the recording of the potential difference between the two electrodes. The potential difference is measured in volts but the amplitude or height is measured in micro-volt. The potential difference and amplitude both are directly proportional to each other. But the duration of potential is a measure of time from onset of the electrical potential.

Processor Phase

The amplifier is main part of the processor phase, as it amplifies the small myoelectric signal to the electric potential. But sometimes, along with the electromyographic signal, the noise is also recorded from the static electrical activity in the air and power lines. For controlling the unwanted noise, the differential amplifier is used, as noise is transmitted to the amplifier as a common mode signal. When the difference of potential is reduced at both the ends, the noise being cancelled out at both the ends of amplifier.

Important points considered under this *i.e.* processor phase are:

a. **Common mode rejection ratio:** By using the differential amplifier, we eliminate the noise because sometimes the noise is reflected by the recorder voltage. But by CMRR (common mode rejection ratio) we can measure how much the desired signal voltage is amplified, relative to the unwanted signal. For example, if the CMRR is 1000 : 1, this shows that the wanted signal is amplified 1000 times more than the unwanted signal. It is actually described in terms of decibels (db).

$$=> 1000 : 1 => 60 \text{ db}.$$

In a good differential amplifier, the value of CMMR will be more than 10,000 : 1.

b. **Signal to noise ratio:** There is one more component present in the processor phase, that is signal to noise ratio, which is the ratio of the wanted signal to the unwanted signal. As we have discussed earlier, the noise can be produced internally or externally in the circuit no matter, but often the oscilloscope gives a hissing sound of the noise.

c. **Gain:** It is the most important part of the processor phase. As it is known that the amplifier is the vital part of the processor phase, thus the amplifier should be capable enough to amplify the smaller signal to larger signal so that it can be better displayed.
The term gain refers to the ratio of output level of signal to the input level of signal. There will be gain if the value of output level of the signal is more than the input level. This shows that amplifier has succeeded in amplifying such a small signal to big one, which is required in clinical electromyography.

d. **Impedance (Input):** Actually impedance is the resistive property present in the alternating current circuits. Impedance is present at the input of the amplifier and as well as at the output of the electrodes and they are directly related to the voltage. So according to this law, "If the impedance at the amplifier is more than the impedance at the electrodes, the voltage drop will be more", and more accurately it represents the signal but on contrary, if the impedance at the electrodes is more than the impedance at the amplifier, the voltage drop will be less *i.e.* very less of electrical energy is transmitted to the amplifier.

Moreover, the impedance depends upon many factors:

i. Skin resistance
ii. Electrode material
iii. Size of the electrode
iv. Length of the leads
v. Electrolyte, and
vi. Along with skin, blood, adipose tissue and blood offer resistance to the electrical field.

e. Frequency response: The frequency is usually measured in hertz, as the amplifier processes the different signals of different frequencies into one, in the form of a wave in electromyography. But it has limits, it has a range within it, amplifier amplifies the frequency *i.e.* set in SE 10–1000 Hz. This is done by frequency bandwidth 20–2000 Hz in fine wire electrode.

Output Phase

In this phase, the amplified signal is displayed by audio or visual means. Moreover, it depends on the desired information required and the available instruments. Usually in the clinical electromyography, it is displayed with the help of cathode ray oscilloscope (CRO). It is a kind of visual display.

A cathode ray oscilloscope consists of the electron gun, screen, horizontal and vertical plates. The working of the CRO is – the electron which projects the electron beam towards the screen interiorly is phosphorescent in nature. There are two sets of plates, that is, vertical and horizontal (as shown in the diagram) arranged. As the electron beam passes, there is deflection at the vertical plate and sweep at the horizontal plate. This is shown at vertical plate signal voltage in micro volts (μV) and sweep at the horizontal plate shows the duration of signal in millisecond, but by conversion, there is positive as well as negative deflection above and below base line. These signals are displayed by the loudspeaker which records both. The CRO image sound and ink pen writers are also sometimes used but they are limited to frequencies. Alternatively, camera can be connected to the CRO and then photographs can be made for permanent record. Computers can also be used so that it performs the complex analysis of motor unit potentials and send results to printer.

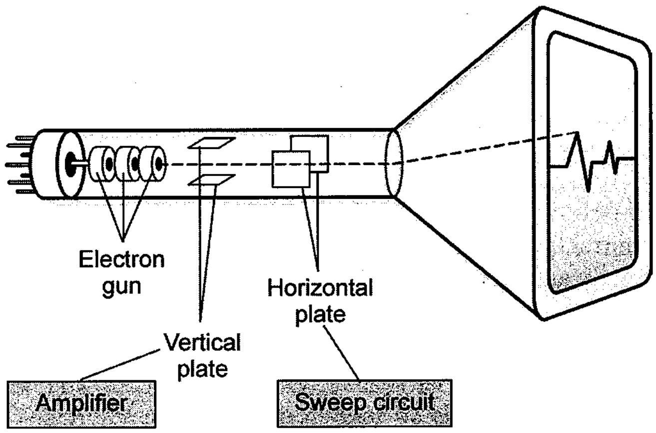

Fig. 16A.6 *Cathode Ray Oscilloscope*

Kinesiologic Electromyograph Displays

Kinesiologic electromyography study was done by several type of recorders such as pen and chart recorders. In the past, though they had the limitation in terms of the frequency response, but now in the present technology, there is recording of the raw and integrated electromyography signals on magnetic tape or using a computer or printer.

CLINICAL EXAMINATION OF ELECTROMYOGRAPHY

An electromyography examination, used to access the function of neuromuscular system, includes upper motor neuron, lower motor neuron, the neuromuscular junction and muscle fibre.

The test is done for detecting the muscle action potential in a group or individual in the different stage of contraction. Peripheral nerve lesions are also detected by the electromyography.

THE TECHNIQUE OF RECORDING THE ELECTRIC POTENTIAL

Patient is asked to relax and needle electrode is inserted at the contracting muscle simultaneously. At the same time, there is spontaneous burst of the potential, which is observed by the electromyographer. This insertion activity means needle breaks the fibre membranes. The needle is repositioned but it lasts for less than 300 milli sec. According to the magnitude and speed of movement of the needle in the muscle, the insertion activity can be normally reduced or increased. There are some wavy deflections even after the cessation of insertion activity due to sensitivity of high amplifier but also, there is silence electrically, shown by relaxed muscle potentials arising during this period. This is shown as abnormal findings because the normal spontaneous potential is differentiated by its shape, sound and low amplitude.

When the patient is at rest, ask him to contract the muscle minimally. Now such a minimal voluntary contraction causes the motor units to contract and finally ask him to progress the number of contractions.

Normally, the motor unit potentials are evaluated under the headings of:

1. Amplitude
2. Duration
3. Shape
4. Sound
5. Frequency.

Normal motor unit action potential: The normal motor unit action potential is the sum of electrical potential of the muscle fibres present in the single motor unit, having the capability of being recorded by the electrodes. The normal MUAP depends on the given five factors that is amplitude, duration, shape, sound and frequency.

In normal muscle, the amplitude of a single motor unit action potential may range from 300 mV to 5 mV from peak to peak. The total duration measured from initial baseline will normally range from 3 to 16 m sec.

The shape of a motor unit action potential is diphasic or triphasic with a phase representing a section of potential. There are sometimes polyphasic potentials in two or more phase.

The sound is a clear distinct thump and there is capability of the motor unit that it will fire upto 15 times per second with strong contraction. Usually when muscle is at rest, it represents electrical silence but if there is an activity, it is considered as abnormal and denoted by spontaneous activity which is not represented by normal voluntary muscle contraction.

There are four classifications of the spontaneous activity:

1. Fibrillation activity
2. Positive sharp waves
3. Fasciculation potentials
4. Repetitive discharges.

Fibrillation Potential

Fibrillation potential is seen in the denervated muscle as they give spontaneous discharges because they are hypersensitive to circulating acetyl choline. Some times, *e.g.* there is fibrillation potentials arising from the spontaneous depolarization of the single muscle fibre.

Classically, it is seen in lower motor neuron disorders such as:

i. Peripheral nerve lesions
ii. Anterior horn lesions
iii. Radiculopathies
iv. Polyneuropathies with axonal degeneration but in smaller extent, it is seen in myopathic disease.
   a. Muscular dystrophy
   b. Dermatomyositis,
   c. Polymyositis,
   d. Myasthenia gravis.

The fibrillation potential is represented with following data:

Phase	–	It is up to three phases,
Amplitude	–	20 – 300 mV,
Duration	–	2 m sec.,
Sound	–	High pitched click, and
Frequency	–	30 per sec.

Positive Sharp Waves

It is a form of electrical potential associated with fibrillating muscle fibres which are recorded as a biphasic, positive negative action potential initiated by needle movement and recurring in uniform patterns. The initial positive phase is of short duration that is < 5 m sec, and large amplitude up to 1 mV. The second negative phase is of long duration 10–100 m sec. and low amplitude. The discharge frequency may range from 2–100 per sec. It represents a typical thud sound, which is dull in nature.

Positive sharp wave is seen in primary muscle disease like muscular dystrophy, polymyositis but sometimes it is also seen in upper motor neuron lesions. These waves are characteristic features of denervated muscle.

Fasciculation

A random spontaneous twitching of muscle fibre or a group may be visible through skin. This is seen in irritation or degeneration of anterior horn cell.

- Nerve root compression
- Muscle spasm or cramps
- Motor neuron disease
- Pathology of spinal cord
- Pathology of root level.

The data of fasciculation is:

Amplitude	–	300 mV–5 mV,
Duration	–	3 to 16 m sec.
		May be di, tri or polyphasic.
Frequency	–	50 per sec., and
Sound	–	Low pitched thump.

In fasciculation potential, spontaneous discharge is from motor units, not under the control if the needle is near the motor point.

Repetitive Discharges

These are also known as bizarre high frequency discharge. The potential of repetitive discharge represents various forms. The characteristic features of the repetitive discharges are:

Frequency	–	5–100 per sec.
Amplitude	–	50 mV–1 mV.

But in case of myotonia, the amplitude varies.

It sounds like a live bomber. They are seen in lesions of anterior horn cell and peripheral nerve lesions along with myopathies.

The above mentioned abnormal potentials are produced when the muscle is at rest but there is abnormal potential too when the muscle is contracting voluntarily. This is known as abnormal voluntary potential.

Abnormal Voluntary Potential

In case of typical myopathies and peripheral nerve involvement or in primary muscle disease, there is polyphasic potential with short amplitude and duration.

This is due to pathology in a motor unit. There is a decrease in number of active muscle fibres to contract. This is seen in regeneration of action potential as some of the fibres are reinnervated and others are still to reinnervate, so fewer fibres of muscles contract and give a asynchronous depolarization. The polyphasic potential with the characteristic feature of small duration and amplitude than normal units are considered nascent units.

Ironically, in the neuropathic involvement such as anterior horn cell disease by collateral sprouting of the axons to the fibres of denervated motor units, there is hypertrophy of an intact motor unit, resulting in giant motor unit in which there is polyphasic potential with peak-to-peak amplitude and duration much greater than normal ranges.

Technique of Reporting the Result of the Clinical Electromyography Examination

The electromyography is given in the patient's chart or medical record. The data includes:

1. The specific muscle or muscles tested including the side of the body and innervation of these muscles.
2. The response seen during electrode interaction.
3. The response seen whether there is spontaneous activity or specific potential or electrical silence is there.
4. Response with voluntary contraction (motor unit potential).

Data should include the five parameters that are of electrical potential:

i. Amplitude
ii. Duration
iii. Shape
iv. Sound, and
v. Frequency.

Along with clinical assessment with electromyography, the history of the patient is taken:

i. His laboratory test
ii. Physiotherapy assessment like manual muscle testing
iii. Sensory test
iv. Range of motion test.

INDICATIONS OF CLINICAL ELECTROMYOGRAPHY TEST

1. **Disorders of peripheral nerve:** Electromyography findings are useful only when there is axonal degeneration and they assist in the identification and progress of the diseases. In the disorders of peripheral nerve, the lesions are of three types:

   a. Neuropraxia
   b. Axonotomesis
   c. Neurotmesis.

a. **Neuropraxia:** When there is destruction, injury or blockage (local) in the myelin sheath, conduction above and below the blockage is usually normal. In neuropraxia lesions, the compression disorders are most common. For example, Bell's palsy, Saturday night palsy (Radial nerve palsy), compression in the spiral groove, pressure over the peroneal nerve at the fibular head, carpel tunnel syndrome (median nerve entrapment).
In this lesion, the nerve conduction test is more useful to detect the demyelination in comparison to axonal degeneration. In acute condition, when there is no denervation, the electromyography will be normal at rest.

b. **Axonotomesis:** Axonotomesis occurs when the nuclei or cell of the axon is destructed or it may be due to long-standing neuropraxia or it may occur from traumatic lesion. In electromyography, there will be fibrillation potential and positive sharp waves two to three weeks, following degeneration depending on the axon from the cell body.

c. **Neurotmesis:** If the neuron is out or there is total loss of axonal function with disruption of neural tube, conduction ceases below the lesion. In this nerve conduction, velocity test can not be performed but in electromyography, spontaneous potential will appear with the muscle at test and no activity is produced with the attempted voluntary contraction.

2. **Polyneuropathies:** In polyneuropathy, there are sensory changes, distal weakness and hyporeflexia. In the neuropathic condition, there is axonal damage or demyelination of axons. The electromyography results with polyneuropathy, represents decrease in the amplitude and duration of the motor unit potential and there is typical fibrillation potential, positive sharp waves and fasciculations.

3. **Motor neuron disease:** This includes degenerative disease of the anterior horn cells. They include:

i. Syringomyelia,
ii. Poliomyelitis.

Some diseases characterized by degeneration of both upper and lower motor neurons are:

iii. Amylotrophic lateral sclerosis,
iv. Progressive muscular atrophy,
v. Progressive bulbar palsy,
vi. Spinal muscular atrophies.

In electromyography, they represent fibrillation potential and positive sharp waves at rest. There is significant feature, that is single motor unit pattern. There is polyphasic potential with increased amplitude and duration due to reinnervation and sprouting.

4. **Myopathies:** This is actually a muscle disease, for example polymyositis or dystrophies. There is significant degeneration of the muscle fibre but the motor unit is intact. On electromyography, the features have prolonged insertion activity due to instability of muscle fibre or membrane. In the early stages, there is fibrillation potential, positive waves with repetitive discharge, polyphasic potential with short duration and low amplitude. But in later stages, there is no electrical potential seen because the contractile tissue is replaced into fibrous tissue.

5. **Myotonia:** In myotonia, there is delayed relaxation of previously contracted muscle. This causes muscle stiffness. The characteristic feature on electromyography will be high frequency repetitive discharge with waxing and wanning of amplitude. It produces dive bomber sound with frequency of 150 pulse per second. All these combined features are said to be myotonic discharge.

6. **Myasthenia gravis:** This is auto-immune disorder characterized by weakness and excessive fatiguability confined to ocular muscle, palatal or pharyngeal muscle. We can say disorder of muscular transmission characterized by weakness followed by repetitive contraction. Electromyography will represent normal electromyography at rest but there is fibrillation potential and positive sharp waves, which may be present in severely affected muscle, which indicates the loss of innervation.

7. **Radiculopathy:** Radiculopathy means nerve root involvement at all spinal levels. Electromyography often assists in identifying the cause for radiating pain, persistent weakness, hyporeflexia and fasciculations. The electromyography shows increased insertion activity, fibrillation, potential, positive sharp waves at rest. In early stages, low amplitude polyphasic potential and at later stage high amplitude polyphasic potentials are shown.

Electromyography is also indicated in:

8. **Spinal cord compression:**

i. Spinal cord tumors
ii. Cervical spondylosis
iii. Lumbar disc lesions.

9. **Facial nerve palsy.**

10. **Movement disorders:**

i. Spasticity
ii. Rigidity.

Use of Kinesiologic electromyography in clinic: There is a vast role of kinesiologic electromyography in the clinic. Electromyography is used to examine muscle function during specific purposeful task or therapeutic regimes. This is not limited to examination of single motor unit potential but also considers:

- Patterns of muscle response in relation to effort.
- Type of muscle contraction.
- Position.
- Onset and cessation of the activity.

These activities help the therapist to plan the treatment.

CLINICAL APPLICATIONS

The use of electromyography helps the patient in assessment as well as planning the treatment as it provides the information about the effectiveness of a specific procedure.

Selection of Muscle

The action and the general movement or functional movement performed by a muscle or a group of muscle is seen. It is very difficult to see the function of a single muscle responsible for the movement, therefore choose the muscles that are representative of the group that are considered as prime movers. The therapist must determine which muscles combined to perform the movement because the surface electrodes should be kept over the muscle belly, when we want to see the activity of single muscle.

Motor Control

Electromyography helps in measuring the level of motor unit activity but cannot measure the tone of muscles. Motor unit activity is facilitated by stimulus such as passive stretch, by treatment modality, with change in position, and voluntary contraction and reflex activity give the same results. Electromyography also monitors associated reactions or exercise overflow. Exercise overflow means electromyography activity recorded in unexercised muscle during contraction in another body part. It may be ipsilateral or contralateral. These activities are observed during resistive exercise, during position changes or applying load. But cryotherapy, resistance exercise, positioning will generally not interfere with valid electromyography recording.

i. While doing manual muscle testing, electromyography can be used to evaluate the degree of effort. Associated reactions may also be recorded at the electrodes. Electrodes should be kept at different places around the muscle to get the differentiation.
ii. When the patient is sitting or standing, the electromyography is used to assess the patterns of response by seeing the amplitude and turning of onset of the activity. The aim of doing electromyography is to facilitate or inhabit specific muscle group to enhance balance reactions and weight shifting.
iii. **Gait**—Electromyography can be useful to assess muscle activity during gait. This is done by film, videotape, electrogoniometres on contact foot switches for delineating swing and should also be considered while seeing the effect on electromyographic activity.

Passive Movements

Electromyography can help to identify whether movements are truly positive. If passive movements are done in a normal relaxed muscle, we will not get the appropriate electromyography results, but if the patient voluntarily relaxes to allow full passive movement, it will give better results.

Movement Patterns

Therapist can use electromyography to observe the effect of treatment on patterns of muscle response. Electromyography helps when it is difficult to observe the movement. It helps in examination of agonist and antagonist, co-contraction or reciprocal inhibition or activity like mat exercise and traction, PNF patterns isokinetic exercises as well, but it has controlled velocity of movement.

PART B

INTRODUCTION

Biofeedback is a technique to reveal to human beings some of their internal physiological events; normal or abnormal in the form of visual and auditory signals in order to teach them to manipulate these otherwise involuntary or unfelt events by manipulating the displayed signals.

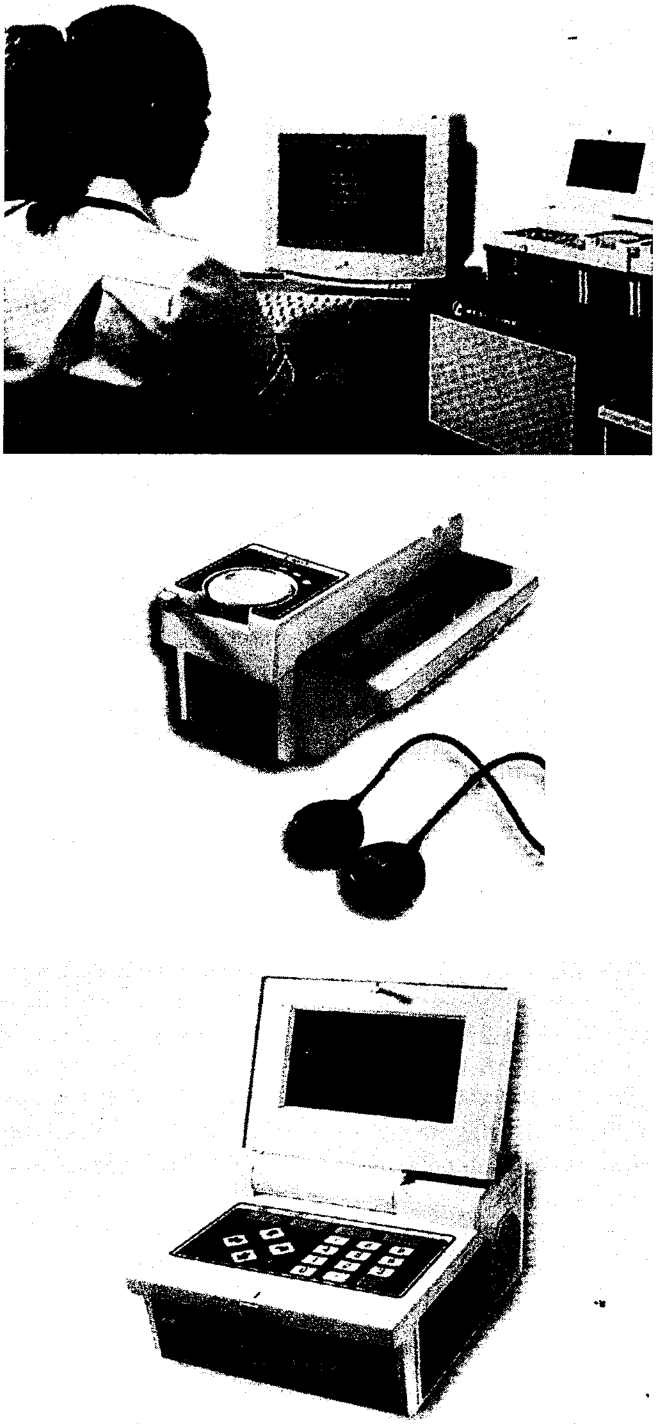

Fig. 16B.1 *Diagram of EMG Biofeedback Unit*

Biofeedback can be used to inform the patient about physiological events like blood pressure, skin temperature, heart rate and other things like force, joint displacement so that by seeing these the patient is able to control these activities, in order to understand biofeedback (Fig. 16B.2).

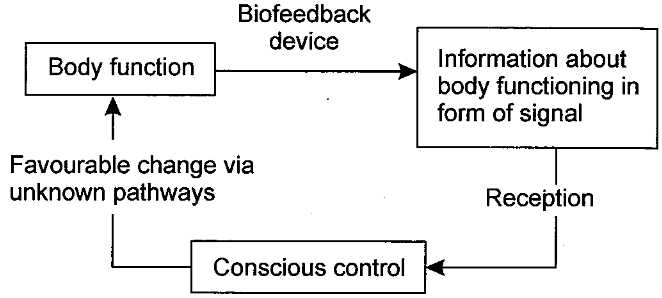

Fig. 16B.2 *Schematic diagram of biofeedback*

The motor learning can be facilitated by improving the motor performance. This is the main aim of biofeedback in physiotherapy. Motor learning includes a behavioural positive reinforcement or reward, which helps the patient to improve his motor behaviour. This is given in the form of visual feedback stimulus or verbal information. Therapist's comment can also be used. Then the therapist uses these signals to improve the motor behaviour.

If a sensitive skin thermometer is applied to the skin of the finger, most people are able to make a small alteration of the skin temperature at will (Fig. 16B.3). This may take a little time and some practice but can be done provided the subject can see the thermometer reading and thus has immediate information of any change in skin temperature. This is the 'Feedback'.

Many physiological changes of which people are normally unaware can be made visible or audible in suitable electronic instruments. This has enabled biofeedback control to be practised for a whole range of activities such as the control of blood pressure, heart rate, skin temperature but principally for the contraction and relaxation of voluntary muscle electromyographically. This effect can also be demonstrated in animals. Experiments have shown that the heart rate in rats and dogs can be controlled in some cases, by operant conditioning.

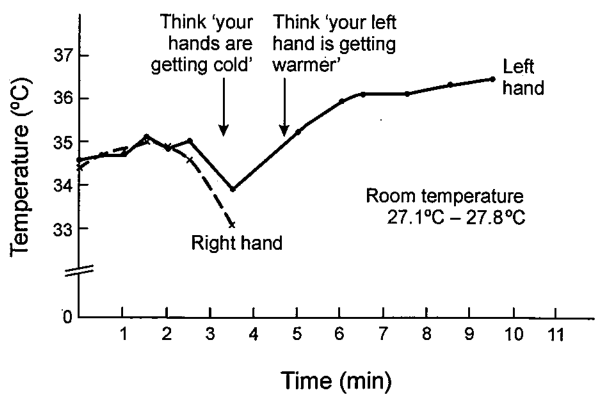

Fig. 16B.3 *Skin temperature as recorded over 10 min for the left and right middle fingers of a 50 years old normal subject*

The concept can be expressed in principle by the feedback loop shown in Fig. 16B.3.

The physiological change is detected or measured by some device, *e.g.* the skin temperature alters the resistance of the thermistor. The output of this measurement is displayed on a digital indicator. The subject perceives this information about the temperatures and he or she now makes conscious attempts to alter it, *i.e.* to warm or cool the finger (Fig. 16B.3). Exactly which neuronal pathways are involved in this last part of the loop is not understood, but the fact that it is possible to exert some control, albeit to a limited extent, indicates that such pathways exist.

This is not different in principle from the re-education given by physiotherapists in providing feedback for the correction of posture on the initiation of a muscle contraction. All human movements are controlled by feedback. Information comes from muscle spindles, joint motion and position sensors, the vestibular apparatus, skin sensors and visual cues.

For Example: If the patient is doing the elbow flexion and he gets audio or visual feedback which indicates that he is doing incorrectly and when again undesired pattern in seen on visual display, the patient will try to achieve the correct pattern of movement thereby participating in the control of signals and gradually learns the correct pattern.

The process of making aware to the patient about the physiological events by biofeedback device and how the patient becomes conscious to these events, can be explained by a loop.

Patient's motor behaviour or physiological change

↓

This can be detected by measuring device or biofeedback device

↓

The following changes are displayed (audible or visual) by indicator

↓

This information is perceived and develops understanding towards the changes

↓

Now he has conscious control over the motor behaviour and the process continues.

USES OF BIOFEEDBACK

The use of biofeedback is classified for two broad criteria:

a. To improve the control over the defective muscle or defective movement
b. For the control of stress related conditions.

How Biofeedback Works for the Control of Muscle Activity and Movement

Electromyography biofeedback is used in this context. This is used for the diagnostic purpose. The mechanism is as follows:

When all the muscle fibres in a motor unit contract to produce a motor unit action potential, this leads to generation of electric signals when we place the surface or needle electrodes amplified by the amplifier and displayed on an oscilloscope screen or by chart recorder. The amplifier signals are represented in terms of amplitude, duration, sound, frequency and phase. On the basis of this data, it is detected whether the movement or muscle activity is normal or not and thus re-education is given to improve the muscle activity.

Motor Control

Electromyography biofeedback is used for improving the motor control.

1. **For Example:** Treatment of hemiplegia is done by electromyography biofeedback. As the hemiplegic patient has the poor dorsiflexors and gait, by means of electromyography biofeedback, we can improve the dorsiflexors like Tibialis anterior and reduce the spasticity present in the plantar flexors. Deltoid is also treated to have the better control over pectorals.
2. It also helps in reducing and control of spasticity in case of cerebral palsy.
3. It helps in the dystonic conditions because the patient suffers from uncontrollable movement or postures, thus treatment is given by electromyography biofeedback.
4. Spasmodic torticollis is a condition in which the biofeedback is given to sternocleidomastoid.
5. Helps in recover of peripheral nerve injuries.
6. Electromyography biofeedback helps in re-educating the specific muscle activity.
7. Posture control is also done by the electromyography biofeedback. In this, monitor gives warning by signals, which tilts away from the vertical.
8. It is also used in the treatment of patient with functional breathing disorders, for example: Shallow breathing or hyperventilation.
9. Foot drop due to stroke.
10. Pain due to muscle spasm, which is chronic.

11. Bell's palsy.
12. Lower motor neuron lesions.
13. Paralytic muscles.
14. Immobilization (following orthopaedic trauma).
15. Low back pain.
16. Blepharospasm.
17. Spinal cord lesions (Incomplete).
18. Joint repair.
19. Parkinson's disease.
20. Writer's cramp.

Application of Electromyography Biofeedback

When the muscles contract or relax, the information produced can be transmitted through electrodes on the skin, recorded and displayed usually as a pen tracing. This is known as electromyography. The record can also be feedback to the person undergoing electromyography as a tone which changes in pitch, tension and relaxation of muscle. This technique has been used in biofeedback in a number of conditions.

The position and support of the patient must be carefully chosen for this treatment. If relaxation is to be attempted, then the whole body must be fully supported lying or half lying so that all postural muscles must be relaxed. In the electromyography biofeedback, there is a voltmeter with a speaker and motor attached, an electromyography instrument to detect the electrical signal if there is potential difference between the two poles. Now it is the duty of the biofeedback instrument to condition the positive and negative impulses, the quality of the machines and therefore, its output is chiefly indicated by its input impedance, common mode rejection ratio (CMRR), frequency response, noise level and ability to cope with non-electromyography artifacts.

As a rule, electromyography instruments should have at least one thousand times as much as input impedance as that measured between two active electrodes. The electrode size also alters the effective resistance given by the amplifier. Greater resistance is accessed with needle electrodes as they contain small surface area. Larger electrodes have lower resistance.

As with input impedance, higher is better. Common mode rejection ratios should be at least 2,00,000 : 1 frequency response. In general, a frequency response of 32–500 Hz is adequate for surface kinesiologic electromyography feedback.

The noise levels in high quality components is 2mV or less because in general the lower the noise, the better. Same artifacts are also there in electromyography biofeedback *viz.* volume conduction and movement.

In the treatment session, no matter what the diagnosis, biofeedback technique and treatment approach is similar.

1. Select a muscle whose electromyography signal is relevant to the muscle activity.
2. Have the patients practice controlling the signal.
3. Withdraw the feedback as function is gained.

Other Uses of Biofeedback is Stress Related Conditions

Usually stress related condition requires relaxation. Biofeedback technique is very helpful in providing the means and motivation for practicing the relaxation. So nowadays such type of instruments have been introduced for measuring stress and teaching relaxation. It is used in the stress related conditions like:

1. **Essential hypertension:** Studies and experiments have shown that if the blood pressure of the patient is monitored and displayed, the patient can learn how to control the blood pressure. By practising, he can control up to 35 mm of Hg.
2. **Cardiac arrhythmias:** Similarly, heart rate is monitored and displayed to the patient by biofeedback. He learns to control by slowing the heart rate. Simultaneously, patient can control blood pressure also.
3. **Raynaud's disease:** In case of Raynaud's disease, the means of biofeedback, the temperature of the finger is monitored using a suitable skin thermometer and patient learns voluntarily to increase the temperature.
4. **Migraine:** An attack of migraine is caused by dilatation of blood vessels over the surface of the brain. As the vessel wall stretches, they trigger pain sensitive receptors. Pain is severe and unilateral. In early stage, it is throbbing type but later on it becomes constant. So biofeedback in the treatment of migraine has involved attempts to increase peripheral blood flow usually to hands and fingers.
5. **Tension headache:** It is believed that tension in the occipitofrontalis and postural neck muscles is the cause of these headaches. This causes chronic pain and muscle tension at other sites. So relaxation of these muscles with biofeedback displays that the electromyography of these muscles is done.
6. **Epilepsy:** By experiments, it has been discovered that it is possible for the patients to reduce the frequency of epileptic fits by producing a special rhythm in the electroencephalogram *i.e.*, the sensory motor rhythm.

So we can say that relaxation training combined with the biofeedback has been found to be the most successful treatment.

OTHER FORMS OF BIOFEEDBACK FOR CONTROL OF ACTIVITY

Muscle strengthening devices have electronic displays, which indicates the strength or power developed. In case of gait training, the amount of weight taken through one foot can be monitored with pressure sensitive pad in the shoe. In case of partial weight bearing training, there is a sound when the patient takes sufficient weight and the sensitivity of the device can be decreased as he or she improves. Nowadays for the myoelectric artificial limb, control of the limb is done by the electromyography biofeedback.

Biofeedback in Rehabilitation

When using biofeedback, the patient must:

1. Understand the electronic signal to the desired functional task.
2. Practise controlling the biofeedback signals.
3. Perform the functional task until it is mastered and patient no longer needs biofeedback.

Biofeedback is simply one technique that therapist may imply to help convey her/his message about motor programmers and biomechanical scheme to the patient.

Biofeedback assists the rehabilitation process by:

1. It provides clear goal to the patient, which the patient has to achieve.
2. It helps the therapist and patient to perform various processes to achieve the goal.
3. Reinforcement for getting appropriate behaviour.
4. Providing a process, which gives orientation, time and accurate knowledge of results of the patient's efforts.

Both the therapist and the patient must, therefore, understand the meaning of the feedback signal.

TREATMENT DURATION

There are no specific criteria for the duration of the treatment with biofeedback devices. However, favourable results are likely to occur with the use of the biofeedback devices for 10 to 30 minutes per day.

ADVANTAGES

Biofeedback provides corrective information to the patient immediately. Patient gets involved actively in his own treatment. Biofeedback may not require sophisticated understanding of the skill by patients. Biofeedback devices can be used during ongoing activities. It may save physiotherapist's time.

DISADVANTAGES

Biofeedback treat symptoms and not the underlying cause of symptoms. Biofeedback training or treatment is uneconomical as all of these devices are not available commercially at all the places. Biofeedback devices are unacceptable to patients who won't like to put wires and electronic boxes over their body. Sometimes physiotherapists may need special training for the use of biofeedback. Biofeedback could be just a form of training rather than treatment.

SUMMARY

Biofeedback is the process of furnishing an individual with information about body functioning so as to get some voluntary control over it. This information regarding body functioning can be given to the individual via visual or auditory signal through a suitable instrument. Various forms of biofeedback include myoelectric feedback, postural biofeedback, feedback goniometers, pressure or force biofeedback, orofacial control devices, toilet training devices, stress related devices, cardiovascular biofeedback, etc. These biofeedback devices provide corrective information to the patient immediately. There are no specific criteria for the duration of the treatment with biofeedback devices.

CHAPTER

17

ELECTRODIAGNOSIS

- Introduction
- Physiological Basis of Electrodiagnosis
- Electrical Properties of Nerve and Muscle
- Strength-duration Curve (S.D. Curve)
- Apparatus
- Method
- Rheobase
- Chronaxie
- Accommodation Quotient
- Advantages of S.D. curve
- Disadvantages of S.D. curve
- Other Electrodiagnostic Tests

INTRODUCTION

A motor unit consists of the nerve cell, the nerve fibre and its terminal branches, the neuromuscular junction and the muscle fibres and their constituent myofibrils, is the final pathway through which nervous activity gives rise to voluntary movement. The function of electrodiagnosis by different methods and SD curve plotting in physiotherapy is to study the integrity of different portions of motor unit. The function of nerve and muscle is inaccessible from the surface, thus their function can be studied only by recognizing the appropriate clinical signs and the data obtained after the result of an electrodiagnostic test.

Electrodiagnosis is concerned with the study of electrical activity in motor units when stimulated by electrical pulses. It also considers the normal and abnormal behaviour of the response of a motor unit when stimulated and of the interpretation of its results for diagnosis and Prognosis in disorders of the neuromuscular complex of the locomotor system.

Neuromuscular function disorders: Reduction of voluntary muscle contraction due to faulty conduction at the neuromuscular junction.

Muscle lesion: Muscle weakness or disease but there is no motor nerve degeneration. The reaction to electrical stimulation are of normal type but are reduced in strength.

Functional disorder: Loss of voluntary power may be due to hysterical paralysis.

Neuropraxia: Physiological interruption of nerve conductivity due to pressure or ischaemia. Recovery is generally expected.

Axonotmesis: Degeneration of axon takes place. The sheath of the nerve remains intact *e.g.* radial nerve damage at the level of shaft of the humerus fracture.

Neurotmesis: Discontinuity of the whole nerve following complete section. There is no stimulation response; fibres degenerate below the site of lesion.

UMN lesion: No change in the LMN or muscle although sometimes the nerve and muscle are hyperexcitable and react to a lower intensity of current than that normally required.

PHYSIOLOGICAL BASIS OF ELECTRODIAGNOSIS

The physiological basis of electrodiagnosis is the mechanism underlying normal electrical activity of muscle and nerve when stimulated by electrical impulses.

Stimulation of Nerve fibre: In the resting state, a neuron is a charged cell not conducting a nerve impulse. The difference in electrical potential of 90 mV between the tissue fluid outside and the intercellular fluid inside the neuron maintains the dynamic equilibrium of the resting neuron and underlies the generation and propagation of the nerve impulse and impulse between 0.02 ms and 1ms is sent to the nerve. It will be sufficiently long to stimulate the nerve and cause depolarization followed by muscle contraction. Nervous tissue demonstrates the **phenomenon of accommodation,** by which the threshold of stimulation increases as the stimulus develops. If the ratio of the stimulus is slow, as in triangular or saw tooth pulses, it will fail to overtake the increasing threshold and excitation does not take place. So a slow rising pulse with the same intensity as a sharply rising long duration pulse will fail to excite a nerve.

Stimulation of the biceps muscle at its motor point (minimal contractions)

Pulse duration	Shape of pulse	Intensities
1 ms	Rectangular	30 volts
0.02 ms	Rectangular	55 volts
100 ms	Rectangular	30 volts
1000 ms	Rectangular	30 volts
1000 ms	Triangular	55 volts

Generally the intensity needed to produce a minimal perceptible contraction is always less than 2.2 times that needed to produce a contraction with 100 ms pulse duration. If ever it is greater than 2.2 times, the rheobase value at 100 ms, then it denotes denervation.

Tetanic-like contractions at 100 ms need an intensity of twice the rheobase generally. If it is less than twice the rheobase, this denotes denervation.

Stimulation of muscle fibre: Like nerve fibre, muscle is bounded by a cell membrane, which has a potential difference of 70 mV. It has a highly specialised neuromuscular junction where the nerve enters the muscle. It is possible to excite the muscle directly and produce depolarisation of the muscle membrane causing excitation of the muscle using pulses of varying duration.

Muscle has a much smaller accommodation property and thus will respond better to slow rising long duration pulses. This is particularly seen in denervated muscles, where a good response is obtained from a slow rising triangular pulse with a duration of 1000 ms. It is difficult to obtain a contraction with shorter rectangular pulses if the muscle is denervated.

ELECTRICAL PROPERTIES OF NERVE AND MUSCLE

Electrical properties of nerve and muscle must be considered in electrodiagnosis.

Electrical excitability is characterized by three factors:

1. Intensity of current
2. Duration of current flow
3. Speed at which peak intensity is reached.

In cases of partial or complete denervation, electrical excitability is altered specifically.

Refractory period is the time in which tissue is excited by means of a stimulus and does not respond to second stimulus. In denervated muscles, the refractory period is longer.

Accommodation is the property of a tissue to adapt itself to slowly increasing stimulation intensities. If a muscle is denervated, it has lost most of its power of accommodation and only those pulses with a long duration and a slow rise in peak intensity will be able to produce a brisk contraction.

Action potential is the ability of nerve and muscle membrane to develop transient changes in potential which can be transmitted from one point to another and which confers upon nerve and muscle the special property of excitability. The propagated change of membrane potential is action potential or impulse.

Reaction of Degeneration (RD): In 1868, Erb made his classical observation on the reaction of degeneration if muscles deprived of their nerve supply. Since then much progress has been made in the use of this observation for diagnosis. The term used today in the same context is denervation. Reaction of degeneration describes the failure of muscle to contract when stimulated by a tetanising current. The tetanising current may be an interrupted current or a rapid sinusoidal current. It is generally of 1 ms pulse duration and the muscle is stimulated through its motor point. A bipolar technique could be used for the testing purpose also. The presence of RD means the muscle is denervated. The absence of RD means that the muscle is normally innervated.

Partial Reaction of Degeneration (PRD): If trauma, disease, or other factors have produced a partial lesion of the motor unit, there will be an obvious diminution in the contractile responses when a tetanising current is applied to such a muscle. This response is called partial reaction of degeneration. If with the progress of time, PRD is less apparent, then the prognosis is good. It is also termed as **partial denervation** which means some of the muscle fibres have conducting nerves while in other muscle fibres, the conducting nerves have been damaged.

Complete Reaction of Degeneration (CRD): If the lesion totally obstructs the activity of the motor unit, there will be no response when a tetanising current is applied to the affected muscles. Depending on the extent of lesion, the muscles will respond to the long duration rectangular pulses or slow rising saw tooth or triangular pulses. If the denervation is more profound, pulses of 1000 ms with a trapezoidal or saw tooth shape will be most effective. This is also termed as **complete denervation**.

Absolute Reaction of Degeneration (ARD): When denervation with marked degeneration has been present for over a year, muscle atrophy, with replacement of muscle fibre by fibrous tissue, takes place and there will be no response to any electrical stimulus. Sometimes a long duration pulse of 2000 ms, triangular in shape, may produce a sluggish reaction. This is termed as absolute reaction of degeneration.

Occasionally denervateds muscles, that have been exposed to cold and are poorly nourished may, within a year from onset, show no response to electrical stimulation. In such a case, it is necessary to assess the extent of damage with an EMG report and bear in mind the history of the lesion. Here the lack of response is due to high resistance from the skin & superficial tissues and poor nourishment. Do not misdiagnose.

STRENGTH DURATION CURVE (S.D. CURVE)

The plotting of S.D. curve is the most satisfactory method at present available for the routine testing of electrical reactions in peripheral nerve lesions.

Method of SD Curve Plotting: SD curve should be plotted after 20th day of injury/lesion. The degeneration is complete in 20 days. Only after the 21st/22nd day, regeneration of nerve will start, if the nerve is subjected to electrotherapy or drug therapy alongwith exercise therapy. Generally it takes about 270 days to regenerate the nerve fibres.

At present the most commonly used method in physiotherapy is to plot **S.D. Curve** (strength and duration curve) also known as I.T. Curve (intensity and time curve).

The purpose of S.D. Curve plotting is to know whether the stimulated muscle is innervated, denervated or partially denervated. This method of diagnosis in physiotherapy is termed as electrodiagnosis. There are also other methods for this purpose like **Electromyography** (EMG), **Nerve Conduction Velocity Test** (N.C.V.) but they are performed by neurologist.

APPARATUS

The apparatus used for plotting strength duration curves supplies rectangular impulses of different durations. Both the form and the duration of the impulses must be accurate, so it is necessary to use a stimulator specially designed for muscle testing. Impulses with duration of 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30, 100 and 300 milliseconds are required and the apparatus should be checked at regular intervals to ensure satisfactory working.

The stimulator may be of either the constant current or the constant voltage type. The former records the intensity of current used and latter the voltage. Recent work indicates that the differences in the results obtained with the two types of stimulator have in the past been overestimated. The constant current stimulator was thought to produce the more accurate results but the constant voltage stimulator is rather more comfortable for patient.

METHOD

Before applying the current, the skin resistance is reduced by the methods used prior to other muscle stimulation. The patient must be warm, fully supported and in sufficient light. An indifferent electrode may be applied to some convenient area usually on the midline of the body or over the origin of the muscle group, and the active electrode over the fleshy part of the muscle or two small electrodes may be used, one over each end of the muscle belly. In either case, the active electrode should be fairly small, so that the muscles may be isolated from each other.

Current is applied using the longest stimulus first and increased until a minimal contraction is obtained. This may be assessed visually or by palpation of the tendon, depending on the muscle being treated. The intensity of the current (or voltage) is noted and the impulse shortened. This procedure is repeated with each stimulus in turn, the intensity of current being increased as required. Utmost precision is essential if the results are to be accurate. A minimal contraction is used, as this makes it easy to detect any change in strength, and it is important that the active electrode is held on the same point over the muscle throughout the test.

The strength duration curve is plotted from the results of the test, and although it will be further to the left with the constant voltage than with the constant current stimulator, it is the shape of the curve that is the essential feature.

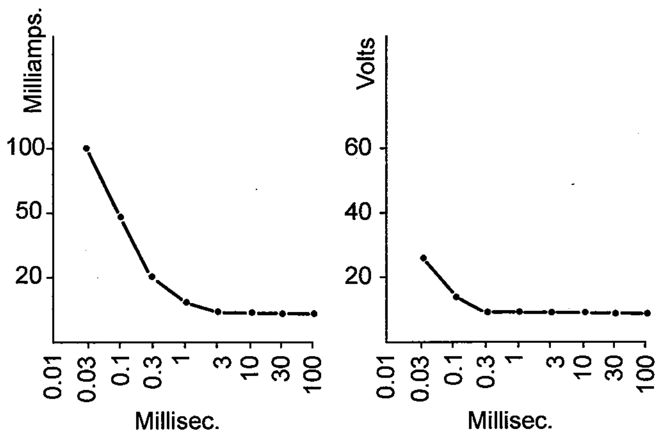

Fig. 17.1 *Strength-duration curves of normally innervated muscle*

Normal Innervation: When all the nerve fibres supplying the muscle are intact, the strength duration curve is that of normally innervated muscle (Fig. 17.1). The curve is of this typical shape because the impulses of longer duration all produce a response with the same strength of stimulus, irrespective of their duration, while those of shorter duration, require an increase in the strength of the stimulus each time the duration is reduced. The point at which the curve begins to rise is variable, but is usually at a duration of impulse of 1 millisecond with the constant current and 0.1 millisecond with the constant voltage stimulator.

Complete Denervation: When all the nerve fibres supplying a muscle have degenerated, the strength

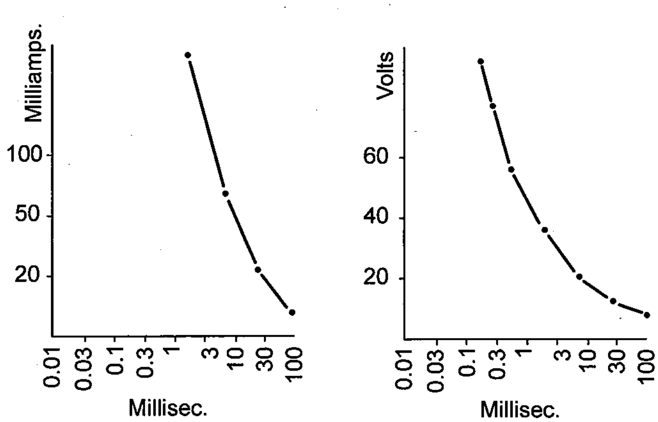

Fig. 17.2 *Strength-duration curves of completely denervated muscle*

duration curve is that of complete denervation. When the duration of impulse is 100 milliseconds or less, the strength of the stimulus must be increased each time the duration is reduced and no response is obtained to the impulse of very short duration. So the curve rises steeply and is further to the right than that of normally innervated muscle.

Partial Denervation: When some of the nerve fibres supplying a muscle have degenerated while others are intact, the curve obtained is that of partial denervation. The impulses of longer duration can stimulate both innervated and denervated muscle fibres, so a contraction is obtained with a stimulus of low intensity. As the impulses are shortened, the denervated fibres respond less readily, a stronger stimulus is required to produce a perceptible contraction and the curve rises steeply like that of denervated muscle. With the impulses of shorter durations, the innervated fibres respond to a weaker stimulus than that required for the denervated fibres, so contraction of the latter is not obtained and this part of the curve is similar to that of innervated muscles. Thus the right hand part of the curve resembles that of denervated muscle while the left hand part that of innervated muscle, and a kink is seen at the point where the two sections meet.

The shape of curve indicates the proportion of denervation. If a large number of fibres are denervated, the curve rises steeply and the greater part of it resembles that of denervation.
If the majority of the fibres are innervated, the curve is lower & flatter and bears a closer resemblance to that of full innervation.

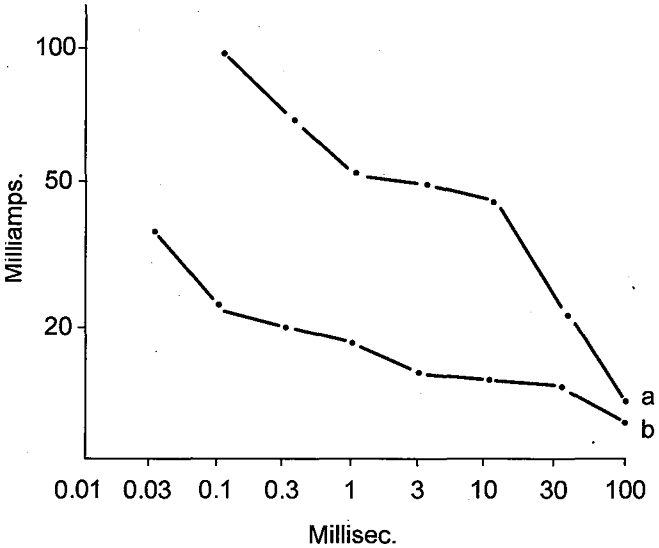

Fig. 17.3 *Strength-duration curves of partially denervated muscle, showing different degrees of denervation*

An early sign of restoration of the nerve supply to a muscle may be changes in the shape of the SD curve. A kink appears in the curve and as re-innervation progresses, the curve moves down and to the left. Progressive denervation is indicated by the appearance of a kink, increase in the slope and shift of the curve to the right.

The advantages of this method of testing electrical reactions are that it is simple and reliable and indicates the proportion of denervation, while a series of tests show changes in the condition. Its disadvantages are that in large muscles, only a proportion of the fibres may respond, so that the full picture is not clearly shown and that it does not indicate the site of the nerve lesion. The latter may be remedied by testing nerve conduction.

RHEOBASE

When stimulation is given using the maximum pulse width available on stimulator, the intensity of current required to produce a twitch is called Rheobase of the muscle.

Generally pulses of 100 or 300 ms duration are used to record rheobase. The shape of the pulse is always rectangular. It is measured in milliamperes or volts depending upon whether it is a constant current or constant voltage machine.

Rheobase is measured using the cathode on the motor point of the nerve or by using a bipolar technique. Normal values of rheobase are 2 to 18 mA or 5 to 35 volts.

Some examples of the normal rheobase values (mean values) of different muscles are:

Deltoid	14 volts, 5 mA
Triceps	18 volts, 5 mA
Abductor digiti minimi	30 volts, 8 mA
Frontalis	14 volts, 4 mA

The actual value obtained in a rheobase test is often variable and is dependent on many factors such as:

1. **Resistance of skin and subcutaneous tissue:** Generally the palms of the hand and the skin over the lower leg, which are exposed to the environment, have high skin resistance and need higher intensities (14 to 50 V). Following denervation, trophic changes occur in the skin due to the loss of sympathetic nerve supply and the skin becomes dry and scaly. This will alter the rheobase value.

2. **Oedema and inflammation** will make it difficult for the impulse to reach the muscle membrane. The excessive fluid will dissipate the current and high intensities, too uncomfortable to bear, would be needed to obtain a contraction.
3. **Ischaemia and underlying pain** will make it difficult for the patient to tolerate any intensity at all.
4. **Temperature variations** will alter rheobase values. Heat lowers the rheobase value and cold raises it.
5. The value of rheobase depends on the **position of the stimulating electrodes.** Minimal values are found if the cathode is placed on the motor point, or if the cathode is placed on the distal end of the muscle in a bipolar technique.
6. **The amount of subcutaneous tissue** between electrode and muscle will distort rheobase values.
   In clinical studies, the following deductions can be made from a diagnostic point of view.
7. **Degeneration:** For about 10 to 15 days after a nerve lesion, the rheobase is increased.
8. **Denervation** lowers the rheobase value to about 59% of its normal value. Often it will be found that rheobase values are high, but this is due to many factors that alter rheobase. It can fall below normal 10 to 20 days after denervation and remain low. This is not a uniform finding.

   Partial denervation generally produces no change in rheobase.
   Re-innervation can show a sharp rise in rheobase which heralds clinical recovery.

Values rise to 5 to 6 times normal than slowly fall. After nerve repair, the threshold increases abruptly when nerve fibres have reached the muscle and then returns to normal. For sometime it was thought that the phenomenon of low threshold during denervation with increase of values on neurotisation, would be adequate to determine the state of neurotisation, but as so many variables factors affect the value of rheobase, it is not possible to make a positive diagnosis or prognosis.

CHRONAXIE

At the double intensity of rheobase, the minimum pulse width required to produce the twitch is called **Chronaxie of muscle**.

Chronaxie is an index of excitability and is the time, in milliseconds, necessary to induce minimal visible contractions with a stimulus of twice the strength of the rheobase. Any measurement of the chronaxie must include the rheobase.

Normal values of chronaxie are less than 1ms (0.05 to 0.5 ms). There are variations depending on whether a constant current machine or a constant voltage machine is used.

Some mean values for chronaxie:

Muscle	Constant voltage	Constant current
Deltoid	0.01ms	0.1ms
Abductor digiti minimi	0.04ms	0.2ms
Tibialis anterior	0.04ms	0.1ms

At birth, chronaxie is 10 times higher than normal. At the 3rd month, the values are lower but are still high. By the 18th to 20th month, the chronaxie falls to normal values. Chronaxie values of proximal muscles are higher than those of distal muscles. Chronaxie values of facial muscles are small.

Several variables affect the values of chronaxie including:

1. **Texture of skin:** A dry skin will alter chronaxie values or make it difficult to obtain the values.
2. **Ischaemia** raises threshold values and decreases muscle excitability. Chronaxie rises by 100% under ischaemic conditions.
3. **Oedema** causes difficulty in obtaining chronaxie values.
4. **Fatigue:** If the muscle is tired, the chronaxie is increased to double, but then reverts back to former value.
5. **Position of stimulating electrode:** If the stimulating electrode is not positioned on the motor point of the nerve, then the value of chronaxie is that of the muscle, which is generally at least 10 times greater than the chronaxie at the motor point; in small muscles particularly, incorrect positioning greatly alters the chronaxie values.
   In clinical studies, the following deduction can be made from a diagnostic point of view.
6. **Denervation** causes a rise in chronaxie if the whole muscle is affected. The rise is 50 to 200 times the normal value, going up to 25ms. It then drops down to about 15ms by the 30th or 40th day after denervation.
7. **Partial denervation:** This depends on the extent of the lesion; if part of the nerve is intact following the lesion or in a slow progressive lesion, there is little change.

8. **Re-innervation:** A progressive fall of chronaxie values occurs with neurotisation.
9. **Nerve root lesions:** There is evidence of raised chronaxie levels in the muscles supplied by the affected nerve root. For example, in a nerve root lesion of the fifth lumbar and 1st sacral nerve roots, the chronaxie of gastrocnemius is high.
10. **Peripheral neuropathies,** that are caused by infective industrial and toxic substances, produce increased excitability of the nerve followed by lowered levels of excitability. It was found that in industrial lead workers, there was hyperexcitability of extensor digitorum showing reduced chronaxie levels before clinical evidence of toxicity.
11. **Myopathies:** There is no significant change.

Rheobase and Chronaxie Measurement Equipment Required

1. Low frequency generator with varying pulses from 0.02 to 1000 ms.
2. Moist saline pads
3. Electrodes
4. Leads
5. Bandages
6. Plastic protectors (Jaconet).

The patient is positioned with the affected muscle placed in a supported and relaxed position. The muscle is maintained in the neutral resting position. The area to be treated is warmed for 10 to 15 minutes after all dry skin has been removed and the part washed. A large dispersive electrode is positioned at a convenient position away from the affected muscles and the course of the nerve.

The active electrode (cathode) is positioned over the motor point of the muscle. The dials of the machine are positioned at 100 ms or 300 ms pulse duration and a suitable frequency (if needed). The current intensity is turned up until a good brisk contraction is obtained. This is performed 8 or 10 times, then the intensity is turned down until a minimal perceptible and palpable contraction is obtained and the rheobase value determined.

The next step is to raise the intensity of the current to twice the rheobase. At this intensity, varying pulse duration are selected starting from 300 ms to 0.02 ms to search for the duration, which will give a minimal perceptible and palpable contraction. The time of this pulse duration represents the chronaxie value for the muscle. There are generators available which specialise in the readings of chronaxie and are termed chronaxiemeters.

In practice each pulse duration should be tried 5 to 8 times. It is important to keep the electrodes on motor point with uniform pressure and to soak the pad in 1% saline solution constantly. Make sure the water does not drip over the patient.

First the normal side is tested and then the affected side.

Determination of Accommodation

Accommodation is the property of nerve or muscle membrane to react less strongly to a slowly increasing current intensity by accommodating the electrical impulse.

The measure of the constant of accommodation is **lambda.**

Lambda or accommodation ratios are calculated from the ratio of rectangular wave rheobase and the value for the progressive current rheobase, using a 1000 ms pulse duration. If the ratio is in the neighbourhood of 3 to 6:1, it means that the progressive current impulse is 3 to 6 times greater than the rectangular pulse. Ratios of 1.5 to 1.9 : 1 indicates denervation. With a quotient of 1, accommodation ceases entirely.

$$\text{Accommodability (lambda)} = \frac{\text{Triangular Impulse Threshold in Milliamp or Volts}}{\text{Rectangular Impulse Threshold in Milliamp or Volts}}$$

Normal	3 to 6
Denervated	below 3
No accommodation	1 and below

The test will give same indications of the presence and extent of the lesion. It should be done in conjunction with the strength-duration curve and great care taken in reading the threshold values of the various pulse durations. It is valued only if meticulous care with threshold value testing is exercised.

ACCOMMODATION QUOTIENT

When repeated stimulations are given to a muscle, after sometime it accommodates. If the muscle is stimulated by triangular impulses and rectangular pulses at different time frames, the triangular impulse requires more intensity to produce the contraction of the same strength as that of rectangular ones. The intensity of current used by triangular impulse divided

Rheobase and chronaxie values as found with voltage-stabilised and current-stabilised stimulators

Rheobase						Chronaxie in Milliseconds			
Muscle		Volts		Milliamperes		Voltage stabilized		Current stabilised	
Upper Limb		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Proximal	Deltoid	14	10–22	5	3–7	0.010	0.008–0.013	0.11	0.06–0.20
	Pect major	12	4–20	7	4–11	0.011	0.008–0.015	0.08	0.04–0.12
	Biceps	8	4–13	4	2–6	0.009	0.007–0.010	0.11	0.08–0.20
Distal	Triceps	18	13–24	5	2–8	0.023	0.010–0.050	0.14	0.05–0.30
	Flex. dig. subl.	13	3–20	4	2–6	0.014	0.008–0.020	0.13	0.08–0.30
	Flex. carp. rad.	13	5–20	6	4–8	0.011	0.007–0.020	0.09	0.07–0.10
	Ext. dig. comm.	18	9–25	7	3–8	0.040	0.015–0.100	0.18	0.09–0.30
	Ext. carp. rad. long	18	10–28	6	3–9	0.030	0.010–0.070	0.19	0.07–0.40
	Dorsal inter. (1)	35	20–50	6	5–9	0.050	0.010–0.100	0.11	0.50–0.20
	Abd. Dig.	30	15–53	5	2–7	0.040	0.010–0.080	0.22	0.10–0.40
Lower Limb									
Proximal	Rectus femoris	17	9–22	9	5–14	0.026	0.010–0.050	0.07	0.06–0.09
	Vastus medialis	18	12–26	8	4–12	0.020	0.010–0.050	0.08	0.07–0.10
	Biceps femoris	22	13–29	12	6–18	0.085	0.018–0.200	0.15	0.02–0.30
Distal	Gastrocnemius	18	14–20	6	3–9	0.066	0.050–0.100	0.12	0.10–0.17
	Tibialis anterior	19	14–22	5	2–9	0.042	0.010–0.080	0.10	0.02–0.15
	Peron. longus	19	13–24	5	4–7	0.082	0.020–0.170	0.25	0.06–0.50
	Ext. dig. longus	21	18–23	10	8–11	0.068	0.025–0.100	0.13	0.08–0.22
Facial	Frontalis	14	8–24	4	3–6	0.070	0.020–0.200	0.18	0.08–0.30
	Orbicularis oculi	10	6–18	3	2–5	0.110	0.040–0.300	0.18	0.10–0.25
	Mentalis	18	7–25	4	2–6	0.076	0.020–0.100	0.16	0.10–0.30

by rectangular is called A.Q. (Accommodation Quotient), which further reveals the state of denervation of the muscle under the test.

Different A.Q. values show you the state of innervation, denervation and partial innervation of muscles. Broad range to understand is as under:

A.Q. = 1 If the dysfunction of the muscle persists for more than 6 months (4320 hours) then there is difficulty to regenerate the nerve by electrotherapy, thus no further plotting is required.

A.Q. = 2–4 The nerve has degenerated but it will respond to electrotherapy.

A.Q. = 4–6 The neuromuscular system is unimpaired and it will respond to electrotherapy and the muscle will get back to almost within 3 weeks (21 days) or so.

Clinical Observations: It is important to keep in mind the clinical limitation of any method of electrical excitation by percutaneous method. **The SD curve has no concern with neuro-muscular pathology.** They only let us know whether normal, denervated or partially innervated muscle lies below the electrodes. The discrimination between a completely normal and a completely denervated muscle is absolute and 100% reliable if SD curve plotting is done carefully.

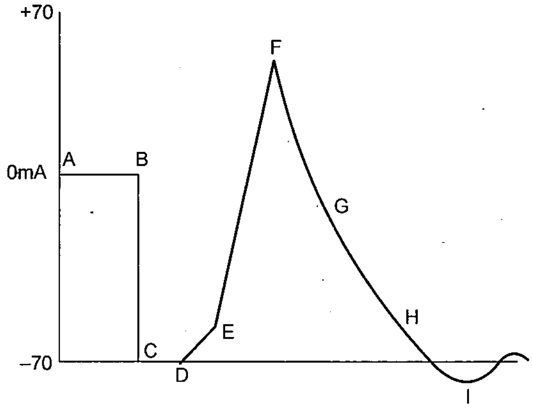

Fig. 17.4 *Action potential graph and its parts*

A. Both electrodes are stimulating
B. Introduction of stimulation
C. Stimulation applied
CD. Latent period
D. Membrane potential changing
E. Firing potential
F. Spike
G. Rapid repolarization
H. After depolarization
I. After hyperpolarization.

Advantages of Strength Duration Curve

Strength duration curve is simple, reliable and cheaper. It indicates proportion of denervation. It may be less time consuming as compared to electromyography. It can be used as hand side method.

Disadvantages of Strength Duration Curve

In large muscles, only proportions of fibres may respond hence picture is not clearly shown. It's a qualitative rather than quantitative method of testing innervation. It won't point out the site of lesion. However, the site of lesion may be determined by nerve conduction test.

OTHER ELECTRODIAGNOSTIC TESTS

Pulse Ratio

Pulse ratio is the ratio of current needed to produce a muscle contraction with an impulse of 1 millisecond to that of 100 milliseconds. In case of innervated muscle, very small or no increase in current is required when impulse is reduced from 100 msec to 1msec. So the ratio is small and it is around 1 but it may vary upto 2.2 for innervated muscles (1 : 2.2). In case of denervated muscles, amount of current required to produce a contraction is more and consequently the ratio is more than 2.5. Advantage of pulse ratio is that it can be performed swiftly. But the disadvantage is that the picture of innervation is not clear if a muscle is partially innervated.

Faradic IDC Test

It is also vaguely termed as faradic galvanic test rather than calling it as faradic interrupted direct current test. (Since galvanic current term indicates direct current and not modified direct or interrupted direct current). It was widely used in past to rule out whether a muscle is innervated or denervated. Pertaining to characteristics of faradic current (pulse duration 0.1 to 1 msec and frequency 50 to 100Hz), it will stimulate only innervated muscles and not denervated muscles. Interrupted direct current with pulse duration such as 100 msec will stimulate both innervated and denervated muscles. If a muscle responds to interrupted direct current with 100 msec duration or higher duration but not to faradic current, then it may be a denervated muscle.

Nerve Conductivity Test

I personally prefer to call it as nerve transmission test in order to avoid the possibility of the confusion between nerve conductivity, nerve distribution and nerve conduction velocity tests. Normally, a stimulus to a nerve trunk can produce the contractions of muscles supplied by it. But if the nerve fibres are degenerating, then conductivity distal to the lesion is lost. For nerve conductivity test, interrupted direct current with pulse duration of 0.1 or 0.3 millisecond is used. After applying this stimulus to a superficial nerve trunk, contractions of muscles supplied below this point is noted. If it produces the contractions, then it suggests that at least few or all the nerve fibres are intact and functioning. If this test is performed along the course of a nerve, then it may give us a clue about the possible site of the lesion.

Nerve Distribution Test

Stimulating the nerve trunk and observing the resultant muscle contractions can determine the distribution of nerve and thereby we can find out if there is any individual variation in it. This can help us to find out if there is any variation in the distribution of nerve.

Neurotization Time

Neurotization time is a useful index that represents the ratio of the duration of neuropathy to the theoretical time necessary for re-innervation to take place. In order to calculate the neurotization time, measure the distance from the probable site of the lesion upto the distal most muscle supplied by the affected nerve in millimetre. Since the regeneration of nerve can occur at a rate of approximately one millimetre per day, calculate the anticipated number of days accordingly (Remember that rate of nerve growth can vary from 1 to 5 mm per day). For instance, if the distance of lesion is 105 mm, then anticipated time is 105 days. Now find out the elapsed time in days from the patient. Calculate the neurotization time by following formula:

$$\text{Neurotization time} = \frac{\text{Elapsed time in days} \times 100}{\text{Anticipated time}}$$

Less than 100% neurotization time indicates that a minimal time is elapsed for re-innervation. When neurotization time is 250% or more and it is accompanied with no electrodiagnostic evidence of regeneration, then the prognosis is poor and surgical intervention may be considered.

Galvanic Tetanus Ratio

Galvanic tetanus ratio (GTR) is also called as tetanic frequency ratio or the tetanus twitch ratio. Normally frequency of 20 to 50 cycles per second is required to get tetanic response with pulse duration equal to chronaxie, but in case of denervated muscle, it gets reduced to 5 to 10 cycles per second. This happens because of loss of accommodation to long durated impulses and slow type of contraction in denervated muscle. GTR requires the use of a stimulator with variable impulse frequency output of 1 to 50 per second and calibrated duration of impulses. For testing denervated muscle, this duration must correspond to the chronaxie. It is convenient to stimulate the muscle with a single active electrode and with a current intensity sufficient to cause minimal contraction. Gradually vary the frequency, starting at a lower range, like one per second until tetanus is produced.

Dermo-ohmometry

The study of human skin resistance is known as dermo-ohmometry. It may also be called as neurodermometry or galvanic skin response. It can be studied with GSR device that is at present rarely used for this purpose but it is nowadays used for relaxation purpose by incorporating it with biofeedback kind of devices. Normal skin resistance may vary from 10,000 to 20 million ohms depending on the distribution of the sweat glands. In complete lesion of a mixed nerve, there is anhydrosis due to reduced activity of the sweat glands. As a result of anhydrosis, there is increase in the skin resistance due to reduced sweat that permits easy passage of the current.

Polar Formula

It is also known as Erb's polar formula. Normal response obtained to cathode and anode is CCC>ACC>AOC>COC. Here CCC stands for cathodal closing current, ACC for anodal closing current, AOC for anodal opening current and COC for cathodal opening current. It means, normally a better contraction is obtained with cathodal closing current than anodal closing current. Closing and opening terminologies are used because when this experiment must have been tried at that time, simple key switch, which is on by closing and off/by opening, must have been used. In denervation, reversal of this formula may be noted. In denervated muscle, it may be ACC>CCC>AOC>COC.

Myotonic Reaction

In myotonic cases, typical response to the faradic stimulation occurs. The muscles remain in tetanic contraction for some time as long as twenty seconds even after the stimulus has ceased. This response can be obtained initially and later on due to the exhaustion of the muscle contraction response ceases altogether but the same response once again can be obtained after a period of rest.

CHAPTER 18

TENS

- Introduction
- Types of Spinal Tract
- Gate Control Theory
- Production
- Parameters
- Types of TENS
- Method of Application
- Indications
- Contra-indications
- Precautions
- Preparation of Patient
- Electrode Placements

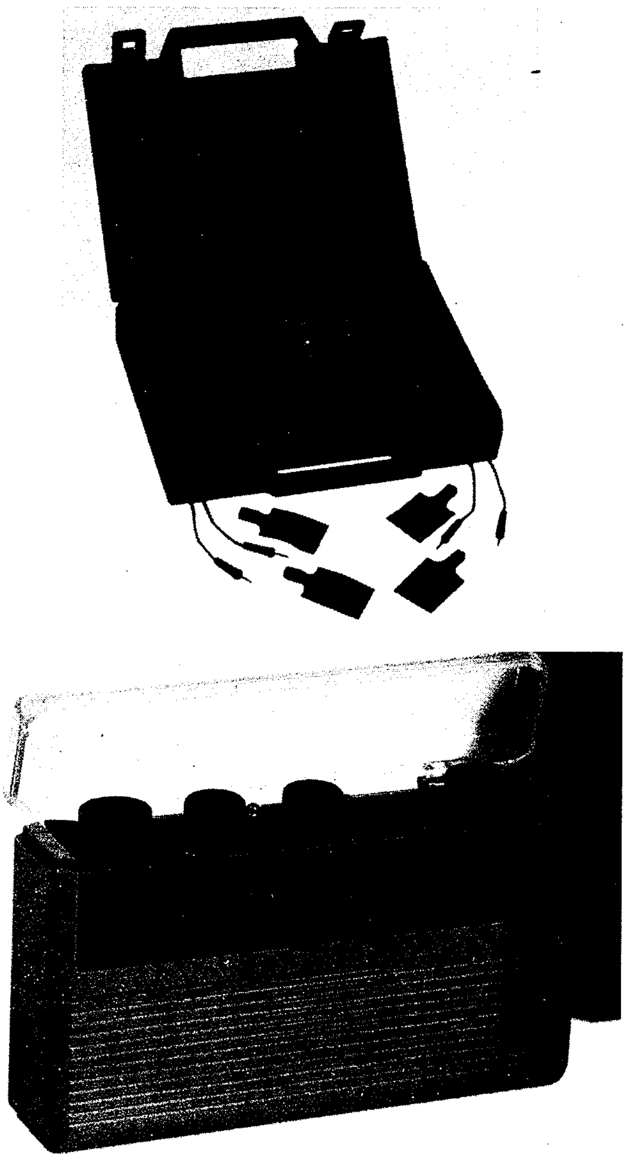

Fig. 18.1 *Diagram of TENS unit with accessories*

INTRODUCTION

Low frequency current is mainly used in the management of pain, both acute and chronic type. TENS controls pain non-invasively and without narcotics. TENS is also used either to produce muscle contraction or to introduce chemicals into body (iontophoresis).

TENS (Transcutaneous Electrical Nerve Stimulation): TENS is a low frequency current modality most widely used as **analgesic physiotherapeutic modality**, which is based on gate control theory. The machine used is called TENS unit which may be single or multichannel machine.

Pain is an undemonstrative subjective feeling accompanying the stimulation of nociceptors. Nociceptors are basically receptors of pain. These are free nerve endings, which don't have any specific structure and are present in almost all types of body tissue.

If nociceptors are stimulated by any physical, chemical, mechanical or thermal stimulation beyond the level of tolerance will cause pain.

The information about the pain is sensed by receptors or nociceptors and is carried to the higher centres in the brain through the fibres. These fibres group themselves into tracts in the spinal cord and send the impulses to and from the brain through these tracts called Spinal Tracts.

TYPES OF SPINAL TRACT

There are many types of tracts in the spinal cord; few of them are described below:

Funiculus Gracialis and Funiculus Cuneatus: These fibres carry muscle and joint sensations. These lie between the posterior median and the postero-lateral sulcus. In the cervical and thoracic regions, these tracts are separated by a septum.

Lateral Spinothalamic Tract: These tracts mediate pain and temperature sensation. It arises in the posterior column of spinal cord, crosses to opposite side in the anterior commissure and ascends in the lateral funiculus to the thalamus.

Ventral Spinothalamic Tract: This tract transmits impulses of touch. It also arises in the posterior column of spinal cord, crosses in the anterior commissure to posterior side, and ascends in the anterior funiculus to the thalamus.

Dorsal Spinocerebellar Tract: This tract transmits impulses from leg muscles and trunk between C_6 and L_2 segments. It is located on the lateral surface ventral to the postero-lateral sulcus and ascends to the cerebellum.

Spinotectal Tract: This tract arises from the cells in the posterior gray column, crosses over and ascends in the lateral funiculus, and ends in the corpora quadrigemina.

Rubrospinal Tract: This tract carries impulses for cerebellar reflexes. It arises in red nucleus and crosses over, and descends near the centre of lateral funiculus.

Lateral Pyramidal Tract: This tract carries impulse to the primary motor neuron. It arises from large cells in the precentral gyrus and after decussation in the medulla enters the lateral funiculus, lying between the dorsal spino cerebullar tract and lateral funiculus.

Tectospinal Tract: This tract mediates optic and auditory reflexes.

There is another set of fibres to inhibit the pain sensations. These different fibres are large in diameter, myelinated and fast conducting. These fibres are of substantia gelatinosa cells. If the intensity of these fibres of substantia gelatinosa is more than the intensity of nociceptors, then there will be pain sensation.

GATE CONTROL THEORY

With TENS, an electrical current is applied to nerve endings in the skin, which travels towards the brain along selective nerve fibres or proprioceptive spatial-location data gatherers. According to pain theory of Melzack and Wall, these fibres must pass through a segment of the spinal cord, the substantia gelatinosa, which contains specialized cells involved in neural transmission. These T cells also serve as transmission junctions for these nerve fibres carrying the sensation of pain upward towards the thalamus or 'pain centre' of the brain (fig. 18.2). The small C fibres offer a transmission velocity that is considerably slower than that of the A fibres. Thus a signal along A fibres normally reaches the brain before the C transmission. Both fibres and their respective transmissions must pass through the same T cells in the spinal cord as mentioned, with a preponderence of A fibre input due to their great number present in the system and their rapid rate of transmission. If the T cells are considered as a gate through which these signals must pass, it is conceivable that an overload of a transmission could block the incoming, slower moving C transmission carrying the pain signal to the brain. In this manner, a pain signal could be effectively blocked by the gating mechanism described within the T cell. Pain would therefore be decreased and/or blocked entirely. This is the basic concept of the "gate control theory" of Melzack and Wall.

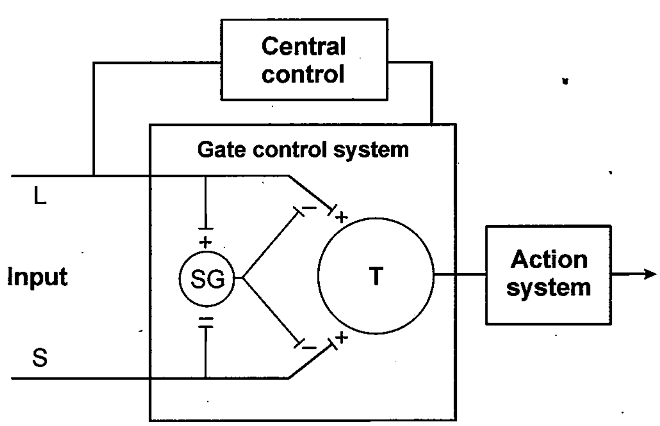

Fig. 18.2 *The gate control theory*

PRODUCTION

To produce the gating effect well, we must increase A fibre transmission without increasing C fibre transmission. How this is accomplished is a tribute to engineering acuity and industrial ingenuity. Researchers found that A fibres respond to a greater extent than do other fibres, to phasic input *i.e.* waveforms that are not sensed by the body as continuous and generally contain multiple phases of positive/negative modes. In contrast, C fibres apparently react best to continuous waveforms or to those sensed by the body as continuous. For example, a high frequency alternating current may be too high in frequency for the body to distinguish individual stimuli and so may be felt as a continuous form. The accepted threshold or tetanizing frequency for normal human system is approximately 30 to 50 Hz.

PARAMETERS

The compact portable TENS devices available today are ideal for patient use at home.

Many different types of TENS apparatus are manufactured and consequently some knowledge of the parameters within which particular unit operates is required by the therapist.

Pulse shape	rectangular type impulses
Pulse frequency	2 Hz–600 Hz, frequency 150 Hz commonly used
Pulse width	100 µs, generally 50 µs – 300 µs use
Intensity	0–60 milliamps (mA), a satisfactory intensity till tingling sensation.

Wide range of variation in pulse width, frequency and intensity gives good result in treatment of chronic pain syndrome.

TYPES OF TENS

1. **High TENS or Conventional TENS:** It is a high frequency and low intensity stimulation.

Frequency	100–150 Hz
Intensity	12–30 mA
Pulse width	100–500 μs

Intensity is turned up gradually until the patient should feel a tingling, pins and needles sensation. When high TENS is applied in this way, the stimulation will cause impulses to be carried along large-diameter afferent nerve and this can produce presynaptic inhibition of transmission of nociceptive Aδ and C fibres at substantia gelatinosa of pain gate. Here physiological block of transmission could be caused in the nociceptive (pain) fibre.

High TENS or conventional TENS is used in both acute and superficial pain.

2. **Low TENS or Acupuncture TENS:** It is a higher intensity and low frequency stimulation.

Frequency	1–5 Hz
Intensity	300 mA
Pulse width	100–150 μs

In this type of TENS, stimulation of high threshold A delta and C fibre leads to the release of endogenous opioid like substances at cord level. The enkephalins and β-endorphins released have the effect of blocking forward transmission in the pain circuits. Low TENS is generally used in chronic and deep pain.

3. **Burst TENS:** It is also called wave train. Burst TENS is a series of pulses, repeated 1–5 times a second. Each train or burst consists of a number of individual pulses like high TENS or conventional TENS.

Frequency	50–150 Hz

Use of this TENS is mainly for pain relief.

4. **Brief TENS:** Long duration impulses 0.2 ms.

Frequency	100 Hz
Intensity	20–50 mA

Its use is mainly for local pain relief. Brief TENS shouldn't be applied for more than 15 min.

5. **Modulated TENS:** Modulation in pulse length, frequency and amplitude of pulse.

Modulated mode has been advocated by some manufacturers to prevent accommodation to stimulation or to improve patient tolerance. Few studies have specifically examined this TENS format. TENS units with this feature automatically change

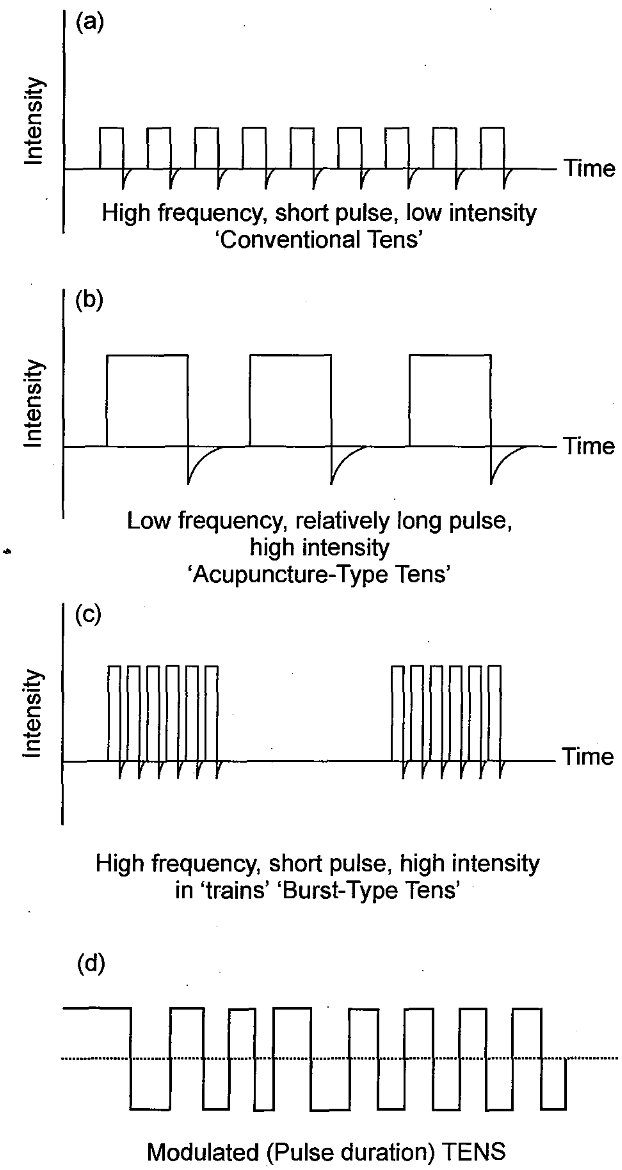

Fig. 18.3 *Different forms of TENS*

(modulate) one or more output characteristics (*e.g.*, pulse duration, amplitude or frequency) by a given percentage from an initially set level. Affected characteristics may be modulated in a manner that decreases their values by upto 60 percent one to two times each. Fig. 18.3(d) illustrates modulation of pulse duration alone. Output characteristics, like the modes discussed above, can thus be altered in a manner that may enhance patient acceptance and pain management.

METHOD OF APPLICATION

There are various pre-defined and well-established electrode positions of TENS, depending on the condition of disease and goal of physiotherapist. Most of the TENS units available in the market provide a literature of the machine as well as the electrode placement diagrams. Remember, the better therapeutic response are not only achieved by placing the electrode on the correct position but it also depends on the mode of TENS, frequency and amplitude of the current applied on the patient and duration of treatment. Several options are considered before selecting the electrode position *e.g.* trigger point or motor point site dermatome distribution of involved nerves over painful area, segmentally related myotomes.

When we apply the TENS as per the demand of therapeutic need, it is better to follow the steps:

1. First select the sites where electrodes are to be placed.
2. Observe the site. The site should be free from wound, dermatological condition or any cut.
3. Clean the site by wet cotton gauze piece or spirit gauze. It reduces the skin impedances, thus lesser intensity of current is required.
4. Place the electrodes with ample quantity of coupling medium (ultrasound jelly). The presence of coupling medium between electrode and skin is a must.
5. Fix the electrodes on the site by elastic band or adhesive tapes. The pressure of the adhesive tape or elastic band should be enough, as light pressure may require higher intensity for stimulation.
6. Turn on the machine.
7. Turn on the amplitude knob and increase the intensity of current until the patient feels tingling sensation.
8. Turn on the frequency knob and increase the frequency *i.e.* pulse rate. In acute conditions, pulse rate should be higher than the chronic condition.
9. Set the timer for required time. If machine doesn't offer timer facility, use a stopwatch.

INDICATIONS

Acute pain of osteogenic, myogenic, neurogenic origin; chronic pain of osteogenic, myogenic, neurogenic origin.

Note: TENS is never used in spasmodic pain (abdominal colic).

CONTRA-INDICATIONS

1. TENS is never applied over eye, laryngeal or pharyngeal muscles, head and neck region.
2. On the neck of patient of cerebrovascular accidents.
3. On the head or neck region of epileptic patient.
4. On the shoulder region of the patient of demanded type pacemaker.
5. On the chest region of patients of cardiac diseases.
6. Never applied on mucosal membrane.

PRECAUTIONS

1. Don't use TENS on a patient with demand type pacemaker in place.
2. TENS can be used in labour pain but not in pregnant patient.
3. Don't place electrode in the area of the carotid artery, in the antero-lateral region of the neck..
4. Should not use continuous application of high intensity TENS with long duration (high frequency). Pulses could produce an electrolyte reaction below the electrodes.
5. Open wounds.
6. Over the insensitive skin.

PREPARATION OF PATIENT

- Skin or area of treatment should be clean and clear of lesions.
- For secure purpose, electrodes are placed on the body with the help of commercial type or household mending tape.
- Longer application may necessitate special tapes/electrodes *e.g.* karaya or other conductive materials.

ELECTRODE PLACEMENTS

Probably one of the most controversial topics with TENS is the question of ideal electrode placement. Many techniques are suggested, based on nerve roots, acupuncture points, and trigger points. All are valuable but vary with each individual case. Unless the clinician is unusually gifted, experimentation is suggested so that the optimum position for the electrodes may be found in each individual case. The use of electrical probes is sometimes effective in locating tender or key points. An experienced practitioner with TENS will quickly be able to establish several key anatomic points to cover most conditions, however, the following are some recommended electrode placements for common conditions.

Placement of Electrodes for the Upper Extremity (Fig. 18.6)

1. C3–C7 nerve roots/dermatomes
2. Point of pain
3. Tip of the acromion
4. Hoku (web space between thumb and forefinger)
5. "Wristwatch" position, dorsal wrist
6. Tip of lateral epicondyle.

Placement of Electrodes for the Lower Extremity (Fig. 18.7)

1. L1–S1 nerve roots/dermatomes
2. Gluteus maximus (Bull's eye) scenter
3. Posterior lateral malleolus
4. Head of the fibula
5. Specifically for the knee: transarthral, medial/lateral knee.

Placement of Electrodes for the Lower Back (Fig. 18.8)

1. Associated nerve roots/dermatomes
2. Gluteal sites as above
3. Popliteal sites as above
4. Crossed pattern: paravertebral at L1 and L5, in a boxlike pattern, with the circuits crossing at L3.

General configurations

1. Associated nerve roots/dermatomes.
2. Point of pain.
3. Acupuncture point proximal to point of pain.
4. Acupuncture point distal to point of pain.
5. If pain can be pinpointed, consider the **crossed-pattern** technique above with the crossing point at the painful site.

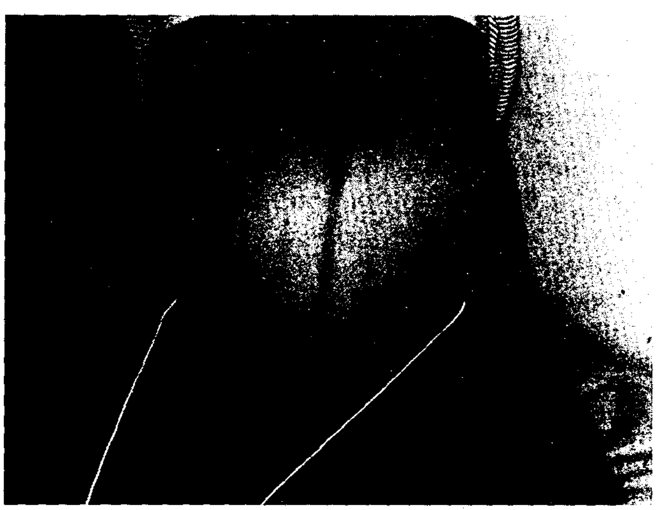

Fig. 18.4 *Second-stage electrode placements*

6. Transarthral placements are effective at the shoulder, knee, elbow, wrist, and foot.
7. Bilateral placements are extremely effective when practical, especially with midback and low-back conditions.
8. Contra-lateral placements are suggested when the pain site is not accessible due to amputation, dressings, open wounds, and casts.
9. Rarely are more than four electrodes needed. If the clinician can't produce analgesia with four electrodes, more are unlikely to be of value.

Fig. 18.5 *Electrode placements for morning sickness and other forms of nausea*

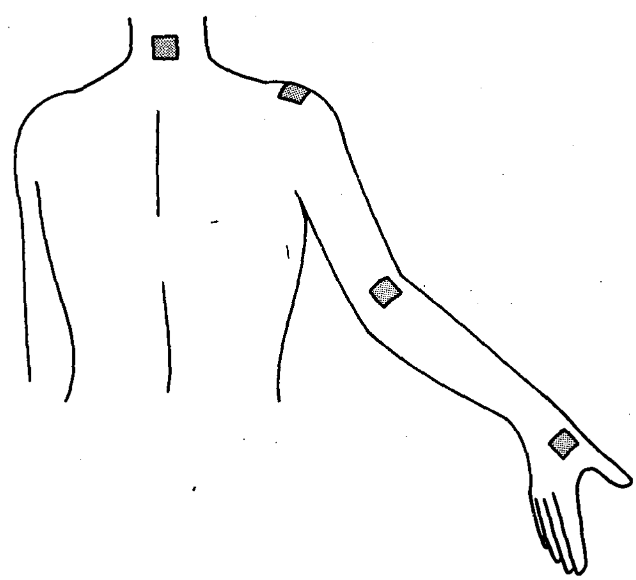

Fig. 18.6 *Upper extremity electrode placements: nerve root, acromion tip, lateral epicondyle*

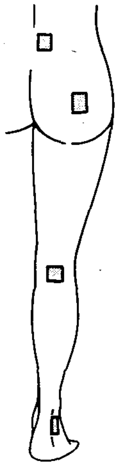

Fig. 18.7 *Lower extremity electrode placements: nerve root, gluteal, popliteal and posterior*

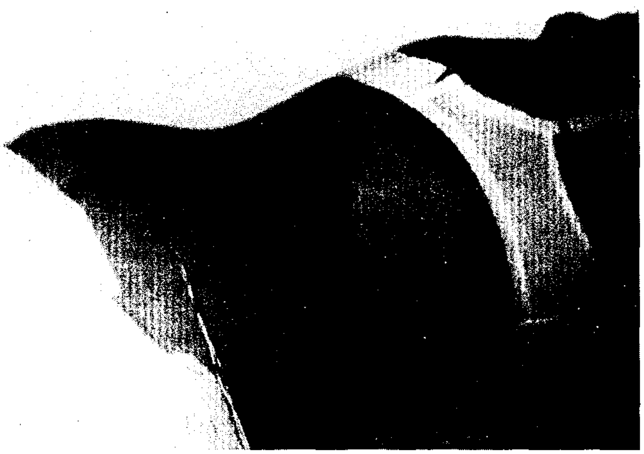

Fig. 18.8 *Lower back electrode placements: crossed-patterns with gluteal and nerve root sites*

Fig. 18.9 *TENS placement for a non-union fracture of the tibia, cast present. Distal electrode(s) placed within the cast at the foot*

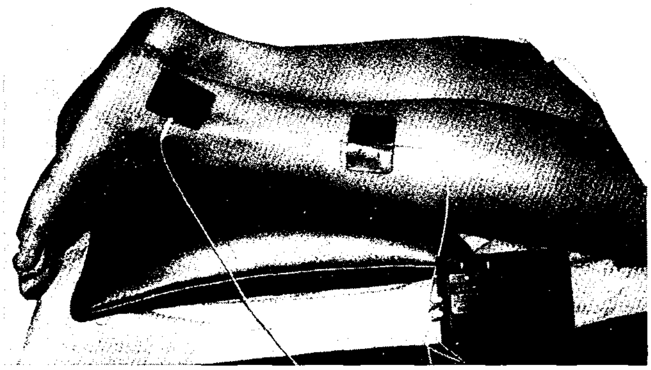

Fig. 18.10 *Linear placement of TENS for a non-union of the lower leg with no cast present*

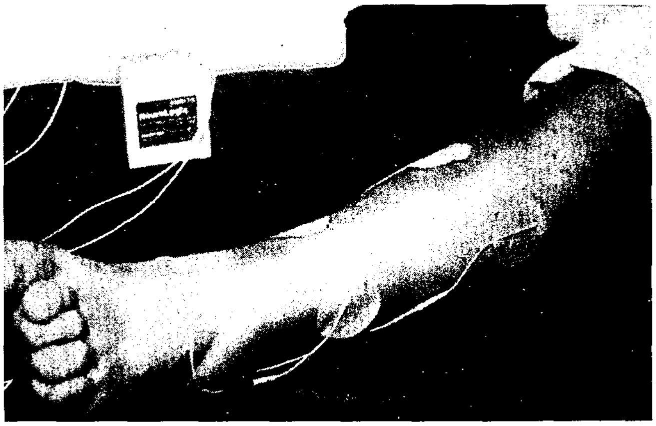

Fig. 18.11 *Crossed TENS pattern for non-united fracture of midshaft tibia*

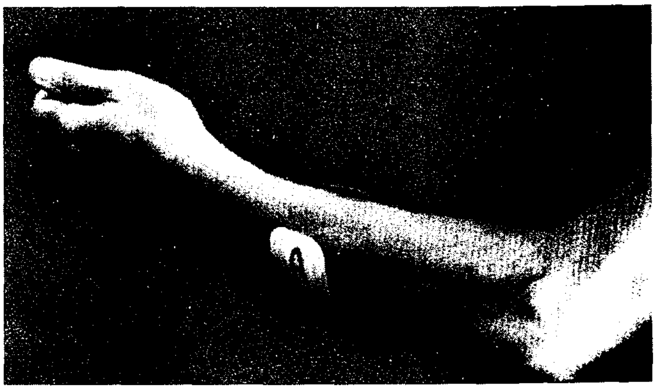

Fig. 18.12 *Placement for non-union fracture of the forearm, with fracture site directly between the electrodes*

Fig. 18.13 *Parallel electrode placement for painful incisional scar (gall bladder)*

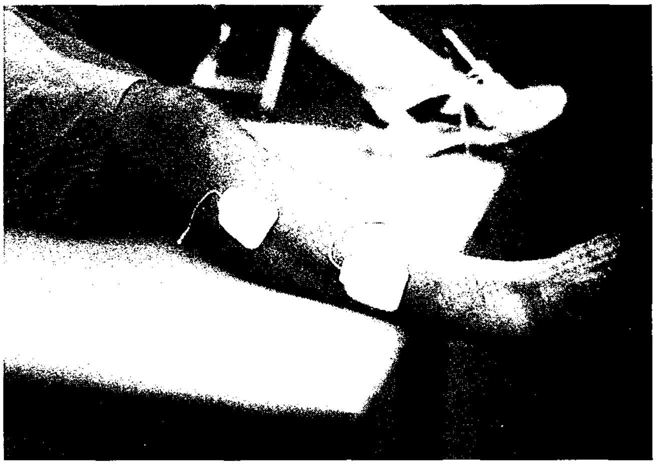

Fig. 18.16 *Electrical stimulation may help increase the range of motion of injured joints in some patients*

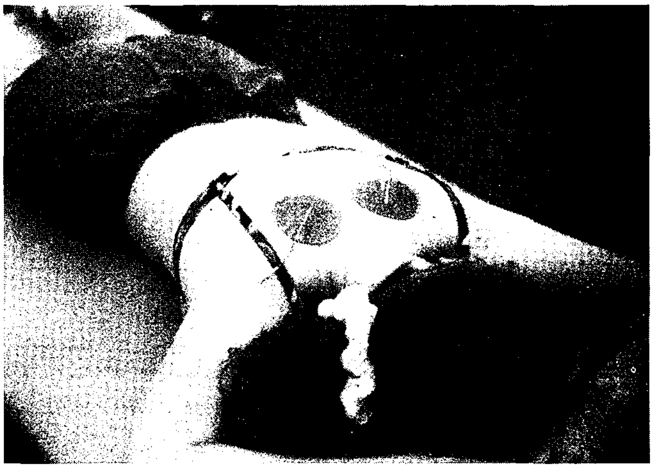

Fig. 18.14 *Brief, intense TENS for pain control (myofascial trigger points)*

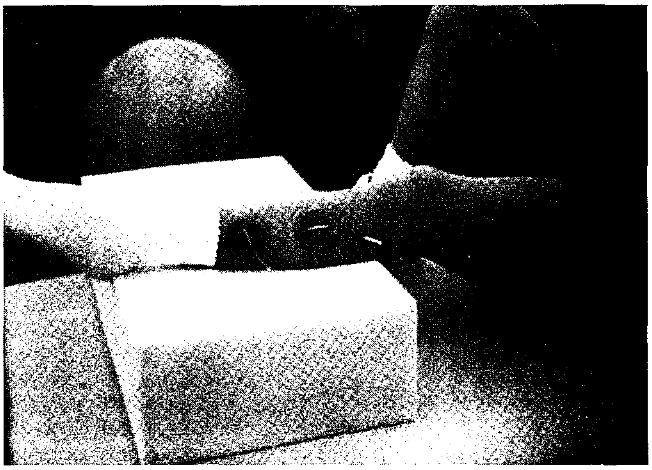

Fig. 18.17 *Electrical stimulation may be used to reduce edema*

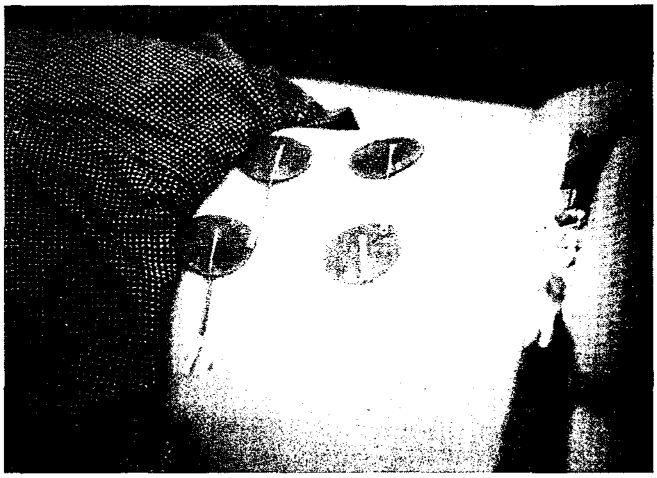

Fig. 18.15 *Electrical stimulation may be used to induce muscle relaxation*

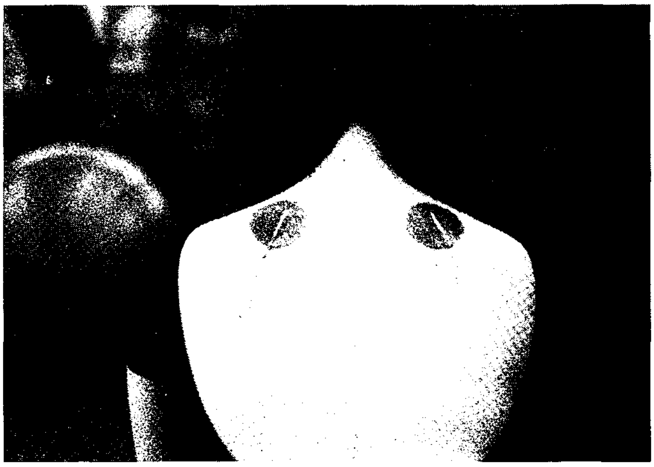

Fig. 18.18 *Classic TENS for pain control*

CHAPTER

19

HIGH-VOLTAGE PULSED CURRENT

- Definition
- Waveform Characteristics
- Current Density
- Importance of Waveform Characteristics
- HVPC Devices
- Electrodes
- Clinical Applications
- Methods of Treatment
- Contra-indications

Fig. 19.1 *High voltage pulsed current unit*

DEFINITION

High-Voltage Pulsed Current (HVPC) has gained widespread use because of its unique waveform characteristics and expanded clinical application. HVPC is associated with a separate class of electrotherapeutic devices. Devices in this class have a "twin-peak monophasic wave form with a fixed duration in the microsecond range (up to 200 µsec) and a voltage greater than 100 volts" (Fig. 19.1). Classes of electrical stimulators are compared in relation to the physiological and electrophysical effects of their waveform characteristics. The key to successful treatment with HVPC is flexibility in selecting appropriate waveform parameters to promote recovery from injury, re-educate muscles, or modulate pain.

Historical Background

In 1945, Haislip and colleagues from Bell Telephone Laboratories developed the first high-voltage stimulator. By decreasing the pulse duration and increasing the voltage, stimulation of deeper tissues occurred without tissue damage. The unit is the DynaWave Neuromuscular Stimulator used for decubiti, acute sprains, strains, lower back pain, and phantom limb pain.

A case report published in 1971 described the use of DynaWave for the treatment of an abscess on the foot of a diabetic patient. A 20 min. electrotherapeutic treatment was given after whirlpool. The only stimulus parameter reported was a frequency of 5 pps. After 3 days of treatment, an increase in circulation to the area and retardation of the infection occurred. The patient received electrotherapy twice a day for 4 weeks until discharge. Rationale for the treatment was to "stimulate muscular contraction around the infected area to increase blood flow to the part to promote healing."

Since then there has been a significant increase in the clinical use of HVPC, as well as in educational programs on its physics, physiology, and clinical operation. To keep pace with clinical demands, manufacturers developed improved units.

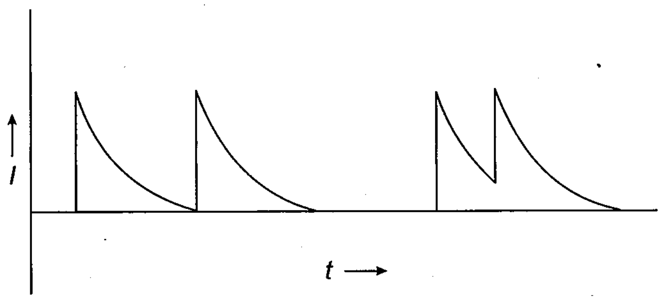

Fig. 19.2 *Schematic representation of a high-voltage pulsed waveform*

WAVEFORM CHARACTERISTICS

The name of this particular electrical stimulator varies: high-volt, high-voltage galvanic, high-voltage pulsed galvanic, and high-voltage pulsed current. The term "pulsed" prevents the therapist from thinking the unit produces continuous direct current (DC). Some descriptors include the term "galvanic", but the shape of the waveform is not similar to the traditional low-voltage interrupted galvanic waveforms (Fig. 19.2). A more complete description of this device is as follows:

HVPC stimulator has a twin peak monophasic waveform with a fixed duration. Duration is expressed in the microsecond range (up to 200 µsec). A (therapeutic) voltage is larger than 100 volts. The units are constant voltage units. Frequency is independently controlled. Depending on the unit, the on/off cycle is either fixed or controlled independently.

"High-voltage" is a term applied to a class of electrical stimulation devices capable of delivering amplitudes greater than 100 volts. A therapist treating with less than 100 volts on a HVPC unit is still using a class of HVPC units. Waveform characteristics are described as follows (Fig. 19.1).

Wave Shape: The pulse is a monopolar twin peak with an instantaneous rate of rise and a slope on the downside of each peak. The pulse is dual peaked because a single peak of ultrashort duration cannot stimulate nerve axons. The wave shape is fixed and cannot be changed by the clinician.

Duration: Duration is the period in which current flows during one waveform (pulse). Measurement of duration varies. For example, duration of the first phase serves as the pulse duration; or, pulse duration is measured at one-half the pulse height. Duration is a fixed value and cannot be changed.

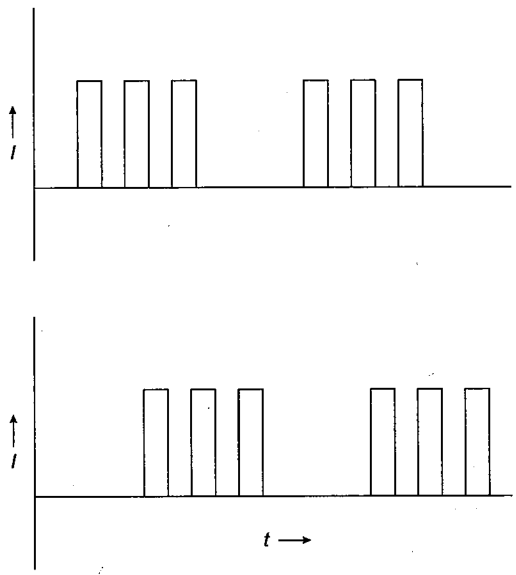

Fig. 19.3 *Schematic representation of a reciprocate mode*

CURRENT DENSITY

Since HVPC units have a high peak and a low effective value of current flow, current density is the parameter to consider. Current density is examined by comparing waveforms. Compare the waveform that has the downslope of the first pulse reaching the isoelectric line (where no electrons flow) with the waveform that has a down slope of the first pulse not reaching the isoelectric line (Fig. 19.2). Note that the second waveform will have more current density, that is, more electrons will flow per unit time.

Current density per unit time is changed by several methods. One is by adjustment of the microspace pulse (or intrapulse interval). This interval is the period between the end of the first phase and the start of the second phase of the waveform. The shorter the intra pulse interval, the larger the number of electrons flowing per unit time.

A second method used to increase current density is to increase frequency. This permits more waveforms per unit time, thereby increasing electron flow per unit time.

Frequency: Frequency is the number of waveforms per second. The unit of measurement is pulses per second. Note that the wave shape has a dual peak. A frequency of 2 pps is a rate of two complete waveforms per second. However, the number of peaks seen on an oscilloscope is four.

Train: The term train refers to the pattern of pulses generated. The three most common modes on HVPC machines are continuous, reciprocate, and surge.

1. **Continuous train** refers to the repetitive sequence of pulses used for the entire duration of treatment. The term refers to a series of pulses and does not mean galvanic (direct or continuous) current. The amplitude of each pulse is at the same pre-selected height.
2. **Reciprocate** refers to alternate on-and-off current flow of one active pad (electrode) in relation to the other. Active pad refers to the pad used to deliver treatment. The dispersive pad completes the patient circuit. Thus, when current is flowing from one active pad for 2.5 sec, no current is flowing from the other active pad. The amplitude of each pulse in the pulse train is at the same pre-selected height.
3. **Surge** is a series of waveforms whereby each successive waveform increases in amplitude until reaching the pre-selected maximal amplitude. An advantage of this mode is that because the amplitude builds up over time, the patient does not experience the maximum preset voltage at the onset of stimulation. Many surge trains have a 2.5, 5 and 10 sec on/off cycle, producing a 1:1 on/off ratio. Some units have independently controlled on/off switches.

The advantages of the surged mode are that (1) the stimulus amplitude will not surprise the patient, that is, amplitude builds up gradually rather than stimulating the patient with the pre-selected maximum on the first pulse; and (2) the gradual build-up in amplitude prevents a stretch reflex in a spastic muscle when stimulating the antagonistic muscle. HVPC is the unit of choice when using NMES for neurologic patients.

IMPORTANCE OF WAVEFORM CHARACTERISTICS

Each waveform characteristic, alone or in combination with other waveform characteristics, produces a variety of physiological and electrophysical responses.

When current passes through a circuit containing resistors, voltage drops occur, thereby losing energy.

Skin offers impedance (a form of resistance) to the flow of electrical current. Impedance of skin may be as high as 100,000 Ω. This phenomenon occurs in some treatment applications with traditional low-voltage units. A high-voltage device produces a spontaneous breakdown in skin impedance. Little if any voltage drop occurs as current flows through the skin.

When a high-voltage stimulus (100V) passes through a circuit, current flows towards the path of the capacitor. Since crossing a capacitor wastes little energy compared to crossing a resistor, the benefits are twofold: (1) more current density beneath the skin to reach target tissues; and (2) negligible, if any, cutaneous vasodilatation. Lost energy due to tissue impedance is converted to heat. This in turn produces direct vasodilatation of cutaneous blood vessels. Since a minimal amount of the high voltage current passes across the resistor side of the circuit, energy loss is minimal. This lessens the occurrence of vasodilatation.

In summary, HVPC passes through the skin with negligible thermal and electrochemical effects. Increased current density is available to target tissues, because of the route undertaken by the current through the skin.

Nerves and muscles are the target tissues treated by most practitioners. Since the HVPC unit has an ultrashort duration, the unit does not stimulate denervated muscle. A denervated muscle requires a pulse duration (chronaxie value) of at least 1 msec. HVPC treatment of partially denervated muscle activates only neurally intact motoneurons.

HVPC DEVICES

The more waveform characteristics controlled by the practitioner, the greater the flexibility in selecting the proper combination of waveform parameters. Various accessories also increase the capabilities of the unit. Since variations exist, the section presents only the most common parts of HVPC units.

Wave Shape and Pulse Duration: The fixed shape (twin peak) and pulse duration cannot be changed by the practitioner. To classify a device as a HVPC unit, the unit has a dual-peak monophasic waveform.

On/Off Timer Control: This switch turns the power on and sets the length of the treatment. When the switch is in the "off" position, no current flows through the patient circuit.

Polarity Switch: The polarity switch sets the polarity of the active electrode in relation to the dispersive electrode. The active pad (electrode) is the pad that delivers the treatment current. The dispersive (inactive) pad completes the patient circuit.

Amplitude Control: The (amplitude) control sets the output voltage of the active electrode within a range from 0 to 500 V. Most units have a reset, safety feature. Turning the unit off without returning the voltage output to zero, activates the reset feature. Current will not flow until the unit is reset, by resetting the amplitude control dial. This safety feature prevents the patient from receiving an unnecessary shock.

Pad Balance: This switch permits independent amplitude control over the two active pads (electrodes). It permits an increase in amplitude of one pad in relation to the other. The advantage of this feature occurs when using HVPC for modulation of pain. A patient tolerates less NMES when an active electrode delivers current directly over the painful site. Therefore, two active pads delivering current at different amplitudes provide a maximal amplitude in each pad. The electrode, directly over the painful site, should deliver less current than the pad in proximity of the painful site.

Pad / Probe Mode Switch: This switch regulates the pattern of stimulation, that is, continuous or reciprocate. Continuous means a continuous flow of pulses through the active pads. The positions 2.5, 5 and 10 sec. reciprocate indicate current alternates by flowing from one, then the other active pad. Depending upon the unit, reciprocate position may be either interrupted (all pulses at the same pre-determined amplitude) or surged (amplitude increasing with each pulse until reaching the pre-determined amplitude).

Surged Train: Several units contain both the reciprocate dial (with interrupted mode) and a separate surge train. When the surged train is separate, the therapist independently controls the on/off cycle. This control permits alterations of the ratio of the on/off cycle upto a 1 : 5 ratio.

Output Meter: A meter (needle deflection) or a digital readout records output from the unit, which may be units of measurement in voltage, peak current or both.

Microspace Switch: Some units have this function, which enables manual regulation of the distance between the two peaks of a waveform (intra-pulse interval).

Indicator Lights: These lights provide the practitioner with a visual acknowledgement that a particular function is in operation.

Output Jacks: Receptacles for the electrode heads are available for the active pads, handle (probe) electrode, and dispersive pad.

Electrodes

The active electrode may be either a pad electrode or a handle (probe) electrode. The number of active pads may vary from one to four. The size of each active pad may range from 5.7 to 7.56 cm. The dispersive pad may be 2.16 by 25.4 cm. The composition of the active pad varies. Some pads consist of a metal plate encased in a rubber housing with a sponge placed between the metal plate and the patient. Other pads are flexible and contain an impregnated conductive medium. The flexible pad has the advantage of conforming to the body part better than the pad with the metal plate.

A major treatment consideration for both active and dispersive pads is the accumulation of dirt and oils on the pad surface. This accumulation increases resistance to current flow and therefore decreases the electrical efficiency of the unit. Frequent changes of the sponge, a disposable covering, or frequent cleansing of the electrodes will prolong the pad effectiveness.

Accessories for the handle electrode increase the clinical usefulness of the electrical stimulator. In some first-generation HVPC units, the handle electrode had a fixed applicator. External applicators include spot (disk) electrode, rectangular electrode, point stimulator (acuspot), and roller. All externally applied electrodes use a conductive medium or a wet-sponge cover. Manufacturers have the capability of manufacturing special electrodes for specific applications.

CLINICAL APPLICATION

To increase the effectiveness of HVPC treatment, the practitioner should take a problem-solving approach. First, the practitioner needs to identify all of the patient problems that can benefit from NMES. More than one problem is treatable with a single treatment. For example, with a painful ankle sprain, both oedema and pain are treated. Second, the practitioner should state the known and postulated rationales for the use of HVPC. Third, the practitioner must identify the intervening tissues through which the current passes before reaching the target tissue. This aids the therapist in determining the effect that each tissue has upon current flow.

Fourth, the physiotherapist visualizes current flow from the active electrode to the dispersive electrode. The dispersive electrode is an integral part of the patient circuit and should be placed properly, because current needs to flow through the target tissue. Misplacement of the dispersive electrode decreases current flow through the target tissue and diminishes the effects of treatment. For the fifth, the final step in the problem-solving approach, proper documentation procedures are essential to measure the effectiveness of the treatment and substantiate its efficacy. The tissues of the body have "fail-safe" mechanisms; that is, they respond to more than one combination to stimuli to maintain viability. Therefore, more than one set of waveform parameters would undoubtedly be effective. The practitioner should be careful to avoid set protocols for patients with similar problems.

In summary, the therapist conducts a thorough assessment for the use of HVPC for treatment. Factors to consider include its electrophysical and physiological effects upon various tissues; optimal stimulus parameters and electrode placement, based upon scientific and clinical literature; and duration of treatment. The physiotherapist may adjust treatment times according to the condition if the standard treatment time of 20 min. is not suitable. Documentation of current permanent and patient response is suggested.

METHODS OF TREATMENT

The protocol is adapted to treat other types of wounds and burns.

I. Documentation: should include, but not be limited to, the following:

1. Measurement of the wound: a set of concentric circles, or tracing the wound on sterile transparent paper are used to measure the wound.
2. Measurement of the depth: measure at the approximate centre.
3. Description of undermining of the wound.
4. Statement of the type of micro-organism present.
5. Description of the general characteristics of the wound.
6. Record of the medications and dressings.
7. Photography: a weekly photograph, taken at a standard distance from the wound, is a valuable documentation procedure.

II. Procedure:

A. Treatment out of water:

1. Remove housing and sponges, and wrap the active electrode in sterile gauze. Soak them in sterile saline.

2. Attach one or more active electrodes directly over the wound, or attach one active electrode over the wound and a second active electrode distal to the first.
3. Attach the dispersive pad proximally. Visualize the current path to be sure that current flows through the wound and does not circumvent it.

B. Treatment in water

1. Use either a plastic container or a whirlpool with a recent electrical safety check. The whirlpool and electrical stimulator are plugged into a ground fault interruption receptacle.
2. Remove housing and sponge from the active electrode and wrap them in gauze.
3. Attach the active electrode distal to the wound. To increase the effectiveness of the treatment, the active electrode must be attached to the body.
4. Attach the dispersive electrode out of the water and proximal to the wound. Visualize the path of current flow, so current flows through the wound.

III. Treatment Parameters:

A. Frequency: High.
B. Amplitude: Sub-threshold to muscle contraction. Amplitude is increased as accommodation occurs.
C. Polarity:
1. Negative polarity is used if micro-organisms are present. Continue to use negative polarity until the wound is culture-free for 3 days.
2. Positive polarity is used if the wound is culture-free or is used after the wound is culture-free for 3 days.

D. Duration and frequency of treatment: Since most of the studies on the use of electrical stimulation for wound healing used direct current, the length and frequency for treatment is adjusted to permit the greatest amount of current flow per unit time.

E. Rate of healing: A healing rate of 1 mm per week has been documented. If the wound healing slows, polarity is changed for ONE treatment only. Switching polarity is hypothesized to reactivate the wound healing process.

IV. Assessment: Assess the wound after each treatment and perform a complete assessment weekly.

V. Sterilization of the Electrodes: Appropriate sterilization procedures, particularly for the flexible electrodes, are provided by manufacturers.

Clinical Application: The following section describes three conditions treated with HVPC. Guidelines for documentation and treatment are adapted from those procedures described.

Burns: HVPC treatment before debridement affects pain modulation and aids healing. HVPC (negative polarity) applied over scar tissue facilitates movement of the injured part as it causes reduction in pain.

Post-surgical Wounds: The active and dispersive electrodes are placed on either side of the wound (similar to TENS). Both pain modulation and wound recovery can benefit from HVPC treatment.

Hand Injuries, Traumatic and Post-surgical: HVPC is used for pain modulation, wound healing, and oedema reduction. When treating in a pan of water with amplitude of stimulus sub-threshold to muscle contraction, the patient can voluntarily exercise the hand muscles. This voluntary exercise will also reduce oedema via muscle pump action.

NMES producing muscle pump action can also be used. The active electrode is placed over the area of oedema or of distal nerve distribution and the dispersive electrode placed proximally. Treat with 2 to 8 pps for about 30 min. A decrease in oedema, as measured by circumferential measurements, and an increase in total active motion, documents treatment outcome.

Oedema Reduction

Oedema due to physical disruption of blood vessels may be alleviated with HVPC. The electrical stimulus parameter, polarity, is used to induce muscle pump action and to shift fluid from the area. Muscle pump action is voluntary or elicited by NMES. Polarity repels fluid from the area. All blood cells and plasma proteins are negatively charged at normal blood pH of 7.4.

Treatment Planning: The treatment guidelines given below are for oedema due to physical disruption of blood vessels and not for oedema caused by other factors.

I. Documentation: should include, but not be limited to, the following:

A. Measurement of the region: circumferential, volumetric, or both.
B. Range of motion of the site and points above and below the site.

II. Procedure:

A. Attach the active pads over the site of oedema. If this is not possible, then attach the pads distally.
B. Attach the dispersive pad proximally. The path of current flow is visualized to be sure that current flows through the oedematous area.
C. The treatment can be performed in cool water.

III. Treatment parameters:

A. Polarity of the active electrodes is negative.
B. Frequency and amplitude: A frequency between 20 and 50 pps is used to produce a tetanic muscle contraction, for muscle pumping by NMES. An on/off cycle of 1:4 or 1:5 delays onset of muscle fatigue. Amplitude is increased to patient tolerance. High frequency and amplitude sub-threshold to muscle contraction are used if no muscle contraction is desired or if the patient can voluntarily perform muscle contraction.

IV. Assessment: Assessment should occur after each treatment to document the effects of treatment.

Clinical Application

Muscle Sprains and Strains: HVPC can decrease pain and oedema and aid recovery. The use of ice or positive compression, in combination with NMES, is suggested for immediate treatment of sprains.

Hand Injuries: The earlier section on wound healing contains a complete description of treatment.

Post-operative: Pulsed NMES is for used oedema and pain reduction in patient's podiatric following surgery used.

Clinical Application: Most conditions associated with pain that respond to TENS are treatable with HVPC. Listed below are some examples of painful disorders successfully treated with NMES.

- Identification and treatment of trigger points
- Cervical or lumbar pain
- TMJ dysfunction
- Cancer pain
- Post-surgical pain
- Pain associated with arthritis, with ranging joints (*e.g.*, frozen shoulder)
- Acute and chronic sprains
- Pain associated with debridement
- Phantom limb pain.

TMJ: TMJ dysfunction can be treated either extra or intra-orally. Assessment includes the head and neck region as well as measurements of vertical mouth opening and visual analogue scale. The patient relaxes in a supine position. Intra-oral treatment consists of 50 to 80 pps frequency with amplitude to patient tolerance. A specially designed intra-oral probe delivers current to the pteryoids and masseter. Treatments last several minutes per muscle. External NMES is applied with pads or a disk electrode. Treatment occurs over the TMJ and muscles of mastication. Stimulus amplitude is to patient tolerance, but sub-threshold to muscle contraction. Treatment time for external application of NMES may last up to 20 minutes.

Neuromuscular Stimulation

HVPC has been used for both muscle re-education and maintenance or muscle integrity in patients with disuse atrophy. HVPC may be used for functional electrical stimulation (FES).

Frequency and on/off cycle are important characteristics for NMES of intact muscle. As frequency of the electrical stimulus increases (providing amplitude and duration are appropriate), individual muscle twitches summate and incomplete tetanus occurs. Further increase in frequency results in complete tetanus. A frequency of 20 pps produces complete tetanus in some muscles. Benton and colleagues have noted that a 20 to 30 pps stimulation rate was optimal for muscle contraction. Higher frequencies (50 to 100 Hz) cause faster muscle fatigue than frequencies of 20 pps. The on/off cycle is another parameter that delays the onset of muscle fatigue. A 1:5 on/off ratio is the most effective, as suggested by Benton and colleagues and by Kots. Benton and associates have noted that a 1:1 ratio fatigues muscle more quickly than do other ratios. In summary, frequency and on/off cycle are the two most important NMES parameters to consider when developing a treatment plan.

Many techniques exist for the maintenance of muscle integrity in an immobilized muscle. To date, limited histological and biochemical analysis demonstrates an increase in muscle strength in healthy or injured muscle. Following knee surgery, a profound inhibition occurs in the quadriceps femoris muscle. This inhibition is due to disruption of the joint capsule and to profound activation of the joint receptors. Voluntary exercise and HVPC may override this profound inhibition.

Since analysis of muscle tissue has not shown significant changes in either morphology or biochemical composition, alteration must be occurring at the nervous system level. With continued NMES and voluntary muscle contraction, a "motor template" forms. That is, facilitation of the activated motor units occurs when voluntary movement is performed. The therapist observes an apparent increase in "strength". The evidence for such a template is indirect and is measured by an increase in force production.

Treatment Method

I. Documentation: Appropriate assessment of the individual with neurologic or neuromuscular dysfunction in conducted.

II. Procedure:

A. Place the active electrode over the motor point of the muscle.
B. Place the dispersive electrode proximally.

III. Treatment parameters:

A. Frequency: A frequency to produce muscle contraction, but below one that would produce fatigue, is used. A range of 20 to 30 pps is acceptable.
B. Negative polarity: Erb's law states that negative polarity requires less amplitude to activate axons than does positive polarity.
C. On/off cycle: A 1:5 on/off cycle and amplitude to produce muscle contraction is used. Due to a training effect, the "off" part of the ratio is decreased with continued treatment.
D. Train: A surged train to pulses produces a gradual buildup of amplitude. A gradual buildup is beneficial in the treatment of the stoke patient, as it does not elicit a stretch reflex due to stimulation of the antagonistic muscle. A reciprocate mode is used for alternating agonist-antagonist muscle contractions.

Clinical Application: The above treatment technique has several benefits. In addition to producing muscle contraction, the waveform parameters also produce pain relief. Electrically induced muscle contractions are also used when oedema is present. Documentation of treatment outcome are based on those problems being treated with NMES.

CONTRA-INDICATIONS

Contra-indications and precautions are:

i. Patients with circulatory impairment;
ii. Stimulation over the carotid sinus;
iii. Stimulation across the heart, particularly in those patients who have demand pacemakers;
iv. Pregnant females; and
v. Individuals prone to seizures.

SECTION V

- Interferential Current
- Russian Current
- Diadyanamic Current
- Sinusoidal Current

CHAPTER

20

INTERFERENTIAL CURRENT

- Definition
- Principle
- Types of IFC
- Methods
- Application of Interferential Therapy
- Parameters
- Effects of Interferential Currents
- Main Indications
- Contra-indications
- Dangers
- Comparative Effects
- Treatment of Specific Diseases by IFT
- Method of Placing Electrodes

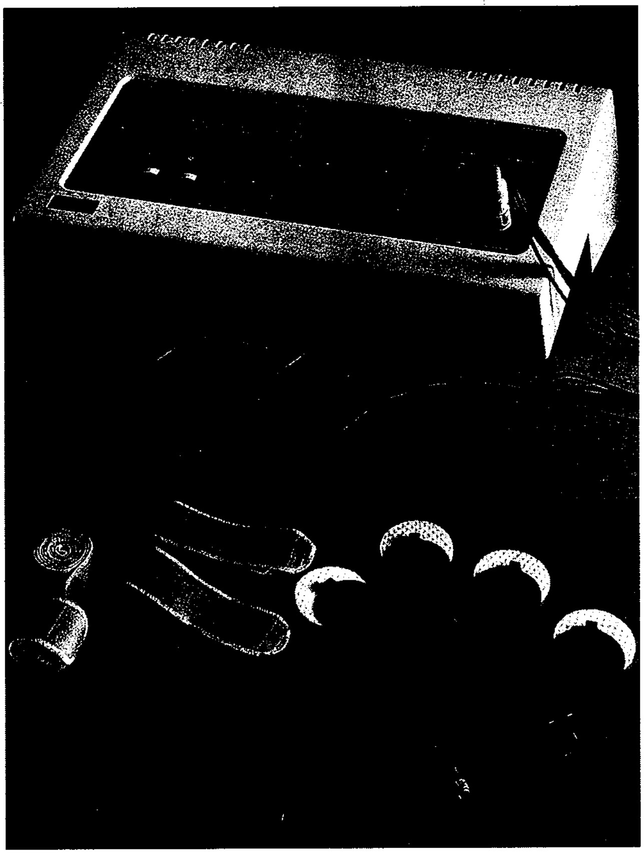

Fig. 20.1 *Interferential therapy unit with accessories*

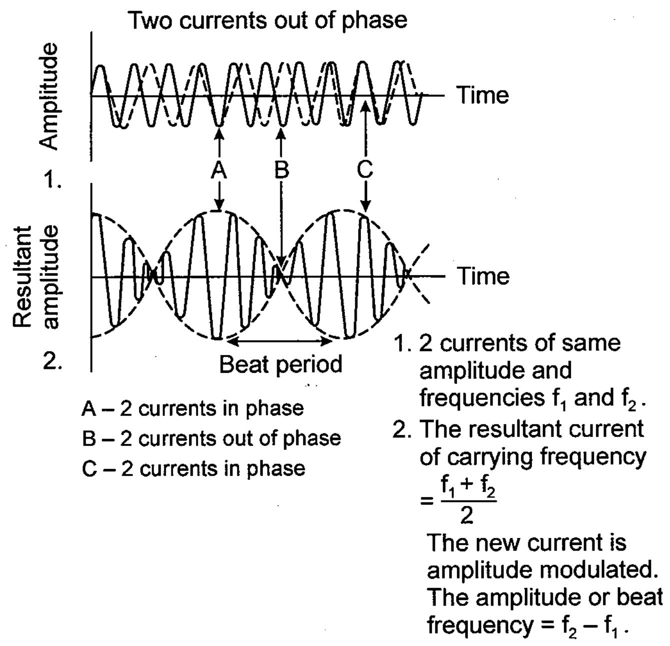

Fig. 20.2

DEFINITION

Application of two medium currents produces a low frequency current effect at the point of intersection of the two currents. This is the basic principle of IFT.

Interferential Current Therapy is the application of electrical energy through the tissues in which two medium frequency alternating currents of around 4000 Hz, slightly out of phase, produce an Amplitude Modulated Current of low frequency through the effect of interference.

A — 2 currents in phase
B — 2 currents out of phase
C — 2 currents in phase
1. 2 currents of same amplitude and frequencies f_1 and f_2.
2. The resultant current of carrying frequency $= \frac{f_1 + f_2}{2}$.

The new current is amplitude modulated. The amplitude or beat frequency = $f_2 — f_1$.

Interferential current was originally devised for therapeutic application by the Austrian Scientist **Hans Nemec** in the year 1949. It has recently gained popularity and is being used more extensively now than in the past. The interest is partly due to developments in electronic circuitry, which has made compact and relatively cheaper machines available.

PRINCIPLE

As stated earlier, the principle of Interferential Current Therapy is that when two medium frequency alternating currents of slightly different frequencies are passed through the tissues. At the same time, they interfere with one another to produce a low frequency current effect at the point of intersection. The resultant amplitude of this new current is the sum of the individual current amplitudes at any given point. Thus when two peaks of amplitude in the same direction coincide, the resultant amplitude is at the maximum (Summation of current as at A and C). When the two peaks are in the opposite directions, there will be no current (cancellation effect as at B). This summation and cancellation of current values produces the amplitude-modulated beats that are characteristic of Interferential Current. Providing the amplitudes of the two currents are the same, the resultant carrying frequency will be the average of the two individual frequencies. If the frequency of the first current is 4000 Hz and the second is 4100 Hz, the Resultant Current Frequency is 4050 Hz $\left(\frac{4000 + 4100}{2}\right)$.

This resultant current varies in amplitude *i.e.* it is Amplitude Modulated. The frequency with which the amplitude varies is called the Amplitude Modulated Frequency or Beat Frequency or the Treatment Frequency and is equal to the difference in frequencies between the two interfering currents — in the above instance, 100 Hz. It is this beat effect that acts like any other low frequency current and stimulates nerves and muscles.

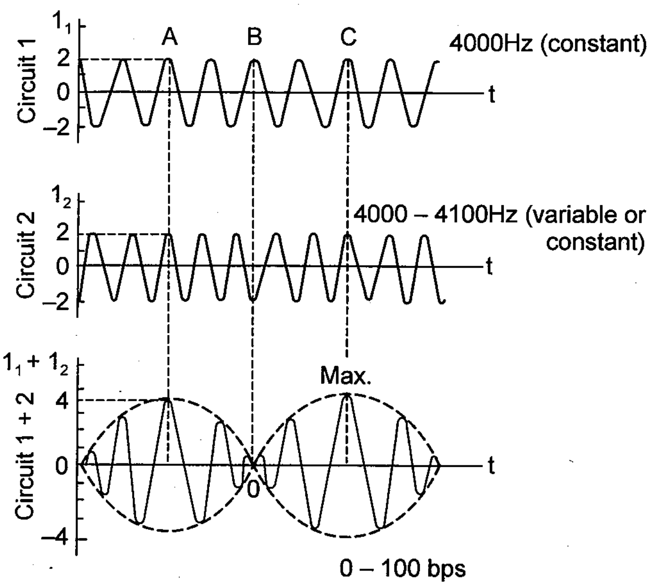

Fig. 20.3 *Amplitude-modulated beats of IFC produced by summation and cancellation of superimposed phases from two independent AC circuits. A difference of* 100 *Hz between the two circuits gives a beat frequency of* 100 *bps*

If the two medium frequencies remain constant, the beat frequency will also be constant. The current at constant frequency may lead to a gradually diminishing response due to habituation of tissues to this particular current. It is also considered desirable to stimulate different nerve types and diameters during treatment. Both these deficiencies are corrected by continuously varying the beat frequency. This is called Frequency Swing/Frequency Sweep.

Therefore, the Interferential machines have one medium frequency current at constant frequency, say at 4000 Hz, while frequency of the second one is variable *e.g.* between 4000 Hz and 4100 Hz. This allows a variable beat frequency between 0 to 100 Hz. The machine can be set to automatically change one of the medium frequency currents continuously to give a continuous varying beat frequency. The variation can be made to occur between some pre-set pair of frequencies over a specified time period *e.g.* between 20 Hz – 80 Hz over a period of 6 seconds and back over the next 6 seconds during which it swings back from 80 Hz to 20 Hz.

Besides the frequency of the modulation, the Amplitude Modulation is also characterized by the depth of the modulation (M).

DEFINITION AND TERMS APPLIED WITH INTERFERENTIAL THERAPY

Interferential current is the resultant current produced when two or more alternating currents are applied simultaneously at the point of intersection in a given medium.

Impedance: Resistance, capacitance and inductance all these collectively form the IMPEDANCE of the circuit.

This impedance is a type of resistance produced by the tissues against any electrical stimulation of low frequency.

Impedance is denoted by "Z".

$$Z = \frac{1}{2\pi FC}$$

where, F = Frequency in Hertz
C = Capacitance of skin in microfarads
Z = Impedance, in ohms

Phase: The current travelling from 0° to 180° is called to be in the same phase and the current travelling from 180° to 360° is called to be in opposite phase *i.e.* if current A is travelling to B and C, then A to B is called to be in same phase and from B to C is called to be in opposite phase.

The Modulation Depth is expressed as a percentage and can lie between 0% and 100%. A 100% modulation depth has an optimum stimulating effect & as such merits preference in therapy.

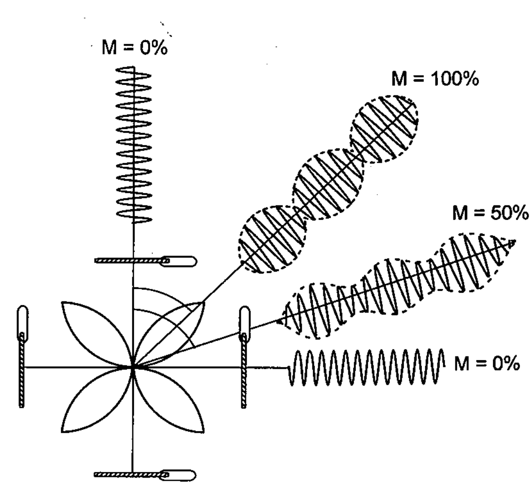

Fig. 20.4 *Polar diagram of the modulation depth (M) (4-pole technique) with perpendicular superimposition*

METHODS

To achieve maximum therapeutic effects, following methods of IFT production are used.

a. **The two pole method:** Two electrodes are used with this method and the two medium frequency A.C. are superimposed inside the machine, with the result that interference occurs throughout the region between the two electrodes. The signal leaving the equipment is modulated.

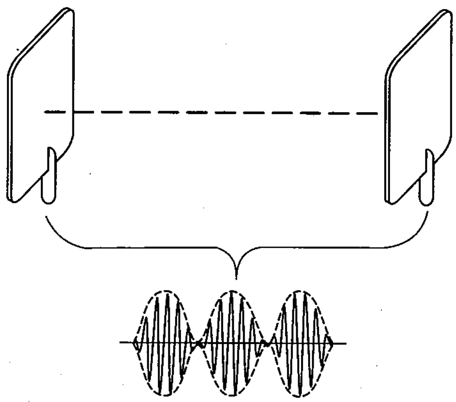

Fig. 20.5 *Linear superimposition (2-pole technique)*

This method is occasionally known as "**Electrokinesy**". The two electrodes are placed opposite one another so that part to be treated lies between them. Because the current modulation occurs throughout the area, including the superficial tissues and skin, there tends to be more sensory stimulation than that with four-pole technique. With the two-pole method, the depth of modulation in the tissue has the same value in all directions. The modulation is always 100%.

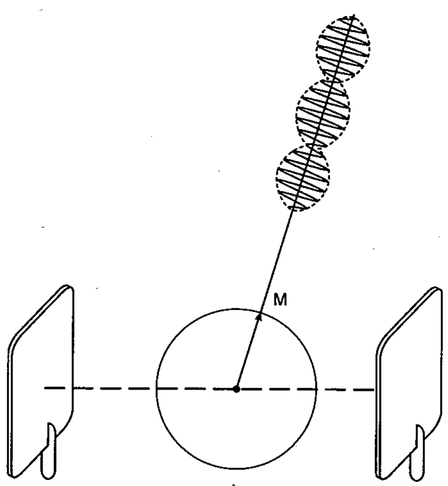

Fig. 20.6 *The modulation depth (M) in* 100% *in any direction (2-pole technique)*

The amplitude, however, varies between 0% & 100%. (The amplitude is the maximum current intensity). The amplitude is greatest in the direction of the line joining the two electrodes and zero in the direction perpendicular to that time.

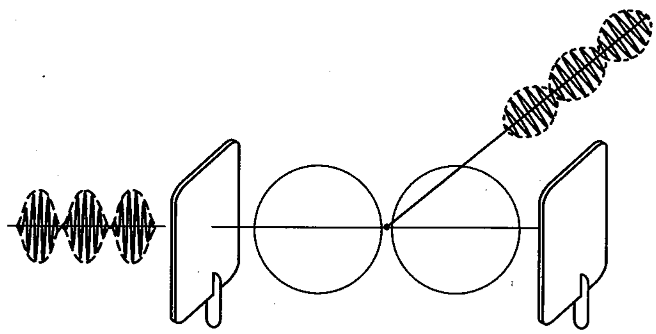

Fig. 20.7 *Distribution of the current intensity with linear superimposition (2-pole technique)*

b. **The four-pole method:** With this method, four electrodes are used in two pairs. Each pair is colour-coded to ensure correct arrangement of the circuit. The electrodes of each pair are placed diagonally opposite one another in such a way that the interference effect/beat frequency is produced in the desired tissues, which may be very deep (as is shown in Fig. 20.8).

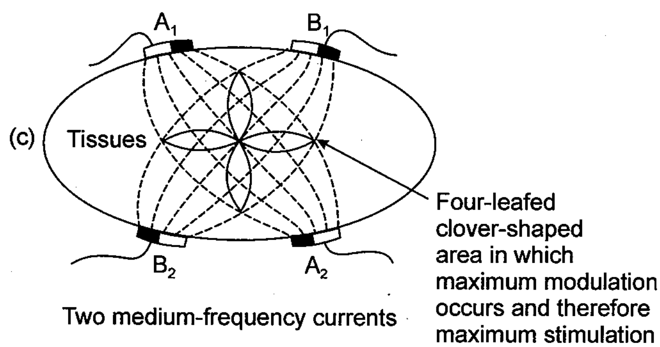

Fig. 20.8 *The Clover-Leaf Model*

The current of first circuit is carried via electrodes A_1 & A_2 and that of second circuit by electrodes B_1 & B_2, thus generating interference field in the deep tissues.

Whereas with four-pole technique, the depth of Modulation depends on the direction of the currents and can vary from 0% to 100%. It is 100% only on the 45° diagonals.

When two equal forces (circuits) intersect at 90°, the maximum resultant force is half way between these two forces (45° diagonally from each circuit) as shown in Fig. 20.9.

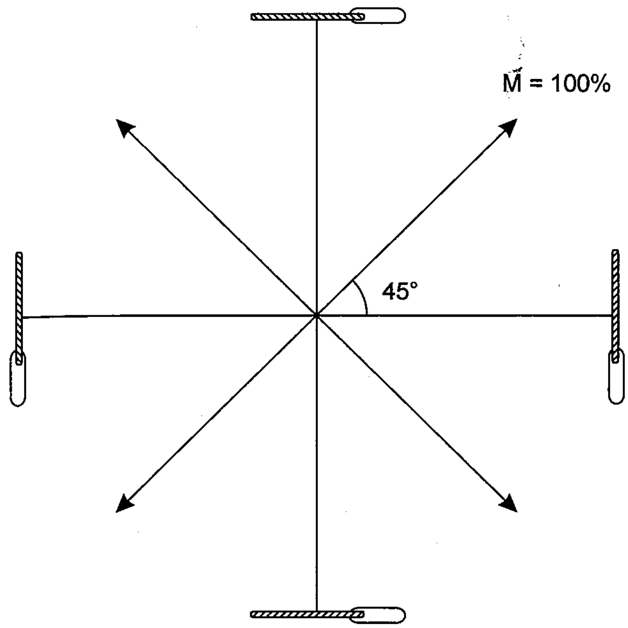

Fig. 20.9

The position of the lines on which the depth of modulation is 100% and the amplitude greatest, will depend on the location of the four electrodes.

c. **The four-pole method using the automatic vector scan:** As is shown in the diagram, the area of maximum stimulation is not square as might be expected, but of a four-leafed clover shape. It must be understood that this area merely shows the site of maximum current interference in a homogenous medium with small electrodes. The real interference field would pervade all tissues between electrodes & would be distorted by different electrical properties of various tissues, fat and muscles etc. The clover leaf shape of maximum current modulation is due to the fact that the two currents are summated not only in magnitude but also in direction *i.e.* **Vector Addition.** This is a static pattern but by varying the current interference in a suitable manner, it is possible to move the clover leaf pattern of maximum modulation to and fro through 45°, in the region of intersection, thus giving a more uniform total distribution of Interferential Current in the tissues.

Such mechanism has been given various names—**'Vector-sweep', 'Scanning', 'Rotating Vector System'** or **'Dynamic Interference Field System'**. It serves to increase the area of effective treatment. The patient must experience the varying sensation of the current.

Interferential Machines may allow for the automatic application of Interferential Current of selected frequencies and modes. The choice of frequency and mode depends on the therapeutic requirement.

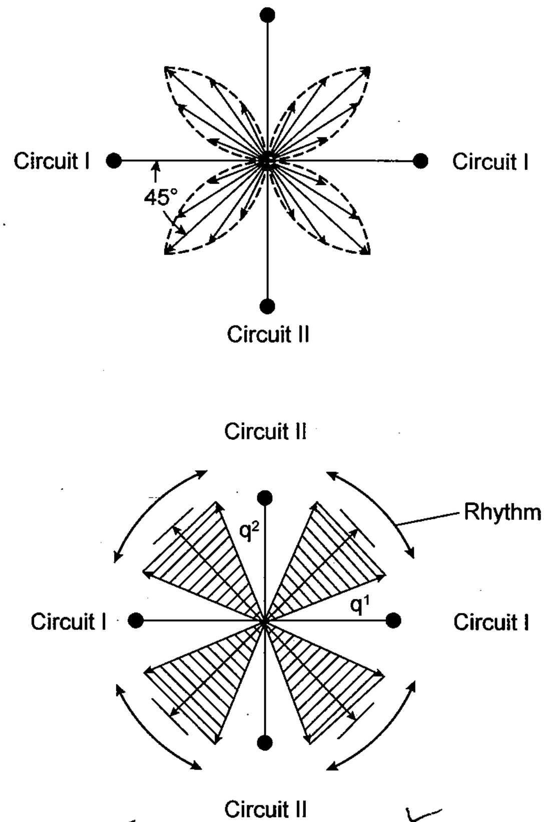

Fig. 20.10 *(a) Static interferential field. (b) Dynamic interferential field*

APPLICATION OF INTERFERENTIAL THERAPY

Interferential Currents are applied by means of electrodes, which may be malleable metal or carbon rubber electrodes with a water-soaked pad to pass current to the skin. Carbon rubber electrodes are secured by rubber straps or alternately by suction. Suction units can be connected to the Interferential Machine. Flexible rubber cups of different sizes are connected by tubes to a pump that can provide a negative pressure. This suction may be continuous or variable, the variable suction diminishes the risk of skin damage. Metal electrodes mounted inside the cups are connected by wires carried within the tubes to the interferential source. Contact is made by moistened sponges placed inside the cups between the metal electrode and skin. Suction maintains good electrical contact, and is convenient to apply and has a gentle massaging effect on the skin, stimulating cutaneous sensory nerves and causing slight vasodilatation benefitting the condition being treated, due to the increased blood flow. The leads and the suction tubes are colour coded to ensure correct arrangement of the circuit.

The five basic methods are as follows:

1. **Plate Electrodes and Pads:** These electrodes represent the standard method of application for interferential currents. Modern plate electrodes of various sizes are enclosed or used with a removable sponge jacket. It is important to ensure a firm even pressure over each electrode and a variety of elasticated straps are available for this purpose.
2. **Suction Cup Electrodes and Pads:** These electrodes provide a useful means of attaching electrodes to certain body parts *e.g.* the shoulder. However, their use is contraindicated in case of acute oedema. Several types of suction units are available. Some provide independent control of the vacuum pressure in each lead/electrode. Others allow the same pressure to all four lines, while these electrodes are convenient; they have a disadvantage of needing extreme care with vacuum pressure.
3. **Quardipolar Plate Electrodes:** A collection of specialized electrodes is embedded in a single pad. The entire pad is then moved on the patient's skin until the stimulation is localized to the required areas.
4. **Quadripolar Suction Cup Electrodes:** This method has a single suction cup containing four small electrodes. Since it has single vacuum connection, it is important to keep the pressure below 0.25 atm.
5. **Combination of Plate and Suction Cup Electrodes:** On most interferential units, which have a vacuum unit, it is possible to combine plate and suction cup electrodes *i.e.* 2 cups and 2 electrodes to be used at the same time. The ability to combine plate and suction cup electrodes allows a measure of flexibility in the application of electrodes to the patient. It also allows the unit to be used if a single electrode becomes defective.

Besides the five basic methods, there are other methods of application of IFT too.

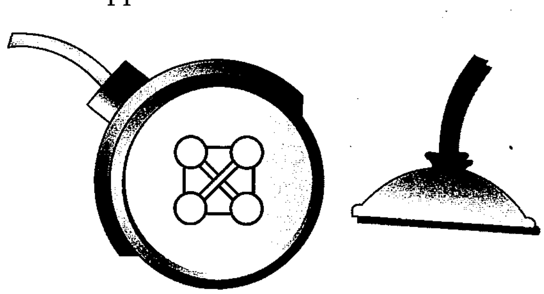

Fig. 20.11

1. **The glove electrode:** The use of this electrode is effective in certain cases because it is easily shifted in the course of treatment.

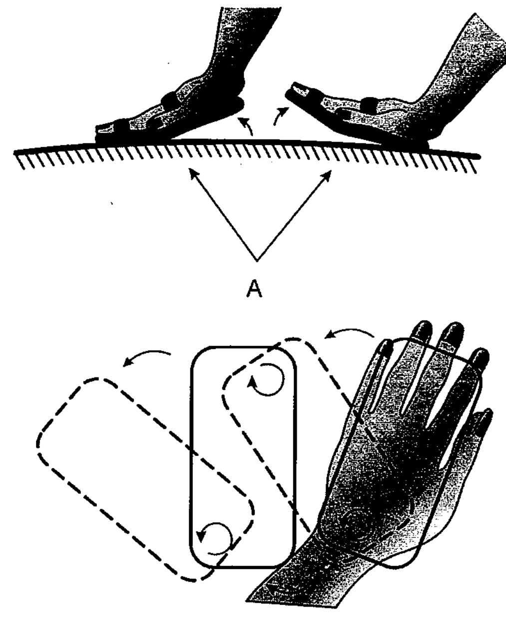

Fig. 20.12

2. **The disc and point electrodes:** These electrodes are most suitable for point stimulation. The indifferent electrode is best placed opposite the stimulating electrode in order to obtain a greater depth effect. The current density is greater under the smaller electrode.

The positioning of the electrodes on the body is of crucial importance since current must be made to cross in the area to be treated — **the target area.** The patient should be able to perceive or appreciate the pre-determined interferential effect as explained to him. If the pre-determined localizing effect is not achieved, the electrode should be re-positioned to have the desired effect.

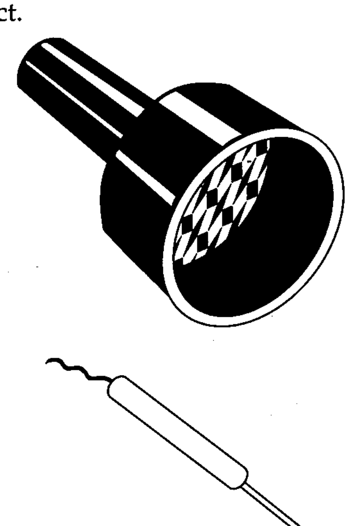

Fig. 20.13

The electrodes may be placed with co-planar arrangement or contra-planar arrangement using quadripolar or bipolar technique. The nature and effect of the treatment should be explained to the patient and re-assurance given that it is a harmless treatment producing no unpleasant sensations.

Interferential therapy should be applied to the tissues with the following steps:

Step 1: The patient should be suitably positioned ensuring maximum comfort and suitable exposure of the part for the application of interferential current.

Step 2: Prepare the area to be treated. The skin should be inspected and then cleansed to reduce the skin impedance and to achieve the best conduction.

Step 3: The points where electrodes are to be placed should be marked.

Step 4: The size of the electrodes is selected depending on the affected area.

Step 5: The electrodes should be applied on the marked points and held in position firmly with the help of straps or suction force.

Step 6: The parameters on the machine should be selected and set.

Step 7: The patient should be explained about the subjective sensory motor feeling, which he will experience. The patient should experience a sensation of deep, sufficiently strong but pleasant vibrations by rhythmical frequencies and a pleasant tingling sensation at a constant frequency of 100 Hz.

Step 8: The intensity is gradually and uniformly increased to low, moderate and high levels depending upon the stage and nature of disorder.

Step 9: Patient should be explained to immediately inform the therapist, of any unpleasant sensation or any other discomfort.

Step 10: The therapist should promptly but gradually reduce the intensity to zero as and when patient reports of any discomfort.

Step 11: After removing the electrodes, the part should be inspected and the transitory erythema effect may be explained to the patient specially when suction/vacuum electrodes have been used.

PARAMETERS

The various therapeutic effects of interferential current would depend upon the selection of following parameters:

1. Frequency

a. Range/mode (Constant or Rhythmical).
b. Frequency sweep.

2. Dosage

Frequency: The Amplitude Modulated Frequency/Treatment Frequency can be set as desired depending on the nature, the stage, and the location of the disorder. Also on the sensation felt by the patient.

High AMF: 100 Hz – 150 Hz Constant
or
90 Hz – 100 Hz Rhythmic

Useful for relief of acute and severe pain and hypersensitivity. (Because high AMF is felt comfortable, 'more pleasant', or lighter, hence it is also preferred during an initial treatment of patient who shows a fear of electrical stimulation).

50 Hz – 100 Hz Rhythmical.

Used mainly for a sedative and spasmolytic effect in sub-acute stage.

Lower AMF: Frequency below 50 Hz fall under this category.

They have a stimulating effect and excite motor nerves. This influence increases below 25 Hz. Low AMF sensations feel rougher, deeper or heavier. Hence they are used with chronic/sub-acute problems.

0 Hz – 10 Hz Rhythmic.

Useful for stimulation muscles - for their re-education and to obtain movements in articular contractures.

25 Hz – 50 Hz Rhythmic.

Produces tetanic (faradic) like contraction of muscles.

0 Hz – 100 Hz Rhythmic.

These have stimulating as well as analgesic effect. They produce vasodilatation via the Autonomic Nervous System. It stimulates and relaxes vessel walls, giving a sinusoidal effect. It results in active hyperemia, acceleration of lymph flow and activation of cell functions and restores normal tissue reactions. It eliminates promptly toxic metabolic products and promotes dispersion of oedema.

Frequency Sweep Programme: Accommodation can be avoided by varying the AMF. It is achieved by:

1. Varying the width of the spectrum.
   a. A broad spectrum superimposed onto a low AMF (for chronic/sub-acute problem).
   b. A narrow spectrum superimposed onto a high AMF (for acute problems).

2. Varying the mode of spectrum.

   a. _┌: The AMF remains at the base frequency for one second and then abruptly changes to the higher frequency, which is also for one second.

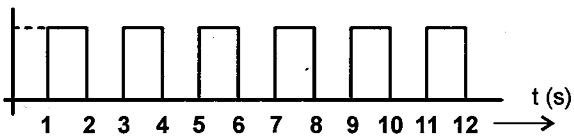

Fig. 20.14

This form of treatment has an aggressive effect and is recommended for sub-acute and chronic problems.

   b. _/‾:— The basic frequency is retained for five seconds, then all the frequencies in the set spectrum are traversed in one second up to the highest frequency, which is then maintained for five seconds, whereafter the AMF returns in one second to the lowest set value.

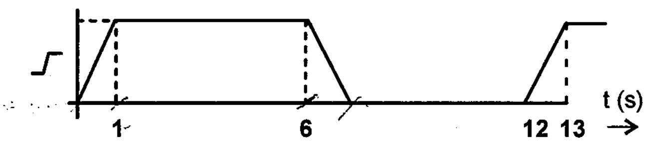

Fig. 20.15

This form of treatment is much milder in character and is more easily tolerated by patients and is recommended for acute disorders.

   c. \/\ :— Frequencies are not kept constant but are continuously changed. In the first six seconds, the frequency increases to the highest set frequency and in the next six seconds it decreases again to the basic frequency of the three possibilities. This last variation is the mildest and is recommended for acute disorders, which are painful. Despite the spectrum variation, a slight increase of the current intensity will be necessary in many cases in order to prevent accommodation.

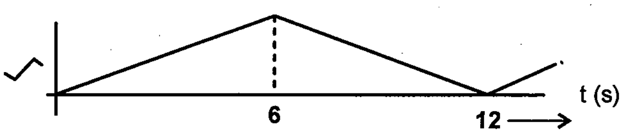

Fig. 20.16

Dosage

Intensity of Current: Intensity of current should be gradually increased till patient feels comfortable tingling sensation.

Duration of Treatment: 10 – 30 minutes.

For Acute Cases: Relatively low intensity with short period of time & short intervals may be given daily or two times per day.

For Chronic/Sub-acute Cases: Relatively high intensity with a longer treatment time may be given three to four times per week.

EFFECTS OF INTERFERENTIAL CURRENTS

Different beat frequencies lead to different effects. In general, the higher beat frequencies, around 100 Hz, are used for their analgesic effect whereas the lower beat frequencies, around 10 Hz, produce contraction of innervated muscle. All the effects appear to be due to stimulation of nerve tissue, which leads to various secondary effects, such as muscle contraction and vasodilatation.

Pain Relief

This is the most important effect and can be achieved by several mechanisms:

1. **Activation of the 'Pain Gate Control' Mechanism:** Stimulation of large diameter afferent nerve fibres closes the 'gate' to nociceptive impulses in the substantia gelatinosa of the posterior horn of the spinal cord. Impulses of very short duration at a frequency of 100 Hz should selectively stimulate these large diameter nerve fibres.
2. **Activations of Nociceptive Fibres:** Activation of the nociceptive fibres themselves can diminish pain by means of the descending pain-suppressor system. In this system, nociceptive impulses passing up to regions in the mid-brain provoke impulses in neurons travelling back down the spinal cord to inhibit nociceptor neurons at the original level.
3. **Physiological Block:** It is possible, though not proven, that high frequency electrical stimuli above 50 Hz could cause a temporary physiological block in both finely myelinated and unmyelinated nociceptor nerve fibres (A-delta and C fibres).
4. **Increased Blood Flow:** Pain suppression can also be due to an increased local blood flow and tissue fluid exchange. This may hasten the removal of chemical irritants acting on pain nerve endings and reduce pressure due to local exudates. Vasodilatation may occur as a result of stimulation of the autonomic nervous system and the regular

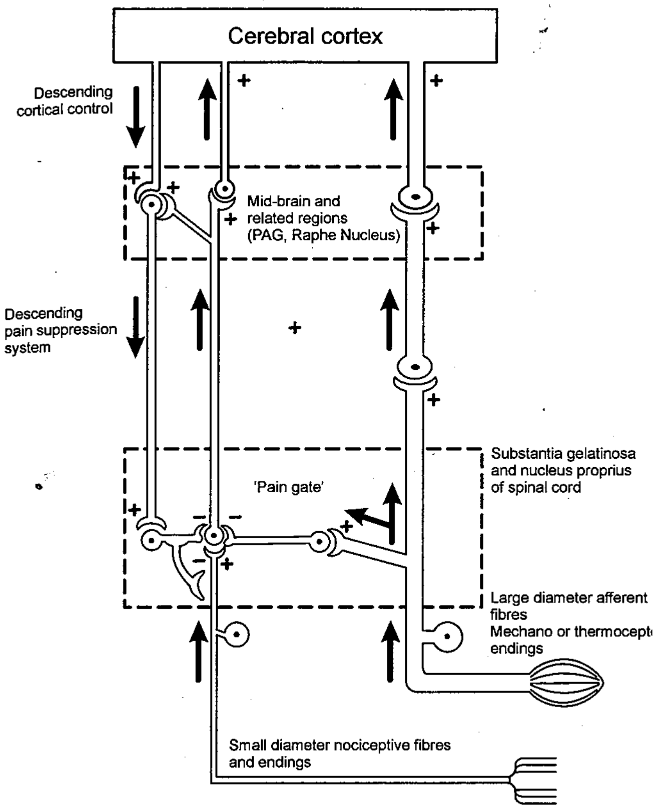

Fig. 20.17 *"Pain Gate Control" Mechanism*

mild muscle contraction has a pumping effect on vessels. (The varying suction pressure, when interferential current is applied by this method, may contribute to both the vasodilatation and the pumping effect).

5. **The Placebo Effect:** Since the placebo effect occurs in all treatments, it would be surprising if it did not contribute to pain relief with interferential treatment, especially since the machines are technically impressive and produce an unfamiliar and not the least an unpleasant feeling.
6. **Absorption of Exudates:** This is accelerated by a frequency of 1–10 Hz rhythmic as a rhythmical pumping action is produced by muscle contraction, and there is an effect on the autonomic nerves, which can affect the diameter of blood vessels and therefore the circulation. Both of these factors help absorb exudates and thus reduce swelling.
7. **Muscle Contraction**: The lower beat frequencies stimulate motor nerves leading to contraction of voluntary muscle (mainly at 10–50 Hz) and smooth muscle, via automatic nerves, extending to lower frequencies. Muscle contraction can be quite strong without any discomfort because there is little skin effect. When the beat frequency is varied, rhythmic muscle contraction will occur, helping to reduce oedema or congestion by the pumping action of soft-walled vessels. It may also aid muscle control as in the treatment of incontinence.
8. **Vasodilatation:** Stimulation of the sympathetic ganglia with 100 Hz produces reflex vasodilatation and is valuable in the treatment of causalgia. Skin temperature increases of 2-3° are possible.

MAIN INDICATIONS

The following conditions have been reported to be effectively treated by Interferential Current Therapy either alone or in combination with other therapeutic methods.

1. **Pain & Muscle Spasm:** Interferential Current Therapy is widely used for relief of pain. It is effective in relieving pain of neurogenic nature such as post herpetic neuralgia, causalgia, phantom limb pain, shoulder-hand syndrome etc. Also musculotendinous, ligamentous and skeletal disorders such as myalgias, fibrositis, tendinitis, bursitis, tenosynovitis, epicondylitis, chronic ligamentous lesions, sprains and strains, arthritis, lumbago and discopathies, rotator cuff lesions etc.
2. **Delayed Union and Sudek's Atrophy:** Encouraging results have been obtained by using a constant 100 Hz with a moderately strong dosage for 15–20 min for 2–3 weeks daily.
3. **Haematoma:** During the first 24 hours, 100 Hz constant, together with ice packs is useful for resolution of haematoma.
4. **Chronic Oedema:** The muscle pumping and autonomic effects are useful in the treatment of post mastectomy or other chronic oedema.
5. **Gynaecological Conditions:** Rhythmic modes of 0–100 Hz and 90–100 Hz have been reported to be beneficial with anterior and posterior placement of electrodes so that current crosses in the pelvis.
6. **Stress Incontinence:** Since deep muscles can be effectively stimulated by interferential currents with little skin effects, rhythmic modes of 0-10 Hz or 0–100 Hz have been convincingly used to exercise the deep weakened pelvic floor muscles. The electrodes are to be positioned anteriorly on the lower abdomen and posteriorly on the upper medial aspect of the thighs with the patient in the half lying position.
7. **Contractures:** They are caused by prolonged immobilization.

8. **Other Conditions** like asthma, migraine, insomnia, sports injury, muscle weakness, neuritis, disuse atrophy, lymphoedema, spondylosis, circulatory disorder are treated with Interferential Therapy.

CONTRA-INDICATIONS

1. **Arterial Disease** is a contra-indication to interferential therapy as the stimulatory effect of the current could produce emboli.
2. **Deep Vein Thrombosis or Thrombophlebitis** in acute stages should not be treated as it could dislodge the thrombi or increase the inflammation of phlebitis.
3. **Acute Infections** are a contra-indication as it may exacerbate and provoke the further spread of infection.
4. **Pregnant Uterus:** Direct stimulation of the pregnant uterus should be avoided, but in cases of sacroiliac strain during pregnancy, IFT may be used if superficially placed over the sacro-iliac ligaments.
5. **Danger of Haemorrhage:** The stimulating effects of the interferential can cause further bleeding.
6. **Malignant Tumours:** It may stimulate growth of neoplastic tissue or encourage metastasis if used directly.
7. **Artificial Pacemakers:** Cardiac pacemakers could be affected if the current were passed close to the heart or the implanted pacemaker itself.
8. **During Menstration:** It is contraindicated over the abdomen only.
9. **Febrile Conditions:** These may be exacerbated by interferential.
10. **Large Open Wounds:** These will cause concentration of the current and distortion of the interferential field.
11. **Unreliable Patients:** Patients who are unable to understand the warning and instructions, very young or very old patients.
12. **Dermatological Conditions:** Interferential may exacerbate any dermatological conditions in the area being treated.

DANGERS

1. **Burns:** Burns may occur by:

a. Bare metal electrode against the skin.
b. Skin current if the electrodes, that lie close together, are of the opposite polarity.
c. Increased intensity with skin currents.
d. Insufficient moisture in the pads.

2. **Haematoma**: The vacuum pads may produce a haematoma if the pressure is high and the speed is too fast.

Poor results may be due to:

a. Faulty positioning of electrodes.
b. Poor balancing of the circuits if the calibration dials are not properly positioned.
c. Incorrect choice of frequencies.

Interferential Currents	Conventional Low Frequency Currents
1. Skin impedance much lower *e.g.* for a 4000 Hz, the skin impedance offered is approx. 50Ω. Therefore, better conductivity with least skin irritation or discomfort to the patient. Lower intensity of current is required for a deeper and complete effect of stimulation.	1. High skin impedance *e.g.* for 50 Hz current, skin impedance offered is approx. 1000Ω. Therefore, skin irritation is appreciable, limiting intensity of current to be tolerated by patient.
2. Spread of current is more uniform.	2. Spread of current is less uniform.
3. Stimulation is not close to the surface, but reaches the tissues between the electrodes. Hence most suitable for stimulating deeply placed structures with appropriate technique of application.	3. The maximum stimulation is close to the surface in the vicinity of the electrodes and to reach the deep lying organs and tissues, a current of intolerable intensity must be applied. Hence suitable only for treating skin regions and sub-cutaneous tissues.
4. The variable beat frequency does not cause accommodation of nerves/muscles/tissues and hence prevents fatigue.	4. May cause accommodation of nerves/muscles and early fatigue.
5. No polar effects.	5. Polar effects present.

COMPARATIVE EFFECTS

Therefore, a considerable depth effect combined with a low strain in the skin are the essential advantages of medium frequency currents over low frequency currents. A further reduction of strain on skin results from use of four pole as compared to two pole.

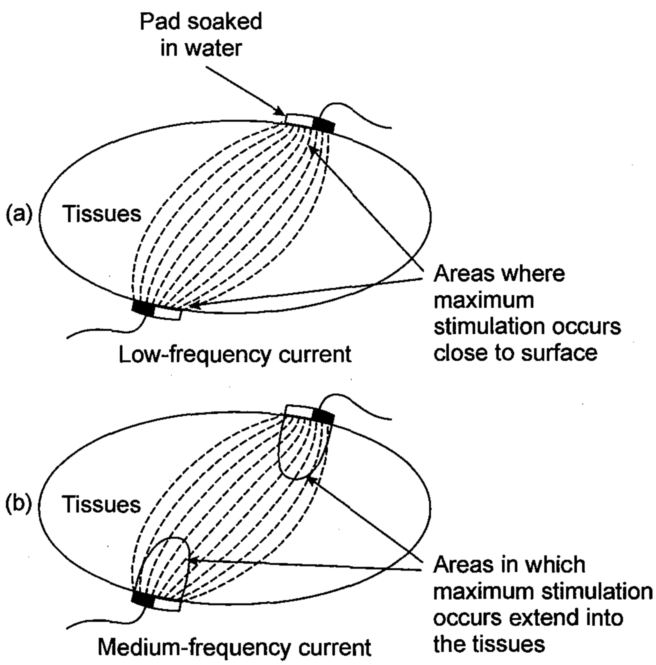

Fig. 20.18 *Medium-frequency current*

TREATMENT OF SPECIFIC DISEASES BY I.F.T.

I. Treatment of Recent Injuries: Interferential therapy is often the treatment of choice for recent injuries. It should be initiated at the earliest possible moment to produce the most rapid and satisfactory result clinically. There appears to be no danger of increasing bleeding or bruising.

As there is no concentration of current on areas deficient in the stratus commune, treatment may be given without pain even if the skin is broken, though if the electrode is placed on an abraded area, sterile precautions must be observed.

Because a badly bruised area may be painful due to the pressure caused by bandaging on an electrode, the four electrode method should be used, the electrodes being placed above and below the affected part and directing the current through it. If there is no undue tenderness, then the two-electrode method may be used.

Aims of Treatment

To relieve pain
To reduce swelling
To promote healing
To restore function.

1. **Relief of Pain:** Relief of pain is of foremost importance because pain produces spasm, unnatural movement and production of further strains. However, it must not be forgotten that spasm may be protective and its removal may leave the injured structure open to repetition of the original injury. Therefore, when spasm has been relieved, support must be given with bandage or strapping to prevent uncontrolled or excessive range of movement. This must also follow if an anesthetizing dose is part of the treatment.
Method: Using the four-electrode, the site of injury is located; two electrodes are placed immediately above and two below so that the current can cross at the site of injury. The electrodes should be as large as can comfortably be accommodated as this allows a greater intensity of current to be passed without discomfort. In a tapered limb, it may be necessary to use smaller electrodes below the injury than above but as each circuit has one large and one small electrode, they are still in balance.

A constant frequency in the sedative range (100–130 Hz) is selected. 130 Hz being there most effective if this is available. The current intensity is increased to produce a definite pricking well within the patient's tolerance and allowed to flow for 10–15 minutes or even longer if the spasm is not relieved. If a single point of acute tenderness can be located, a strong dose may be given to anaesthetize the part by passing the maximum current the patient can tolerate for three minutes.

Either treatment produces a numbing effect, so strapping is applied immediately and correct movement taught. Prolonged exercise must be avoided for at least an hour. The longer the period of rest between treatment and exercise, the longer the freedom from pain will last. In hospital, this rest period is often difficult to achieve because of paucity of space in the department. At subsequent sessions, the re-education and exercises should be given before the interferential therapy, and the patient is encouraged to have a considerable rest period before doing his home exercise. At the second treatment, checking the movements give a good assessment of the first treatment. The strapping need not be removed unless reduction of swelling has made it slack and ineffective.

Electrodes can be placed above and below the strapping, as the removal of the strapping at each session will cause only discomfort and unnecessary wear and tear on the skin.

If the part is still very painful and spasm has returned, treatment has to be given exactly as the first treatment previously described.

If the patient reports that there was not even transitory relief, the position of the electrodes should be varied as, clearly, the crossing of the currents had not been at the current place.

If the pain is less and the spasm reduced, treatment is given in the analgesic range (100–130 Hz) constant for 10 minutes followed by a small sweep, say of 10 Hz, round 100–130 Hz.

Treatment is then repeated daily, gradually increasing both extent and duration of the sweep as the condition improves until the patient is receiving 10–100 Hz. If it is found that introducing the sweep increase the pain, or the relief from pain is not satisfactory, treatment is given with analgesic frequency so as to introduce the sweep. Daily treatment is given until the pain does not return significantly between treatment, then dropped to alternate days.

An area which is not unduly sensitive to pressure may be treated in exactly the same way using the two-electrode method. In this case, one electrode is placed immediately over the lesion and a larger directing electrode ideally placed opposite to it or, in some site, a coplanar treatment may be preferable. This treatment is often less comfortable, but is easier to place accurately. The directing electrode is moved over the part until the pain execrated and then secured in this position, as the increase of pain indicates that the current is passing through the site of injury. The pattern of treatment is exactly as that for the four-electrode method. Obviously the two-electrode technique cannot be employed as strapping has been applied to the part, but can be reverted to on the days the strapping has to be removed.

2. **Reduction of Bruising and Swelling:** Reduction and/or removal of bruising and swelling, with minimum delay, is important because organization of the exudates leads to the formation of adhesions and impairment of function.

Since no passive congestion is produced by interferential therapy, it is possible to institute treatment immediately after injury without risk of exudates, but care must be taken to avoid introducing any infection.

A constant analgesic current is used initially while the bruise is painful followed by a sweep, increasing to 10-100 Hz as soon as possible as this is the major part of the treatment. Frequencies of 10–150 Hz stimulating the parasympathetic nerves increase the blood flow through the part assisting in resolution. The contractions of voluntary muscle, which are produced by the lower frequencies, assist in the dispersal of excess fluid. For this reason, the intensity of current is slightly greater when using the sweep that for the constant frequency. While it would be contraindicated to allow a muscular contraction at 100 Hz constant (because such a held contraction would cause after pain), when using a sweep, the intensity should be such that a contraction is just produced in the lower frequencies to which the voluntary muscles are most sensitive, but relaxation in the higher frequencies where a stronger current would be required.

The colour of the bruise will be seen to change from the first treatment, though deep and extensive bruising, or a haematoma, may take several weeks to disperse. This method of treatment may safely be employed where there is bruising of the thigh or the brachial muscles while in bruising of other areas, it is contra-indicated for fear of myositis ossificans. Indeed, it has been reported that a case of myositis ossificans, which had been confirmed radiographically, and treatment by interferential therapy was continued, clearly completely with no calcification being demonstrable after three weeks. If it is possible to do so on the apparatus available, the lowest frequencies, 0–5 Hz, should be cut out to avoid stimulation of the sympathetic nerves.

3. **Promotion of Healing:** While the method by which healing is accelerated is obscure, it can be observed clinically that recovery is assisted. This may be because of the active increase of circulation, but probably also by altering the electrical state of the cell which has been changed by injury.
4. **Restoration of Function:** When there is noticeable muscle wasting, treatment may be given in addition with a sweep of 5–50 Hz with a view of stimulating the striped muscle. It will be noticed that while a sweep of 0–100 Hz is applied for a proportion of the time, the patient will be receiving the lower frequencies which stimulate the muscle. The object of giving the extra dose in the lower frequencies only is to enhance the effect. To increase the effect, the electrodes should be moved for this part of the treatment so that the belly of the affected muscle lies in the path of the interference current, not the site of the injury. In many cases it is more convenient to stimulate the muscle with faradic current rather than treating with interferential current.

Treatment with interferential therapy does not replace, but only augment re-education of muscles and exercises. By applying these principles, the treatment for an individual injury may be decided.

II. Treatment of Rheumatic Conditions: The interferential therapy is the treatment of choice for all types of rheumatic conditions. It can be used effectively in the acute and chronic conditions of rheumatoid arthritis, osteoarthritis and spondylitis.

1. **Rheumatoid Arthritis:** The aims of the treatment are three fold – the relief of pain, decrease of inflammation, and increase of range of movement. Restoration of function is taken care of by other means. The relative priorities vary with the phase of the disease.

a. Acute Phase: In the acute phase, the prime consideration is the relief of pain and swelling. Treatment is given usually by the four-electrode method to avoid causing pressure on the painful joint. The electrodes are placed well above and below the joint to include a side area. If an acutely inflamed joint is resting in Plaster of Paris splints, treatment may still be given with the electrodes in this position. The largest electrodes, that can be accommodated, are used to give the deepest possible penetration. A constant sedative of 100–130 Hz current is passed for 10 minutes at a comfortable tickling intensity but short of producing any contraction. Too great intensity causing contraction will certainly cause after pain and must be avoided.

If there is any doubt about the patient's appreciation of when is required, it is better to underdose rather than overdose at this stage. Provided this is understood, the treatment will give relief even in the most acute phase of the disease, when the joints are red, shiny and swollen. The relief may be short lived at first, but treatment is repeated daily and freedom from pain increases at each treatment. In most cases, it will shorten the acute phase. Duration of treatment is increased to 15 minutes but the current is kept low until the acute phase has passed.

b. Chronic Phase: In the chronic phase, in addition to the sedative treatment, it is desirable to treat with those frequencies which influence the blood vessels and muscles. The 10 minutes treatment is followed by a period of sweep. In the sub-acute phase, the sweep is introduced gradually, beginning with a sweep of 20–30 Hz just below the sedative frequency (*e.g.* if a 130 Hz current was used for the acute phase, the sweep would be 100–120/130 Hz) for three to four minutes according to the condition of the patient and increasing both range and duration until a sweep of 10–100 Hz is being given for 10 minutes. This progression depends on the report of the patient about improvement and the observable improvement in the condition of the joint. If the patient presents in the chronic phase, the full sweep may be introduced at once. The intensity of current is such that it just fails to produce a contraction for the constant treatment, but during the sweep produce a contraction only as the optimum frequency for stimulation of the motor nerves is reached followed by relaxation for the rest of the cycle.

In addition to the local application, treatment is also given to that region of the spine from which the joint is enervated. Using the four-electrode method, five to seven minutes treatment is given with a sweep of 10–100 Hz sweep producing an active increase in circulation. The effect is quite different from that of the electrical treatment, such as short wave diathermy, which are often given. These treatments, by producing heat and so a passive congestion in and around the joint, cause increased exudates and consequently increased tension in an already tense joint. This causes an increase of pain and improvement is felt only after a time. The active congestion produced by the interferential is an increased rate of blood flow, absorption of increased exudates and decreased tension. The patient therefore leaves the department feeling more comfortable. The additional time spent at each session in treating the spine is well compensated for by the decreased number of sessions required to produce the desired results.

2. Osteoarthritis of the Hip Joint: Treatment of the osteoarthritic hip is particularly rewarding. The patient is treated in crook side lying on the good side with the affected leg supported on a pillow. This is a comfortable position for patients. The lower electrodes are placed opposite each other on the front and back of the thigh just below the ischial tuberosity. The upper ones are placed on anteriorly over the abdomen just above the centre of the inguinal ligament and the other on the back opposite. The two currents so then cross in the hip joint. Seven minutes sedative frequency (100 or 130 Hz) is given followed by seven minutes 10–100 Hz sweep.

With the patient in the same position, the electrodes are moved to treat the lumbo-sacral spine with a sweep of 10–100 Hz for seven minutes. After treatment, the patient should rest for at least 10 minutes, preferably longer, and undertake no severe exercises for at least an hour. The longer the rest period, the longer the relief from pain will last. If an exercise class is a must, it should precede, not follow the treatment. Immediately after treatment the patient has less pain and the range of movement is increased. This may last only a short time at first but is more prolonged after each treatment. Treatment is given two or three times a week for 12 treatments. Daily treatment is not necessary, but once a week is ineffective. After 12 treatments, the patient should cease attending for a month to prevent him becoming overtired.

3. Osteoarthritis of the Knee Joint: In treating the knee, it cannot be overemphasized how good are the results if the lumbar spine is treated as well as the knee joint. This is not convenient as with the hip because the position of the patient has to be changed. As with the hip, the maximum effect on the circulation is achieved through the automatic supply arising in the lumbar spine.

With the knee joint it is also possible to vary with the position of the electrodes from one treatment to another so as to be certain that all aspects of the joint are treated. Thus one treatment may be given with the electrodes placed laterally, one pair above the knee, and one pair below the knee. At the next treatment they are placed anteriorly and posteriorly above and below the knee; while at the next session the patient can be sitting with the knee flexed, one circuit traversing the knee from side to side and the other from the supra patellar pouch to the calf, as in the treatment of the cruciate ligaments.

While the most effective position can be found for each patient, variations should always be tried to achieve the best result. Some patients find that treatment with the two-electrode method is more effective. Here, one pad is placed over the most painful area and the other directly opposite directing the already modulated current straight through the joint. The patient usually reports that the current is picking out the painful spot. If he does not, the electrode is moved until he does. The increased pain dies away after a few minutes and relief persists after treatment. Why some patients respond to the two-electrode method rather than the four is obscure and unpredictable, but in any one patient it is remarkably constant over the years.

Some patients, even in the chronic stage, find relief from the constant current but increased pain if any sweep is introduced. In this case, the whole treatment of 15 minutes is given with the sedative current and a good result is obtained but more slowly. Treatment to the spine with a sweep may be tolerated, if not, the constant frequency is applied here also.

Arthritic patients are often elderly, and may have a cardiac condition which is not associated with the arthritis. In such cases, treatment to the spine, even in the sitting position, may cause respiratory distress due to too great an alteration of the circulation. These patients must be watched carefully. At the first sign of distress, however slight, treatment to the spine must be stopped. In some cases it may be advisable not to treat the spine even through the relief of pain will be less effective and recovery slower.

4. Ankylosing Spondylitis: Interferential therapy is also effective in relieving the persisting aching of ankylosing spondylitis. When the pain is diffuse, the four-electrode method is used, treating a wide field with large electrodes to get maximum penetration. Treatment is given for 10 minutes with a constant sedative current (100–130 Hz) at an intensity just short to producing a contracting, followed by a sweep 10–100 Hz. Treatment is given three times a week for a month, followed by a rest of two or three weeks. Interferential therapy must be combined with exercises which encourage extension, performed either before or some hours after the treatment. Pain is reduced and range of movement improved. Most spondylitic patients require a course of treatment two or three times a year to maintain movement.

5. Spondylosis (Spinal Osteoarthritis): Spondylosis or osteoarthritis of the spine is particularly suitable for interferential therapy. Patients often respond to this when all else has failed. If the pain is diffuse, the whole area is treated as for spondylitis. After a few treatments the patient usually reports some localization of pain. The electrodes are placed on the skin at a point of normal sensation and the current is increased to produce a slight prickling. The electrodes are then moved gradually working towards the pain, enquiring if the sensation is less, the same, or more at each point. As the electrode is applied to the tender point, the current feels stronger, though the intensity is the same. When the most tender point is identified, treatment is given with constant frequency and sweep centered at this point. After treatment, the localized current is again applied. It may be found that the point is no longer tender, but if the tenderness persists, the point is treated with a strong local dose. A course of upto 12 treatments is usually given two or three times a week. The local dose is only given when indicated, but not as a routine.

6. Cervical Spondylosis: Treatment of cervical spondylosis is satisfactory if care is taken, but there are difficulties. The most common error is to omit the upper joints by placing the electrodes on the next itself. The Atlanto-occipital and Atlanto-axial joints lie above the hairline. Electrodes are placed on either side of the occiput and prominence (Spine of the seventh cervical vertebra). Bandaging is difficult, but if the patient is treated in half lying, the upper electrodes may be kept in place with a towel round the neck and a soft pillow as a butterfly tucked in each side of the neck.

7. Muscular Pain: Patients with widespread muscular pains over the shoulder girdle will often respond best to interferential treatment only. Using the current of an intensity to produce definite prickling, the electrodes are moved over the whole shoulder girdle. Both electrodes may be moved, whichever may be done most smoothly by the operator. As the pad passes over a tender area, the current is felt more intensely, and the pad is kept at this spot until it is no longer tender. The operator then moves to the next tender spot until the whole has been treated. On returning to the first tender spots, they will now be found to be quite normal. The relief of pain may last hours, days or weeks, and treatment repeated as necessary.

8. Septic Arthritis: Following Septic Arthritis, the patient is often left with gross and intractable stiffness. Treatment with any form of heat is contra-indicated in case of residual infection but with interferential therapy, practically no heat is produced.

The joint is treated from as many aspects as possible. Treatment is given daily beginning with 10 minutes constant sedative current at a very low intensity to relieve pain. This is increased slowly to 15 minutes. If there is no increase of pain, or any sign of flare-up, the duration of the constant frequency is progressively decreased and replaced by gradually increasing sweep until the patient is receiving 10 minutes sweep 10-100 Hz. As this treatment stretches and releases scarring of the skin, so the fibroid tissue within the joint becomes pliable and the range of movement is gradually restored. Daily treatment may be given but a rapid result cannot be expected. Perseverance, accompanied by an increasing program of exercise, can restore full range of movement.

9. Arthritis affecting the Hands: Single interphalangeal joints of finger or thumb, the metacarpophalangeal joint of the thumb, and Heberden's nodes, which are painful and swollen are most conveniently treated using the small electrode wrapped round the finger.

The current, which can be passed, is small but is adequate for the superficial joints. The frequencies and timings are as for any other rheumatic joints. In the case of the inflamed Heberden's nodes, sedative treatment of 100 or 130 Hz only is used. Relief of pain is almost immediate and the hand can be used normally. Two or three treatments may suffice to restore painless function. The nodes will still be present but will no longer cause discomfort to the patient. Treatment is repeated as necessary.

III. Treatment of Shoulder Pain: A frozen shoulder is one of the most troublesome conditions to treat because of the diversity of causes. The importance of accurate diagnosis and localization of the site of the lesion cannot be stressed too strongly, if it is not, then much time will be wasted. The trouble may lie in the subdeltoid bursa, the rotator cuff or the biceps brachii tendon or a generalized capsulitis may be present. Supraspinatus tendinitis may present a similar picture.

It is clear that when using a treatment, which depends for its effect on the crossing of the two currents at the site of the lesion, localization is of paramount importance.

The four-electrode method is generally used. Small pads about 5 cm (2 inches) square are used. It is not satisfactory to use the small combined electrodes as far too little can be tolerated; the distribution of current is too small and too superficial to have much effect.

A constant sedative current (100 to 130 Hz) is passed for 10 minutes. If the condition is acute, the time may be increased at subsequent treatments put 15 minutes until the condition becomes sub-acute. The pads are then moved to treat the deltoid, trapezius and infraspinatus muscles with a frequency of 10–50 Hz at an intensity to produce a slight contraction.

At subsequent treatment, the period of constant frequency is reduced and replaced by a sweep gradually increasing to 10–100 Hz. When the generalized pain is decreased but local pain remains, this point is given a strong dose.

Treatment is given daily till five days or until the pain does not reappear between treatment, then dropped to three times a week for one week, then twice a week. In recent cases, 12 treatments may suffice, but long standing cases take considerably longer. After four weeks, a change of treatment should be considered.

It is found that exercise, particularly immediately after the interferential therapy, retards restoration of function. Rest with interferential therapy restores function.

IV. Treatment of Back Pain and Lesions: Acute back pain is very effectively treated with interferential therapy. Treatment may be begun as soon as possible after onset, even if the patient is confined to bed or on traction.

When the pain is confined to the back, treatment is given exactly as for spondylosis except that progress will be slow and either a constant sedative frequency or a very small sweep in the 90–130 Hz range should be given for several days.

When the pain is referred down the leg, treatment to the spine is followed by treatment to the leg. Two electrodes are placed on the foot and the other two under the buttock so that the current trasverses the whole length of the nerve. Sedative treatment (100 to 130 Hz) is given for 10 minutes.

V. Treatment of Incontinence: Urinary incontinence is the most distressing and obstinate condition, but is amendable by interferential therapy in cases where there is loss of sphincter control. Clearly it cannot be effective for all incontinent patients since many, particularly after childbirth, have gross structural damage which must first be repaired. Unfortunately it often happens that when surgical repair has been made, apparently satisfactorily, the patient remains incontinent due to sphincter weakness or faulty autonomic innervation. This can, however, be treated with interferential therapy with excellent results. It may not be successful in all cases of nocturnal neurosis in children, since there is often an underlying psychological disturbance which no electrical treatment could cure.

Treatment aims at increasing the efficiency of the sphincter by stimulating the unstriped muscle with low frequency impulses to which it is sensitive and also by influencing the autonomic supply. This is more likely to succeed than the more usual methods of faradism and exercises, which can only influence the sphincter indirectly through association with the striped muscle of the pelvic floor. Since it is desirable that the sphincter control is entirely unconscious, it must be treated through the involuntary muscle and the autonomic nervous system. Voluntary muscle of the pelvic floor is also in the path of the current and will receive its share of the treatment, therefore, reacting. Nevertheless, this treatment is found to be effective even when the patient is unable or unwilling to do any voluntary exercise. Passage of current through the pelvic floor also accelerates repair of tissue damaged during delivery or at operation.

Following childbirth, treatment may be initiated as soon as any difficulty is experienced. The condition might well be one that would right itself in time but it is unnecessary to allow it to persist, if it can be cleared up quickly. Should the damage be more serious and require surgical repair, interferential treatment will increase local circulation and accelerate healing. No passive congestion is produced and so there is no danger of haemorrhage.

Treatment Position: The patient is placed in stride sitting or crook stride lying. The elderly patient who comes to the department in a wheel chair need not be moved out of it as this position is ideal. Two electrodes are placed on the lower abdomen just above the outer half of the inguinal ligament. The medium size 10 cm. × 4 cm. electrode is most suitable. The small electrodes are not so comfortable and particularly with an elderly patient with a very fine skin, bruising may result. The other two electrodes are placed on the upper part of the inner aspect of the thigh near the origin of the adductors. These must be placed sufficiently far back to direct the currents through the pelvic floor with the crossing point at the urethral sphincter. Placing the electrodes too anteriorly will direct the current through the superficial tissues, missing the target entirely.

Treatment: A sweep of 0–100 Hz is used. The lowest frequencies stimulate the unstriped muscles directly: 10–15 Hz stimulate the voluntary muscles of the pelvic floor; and 5–100 Hz the autonomic nerves. This can readily be appreciated by the normal subject who knows what to expect. It is helpful in explaining what he could feel if the operator has experienced the current himself.

The intensity of current is that required to produce a barely perceptible contraction of the pelvic floor, occurring only when the frequency is in the 10–50 Hz range followed by relaxation. The current must never be too strong as to produce a tetanic contraction lasting the whole cycle. The first treatment lasts eight minutes and the time is increased by one minute each session upto 15 minutes. The intensity of the current is not increased. In fact, as the condition of the muscle improves, it is often found that less current is needed to produce the contraction.

Treatment is given two or three times a week. If it is given more frequently, it is too tiring for the patient and, in any case, time must be allowed for the muscles to become trained. Less frequently than twice a week is ineffective. A course of 12 treatments should be sufficient. With cases of recent onset, the patients may be cured in fewer treatments and it is not necessary to finish the course. Chronic, particularly senile, cases will need the full course and indeed may require a second course after an interval of two to four weeks. Patients usually report some slight improvement after two or three treatments even in cases of very long standing. Some senile patients cannot report progress and follow-up enquiries must be made with the nursing staff.

Bruised Perineum: The same position of electrodes and the general procedure is followed for the treatment of a bruised perineum following childbirth. Not only is the condition acutely uncomfortable, but, if the brushing is not rapidly resolved, lasting damage may be done to the pelvic floor. As there is pain, a 10 minute constant 130 Hz treatment is given, followed by a 10 minute sweep of 50-100 Hz working put 10–100 Hz as quickly as possible to disperse the swelling. The great advantage of this method is that no electrodes are placed on or near the perineum so reducing the likelihood of introducing infection or causing pain to the patient. The presence of clips or sutures presents no obstacle. The patient can wear normal protective clothing or a pad during treatment. Treatment is not uncomfortable and the slight contraction relieves the tension from the first treatment. Treatment is given daily until the bruising has gone, decreasing the time of the sweep as the pain decreases.

The treatment may also be used in treating incontinence following prostatectomy and also for the relief of a non-specific prostatitis.

VI. Treatment of Thoracic and Circulatory Conditions

1. Asthma: Treatment with interferential therapy often gives considerable relief to patients suffering from asthma. In this condition, expiration is impeded by spasm of the unstriped muscles of the bronchioles. The aim of the treatment is to relax these muscles, enabling the lungs to collapse as the inspiratory muscles relax.

Treatment Position: The patient is treated sitting in an upright chair. Two electrodes are placed on the back over the upper part of the trapezius and two anteriorly over the lower ribs. If the patient is having difficulty in breathing while treatment is in progress, he may find it more comfortable to sit leaning slightly forward with his arms supported on a table. In this case, the upper electrodes are placed anteriorly over the lungs and the lower electrodes posteriorly over the lower ribs. This position may also prove more convenient for a well developed lady.

Treatment: A sweep of 10–100 Hz is applied for 10 minutes at the first treatment increasing by one or two minutes at each session upto a maximum of 20 minutes. Treatment is given three times a week for a month.

Because the heart is in the path of the current, this treatment should not be given to patients with a history of cardiac disease. All patients must be kept under close supervision during treatment and the current must be turned off at the least sign of distress.

During and after a course of treatment, the breathing becomes progressively easier and the frequency of the acute attacks is reduced. A mild acute attack does not contra-indicate treatment since the patient is in no way restricted and indeed the relaxation induced will abort the attack.

2. Treatment of Circulatory Diseases: Interferential therapy is indicated in many cases of impaired circulation. Its action is directly through the stimulation of the muscular coats of the blood vessels and also by stimulation of the parasympathetic system. This is in contrast of the effect of most forms of electrotherapy which, by generating heat in the part, produce a passive congestion and so often an increase of swelling. Sympathetic stimulation would produce a vast constriction and is therefore contra-indicated. Therefore, the frequencies 0–5 Hz must be avoided. Using apparatus, where this is impossible, it must be borne in mind that in using frequencies 0–100 Hz., 5% of the cycle will be counter productive. It there is a history of thrombosis, interferential must never be used on the affected limb. If a person has had a coronary thrombosis, interferential must not be given.

To Improve Circulation: To increase the circulation of a leg, two electrodes are placed one on either side of the lumbar spine, one on the dorsum and the other on the sole of the foot. A sweep of 10–100 Hz is applied at an intensity, which produces a very gentle contraction in the motor part of the cycle only. A tetanic contraction of the voluntary muscle during the whole cycle is obviously contra-indicated, but the intermittent contraction of the muscles enhances the direct effect of the current on the blood vessels themselves.

Treatment is given three times a week for a month. For a condition such as chronic chilblains, which recurs year after year, treatment is best given in the autumn before the cold weather starts as preventive measure and repeated if, or when, the chilblains appear. The treatment may have to be repeated for several years before the effect is permanent, but the condition becomes progressively less severe.

The same treatment is used for chronically cold feet and for erythema nodosum. If the condition has led to ulceration, this is no contra-indication as the electrodes are placed above and below the ulcerated area without disturbing the dressing. The rate of healing is accelerated and the patient is much more comfortable. The type of dressing and frequency of renewal is discussed with the physician in charge of the patient.

Intermittent Claudication: Treatment of intermittent claudication though may not be entirely satisfactory, keeps the condition partially under control. While he is taking treatment, the distance walked without pain increases and the foot remains warm with no sign of gangrene. On ceasing treatment, unfortunately the disease slowly relapses. Treatment is given twice a week with two electrodes on either side of the calf just below the knee and two on either side of the ankle. A sweep of 10–100 Hz is applied for 10 minutes initially, rising by two minutes each treatment to a maximum of

15 minutes. It may be necessary to continue the treatment indefinitely with suitable breaks for holidays, but other methods are no more satisfactory.

Lymphoedema: Patients with grossly swollen legs, either idiopathic or due to inactivity through being confined to a wheel chair or paralyzed, are best treated with a sweep of 45–90 Hz. This is because these frequencies have the greatest effect on the muscle coats of the blood vessels. Treatment is given with the electrodes placed as before at an intensity that produces marked but comfortable prickling. Care must be taken not to give an overdose as the limiting feeling of "tightening" will not be present in a paralyzed limb. Treatment length starts at 20 minutes increasing gradually to 45 minutes.

This treatment may also be given to a swollen arm following mastectomy. The current is not directed through the site of the primary cancer. The patient reports the limb as feeling lighter and more comfortable.

Sudeck's Atrophy: Sudeck's atrophy is a resistant condition, which responds well to interferential therapy though treatment may have to be prolonged.

METHOD OF PLACING ELECTRODES

The four-electrode method is used. Two pads are placed on the forearm and the other two on the front and back of the hand. If available, the largest size of electrode may be used (if the arm is not too fat). A 100 Hz constant or a sweep of 90–100 Hz is applied at an intensity just short of contraction for 10 minutes working upto 15 minutes. Treatment is given three times a week for four to six weeks.

Both appearances and functions of the hand begin to improve after a few sessions of treatment, but complete recovery may take some time.

Migraine: Sufferers from migraine have reported that interferential therapy applied during an attack relieves the headache slowly, but more quickly than would be expected naturally. If available, a two electrode method is used; one pad over the forehead and the other on the nape of the neck. A mild sedative treatment is given of 100 or 130Hz for 10–15 minutes. If applied in the stage of an attack, it will be aborted.

A course of treatment two or three times a week for 12 treatments reduces both the frequency and severity of attacks.

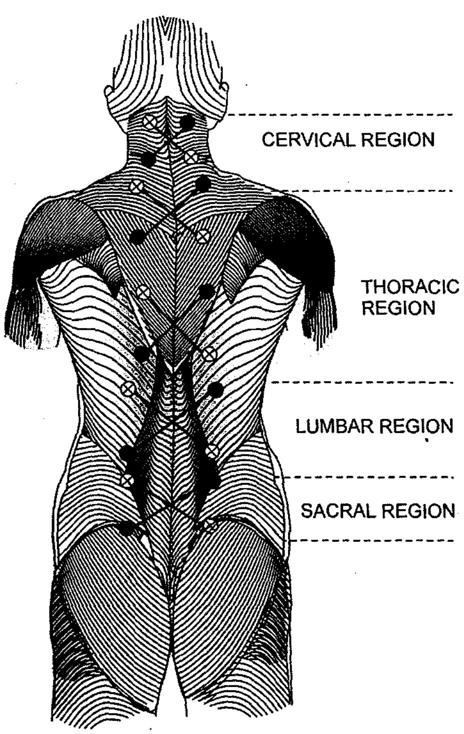

Fig. 20.19 *Four pole interferential current treatment*

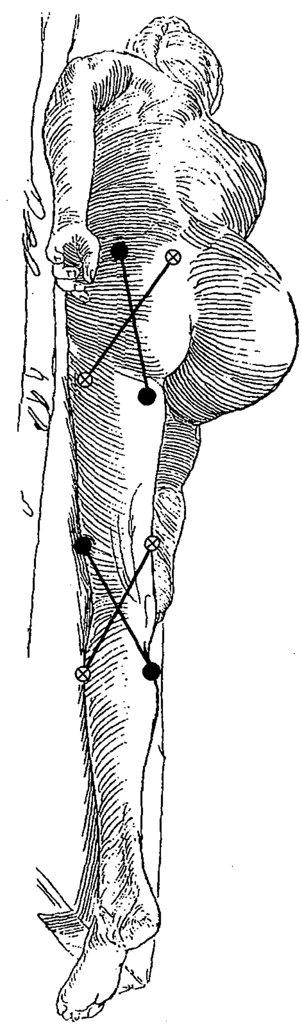

Fig. 20.20 *Four pole interferential current treatment*

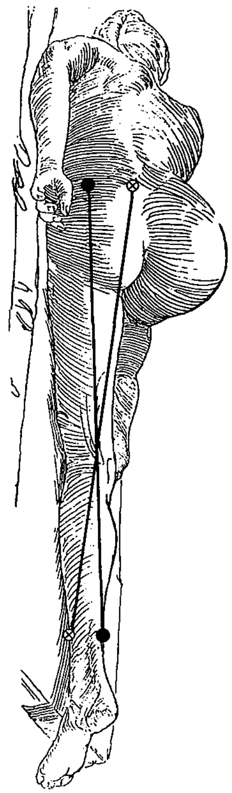

Fig. 20.21 *Four pole interferential current treatment*

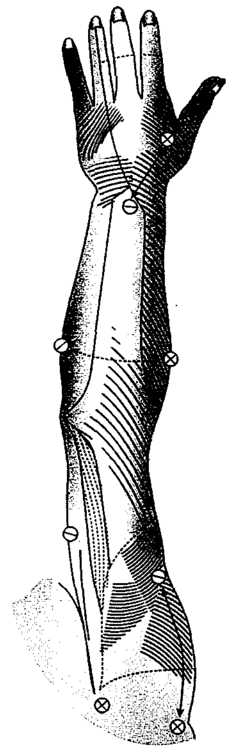

Fig. 20.23 *Two pole pre-modulated current treatment*

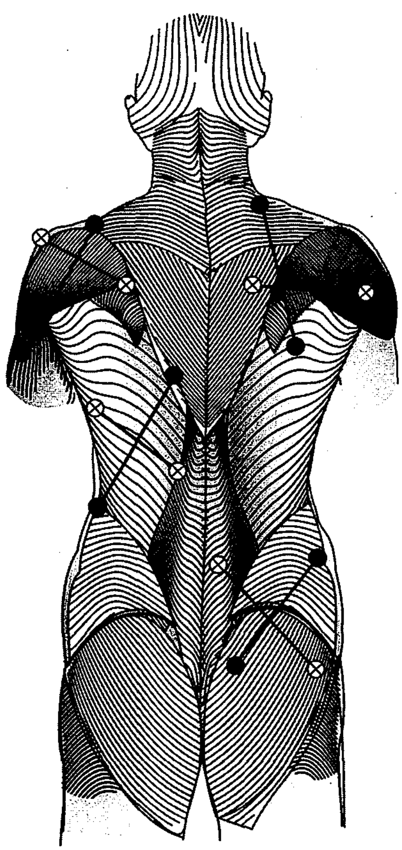

Fig. 20.22 *Four pole interferential current treatment*

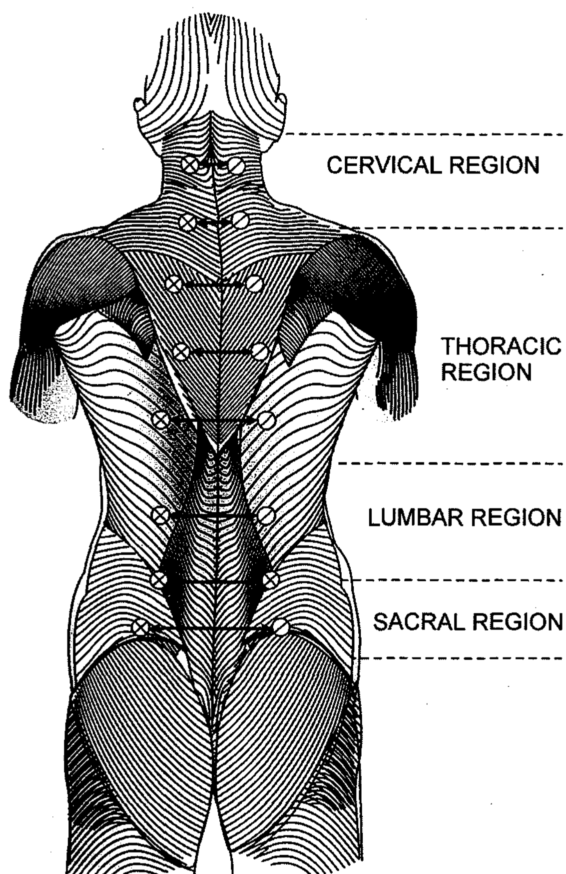

Fig. 20.24 *Two pole pre-modulated current treatment*

CHAPTER

21

RUSSIAN CURRENT

- Definition and Production
- Uses

DEFINITION AND PRODUCTION

'Russian' stimulation consists of frequencies in the 2,400 to 2,500 Hz band, pulsed at various rates. Operating in the higher voltage ranges, 100 to 500 V, this modality has been reported to be effective in the management of athletic type injuries. The term Russian current, applied to stimulators in which a continuous sine wave output of about 2500 Hz, is modulated to yield 50 bursts per sec. (bps). Each burst is actually a polyphasic pulse waveform modulated AC. The generation of such current is illustrated in figure 21.1. Contrary to promotional claims regarding the uniqueness and superiority of such a waveform for muscle activation, electrophysiological evaluation offers sound refutation of these claims. The reason for a carrier frequency of 2500 Hz is unlikely to be a unique medium-frequency effect on comfort of stimulation. The reciprocal of 2500 Hz frequency yields single pulse and phase durations of 400 and 200 μ sec. respectively. Thus, the phase duration is narrowed to a range that correlates with relatively comfortable stimulation. Yet, in accordance with the strength duration curve, one must compensate for the shorter duration by increasing the pulse amplitude. Total current is always between 65 and 70 percent of the peak. To limit total current output, the manufacturer of the Russian approach elected to time modulate the sine wave into 50 bps by creating an interburst interval of 10 m sec. (Fig. 21.1). Such bursts reduce the total current and allow peak current amplitude and thus phase change to increase so that a very powerful motor stimulation can be achieved.

The inefficiency of such an approach is again related to an excessively high total current (90 to 100 mA). Induced muscle contraction at 50 to 65 percent of MVC has been obtained with such current but also with a symmetric biphasic pulse. The latter required only about one-tenth of the total current of the former. Other limitations of Russian current include less comfortable perception, fixed pulse rate in earlier units (that severely limited the number of clinical procedures that it could offer), and a fixed phase duration (so that adjustments for individual patients are not possible).

The main physiological effect of Russian current is at the cellular level, but (indirectly) the tissue, segmental, and systemic levels may also be affected as with other TENS stimulators. Because of its present design, clinical uses are mainly restricted to muscle re-education treatments. Russian current is, therefore, one of the least versatile clinical stimulators presently available and is not cost effective.

USES

- Pain Relief
- Muscle Contraction
- Improve the strengthening of muscle.

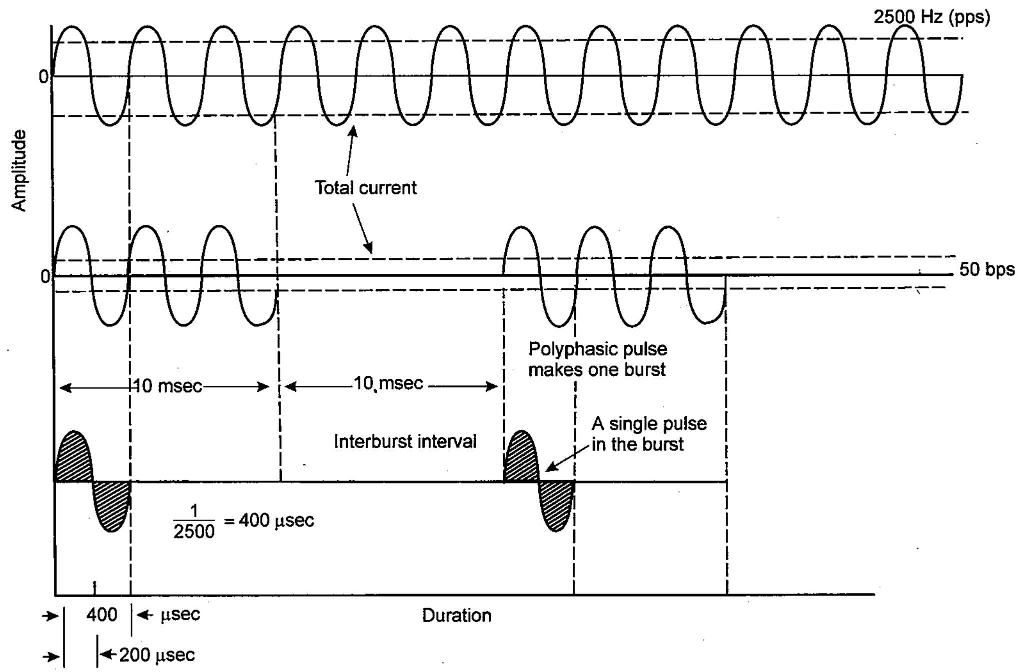

Fig. 21.1 *Russian current. Note that by providing interburst intervals, the total current is reduced*

CHAPTER

22

DIADYNAMIC CURRENT

- Definition
- Physical Properties
- Physiological Effects
- Indications
- Contra-indications
- Method of Application
- Dosage
- Intensity
- Duration
- Frequency

DEFINITION

Diadynamic current is a monophasic pulsed current. It is usually a sine wave at a carrier frequency of 100 Hz, which is either half wave or full wave or full wave rectified. The result is a monophasic pulse of 10 msec phase duration. Half wave rectification yields a pulse rate of 50 pps; full wave rectification yields 100 pps.

The unidirectional current flow, long pulse duration, and relatively short interpulse interval render cellular and tissue chemical changes similar to those of continuous DC. Diadynamic current, like other TENS device, provides direct excitatory responses but, because of its long phase/pulse duration, it is very uncomfortable for the patient over a motor point with large electrode placed proximal to the small electrode.

The major danger with such currents is tissue damage due to the polarity changes. Diadynamic current have been used in Europe for many years and have recently been introduced in Australia. The majority of the literature available is in European journals and is rarely translated into English; therefore, local clinical studies will be welcomed to confirm the benefits of these currents.

PHYSICAL PROPERTIES

There are generally five different currents available for diadynamic therapy.

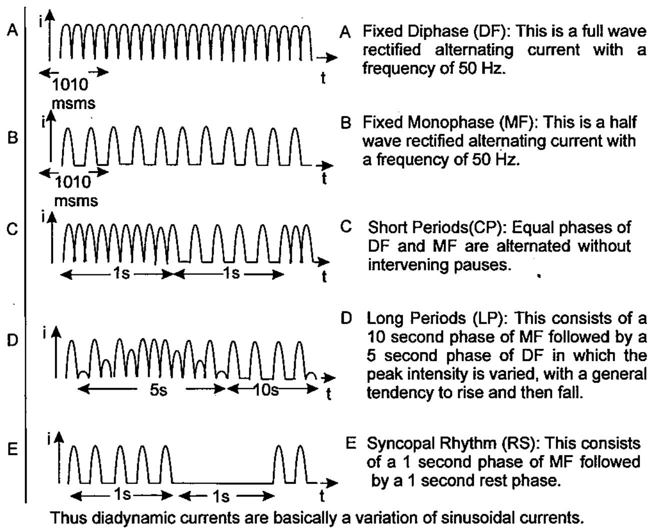

Fig. 22.1 *Five different currents for diadynamic therapy*

PHYSIOLOGICAL EFFECTS

Diadynamic currents have been shown to be primarily effective in the relief of pain. According to Henke (1958), this effect is due to a combination of the following physiological reactions.

1. **Masking:** Stimulation of a sensory nerve may not always cause excitation but its excitability is altered so that the stimulation threshold is raised. Bernard recommends the DF current as being particularly effective in producing masking.
2. **Vasomotor Effects:** Stimulation with diadynamic currents produces vasodilatation and hyperaemia as a result of the release of histamine is the tissues. As the current flows primarily in the superficial tissues, this effect is unlikely to occur in deeper structure except perhaps by reflex activity.
3. **Muscle Stimulation:** Particularly when the CP and LP currents are used, muscle contraction will be stimulated, resulting in an increase in the blood flow to the muscles.
4. **Stimulation of Vibration Sense:** This is said to cause central masking of pain.

INDICATIONS

Diadynamic currents are recommended for the relief of pain and oedema in the following types of conditions.

Soft tissue injury—sprains, contusions, epicondylitis.
Joint disorder—post-immobilisation, arthritis.
Circulatory disorder—Raynaud's disease, migraine.
Peripheral nerve disorder—Neuralgia, neuritis, herpes zoster, radiculopathies.

CONTRA-INDICATIONS

Diadynamic currents should not be used in the presence of any condition, which is a contra-indication to the use of low frequency currents.

METHOD OF APPLICATION

The choice of application should be based on the clinical problems presented. Various methods may be selected.

Pain Spot Application: The two electrodes may be applied as a bipolar technique with the anode applied over the pain spot and the cathode adjacent to it. Alternatively, the cathode may be applied proximally on the limb, or over the nerve root supplying the painful area (monopolar technique).

Nerve Trunk Application: The two electrodes are placed along the course of the appropriate peripheral nerve where the nerve is superficial. The patient should feel a tingling sensation in the area supplied by the nerve stimulated.

Paravertebral Application: The electrodes may be applied on both sides of the spine at the level of the nerve root supplying the painful area. If several nerve roots are involved, the electrodes may be applied alongside the spine at the highest and lowest nerve root levels.

Vasotropic Application: The electrodes are applied along the vascular paths affected in the circulatory disorder being treated.

Myo-energetic Application: To produce muscle stimulation, the two electrodes are positioned at each end of the muscle belly. Alternatively, a monopolar technique may be used with one electrode on the motor point of the muscle and the other proximally to it.

Trans-regional Application: To treat a joint, electrodes may be positioned on opposite side of the joint.

Electrodes are generally available in a variety of sizes, as metal plate electrode.

DOSAGE

DF is primarily used for the initial treatment and before the application of other currents. It is also used in the treatment of circulatory disorders. The patient feels a sensation which subsides after a short time. Muscle contraction occurs at high intensities.

MF is used for the treatment of pain without muscle spasm, following a preliminary application of DF. The patient feels a strong, penetrating vibration, which persists for longer than the sensation of DF. Muscle contraction occurs at lower intensities than with DF.

CP is used for the treatment of traumatic pain. In the DF phase, the patient feels a fine tremor, which rapidly diminishes and in the MF phase, a strong constant vibration with sufficient intensity rhythmic contraction of muscles occurs. LP has a long-lasting analgesic effect, particularly in the treatment of myalgia. It is also used in combination with CP in the treatment of neuralgia. The patient is aware of the strong vibrational MF phase, giving way to the prickling of the DF phase, which rises and falls slowly. RS is used for faradic-type stimulation of muscles and can be used to test the excitability of motor nerves.

INTENSITY

The intensity should be increased slowly until a definite vibration or prickling is felt but without any pain or burning sensation. Continuous (tetanic) muscles contraction should not occur.

DURATION

It is recommended that the total application should not exceed 10 to 12 minutes. Most single applications are given for 3 minutes.

FREQUENCY

Generally 6 or 7 treatments are necessary and these can be given daily or every second day.

CHAPTER

23

SINUSOIDAL CURRENT

- Production
- Physiological Effects
- Indications
- Contra-Indications
- Low frequency Generators offering Sinusoidal currents
- Technique of Application of Unsurged Sinusoidal Current
- Dangers

PRODUCTION

A sinusoidal current is an evenly alternating low frequency current. The sinusoidal currents used for therapeutic purposes have a frequency of 50 Hz and a pulse duration of 10 ms providing 100 stimuli per second. The graph of the current is seen in the following diagram. It is a sine curve. Sinusoidal currents may be used assurged or un-surged currents. The surges can be regulated from 6 to 30 surges per minute. The rate of surging varies with different generators.

The sinusoidal currents produced in low voltage generators are usually sine wave alternating currents produced by multi-vibrator circuits. The sine wave shaped output generally has a peak of 80 volts. The pulse duration is 10 ms and the frequency is 50 Hz. This means that the current stays in the tissues for a period of 10 ms. The meter will register the intensity of the peak voltage in the sine position. The maximum reading on the meter in the sine position will vary with different apparatus.

In treatment, it is important to reduce currents cyclically to zero. When the peak current intensity is increased and decreased gradually, this type of modulation is called surging. If it is necessary to stimulate muscle, then a surged sinusoidal current applied over the nerve to a muscle will produce a muscle contraction. The generators have a dial, which will continuously adjust the surge to the required rate, for example 6 to 30 per minute, or a 1 to 2 second surge.

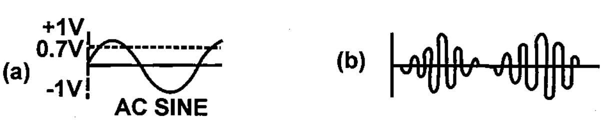

Fig. 23.1 *(a) Sinusoidal current (b) Surged sinusoidal current*

PHYSIOLOGICAL EFFECTS

When an electric current is passed through the body, a change of concentration of ions occurs at the cell membranes. The change in ionic concentration is the actual cause of stimulation of the tissue. If it occurs at the nerve membrane, muscle contraction occurs. If it occurs in other tissues of the body, then there is ionic movement of tissue fluid and other constituents. In the case of the alternating current, we must remember that each individual half wave negates the electrolytic effect of the previous half wave, having an opposite direction of current flow. For this reason any stimulating effect is achieved at the peak intensity of the wave, if the intensity is high enough to reach the threshold value to cause depolarisation and stimulation.

It is not possible to cause a burn with an alternating current unless high intensities are given for a long time, or if the bare metal is in close contact with the skin for a long period of time. In medical sinusoidal currents, the pulse duration is 10 ms, long enough to cause irritation of the sensory nerves.

Effect on Motor and Sensory Nerves: The short pulse duration of 10 ms and the frequency of 50 Hz is adequate to stimulate nerve. If the sinusoidal current is positioned on the motor nerves over the motor points and surged, then a muscle contraction and relaxation will be produced. It will also irritate the sensory nerves and cause a prickling sensation which is not very comfortable. Nevertheless there will be muscle contraction, with superficial cutaneous vasodilatation due to the irritation of the sensory nerves occurring simultaneously. The surged sinusoidal is a tetanic current.

Effect on the Tissues of the Body: If there is any swelling or inflammatory exudate, an unsurged sinusoidal current will help absorption of the exudate by channelling the excessive fluid to the lymphatic and venous channels.

Stimulation of the sensory nerve will cause superficial vasodilatation by the axon reflex and if continued for a longer period, there will be some capillary vasodilatation from the release of histamine-like metabolites. The hyperaemia lasts for at least half an hour after the treatment has ended.

INDICATIONS

Pain

The use of unsurged sinusoidal current is sometimes tried to relieve pain and tenderness. Wall and Sweet's investigations on pain have shown the effect of electrical stimulation of large diameter nerve fibres originating from a painful region. The stimulation interferes with the perception of pain. The effect of 10 minutes of stimulation lasts for at least half an hour.

There is also clinical evidence that unpleasant painful sensations are associated with loss of conduction in some of the efferent fibres. Cases such as causalgia result from partial nerve lesions, post-herpetic syndrome, paroxysms of pain in amputation stumps are characteristic of cases where there are abnormal behaviour patterns in the conduction of the efferent neuron. These patients usually have pain triggered by mild stimuli, which last for varying periods. So in particular patients, the unsurged sinusoidal current would stimulate the last efferent fibres and inhibit pain at the spinal level through the pre-synaptic inhibitory mechanism.

Cases of referred pain and psychosomatic pain do not respond to sinusoidal current.

Pain and Swelling

The accumulation of excessive exudate, that causes pain, can be helped sometimes by sinusoidal current. It stimulates the muscles over the painful area with the limb in elevation and only if the circulatory muscle pump is acting. Superficial vasodilatation helps in the removal of waste products. If the patient is given 10 minutes of surged sinusoidal followed by surged sinusoidal current, alteration of the semi-permeability of the cell membrane allows diffusions and also helps in the absorption of the exudate. It is not a comfortable treatment and patients must be able to tolerate the discomfort.

CONTRA-INDICATIONS

Skin Lesions

Burns, large cuts and abrasions should be insulated with vaseline. Dermatological conditions such as eczema, psoriasis, acne and other such conditions are exacerbated by electrical currents. Infection can be aggravated by electric current.

Impaired Sensation

The sensation of the part being treated must be checked. If there is complete loss of sensation, it could be dangerous, if long periods of current with too high an intensity were given. The density of current in the part is governed by the patient's subject feeling of current tolerance.

LOW FREQUENCY GENERATORS OFFERING SINUSOIDAL CURRENTS

Essential Features

An **output selector**, which clearly indicates a sine wave. Generally these machines do not require a selection of pulse duration and frequency.

An **output meter** which is switched automatically to the sine wave selected and reads the peak voltage on the sine position being delivered to the patient. Some machines do not have an adequate output for therapeutic use. For example, although the Faradic Galvanic unit is labelled as producing upto 120 volts sinusoidal current, it rarely produces more than 80 volts.

A **surge control dial** is continuously adjustable to the required speed. Some generators have 8 different surge rates, that is a frequency between 6 and 30 surges per minute while others have a dial which is continuously adjustable from a 1 second surge to 5 second surge (such as the galvanic faradic unit).

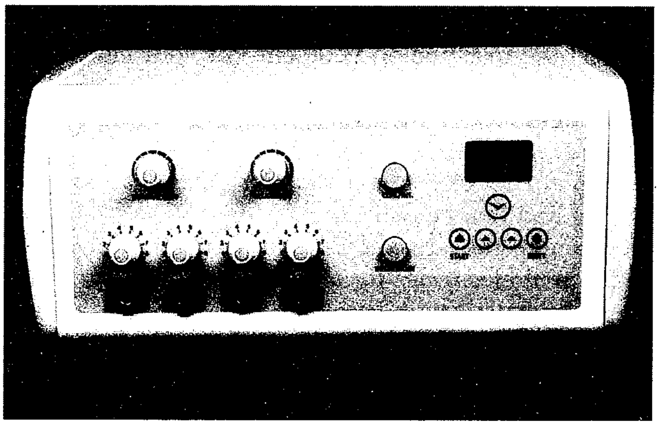

Fig. 23.2 *The selective treatment unit*

TECHNIQUE OF APPLICATION OF UNSURGED SINUSOIDAL CURRENT

Equipment required:

Electronic stimulator	Two metal electrodes	Pad and plastic to cover the active electrode. The pad should be of absorbent material 10 mm thick when compressed.
		Two leads
		A bandage
		Soap
		Cottonwool
		Towels
		a small basin with warm water
		a bath filled with warm water
		Vaseline
		Wooden spatula

Method: Position the patient comfortably with the limb supported on a pillow covered with plastic and a towel. Cover a stool with plastic for the bath.

Explain to the patient the purpose of the treatment (counter-irritant effect).

Skin test the patient for pain sensation.

Select the settings on the machine for a sinusoidal current with a pulse duration of 10 ms and a frequency of 50 Hz. Generally the selector switch shows this specific current and no other frequency or pulse duration dials need to be adjusted.

Connect the leads firmly to the metal electrodes and the machine terminals.

Place the active electrode on the folded pad which should be 10 mm thick when compressed. The pad should be moistened evenly with all excessive water wrung out.

Test the machine on yourself. Put your elbow into the bath and hold the moist active pad and electrode in your hand. Watch the meter to see that it goes up and down smoothly.

Explain to the patient the sensation that you are feeling and that he will experience.

Examine the area of skin under both active and indifferent electrodes for any cuts or abrasions and if present, insulate with vaseline using a spatula.

Wash the skin and leave wet, but ensure that the water is not dripping all over the part.

Bandage the active electrode firmly into position, with the electrode in the middle of the pad.

Place the foot in the bath with the indifferent electrode.

Turn the current up slowly until the patient experiences an intense stinging sensation under the active electrode (you must increase the intensity up to the patient's pain limit).

The response decreases after 20 to 30 seconds when the intensity should be again increased to obtain a similar stinging. Continue this sequence.

After 4 minutes treatment, assess the result.

If the stinging has been adequate, there is immediate marked numbness to touch and pressure and all pain is lost in the treated area. Immediate or partial improvement with numbness or only partial numbness is present. Repeat for another 4 minutes. The erythema and numbness persist for about 1 hour.

If the patient complains of any uncomfortable feeling in the leg at the water line, use a spatula to apply vaseline around this area.

Dosage

Daily treatments for 4 to 6 days may be given although few patients require more than 4 treatments. If there is no improvement with 3 treatments, discontinue.

DANGERS

Burns may be caused by:

a. **Overdose** by too great an intensity for a long period of time.
b. Bare metal electrode on the skin, due to loose bandaging of the electrode and pad, when high intensities are given.
c. Metal in the path of the current.

Shock: The current should be increased slowly. If increased or decreased too quickly, the patient gets a mild shock which is uncomfortable.

Switching on a machine set at a high output may cause a shock.

A dry scaly skin will suddenly conduct when the moisture has seeped through after a few minutes of soaking, causing a shock.

Pain: Over dosage could cause intense discomfort and pain to the patient.

Small raised edges or tiny cuts missed out on observation could cause a burning type of pain as current tends to collect all these points.

SECTION VI

- Heat
- Paraffin Wax
- Hydrocollators
- Contrast Bath
- Hydrotherapy
- Fluidotherapy
- Cryotherapy
- Cryokinetics

CHAPTER

24

HEAT

- Introduction
- Physical Effects of Heat
- Physiological Effects of Heat
- Therapeutic Effects of Local Tissue Heating
- Temperature Regulatory Systems in the Human Body

INTRODUCTION

For a number of conditions and problems, such as pain, spasticity, musculoskeletal lesions, both heat and cold can be effective forms of treatment. Many, though not all of the clinical benefits produced by both heat and cold in treatment, are similar. Therefore, selection is based on a number of factors.

For example: Generally, cold is preferable during the acute stage of inflammation to relieve pain and possibly reduce swelling. Heat in contrast can exacerbate the early inflammatory process.

Also a number of other factors such as patient preference, case of use, area to be treated are kept in mind before giving treatment with heat or cold.

PHYSICAL EFFECTS OF HEAT

A number of physical phenomena result when heat is added to matter due to an increase in the kinetic energy of its microstructure. These are the following:

1. **Rise in Temperature:** There will be an increase in the average kinetic energy of constituent molecules.
2. **Expansion of the Material:** Increased kinetic energy produces a greater vibration of molecules which move further apart and expand the material. Gases will expand more than liquids, and liquids more than solids.
3. **Change in Physical State:** Changing a substance from one physical state to another requires a specific amount of heat energy *i.e.* latent heat. The latent heat of fusion is the energy required for, or released by 1 gram of ice at 0°C in order to convert it to 1 gram of water at 0°C and the latent heat of vaporization is the energy needed to convert 1 gram of water at 100°C to 1 gram of steam at 100°C.
4. **Acceleration of Chemical Reactions:** Van't Hoff's law states that any chemical reaction capable of being accelerated is accelerated by a rise in temperature.
5. **Production of a Potential Difference:** If the junction of two dissimilar metals, *e.g.* bismuth and antimony is heated, a potential difference is produced between their free ends (the thermocouple principle).
6. **Production of Electromagnetic Waves:** When energy is added to an atom, *e.g.* by heating, an electron may move out into a higher-energy electron shell. When the electron returns to its normal level, energy is released as a pulse of electromagnetic energy (a photon).
7. **Thermionic Emission:** Heating of some materials, *e.g.* tungsten, may cause such molecular agitation that some electrons leave their atoms and may break free of the metal. This tends to leave a positive charge, which attracts electrons back. A point is reached where the rate of loss of electrons equals the rate of return and a cloud of electrons then exists as a space charge around the metal. This process is known as thermionic emission.
8. **Reduction in Viscosity of Fluids:** The molecules in viscous fluids are fairly strongly attracted to one another. Heating increases the kinetic movement of these molecules and reduces their cohesive mutual attraction; this makes the fluid less viscous.

PHYSIOLOGICAL EFFECTS OF HEAT

These will depend upon a number of factors such as:

i. Size of heated area;
ii. Depth of absorption of specific radiation;
iii. Duration of heating;
iv. Intensity of irradiation;
v. Method of application.

Physiological effects of heat may be categorised into local and systemic effects:

Local Effects

1. **Cell metabolism:** Chemical reactions involved in metabolic activity are increased by a rise in temperature especially in the region where most heat is generated. As a result, there is an elevated tissue demand for oxygen & nutrients and enhanced output of metabolic waste products.
2. **Blood flow:** When the skin is heated, the surface reddens (erythema) and blood vessels become vasodilated leading to increased blood flow, which is beneficial for healing and results in an increased number of white blood cells and fluid exudates, which assist in destroying bacteria and reducing infection.
3. **Other tissue effects:** The properties of specific tissues may be changed by heating.

E.g.: Tendon extensibility can be increased by heat.

Changes in viscosity of synovial fluid leads to smoother joint movement & increase in range of joint movement.

Rise in temperature induces muscle relaxation and increases the efficiency of muscle action.

Systemic Effects:

1. The immediate systemic response is a generalized skin vasodilatation, which serves to transport heat by conduction and connection from the core to the shell.

2. There is a concomitant reduction in splanchnic blood flow resulting in reduced hepatic clearance rate and reduction in urine flow.
3. There is increased activity of the sweat glands throughout the body. When generalized sweating occurs, there is increased elimination of waste products.

THERAPEUTIC EFFECTS OF LOCAL TISSUE HEATING

1. **Encouragement of Healing:** This occurs due to increased metabolic rate, cell activity and local blood flow. Chronic inflammatory states and the stages of repair and regeneration are all appropriately treated with mild heating including post-traumatic conditions such as Arthrosis, soft tissue lesions and post-surgical healing.
2. **Control of Infection:** Dry surface heating achieved by infrared radiations or hot air, may have a particular role in the control of surface infections, such as chronic paronychia, a fungal (candida) infection, or other infections. Surface drying will diminish bacterial colonization.
3. **Relief of Pain:** Therapeutic heat is widely used for the relief of pain. The increased blood flow after heating could wash out some of the pain provoking metabolites resulting from tissue injury. These include prostaglandins and bradykinin. Other mechanisms that have been proposed to account for pain relief include the reduction of muscle spasm and the sedative effect as well as a decrease in sympathetic nervous system activity which is said to promote vasodilatation in deeper blood vessels.
4. **Reduction of Muscle Spasm:** Rise in temperature induces muscle relaxation and increases the efficiency of muscle action as the increased blood supply ensures the optimum conditions for muscle contraction.
5. **Sedative Effect:** Heat appears to produce definite sedative effects. Heat has been applied as a counter irritant, that is the thermal stimulus may affect the pain-sensation and the action of endorphins.

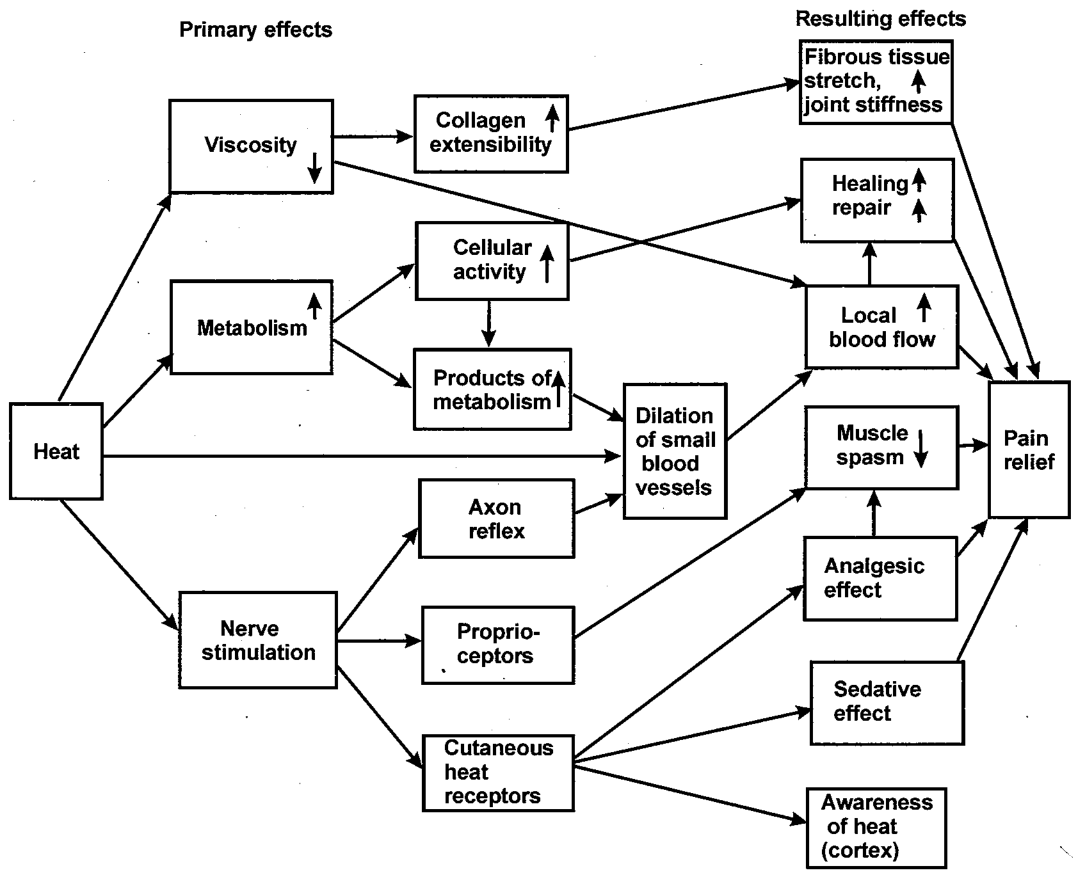

Fig. 24.1 *Simplified diagrammatic illustration of the pathways by which local tissue heating may alleviate pain. Heating the circulating blood will lead to cutaneous vasodilatation in order to regulate body temperature. This is mediated via the hypothalamus and influenced by cutaneous thermoreceptors. This is in addition to the changes shown here*

6. **Prophylaxis of Pressure Sores:** Heat applied to areas of skin subjected to prolonged pressure or friction has been suggested in order to promote a greater blood flow in the skin and thus decrease the risk of skin breakdown. Since the vasodilatation effect is temporary, it lasts perhaps 30–60 min. after the application—it needs to be repeated at intervals.
7. **Increase of Range of Joint-Motion:**
   There seem to be three mechanisms involved here:
   - The analgesic effect of heat allows greater tolerance of stretching.
   - The viscosity of tissues will be reduced, which partly account for the reduction of joint stiffness that occurs with heating.
   - Increased collagen extensibility occurs at higher temperatures.

   Heat is therefore, used prior to passive stretching and exercise to increase joint movement or lengthen scars or contractures.
8. **Oedema of the Extremities:** Heat has been recommended for the treatment of chronic oedema of the hand and foot. This must be given with the part in elevation, since the application of superficial heating will tend to increase oedema if the part is dependent.

Skin Diseases: Fungal infections, which are difficult to control and thrive in moist conditions, *e.g.* paronychia are sometimes treated with regular infrared therapy.
Infrared radiation has also been used in the treatment of psoriasis (effectively treated with ultraviolet).

TEMPERATURE REGULATORY SYSTEMS IN THE HUMAN BODY

The Human Body and Cold: The organism adapts better to warmth than to cold. Nevertheless, it has the means to fight against the consequences of cold. During exposure to cold, the body produces a vaso-constriction. It protects the blood from the skin, as the cold aggressiveness comes from outside. This allows the warmth and constant internal temperature of the body to be maintained. This modification of the blood flow is produced partially by the indirect action of cold on the cutaneous vessels and partially by the centre for temperature regulation (thermo-regulation), which modify the sensitive tonus of the cutaneous blood vessels.

The sensitivity of the tonus in increased with cold and the vessels contract.

Thermo-regulation: The role of thermo-regulation is to maintain the internal body temperature at a relatively constant level during rest or work. This adjustment mechanism uses the principal elements mentioned below.

Thermal Receptors: These central or peripheral receptors react to warmth or to cold. They are connected to the cortex as well as to the regulation centre situated in the hypothalamic centre via nerve fibres. The receptors of the hypothalamic centre react to minimal temperature variations (0.1 to 0.2°C) in the arterial blood flow.

Thermal Effectors: Thermal effectors react to the stimulation received from the receptors and produce the regulatory changes. These thermal effectors are the muscles of the skeleton, the muscles surrounding the arterioles of the skin, the sudoriferous glands and some endocrine glands.

The Hypothalamic Centre: Situated in the hypothalamus, the Hypothalamic Centre coordinates the information received from the receptors with the regulative action of the effector organs. The sensitivity threshold for temperature modification is very low (between 0.1 and 0.2°C).

CHAPTER

25

PARAFFIN WAX

- Introduction
- Physical Characteristics of Wax
- Physiological Responses to Paraffin Wax Therapy
- Indications
- Contra-indications
- Advantages of Paraffin Wax
- Disadvantages of Paraffin Wax
- Procedure for Use
- Method of Application of Paraffin Wax

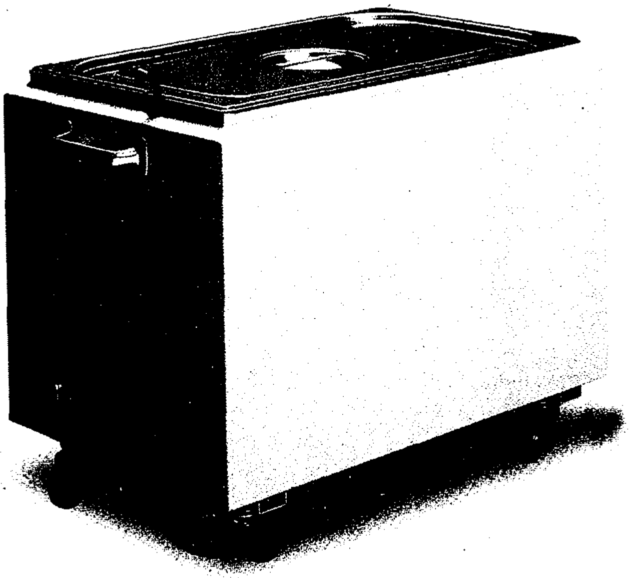

Fig. 25.1(a) *Paraffin wax unit*

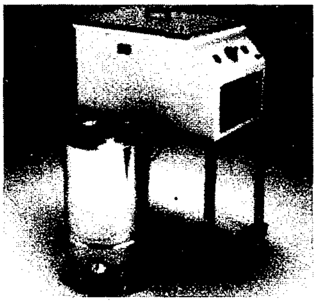

Fig. 25.1(b) *Portable paraffin wax unit*

INTRODUCTION

Paraffin wax for therapy is one of the most convenient, reasonably efficient method of applying conducted heat to the extremities. Paraffin wax of low melting point (55°C) is used. In order to keep the wax liquid at lower temperature, and to prevent burns, liquid paraffin mineral oil is added to the melted wax. The paraffin wax then remains melted at a temperature of 40° to 44°C.

PHYSICAL CHARACTERISTICS OF WAX

Wax has a low thermal conductivity, and therefore it gives off heat slowly. When a part is dipped in wax and the wax is allowed to set, there will be no rapid loss of heat from the treated part. The low thermal conductivity of the wax prevents the patient's feeling as hot as in water of the same temperature.

The wax is self insulating. The first layer creates a thin layer of air next to the skin (no absolute contact) which acts as an insulator.

Sweat does not evaporate and it also insulates. After the removal of the wax, the part cools quickly.

PHYSIOLOGICAL RESPONSES TO PARAFFIN WAX THERAPY

Heat Production: There is a marked increase in skin temperature in the first two minutes, upto 12°–13°C. This drops, while in the wax wrapping, to an increase of about 8°C at the end of 30 minutes. In the subcutaneous fascia, there is an increase of 5°C at the end of the treatment. In the superficial muscles, there in only about 2°–3°C rise in temperature at the end of treatment.

Circulatory Effects: Stimulation of superficial capillaries and arterioles causes local hyperaemia and reflex vasodilatation. This is marked only in the region of the skin. The hyperaemia is due to the response of the skin to its function of heat regulation. The effects of vasodilatation in the muscles are negligible, but there may be some reflex heating in the joints. Skin and subcutaneous tissue temperature drops rapidly after 15–20 min, reducing vasodilatation. Exercise after wax is essential to increase muscle circulation, and to use the sedative effect of heat to obtain more range of movement and muscle strength.

Analgesic Effects: The most important effect of wax is its marked sedative effect on the tissues. The moist heat is remarkably soothing to the patient. It is this effect that is used prior to exercise, in the treatment of superficially placed joints. It is very comfortable for the patient.

Stretching Effects: Wax leaves the skin moist, soft and pliable. This is useful for stretching scars and adhesions before applying mobilization techniques.

INDICATIONS

Pain and Muscle Spasm: Wax reduces the pain and muscle spasm seen in hands and feet, as the moist heat encircles each finger and toe, and relieves pain.

Oedema and Inflammation: The gentle heat reduces post-traumatic swelling of the hands and feet and also swelling in hands affected by rheumatoid arthritis or degenerative joint disease, particularly in the sub-acute and early chronic stages of inflammation.

Adhesions and Scars: Wax softens the adhesions and scars in the skin and thus facilitates the mobilization and stretching procedures.

CONTRA-INDICATIONS

Impaired Skin Sensation: This will be determined by a hot/cold skin test.

Some Dermatological Conditions are exacerbated by moist heat, such as eczema, athlete's foot and dermatitis. Any dermatological condition, which appears after treatment, must be reported.

Circulatory Dysfunction: Patients with varicose veins, deep vein thrombosis and arterial disease must not have any heat applied directly over the affected part.

Analgesic Drugs: It patients are taking strong narcotics for pain, the time and dosage of the drugs must be ascertained. Heat is not administered immediately after intake of drugs, since pain tolerance to heat is impaired.

Infections and Open Wounds: Heat will increase the infective activity.

Cancer or Tuberculosis: In the area to be treated, heat, by increasing the metabolic rate, may increase the rate of growth and spread the disease.

Gross Oedema: With a very thin and delicate skin covering the area, the skin may be damaged and the heat may tend to increase the oedema.

Lack of Comprehension: Patients who cannot understand the nature of the treatment and comprehend the potential danger, for example, children, very old patients, other nationalities.

Deep X-ray Therapy: Within three months prior to treatment decrease blood flow in the area and may cause impaired skin sensation.

Liniments: May cause hypersensitivity to heat, if applied recently. The patient should be asked to apply the liniment after heat treatment.

Open Suture: Wax should not apply on open suture area.

ADVANTAGES OF PARAFFIN WAX

1. Low specific heat allows for application at a higher temperature than water without the risk of a burn.
2. Low thermal conductivity allows for heating of tissues to occur more slowly, thus reducing the risk of overheating the tissues.
3. Molten state allows for even distribution of heat to areas like fingers and toes.
4. First dip traps air and moisture to create more even heat distribution.
5. Oils used in the wax add moisture to the skin.
6. Wax remains malleable after removal, allowing for use as an exercise tool.
7. Comfortable, moist heat.
8. Relatively inexpensive to replace wax.

DISADVANTAGES OF PARAFFIN WAX

1. Effective only for distal extremities in terms of ease of application.
2. Most effective method of application is the bath method, which limits accessibility for other body parts to be treated effectively.
3. No method of temperature control once applied.
4. Heating lasts only about 20 minutes.
5. It is a passive treatment; exercise may not be performed simultaneously.

PROCEDURE FOR USE

The paraffin bath is one of the most useful of the superficial thermal modalities. It is an easy, economical, and efficient way of applying gentle heat to an irregular surface such as the hand or wrist. Perhaps the primary disadvantage of the paraffin bath is the limited number of areas that it can be used on.

METHOD OF APPLICATION OF PARAFFIN WAX

1. Look for any wound, skin infection, rashes etc. on the part to be treated.
2. Clean the skin using tissue paper/cotton.
3. Tell the patient in brief about temperature of wax and the benefits.
4. Drip down few drops of molten wax on the dorsal surface of your hand to check the temperature. This is done before the patient so that he/she can prepare psychologically and fear of heat is minimised.

5. Using 4 inch broad and thin painting brush, paste few inch area on the part of patient. See patient's reaction, tolerance and confidence to bear the heat. Let the layer of wax cool and solidify. Shred downs the layer back into wax bath. Repeat it twice or thrice.
6. After the above steps the patient is always found to cooperate and fear of molten wax and heat is removed from the mind of patient.
7. Now paste the entire area to be treated, and first layer of wax is formed. This layer should not be too thin. Like the same way, second and third layer is coated. When layers are cooled and patient feels temperature has been reduced (when patient feels that wax is cooled), the wax layers are broken down.
8. Always use small quantity of wax on the brush especially when making first layer. Brush movements should be medio-laterally and/or superio-inferiorly.
9. After removing the wax, area is checked for any adverse conditions developed.
10. The wax is applied in cycles for **5 to 20 minutes per day, for atleast 10 days.**

The Paraffin mixture of paraffin wax (six or seven parts) to oil (1 part) is commercially available and is melted and stored for use in thermostatically controlled stainless steel containers. The wax baths come in variety of sizes. Paraffin is most commonly used for the distal extremities, including the fingers, hand, wrist and elbow in the upper limb and toes, foot, ankle, knee in lower limb.

There are two principal techniques of applications—

1. Dip method
2. Immersion method
3. Brush method
4. Bandage method

Dip Method

It provides mild heating. The patient should wash and dry the part to be treated. The therapist instructs the patient to dip the body part in the bath and then remove it until the paraffin solidifies and a thin layer of adherent solid paraffin is formed which covers the skin. Dipping is repeated until a thick coat is formed. In other words, at least 8 to 12 times until the wax has formed a thick glove over the part. Once the thick glove of wax is formed, the treated area should be wrapped first in plastic and then over wrapped with towel. If oedema is a concern then the area may be elevated. The effective duration of this treatment is 10 to 15 minutes. At the end of this treatment time, the glove of solid wax is peeled off or removed by slipping a finger beneath the glove and sliding the wax off and into the plastic sack, which covered it during the treatment. The sack is then discarded or the wax is emptied into the bath unit.

Immersion Method

This method of application provides somewhat vigorous heating. The body part to be treated is dipped 3 to 4 times to form a thin coat and then left immersed in paraffin for 20-30 minutes. A thin glove of solid paraffin wax formed slows the heat conduction. Use of the immersion method requires cooperation and tolerance by the patient in a dependent position. Care should be taken to ensure that the patient is in comfortable position during the treatment. With immersion method, the temperature elevation of the body tissue is 2°C higher than dipping method.

Brush Method

It is a less commonly used method of paraffin wax application. In this method, 8 to 10 coats of wax are applied to the area with a paintbrush using even and rapid strokes. The area is then wrapped with towels for 10 to 20 minutes and after this time, paraffin wax is removed and discarded.

Bandage Method

In this method, bandage of a suitable size and mesh is soaked in hot wax and then it is wrapped around the limb. Additional wax then can be poured or brushed over the bandage.

CHAPTER

26

HYDROCOLLATORS

- Introduction
- Method
- Biological Effects of Hydro Collator Packs
- Indications
- Contra-indications
- Advantages
- Disadvantages
- Technique of Application

Fig. 26.1 *Hydro Collator Unit with hot packs*

INTRODUCTION

The use of moist heat as a therapeutic agent is one of the oldest forms of medicine. These days efficient automatic units produce a uniform and constant temperature to heat steam packs. They provide physiotherapists with a constant supply of ready to use heated packs. The heating unit is called a hydro collator unit.

The hydro collator unit is a stainless steel tank in which silica gel packs are heated. The capacities of the machines vary, and all units have insulated bases, the larger machines being insulated with fibre glass. The units contain a wire rack which acts as a divider for the packs and prevents contact of packs with bottom of the tank. The heater is thermostatically controlled and maintains water in the unit at a temperature between 76°C and 80°C. It can be left on continuously as long as there is sufficient water in the tank.

A hydro collator pack is a fabric envelope containing silica gel. The main property of gel is its capability to absorb many times its own volume of water and when heated, to give off moist heat for 30-40 minutes. The packs are heated in a hydro collator unit.

Packs come in varying sizes and shapes. They are designed to fit on nearly any body contour and are used repeatedly, being returned to hot water after each use.

The packs generally last for about six months. When they begin to wear out, the filter leaks out and makes the water cloudy—they should then be replaced.

Hydro collator packs are used to give gentle moist heat to superficial regions of the body, mainly for the relaxation of pain and muscle spasm in superficial areas.

METHOD

The part selected to be treated must be able to tolerate the pressure of the pack (approximately 500 to 800 gram), and to tolerate a 7° to 10° rise in temperature. It is also necessary to ensure that the circulation can dissipate heat, and that skin sensation responses to thermal differences are normal, as it is easy to produce a burn.

The pack retains its heat for 30 minutes, but after 10 minutes the patient may regard the pack as cool and comfortable. Nevertheless, the rise in temperature of the region under the pack averages 5°C.

The pack is applied to the body after being wrapped adequately in toweling or blankets. Care must be taken to have a layer of toweling, and to avoid excessive pressure by body weight being placed on bony points.

BIOLOGICAL EFFECTS OF HYDRO COLLATOR PACKS

Heat Production: The effect of hydro collator packs on the tissues is due to the heat generated. The conduction depth is governed by the properties of the underlying fat, muscles, connective tissue and bone.

Temperature Elevation will depend upon the potency of the circulation and sensation, and the ability of the tissues to dissipate heat. Bone and fat will impede heat distribution. Fatty tissues having a low specific heat will heat rapidly, and will cause heat conduction away from the site. Temperature rise takes place if the heat generated exceeds the rate at which the tissues can dissipate the heat. Skin tolerance to heat is 44°C. Even lower temperature, such as 42°C, for over two hours can cause a burn. A temperature of 44°C over 30 minutes can cause a burn. Temperature of over 45°C over 5 to 10 minutes will cause a burn. Therefore, a safe but effective application of heat is 44°C for 20 to 30 minutes.

Thermal Gradient in the Tissues: Accurate assessment of temperature rises in skin, subcutaneous tissue, and muscle are not possible, but a rough gauge has shown that hydro collator packs have the following characteristics:

1. **Skin Temperature:** Within 7 minutes there is maximum 7°C to 8°C rise in temperature and then a drop of about 2°C over the remainder of the 20 to 30 minute application period.
2. **Hyperaemia:** There is increased vasodilatation of the main venous channels in the skin through the opening of the arterio-venous anastomosis, by passing the capillaries, since the main function of skin circulation is heat regulation. There is some increase in the flow of nutrients, antibodies, leucocytes and oxygen to the tissues.
3. **Sedative effects:** Moist heat is a safe analgesic and a muscle relaxant.

INDICATIONS

Pain and Muscle Spasm: The moist heat of the hydro collator packs can relieve pain and muscle spasm in superficial regions. The rise in temperature also cause increased circulation which then removes pain metabolites and thus breaks down the vicious cycle of pain and muscle spasm. The sudden rise in temperature can also create a counter-irritant effect, and thus cause a temporary relief of pain. It must be understood clearly that the rise in temperature lasts only for about 20 to 30 minutes. If the effect of heat on pain and muscle spasm is to be utilized, the techniques of physiotherapy needed to restore range of joint movement and muscle strength, must be applied immediately after the heat has been administered.

Inflammation: In case of mild inflammation, temperature elevation of 2° to 5°C will cause an increase in phagocytosis and aid absorption of exudate. It has been used post-operatively for the healing of wounds following abdominal surgery, where there has been delayed healing with no infection, caused by mild haematoma or inflammation.

Oedema: Oedematous areas over a large section of an extremity, in chronic stages, can be treated with a hot pack in elevation to help absorption of the exudate.

Adhesions: Hot packs in conjunction with other physical measures such as mobilization techniques, exercises and other measures will help to stretch adhesions and contractures of tissues. The raised temperature of the collagen will make it easier to stretch the adhesions. Again, this is true only if the adhesions are placed superficially and are not tenacious.

CONTRA-INDICATIONS

Impaired skin sensation: This will be determined by a hot/cold skin test.

Some dermatological conditions are exacerbated by moist heat, such as eczema in the low leg, athlete's foot in between the toes, and severe acne on the back. Any dermatological condition, which appears after treatment, must be reported.

Circulatory dysfunction: Patients with severe varicose veins, deep vein thrombosis and arterial disease must not have any heat applied directly over the part affected by circulatory disease, particularly in the limbs.

Analgesic drugs: If patient is under strong narcotics for pain, the time and dosage of the drugs must be ascertained. Heat is not administered immediately after intake of drugs, since pain tolerance to heat is impaired.

Infection and open wounds: Heat will increase the infective activity.

Cancer or tuberculosis in the area to be treated: Heat, by increasing the metabolic rate, may increase the rate of growth and cause spread of disease.

Gross oedema with a very thin and delicate skin covering the area. The skin may be damaged by the pressure of the pack and the heat may tend to increase the oedema.

Lack of comprehension: Patients who cannot understand the nature of the treatment and comprehend the potential dangers, for example, children, very old patient, other nationalities.

Deep X-ray therapy within three months prior to treatment decreases blood flow in the area and may cause impaired skin sensation.

Liniments: May cause hypersensitivity to heat, if applied recently. The patient should be asked to apply the liniment after a heat treatment.

ADVANTAGES

A hydro collator pack is easy to apply. It saves time for personal, and is efficient in heat conduction depending on area treated.

The packs are of various sizes, which fit most clinical needs. Moist heat has more sedative effect than dry heat maximal temperatures and are more uniform than in electrically heated pads. The patient does not need much handling. The pads can be laid out ready for the patient to place on the affected part.

DISADVANTAGES

A hydro collator pack is not easily applied around shoulder and hips. It is somewhat heavy and should not be used on extremely sensitive patients, since it can increase discomfort. Sometimes moist packs have a tendency to cause a skin rash.

TECHNIQUE OF APPLICATION

Remove the packs and fill the tank three-quarter full of water. The water level should be kept slightly over the top of the pads at all times. This avoids the burning out of the heating element or scorching the packs.

Hold each pack by its loops so that its rectangular sections are horizontal and shake slightly to distribute the dry gel evenly. Place the packs in the water for 2 hours to soak. When placing them in the water, the packs must have the rectangular section facing vertically to permit the loops to stick out of the water.

Check that the thermostat is at 76° to 80°C. Switch on the machine. It takes approximately 2 hour to heat. The unit can be left plugged in for any length of time, provided the water level is maintained.

Check that the room temperature is 21° to 23°C. Position the patient with the part to be treated relaxed and supported fully in a position, which is comfortable, pain free and accessible for pack application and maintenance.

Inspect the area to be treated for abrasions, cuts, wounds, scars, oedema and any circulatory dysfunction. Test for hot and cold sensations. Do not expose the patient unnecessarily. Wrap the rest of the body in order to maintain normal uniform temperature, since a change in body temperative will alter the physiological effects of the hot packs.

Explain to the patient the degree of warmth to be expected, the duration of the treatment and the purpose of the treatment. Ask the patient to inform you if any pain, discomfort, or burning sensation is felt during the treatment.

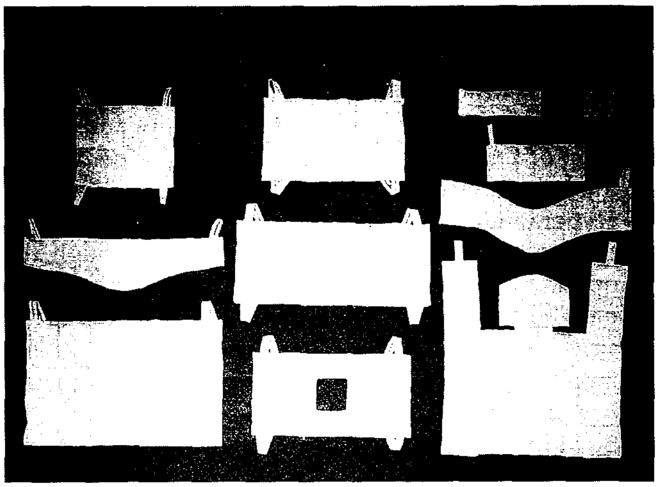

Fig. 26.2 *Two commercially available hot packs*

Fig. 26.3 *Hot pack application to the low back before soft tissue mobilization and exercise. Note that the patient is in the prone position*

Fig. 26.4 *Hot pack application to the cervical prior to exercise*

CHAPTER 27

CONTRAST BATH

- Introduction
- Method of Treatment
- Physiological Effects
- Indications
- Contra-indications

CONTRAST BATH FOR UPPER EXTREMITIES

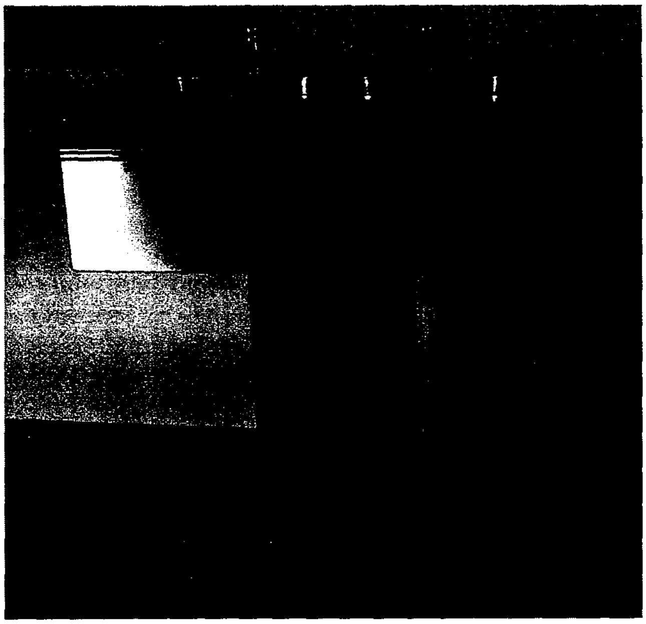

Fig. 27.1 *Contrast bath unit*

INTRODUCTION

Contrast baths are an alternative method of applying heat with a certain amount of control to aid the normal body temperature regulating mechanism. There is alternate immersion of the part in hot and cold water.

In most instances, cold is recommended as a treatment for the inflammation and swelling that accompany an acute injury. During the later stages of healing and repair, when it is helpful to warm tissues prior to stretching, mobilization, manipulation or exercise, heat is often applied. Between these two phases, however, there is a transitional period during which it may be helpful to apply both ice and heat. Alternating applications of ice and heat is referred to as contrast therapy and is directed at improving the circulation in injured tissues.

METHOD OF TREATMENT

Fill two baths of suitable sizes depending on the limb to be treated, one with hot water at 40° to 45°C, and the other with cold water at 15°C. The treatment should begin and end in hot water. Some therapists prefer to end in cold water. Place the limb in hot water for 3 minutes. Immediately afterwards place the limb in cold water for 1 minute. Repeat the cycle upto three times. Maintain the hot and cold water at a constant temperature. The whole procedure should not take more than 15 minutes.

Note: It is important to maintain the temperature of the water during the treatment time.

A second, more practical method of contrast therapy that can be used by a patient at home involves alternating applications of ice packs and heat packs. The patient should be instructed to apply ice for 5 minutes, followed by hot for 5 minutes. This should be repeated two times for a total treatment time of 20 minutes. It is necessary that the patient has two ice packs and two heat packs for this procedure.

Although contrast therapy is clinically effective, there are some significant disadvantages that make it a relatively uncommon form of therapy. Most importantly, the procedure is easy and somewhat cumbersome. Consequently, it is not a widespread form of therapy.

PHYSIOLOGICAL EFFECTS

Marked vasodilatation occurs immediately as the skin temperature increases rapidly. An increase of deeper circulation occurs reflexly. There is also a marked sedative effect.

INDICATIONS

- Post traumatic swelling
- Pain due to swelling
- Chronic inflammation
- Tight amputation stump
- Arthritis of peripheral joints
- Musculotendinous strains
- Joint sprains.

CONTRA-INDICATIONS

- Advanced peripheral vascular disease
- Diabetes
- Arterial insufficiency
- Buerger's Disease.

CHAPTER

28

HYDROTHERAPY

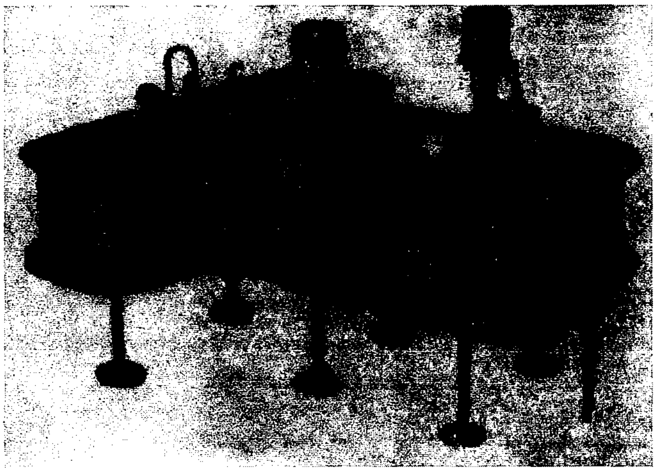

Fig. 28.1 *Hydrotherapy Unit*

INTRODUCTION

Hydrotherapy is one of the oldest therapeutic methods for managing physical dysfunctions. It has been advocated for the treatment of joint stiffness, painful scars, adhesions and arthritis, and as a warm-up to assist with exercise. Water therapy is used for the effects on body tissues of heating, cooling, debridement, pain relief, and relaxation of muscles.

When treatment is not well planned or well executed, it can have side effects, primarily on the cardio-vascular system.

Hydrotherapy is the use of water in the treatment of various diseases. Hydrothermal therapy has in addition, temperature effects, as in hot baths, saunas, wraps etc.

Hydro and hydrothermal therapy are traditional methods of treatment that have been used for the treatment of disease and injury by many cultures.

Hydrotherapy in the medical term implies using water for therapeutic purpose or in simple words, treatment by water. The term hydrotherapy in Greek implies for hydro – water; therapia — healing. Water is used as a medium for exercise and provides several opportunities, which are not available in exercises. In initial stages of treatment, where mostly non-weight bearing is required, it provides very beneficial effects. Warmth and support provided by water is also very helpful in the treatment. Hydrotherapy is now becoming more popular, with the development of knowledge regarding therapeutic effects of water and new pattern of movement in water and more exercises specially done in water. In water, body is acted upon by two forces — gravity (downthrust) and buoyancy (upthrust) and hence a three-dimensional exercise programme can be planned for the patient.

The history of hydrotherapy is very old and it has been used for therapeutic purpose in the past. At that time water was used for combating fever, reducing fatigue, for promoting healing of wounds and for other curative purposes. Later, water was used as an effective treatment for rheumatism, paralysis and burns. In ancient times, people even worshipped running water and used mineral water for many different conditions.

Therapeutic properties of water:

1. **Tonic:** In this effect, the vital activities, body functions, blood circulation and nutrition is increased to restore the body to a normal tone or condition.
2. **Antispasmodic:** Water is also very helpful in relaxation of muscles, thus relieving spasm and convulsions.
3. **Eliminative:** Under this effect, the water promotes the elimination of toxic products from kidneys, skin and lungs.
4. **Antipyretic:** Water is very effective in reducing the increased body temperature.
5. **Refrigerant:** Water also helps in relieving thirst and restoring alkaline property of blood.
6. **Diaphoretic:** An agent that produces sweat is called diaphoretic and water helps in the production of sweat.
7. **Diuresis:** Water increases the excretion of urine from the system and thus helps in detoxication.

PRINCIPLE OF WORKING

The recuperative and healing properties of hydrotherapy are based on its mechanical effects. It exploits the body's reaction of hot and cold stimuli to the protracted application of pressure exerted by the water and to the sensation its gives the nerves carry impulses felt deeper in the body, where they are instrumental in stimulating the immune system, influencing production of stress hormones, invigorating the circulation and digestion, encouraging blood and lessening pain sensitivity.

Generally, heat quiets and soothes the body, solving down the activity of internal organs. Cold in contrast stimulates and invigorates, increasing internal activity. If you are experiencing tension in muscles and anxiety from your stress, a hot shower or bath is in order. If you are feeling tired, stressed out, you might want to try taking a warm shower or bath followed by a short, invigorating cold shower to help stimulate your body and mind.

When you submerge yourself in a bath, a pool or a whirlpool, you experience a kind of weightlessness. Your body is relieved from the constant pull of gravity. Water therapy gives a massage-like feeling as the water gently kneads the body. Water, in motion, stimulates touch receptors on the skin boosting blood circulation and releasing tight muscles.

"Hydrotherapy" and "whirlpool" are used interchangeably. Tanks used for full body immersion are referred to as Hubbard tanks, walking tanks, or hydrotherapeutic exercise tanks or pools. When the body is immersed, thermal energy is exchanged by water in the tank by two methods: conduction and convection.

CONDUCTION, CONVECTION AND RADIATION

Conduction is an exchange of thermal energy in which there is physical contact between two surfaces. If water temperature is higher than skin temperature, heat will be conducted to the skin and temperature will rise. Since fat acts more as an insulator than as a conductor, it has a tendency to hold heat in or to keep it out. This point is important for two reasons: (1) The effect of superficial heating by conduction will be lessened as the body fat composition increases, and (2) higher body fat content compromises the body's ability to dissipate heat, which may cause an increase in body core temperature to dangerous levels. With the obese person, therefore superficial heating with the whirlpool may not achieve the intended effects. Caution must be taken when a large body surface area is immersed, the person may not be able to dissipate internal heat and maintain proper core temperature which may present a dangerous situation, requiring other methods of heat loss, such as evaporation and convection, to work overtime causing dehydration and increased cardiac output. A particular patient's medical condition may not tolerate this situation, such as a patient with a cardiac or peripheral vascular disease.

Convection, which occurs when a portion of the fluid moves from one place to another, is a more rapid process of thermal energy exchange than conduction. Energy transfer by convection occurs when the patient is moving in the water or when the water swirls across the skin surface. Convection plays an important role in heating or cooling tissues, as well as in dissipating or retaining body heat.

Convection occurs between the core and the shell of the body surface. Body heat can be carried by the venous blood towards the core, thus potentially increasing core temperature. Conversely, convection will help with heat dissipation by carrying heat away from areas of the body that are being heated. This method of heat transfer is compromised when the patient has cardio-vascular and peripheral vascular disease. In this case, heating an entire extremity or full body may create dangerous overheating because the extremity or body is unable to dissipate heat from the treated areas to maintain tissues, temperature at safe levels.

The methods of heat transfer discussed so far were used to transport heat in either direction in the body. Two other methods of heat transfer *i.e.*, radiation and evaporation help to dissipate the heat from the body during or following a hydrotherapy treatment.

Radiation is the exchange of electromagnetic energy that occurs when there is a difference in temperature between the skin and the surrounding environment. As convection and conduction bring the heat from within the body to the level of the skin, radiation assists in the transfer of this heat from the skin to the air. This ability to eliminate heat through radiation will be lost in the area immersed in the whirlpool and is further compromised as body surface immersion increases.

THERMAL EFFECTS

The physiological effects of heat and cold apply to hydrotherapy as to other thermal agents, except that a larger body surface area usually is immersed in water than that covered by a hot or cold packs therefore, exposure of the body to varying temperatures will have not only a local effect but also systemic effects on the cardiovascular and other organ systems. The greater the difference in temperature between the water and skin, the more intense the reaction. Cold application to the whole body decreases heart rate and lengthens diastole. The tone of the cardiac muscle is enhanced, and blood pressure is raised as a result of peripheral vasoconstriction. The increase in peripheral resistance requires the heat to work harder to maintain adequate blood flow to the periphery. Other effects of cold immersion can be reviewed.

The application of heat to the entire body will cause an initial increase in blood pressure followed by a decrease in blood pressure as a result of vasodilatation. The initial rise in blood pressure may be quite marked and prolonged if the temperature of the bath is very high, above 40°C. Respiratory rate will increase with the application of heat. Studies says effects of hydrotherapy on cardiac output, oxygen consumption, heart rate, and blood pressure, with study subjects in the resting state (positioned supine and sitting) and while exercising (the step test), the subjects were immersed in the whirlpool to hip level for 20 minutes in 40°C water. The mean cardiac output and oxygen consumption increased but not significantly. Pulse rate increased 1.3 to 1.5 times over the sitting or supine resting level, and the mean blood pressure increased 1.1 times over the supine resting values.

In addition, sweating will be increased, the amount depending on the temperature, the size of the body surface exposed, and the length of treatment. Whether the use of hydrotherapy bath increases diuresis remains controversial, but diuresis seems to be affected by the hydrostatic pressure, which increases with the depth of immersion. This influence of hydrostatic pressure may have more of an effect on urinary output than does water temperature itself.

Increasing tissue temperature and blood flow are physiologic effects of heat that can have therapeutic value. The depth to which this vasodilatation occurs, and its relationship to tissue temperature, are important. If whirlpool does not increase circulation and temperature to sufficient levels to meet therapeutic goals, it may not be the agent of choice when one arm was immersed in a water bath of 45°C for 20 minutes there was a 4.17°C rise in subcutaneous tissue temperature, a 1.4°C rise in muscle temperature of the forearm, and an increase in blood flow. There is a direct relationship between the increase in superficial blood flow and temperature with the arm immersed in water bath from 37°C to 42°C.

MECHANICAL EFFECTS

Whenever the effects of both cold and superficial heat and water are indicated for a rehabilitation program, the use of whirlpool has been advocated. Physiologically, the whirlpool acts as an analgesic agent, relaxes muscle spasm, relieves joint pain and stiffness, improves mechanical debridement, and facilitates exercise. Based on these facts, its use has been suggested for debriding necrotic tissue and dirt before exercising, and for various musculoskeletal problems. The agitation created by the whirlpool serves as a source of mechanical stimulation to skin receptors, which may explain its sedative and analgesic effects. The agitation may act as a counter-irritant, or it may act as a stimulus to large sensory afferent nerve fibres, thus blocking pain input.

GENERAL RULES OF HYDROTHERAPY

1. Take a full case history to rule out contra-indications. Check for cardiac problems or other circulatory issues. Determine the overall state of health (mental, physical, emotional). People with diabetes should not be treated.
2. Take the client's temperature before beginning treatment to determine temperature of treatment. Ask them what is their normal temperature. If they are above normal, use less heat. You may also want to take their pulse and respiratory rate to use as a guideline during the treatment.
3. Always thoroughly explain the treatment before beginning. Include the procedure, length of session, and any other details. Be sure they understand everything and are 100% comfortable with all aspects of treatment.
4. Stay with the client at all times or have an emergency signal such as a bell (be sure it can be heard above anything else). You can also use a baby monitor in the room.
5. Provide a clean room with adequate temperature control to ensure the client does not become chilled or too hot (depending on the treatment).
6. Moderation is the key to a positive treatment. Hydrotherapy can be exhausting and dehydrating to the body. Too much can cause adverse reaction.
7. Keep fresh drinking water available at all times and encourage them to drink regularly.
8. Watch for adverse reactions and stop immediately.

GENERAL HYDROTHERAPY APPLICATIONS

Certain factors need to be considered before starting a hydrotherapy treatment. The more simpler design and construction of pool is the better it proves.

The main factors for consideration are:

1. Pool, design and dimensions
2. Temperature and ventilation
3. Equipment
4. Lighting
5. Facilities
6. Surfaces
7. Noise factors
8. Staffing, care and maintenance
9. Safety and emergency equipment
10. Cost and costing

Pool, Design and Dimensions

There are different varieties of pool like underground, below ground deck level, semi raised or raised. From all the above, the best is a below ground pool with or without a deck.

In a below ground pool without a deck level, the height of the bathside from the surface of water must be kept at minimum. In a pool with large height, the patient faces difficulty in entry and exit. A deck level ensures cease in entry and exit and a less amount of turbulence. Sometimes a brick has to be erected at the side of pool to prevent the outflow of water.

The size of the pool must be such that it easily accommodates the patient and he is able to perform the whole rehabilitation programme easily without any hindrance. The shape of the pool must be simple, say a rectangle, and should not contain any curves.

Pool floors are also of a variety of types like level throughout, stepped or sloping. The best suitable is the stepped one as it provides different depth levels, each one clearly marked. But sometimes there is risk of wrong stepping or slipping.

Entry to pool can also be by different means like steps, ramp, hoists, over the side. The best suitable depth of the pool is six feet. At this depth the patient is able to maintain his vertical balance.

Temperature and Ventilation

The temperature of human body does not remain constant and varies as the body transfers heat to the area in which it is present. The temperature of pool must be decided in relation to the type and severity of the exercise and the duration of the exercise. The best suitable temperature is between the range of 32°C – 34°C or 35°C and should not be higher than this.

This temperature varies according to the condition being treated. It is important to see that if water is cold, the exercise is carried at a more fast pace.

According to Newton's law of cooling, "the rate of cooling of a body in a given time is proportional to the temperature difference between the two mediums". The more the difference, more is the rate of cooling. Hence the air temperature around the pool is kept slightly low, approximately 25 degree Celsius to ensure gentle cooling.

Ventilation must be so effective that no exercises condensation builds up and the humidity is maintained.

Equipment

They are present in pool both in a fixed and movable part, and also can be provided externally.

Hand rails are fixed in pools on either side of the steps for safety purposes. They are made of stainless steel along the whole length of the steps.

Sometime, underwater jets are installed for massaging effect and for resisting the movement and hence providing strength and endurance. They must be installed carefully so that the turbulence produced by their effect does not disturb the balance of the patient.

Some other items used are parallel bars, stools of varying heights, seats, plinths, floats, rings, toys, kick boards, bats and flippers.

Lighting

Proper lighting system must be installed around the pool area so as to have adequate visibility in the whole pool area and along the whole depth of pool. Windows must be set high up in the walls for proper lighting. Artificial means of lighting can also be used for even distribution of light in the whole area.

Facilities

A hydrotherapy unit must have:

1. Changing areas
2. Showers
3. Resting space
4. Toilets.

These all must be present for the convenience of patient. There must be sufficient space along with curtains for changing and showers. All these units must be designed keeping in mind the wheel chair bound patients.

Surfaces

The surfaces in the whole hydrotherapy must be non-slippery, non-abrasive and easy to clean. The surface must be kept dry so as to avoid any danger of slipping. The surface must be properly graded so that the dirty water does not come back into the pool.

Noise Factor

Pools are very noisy places and hence the walls and ceiling of the whole pool area must be made of acoustic material. This checks the excessive noise which can produce anxiety and tension in patients, thus disturbing them.

Staffing, Care and Maintenance

In addition to a physiotherapist, the hydrotherapy department consists of a bath side assistant, cleaning and maintenance staff. They all must be perfectly trained in their job.

Safety and Emergency Procedures

Full care must be taken regarding the safety procedure. During the treatment course, assistance must be kept for help in emergency cases. There must be an emergency kit and every staff member must know how to handle it. The water must be regularly checked for chlorine and pH levels.

Emergency kit consists of a test kit for testing the chemical levels of the water, an alarm system and an oxygen mask.

Costs

The initial cost of installing a hydrotherapy department is very high. But with careful planning, efficient use, good staff and by keeping all the equipments in a good working state, it can be used to its maximum.

- Decreases chronic joint stiffness.
- Relieves pain.
- Relieves muscle spasm.
- Increases blood flow.
- Can assist in removal of oedema and waste products from the areas of injury.

INDICATIONS

- Joint contractures: To stretch tendons and increase flexibility.
- Rheumatoid Arthritis: Heat increases the viscosity of the synovial fluid in the joint.
- Chronic muscle spasm.

EFFECTS OF COLD AND HOT WATER

	Primary Effect	Secondary Effect
Cold Water	- Peripheral vascular constriction - Pallor of skin, chilliness, shivering, chattering, etc. - Increases respiratory rate. - Increases muscular tone. - Increases blood pressure and heart rate.	- Occurs if you warm up: - Peripheral vascular dilation, causing redness of skin. - Decreases in respiratory rate. - Decreases in blood pressure and heart rate. - Muscle relaxation.
Hot Water	- Increases Body temperature. - Increases Pulse rate (by 10 for every 1 degree increase in body temp.). - Increases respiration rate. - Increases oxygen consumption and metabolic rate. - Peripheral vasodilatation. - Increases circulation. - Decreases blood pressure. - pH becomes more alkaline. - Increases in excretiòn from kidneys.	- Generally the same as— - Secondary effects of cold. - Gradual reduction of these effects as body returns to normal.

GENERAL THERAPEUTIC EFFECTS OF HYDROTHERAPY

- Increases the extensibility (ability to stretch) of collagen fibres.

GENERAL CONTRA-INDICATIONS/CAUTIONS

1. **Cancer:** Caution is advised when treating patients with cancer. It is best to work with the consent of a physician. Some physicians may not be aware of the effects of hydrotherapy.

2. **Haemorrhage:** Caution is advised when treating a patient who has a tendency to haemorrhage. Applications of heat and cold which cause vasodilatation and that increase the possibility of haemorrhage.
3. **Decreased Sensation:** Any condition in which the patient has a decrease in sensitivity of the skin. Hydrotherapy is contra-indicated as they may not be able to feel if the skin is too cold or hot.
4. **Weakness:** Hydrotherapy may be contra-indicated in a patient that is weak, as a treatment may make the weakness worse.
5. **Abrasions:** Applications are contra-indicated in the case of broken skin or other skin irritation that may be exacerbated by hold or cold.
6. **Skin Lesions:** Such as pustules, papules, blisters that are infected may rupture due to increased vasodilatation and are contra-indicated.
7. **Pregnancy:** Full body hot applications to a pregnant woman are contra-indicated as they may be associated with an increased incidence of birth defects. This contra-indicated the use of hot tubs as well as local applications of heat to the abdomen.
8. **Tuberculosis:** Full body hot baths may spread tuberculosis and is contra-indicated.
9. **Anaemia:** Full body application of heat increases cellular demands for oxygen that cannot be supplied if the patient is anaemic.
10. **Diabetes Mellitus:** Advanced diabetes, especially Type 1 (juvenile onset), can decrease the patient's ability to sense tissue damage, especially in the lower extremities. The vascular damage caused by this disease also decreases blood flow to tissues. Heat is contra-indicated in these areas. Consult the physician.
11. **Heart Disease:** Heat and cold applications that increase the heart rate and force of contraction are contra-indicated in heart disease as it may overwork an already weakened heart.
12. **Hypertension:** Heat and cold applications that increase the heart rate and force of contraction are contra-indicated due to the stress on the heart.
13. **Peripheral Vascular Disease:** Atherosclerosis and arteriosclerosis patients may have weakened or blocked arteries. Heat applications increase tissue metabolism and demand for oxygen, making heat-applications contra-indicated.
14. **Temperature:** Body temperature should not go above 104 degrees. Temperature above this may cause tissue damage. Monitor with oral thermometer.
15. **Elderly** people and young children should avoid long baths.
16. **Pulse:** Heart rate should not exceed 140 beats per minute as it may overstress the heart.
17. **Post Treatment Rest Period:** The body should be allowed to rest for at least half an hour after a full body hot application to allow the body to return to normal.
18. **Skin Sensitivity:** Cold applications are contra-indicated for patients who have suffered from frostbite previously or who have hypersensitivity to cold due to Raynauds disease or other conditions such as low blood pressure.
19. **Hypothyroidism:** Cold applications are contra-indicated in patients with hypothyroidism which further causes a reduction in basal metabolic rate.
20. **Kidney Problems:** Cold is also contra-indicated in kidney-malfunction or disease.
21. **Inflammation:** Heat applications are contra-indicated in acute conditions of inflammation such as bursitis, arthritis, tendinitis, sprains and strains.

ADVERSE REACTIONS

1. **Headache:** May occur as a result of dehydration or reaction to water. Apply cold compresses to the head or back of the neck and drink more water.
2. **Shivering:** May occur if cold treatment is applied for too long or is not followed by appropriate warming.
3. **Vertigo** (dizziness): May occur as a result of dehydration or reaction to changes in blood pressure. Have patients lay down again and get up slowly.
4. **Insomnia:** May occur after an invigorating treatment.
5. **Heart palpitations:** May accompany dizziness or occur alone as a result of increased temperature of the body.
6. **Skin sensitivity:** May be ticklish.
7. **Hyperventilation:** May occur if patient becomes anxious about treatment or anything else.
8. **Fainting:** May occur as a result of changes in blood pressure from the treatment.
9. **Nausea:** May occur as a result of detoxification or reaction to treatment.
10. **Sensitivity to water:** May cause irritation due to prolonged application of the water.

CHAPTER

29

FLUIDOTHERAPY

- Introduction
- Methods
- Uses
- Advantages of Fluidotherapy
- Disadvantages of Fluidotherapy

INTRODUCTION

Fluidotherapy is a dry heat agent transferring heat energy by forced convection. Borrell and coworkers suggested that for superficial heating, it is irrelevant whether the modality provides wet or dry heat, provided that the skin temperature is raised to the same temperature by both agents. The Fluidotherapy system uses air-fluidized solids as the heat-transfer medium. Warm air is uniformly circulated through the bottom of a bed of finely divided cellulose particles in a container. The solid particles become suspended when the stream of air is forced through them, making the fluidized bed behave and demonstrate properties similar to those of liquids. The viscosity of the air-fluidized system is low, allowing a patient to submerge body parts into the fluidized bed and suspending these parts similar to being in a fluid, thus permitting exercise with relative ease. The heat transfer characteristics within the fluidized bed and to parts submerged in it are similar to those of a mildly agitated liquid. The combination of air flowing around the high surface area of the finely divided particles, and the bulk movement of solids produces high heat fluxes and uniform temperatures throughout, thus providing a strong massaging action, sensory stimulation, and levitation.

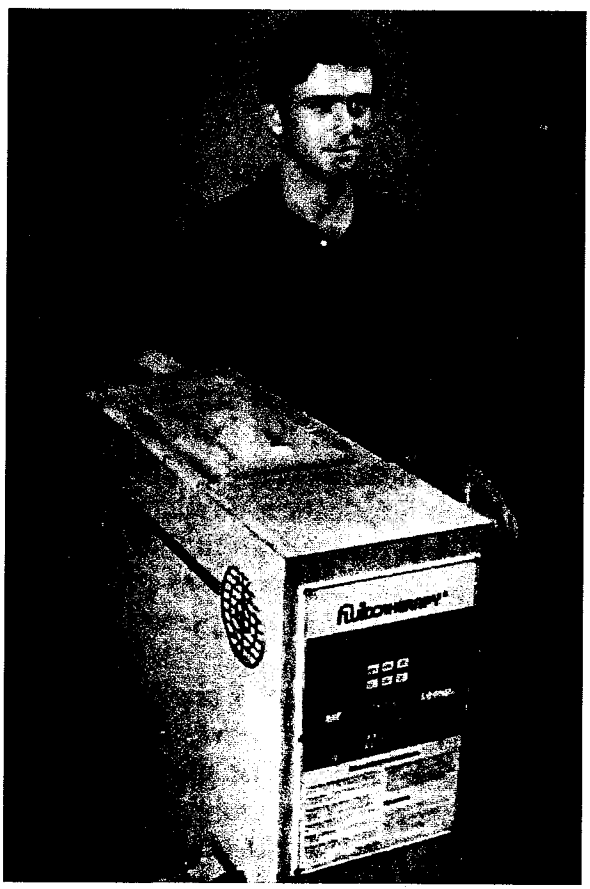

Fig. 29.1 *Fluidotherapy to the hand and wrist*

Fig. 29.2 *Fluidotherapy unit designed to immerse the leg the knee*

METHOD OF APPLICATION

Fluidotherapy units come in a variety of sizes (Fig. 29.2). There are units for treating the distal extremities and larger joints, and there is a larger model available for the treatment of the back. For joints and distal body parts, the patient places the body part to be treated through the entrance sleeve of the Fluidotherapy unit. The sleeve is then secured to keep the cellulose particles from escaping. As the air stream is blown in, the particles become suspended and the treated body part feels as though it is immersed in a moving liquid bath, such as a whirlpool.

Both temperature and the amount of particle agitation can be varied. Temperature ranges for treatment are typically from 38.8 °C to 47.8 °C (102 °F to 118 °F). The lower ranges are recommended for patients who have a greater predisposition for oedema formation or who are in beginning programs for desensitization, when they may not be able to tolerate higher temperatures. Agitation can be controlled for patient comfort. In addition, varying degrees of agitation can be used in a program of desensitization for hypersensitive areas.

Patients can carry out exercises while the affected body part is within the cabinet. This is particularly effective for the distal extremities, such as the wrist, hand and fingers, and ankle, foot and toes. If heat and stretch is desired, dynamic splinting can be used during the time of heat treatment to provide a gentle stretch, or stretching techniques can be used immediately following immersion in Fluidotherapy.

If it is desirable to treat a body part with an open wound, the wound can be protected by a plastic barrier or bag to prevent any fine cellulose particles from becoming embedded in the wound, and to minimize the risk of cross-contamination.

USES

The effectiveness of Fluidotherapy as a superficial heating agent was compared to paraffin wax and hydrotherapy by in vivo temperature measurements. Joint capsule and muscle temperatures in the hands and feet were measured at various depths, with indication that the Fluidotherapy produced the greatest increase in tissue temperatures in all areas. Dry whirlpool Fluidotherapy delivers more heat than paraffin wax or hydrotherapy because higher temperature can be tolerated in a dry environment. This conclusion is questioned, particularly in view of the fact that paraffin wax in particular allows tissues to be immersed into bath with an operating temperature of 45 °C to 54 °C (113 °F to 129 °F), compared with the Fluidotherapy range of 39 °C to 48 °C (102.2 °F to 118.4 °F).

Alcorn and coworkers used Fluidotherapy and exercise in the management patients with sickle cell anemia. They demonstrated a marked reduction in the length of hospitalization (compared with the length of hospitalization by the same patient during previous episodes), a major reduction in the dosage of analgesics previously administered, and a marked improvement in spine, trunk and extremity range of motion, and gait.

ADVANTAGES OF FLUIDOTHERAPY

1. Convenient, easy to administer.
2. Temperature of application can be controlled.
3. Agitation of dry particles can be controlled for comfort.
4. Variety of sizes of units allows for most body areas to be treated.
5. Allows for some active exercise to be carried out during treatment.
6. Dry, comfortable heat.
7. Can be used for desensitization of hypersensitive hand/finger(s) or foot/toe(s).

DISADVANTAGES OF FLUIDOTHERAPY

1. Relatively expensive modality to purchase.
2. Intolerance of some patients of enclosed container.
3. Intolerance of some patients to dry materials used.

CHAPTER 30

CRYOTHERAPY

- Introduction
- Reaction to Cold
- Physiological Effects of Cooling
- Ice Packs
- Ice Massage
- Cold Spray
- Cold Whirlpool
- Cold Baths
- Selecting a Cooling Agent
- Documentation of Treatment
- Contra-indications
- Principal Indications for Cryotherapy with Cold Air

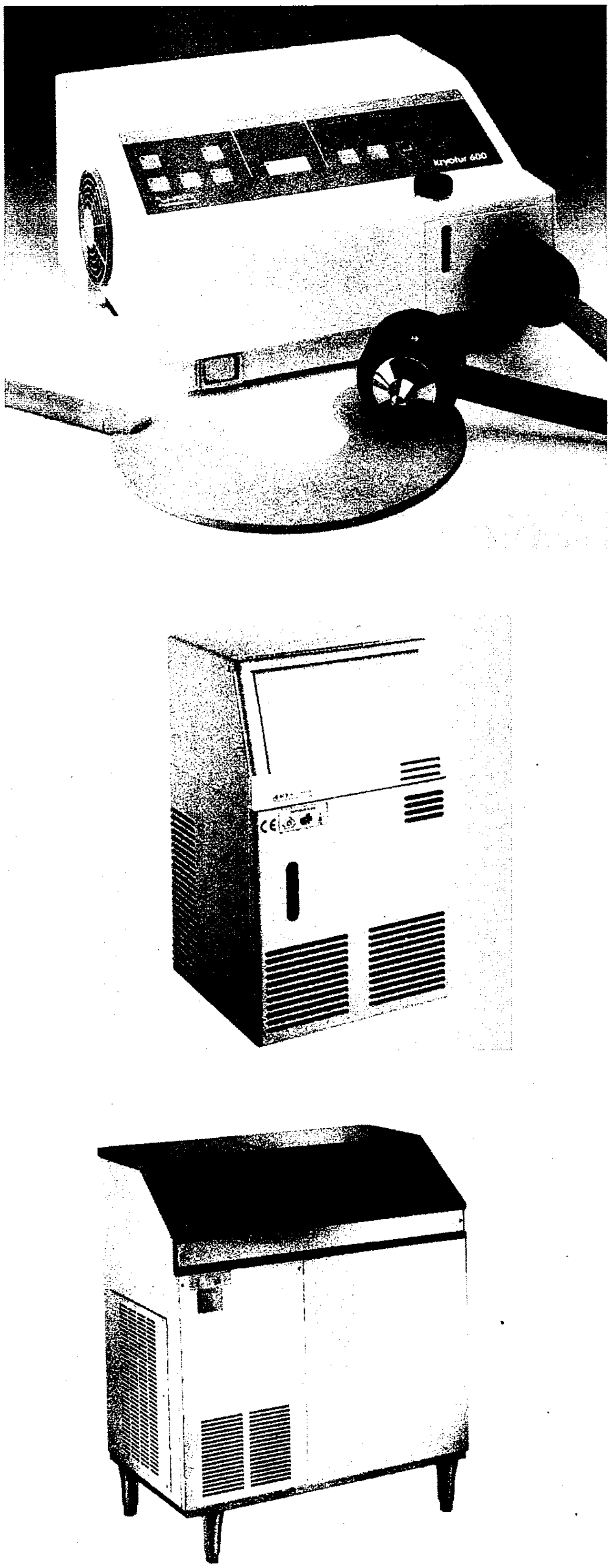

Fig. 30.1 *(a) Cryo Air Unit, (b) Easy ice cuber, (c) Flake ice machine*

INTRODUCTION

Cold agents are used as first-aid measures after trauma and as adjunctive tools in rehabilitation of musculoskeletal and neuromuscular dysfunction. Cryotherapy is an old remedy for pain relief, fever reduction and control of bleeding. Recently it has been applied to prevent or reduce oedema of traumatic origin and inflammation, decrease muscle-guarding spasms and temporarily diminish spasticity before exercise.

A number of agents are available to achieve the goal of reducing tissue temperature. These includes cold or ice packs, ice cubes, ice massage, vapocoolant spray, cold bath and controlled cold compression units.

It is an universally agreed fact that the application of cold is indicated to treat most acute musculoskeletal injuries such as strains, sprains, and contusions. In fact, the traditional rule of treatment for an acute injury is RICE. This includes the application of rest, ice, compression, and elevation. Ice is also used during the acute phase of many inflammatory conditions such as bursitis, tendinitis, and capsulitis.

The primary rationale for applying ice is the initial vasoconstriction that accompanies its use. The resulting reduction in blood flow assists in controlling swelling and oedema that typifies the acute injury. Ice also is used to reduce pain and muscle spasm. Cold, in the form of ice massage or vapocoolant spray, is also used as an adjunct in the treatment of many myofascial pain syndromes.

REACTION TO COLD

The body responds to the application of ice in stages. The initial reaction to cold is local vasoconstriction with a consequent reduction in blood flow. This is useful during the early stage (*i.e.*, acute stage) when it is necessary to control swelling, which is the primary rationale for the use of ice immediately following an injury. In addition to reducing blood flow and fluid accumulation, ice also has an analgesic effect and is often used more to reduce pain than to minimize oedema.

The initial period of vasoconstriction is followed rather quickly (within the first 15 to 30 minutes) by periods of intermittent vasodilatation and vasoconstriction, each lasting from 4 to 6 minutes. This cyclic reaction is referred to as the "Lauris-Hunting" reaction and is a necessary response by the body to prevent tissue injury. With continued cooling the blood vessels in the affected tissues become maximally dilated.

Although there is a great variation in individual reactions to cryotherapy, the physiologic processes are consistent from one patient to another. With the application of cold, the patient should experience the following stages: (1) a sensation of cold, (2) tingling or itching, (3) a burning or aching, and finally (4) numbness or anaesthesia. Patients should be instructed about the sensations that they may expect as well as the relative time frame for each occurrence. As with other modalities or treatment methods, whenever ice is used for the first time, the patient should be monitored to ensure an appropriate response.

PHYSIOLOGICAL EFFECTS OF COOLING

As stated, the response to cooling is consistent from one patient to another. The primary effects of the application of cold are:

- A local decrease in tissue temperature
- Reduction in metabolism
- Vasoconstriction (initially)
- Reduced blood flow (initially)
- Reduced nerve conduction velocity
- Reduction in lymphatic and venous drainage
- Reduced muscle excitability
- Reduced muscle spindle activity
- Decreased formation and accumulation of oedema
- Anaesthesia.

THERAPEUTIC USES OF COLD

Recent Injuries: Cold is widely used in the treatment of recent injuries. If bleeding occurs, cold serves to promote immediate vasoconstriction and makes the blood more viscid; both diminish the flow. Combined with pressure over the wound, such treatment leads to haemostasis. However, the cooling must not be so intense or so prolonged as to delay blood coagulation — clotting time is lengthened by cooling. If bleeding is occurring into the tissues, forming an intramuscular haematoma, for example, the same principle would apply but much longer periods of cold application would be needed to achieve cooling at depth.

The immediate treatment of cutaneous heat burns requires rapid cooling of the area. Prompt cooling lowers the tissue temperature and thus limits tissue damage.

Soft tissue injuries of all kinds are almost universally treated by cold in the early stages. During this time the inflammatory changes occur in a well-recognized sequence: Exudation of plasma into the tissues due to local vasodilatation has occurred. This local oedema distorts the tissues which stimulates pain nerve endings. Pain is also produced by the action of local hormones, such as kinins and histamine, as well as other chemicals. The amount of pain will be related to the rate at which this oedema and chemical irritation occurs. Cooling will diminish the rate of swelling and production of irritants and so alleviate the pain. Compression and elevation of the part will also limit oedema formation. Thus the initial treatment of traumatic injuries can be defined by the acronym ICE, standing for ice, compression and elevation; the addition of rest, which is also highly appropriate in early treatment, turns the acronym into RICE.

Typical methods of treatment of an acute injury of an extremity, *e.g.* a sprain of the lateral ligament of the ankle, would involve the application of ice every 2–4 hours during the first 1–2 days of the injury. This would be combined with rest, elevation and a suitable compression bandage.

Pain: Pain can be alleviated by the application of cold in several ways. Firstly, by the reduction of oedema and decreased release of pain-inducing irritants. A direct effect on the conduction of pain receptors and neurons, reducing the velocity and number of impulses, is another. It is evident that the latter effect would only occur in the skin and than only if the temperature is much reduced. It is unlikely that the unmyelinated C fibres would be affected since they have been shown to continue to conduct at very low temperatures. The thinly myelinated A delta fibres which carry well-delineated 'fast' skin pain, would be more susceptible. However, the pain due to tissue injury would be carried by C fibres and this is the pain that is usually being treated.

Muscle Spasm: Muscle spasm is linked to pain, as the pain of an injury appears to provoke muscle spasm as a protective measure. The application of cold would reduce muscle spasm and so allow an increased range of movement.

Spasticity: Cooling has been used clinically for many years to reduce muscle spasticity. There is good objective evidence to support this, for example cold producing a marked decrease in ankle clonus.

Cooling can affect spasticity by operating at two different sites, one in the skin and the other in the muscle itself. The immediate effect of stimulating cold receptors in the skin is to provide stimulation to the central nervous system. This is used therapeutically to facilitate muscle contraction—briefly stroking with ice over the appropriate dermatome, for example, ice cube stroking over the biceps for 1–2 min. enhances the motor unit activity of subjects who had learned to activate a single motor unit with the aid of electromyogram biofeedback. Cutaneous stimulation also has reflex effects, diminishing gamma motor neuron activity or by diminishing the muscle spindle discharge, thereby reducing spasticity. Sympathetic stimulation may also contribute. Such effects would occur almost immediately as the skin temperature fell; a drop in muscle temperature would take longer, but would also last much longer. It has been suggested that muscle cooling might lead to reduced muscle spasticity because of the differential effect of cooling of the small myelinated fusimotor efferents and secondary afferents on the one hand, and the large thickly myelinated motor nerves to the extrafusal fibres on the other. That conduction in the former is more easily affected by cooling than in the latter (Table 9.1). The muscle spindle activity is diminished, lessening the stretch reflex, while the extrafusal muscle fibres are less susceptible. An alpha nerves, are unaffected. Changes in the viscostatic properties of muscle tissue may also play a part since cooling makes the muscle—both intrafusal and extrafusal fibres—more viscid thus allowing less rapid stretching.

Muscle strengthening: There is evidence that cooling the skin surface can lead to greater strength of the underlying muscles, although there are also conflicting reports of a strength decrease following cryotherapy. Most investigators have concerned themselves with isometric strength. For example, found an increase of around 17% of the quadriceps after 30 min. of ice applied to the anterior aspect of the thigh compared with a control group. Interestingly, this was to some extent retained 24 h. later.

Chronic Inflammatory Conditions: The value of cold therapy for acute inflammatory conditions is well accepted but many degenerative and chronic joint diseases have also been treated successfully with cold therapy, including osteoarthrosis and chronic rheumatoid arthritis. Cold may well be beneficial in these conditions by virtue of its pain-relieving effect or because it may help to control such minor acute or sub acute inflammatory changes as occur from time to time with degenerative joint conditions. Alternating hot and cold packs, or contrast baths, may be effective.

Chronic Oedema and Joint Effusions: Cold treatment reduces chronic oedema is widely recognized. A recent study has attempted to quantify this effect in 9 hemiplegic patients whose swollen hands were intermittently immersed in water of around 10°C for 30 min. Although hand volumes are variable, both between subjects and at different times in the same subject, there was a reduction in hand volume in all patients; it was statistically significant in 8 of them. During both treatment and measurement, these hands were dependent; combining treatment with elevation may lead to even better results.

Interstitial oedema, inflammatory joint effusions are also benefitted by cooling. The application of ice and a compression bandage for an acute joint effusion are almost universally recognized treatments. The application of cold for obstructive oedema, such as due to deep vein thrombosis, is not usually recommended.

Other Therapeutic Effects: Ice massage has been used in treatment of pressure sores, as have ice packs, although the former is considered more effective. The beneficial effects are said to be due to the fact that cooling reduces vascular stasis.

Cooling is also used in conjunction with stretching in the later treatment of muscle tears and other athletic injuries and as prophylaxis against further injury. Cooling — using a vapocoolant spray - and stretching have been shown to be more effective than stretching alone in normal subjects.

CLINICAL APPLICATION OF COLD

Ice Packs

Application of ice packs is the most common form of cryotherapy. Although there is some disagreement regarding the correct application of ice packs, the following rules provide some useful guidelines:

1. Ice should be used during the acute stage (typically the first 48 to 72 hours) following an injury.
2. Fifteen to 20 minutes are adequate for most therapeutic applications; longer applications may actually create problems.
3. Applications should be repeated approximately every 2 hours as needed.
4. To reduce oedema in a limb, ice should be used in conjunction with compression; in most instances, it is probably more productive to leave a properly applied compression device on for 24 hours or longer than to remove it to reapply ice.
5. Patient tolerance to ice varies considerably and must be taken into account.

Note: It is helpful to keep a supply of reusable ice packs of various sizes on hand. These packs may be provided to patients as a convenience. The patient may be sent home with two ice packs of equal size and should be instructed to place both ice packs in the freezer compartment of the refrigerator. Take out one of the ice packs when needed, wrap it in a dry towel and apply it to the appropriate body part. Return the ice pack to the freezer after 15 minutes. The second ice pack will be ready for use when it is time to reapply ice. It is also helpful to provide the patient with written instructions regarding the application of ice at home.

It has been my experience that patient compliance with the use of ice as a form of home therapy is not particularly good. Since the use of ice is uncomfortable, patients often apply it for only short periods of time; in many instances, they do not use it at all.

Ice Massage

Ice massage is most popular in athletes, especially when stretching is a desired outcome. It can be performed by a therapist or as a self-treatment technique. Ice massage is used also as a substitute for the vapocoolant, fluoromethane (Fig. 30.1) spray and stretch technique.

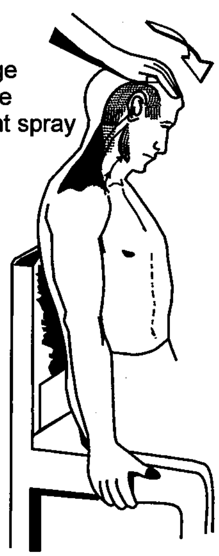

Fig. 30.2 *Ice massage can be used to treat myofascial trigger points*

The following guidelines are suggested:

1. Use a Styrofoam cup filled with water that has been placed in the freezer for several hours. Remove the bottom 1 inch of the cup and invert over the patient.
2. Apply the ice cup in a rotating pattern or in overlapping longitudinal strokes for approximately 10 to 15 minutes, or until the area is sufficiently anesthetized to allow adequate stretching.
3. Follow the application with stretching exercises, either active or passive.

Note: Applying ice directly to the skin with an ice massage results in significant reddening of the area treated. If any mottled or blanched areas appear, this treatment should be discontinued.

Cold Spray

The use of vapocoolant sprays such as fluoromethane was earlier very common. Nowadays, based because of the carcinogenic and environmental effects of fluorocarbons, their use is diminishing. However, these sprays are still used to treat myofascial trigger points. Cold spray is indicated when stretching of an injured part is desired. These cold sprays do not provide the same type of physiologic response as the application of ice. Rather than exerting a thermal response that is similar to the application of other forms of cold, the cold spray serves as a counter-irritant that distracts the patient's attention from sore muscles. This allows the patient to relax and facilitates the stretching process. The primary action of a cold spray is the breaking of the pain-spasm-pain cycle that often accompanies prolonged postural or physical stresses.

The following is a suggested procedure for the use of the vapocoolant spray on myofascial trigger points.

1. Spray the part with the fluoromethane spray in slow sweeping strokes.
2. The strokes should be directed from the trigger point toward the areas of symptoms as shown.
3. Following the spray technique, the involved muscle should be passively stretched.
4. The procedure should be repeated two to three times at a sitting.
5. Following the spray and stretch procedure, the involved muscle should be warmed with a hydro collator pack or a heating pad.

Cold Whirlpool

The cold whirlpool is indicated in the treatment of an acute or sub-acute condition whenever exercise of the injured part during cold application is desired. The following should be considered:

1. A temperature of 50°F to 60°F should be used.
2. The water temperature should be between 65°F to 80°F for total body immersion.
3. Treatment time should not exceed 15 minutes.

Cold Baths

When cooling the distal extremities, immersion of those parts in a cold bath is most practical (unless simultaneous elevation is desired). This approach ensures circumferential contact of the cooling agent. Water temperatures for immersion vary from 13°C to 18°C. The lower the temperature range, the shorter the duration of immersion. In fact, immersion at 13°C often will be very uncomfortable. A basin of water or a small whirlpool filled with water and crushed ice can be used. The patient can also be instructed to use this technique at home.

Controlled Cold-Compression Units

Controlled cold-compression units can be adjusted to selected temperatures (ranging from approximately 10°C to 25°C) and can be maintained during the time the unit is turned on. Cooled water is circulated through a sleeve that is applied over an extremity. The sleeve is inflated intermittently to pump oedema fluid from the extremity. These units are probably most commonly seen in centres, such as sports medicine facilities, that treat a number of acute musculoskeletal injuries.

SELECTING A COOLING AGENT

When selecting a cooling agent, the clinician should consider which body area, and how much of the body surface, is to be cooled. For small areas (such as over a tendon, bursa, or small muscle belly), ice massage may effectively produce the cooling desired. If a distal extremity is to be cooled, a cool bath will most efficiently cover all surfaces.

When cooling around a joint such as the knee, elbow, or shoulder, or a larger muscle mass, such as lumbar or cervical paravetebral muscles, a cold pack or chipped ice wrapped in a terry cloth towel may be the best choice. Compare the abilities of three cooling agents — wet ice, dry ice, and a commercial gel pack— in reducing skin temperature over the gastrocnemius muscle. Average skin temperature before cooling was 29.5°C to 30°C. The greatest temperature reduction, 12°C, was recorded after wet ice (chipped ice in a terry cloth towel) was applied for 15 minutes, while cold gel packs applied for the same amount of time reduced skin temperature by 7.3°C. These authors emphasize the importance of accurate placement of a cold agent over, and completely covering the area to be treated. Skin temperatures proximal and distal to the ice or other cooling agent were not significantly lowered.

DOCUMENTATION OF TREATMENT

As with any therapeutic technique, the use of cold in a therapy program is based on the goals of the treatment. The goals are determined by the patient and the therapist after thorough evaluation of the patient, including the history of the present problem and subjective and objective measures of impairments and current functional status. Documentation includes an accurate recording to the treatment parameters, changes in patient response to treatment during and between sessions and any modifications of the goals or treatment program. Specific parameters for cold applications are the type of cold agent, treatment duration, site of application, and position of the patient. Treatment outcomes may include volume pain status measures, ROMs, and strength grades. Further descriptions of changes in skin temperature or appearance, quality of oedema, and sensation are also documented. Clinical notes include periodic reassessments of the patient's overall functional level, especially in relationship to those impairments directly affected by treatment.

CONTRA-INDICATIONS

1. **Cardiac disease or cerebrovascular insufficiency:** Large areas should not be treated because of the possible effects on the general circulation.
   Ice packs on the left shoulder in patients with coronary artery disease, or a history of myocardial infarct has been a contra-indication in the past, as cooling of the vagus occurs, but this has not been upheld by further research. An ice pack could be applied to the left shoulder with the towel wrung out in warm water and then packed with ice chips, to reduce the first impact of intense cold on the tissues.
2. **Loss of sensation:** Ice should not be applied to any anaesthetized areas as there is a danger of ice burns. Any areas that has had deep X-ray therapy

should not be iced. Tests of hot/cold and pain sensitivity should be performed.

3. **Cancer and sickle-cell anaemia:** Ice should not be applied to large areas as it could upset the general circulation.
4. **Brief icing over the posterior primary rami of the trunk:** Brief icing to the skin supplied by the posterior primary rami of the thoracic nerves can stimulate the deep viscera and cause a chain of adverse reactions.
5. **Emotional subjects and mental instability:** Some patients are apprehensive and nervous and dislike cold intensely. These subjects are best not treated with cold, as they would not allow a satisfactory treatment to be carried out, and this will negate the results. Ice to the sole of the foot or palm of the hand is harmful to the neurotic patient.
6. **Patients who are hypersensitive to cold:** The patient may react adversely or show an abnormal response to cold. The patient's reaction to ice should be tested.
7. **Throat, ear or side of the neck:** These areas should be avoided as adverse visceral or cerebral reactions may occur.
8. **Unreliable patients:** Patients who are too old, too young or who are unable to understand the potential dangers of ice.
9. **Severe blood pressure abnormalities:** Alternations to the blood pressure produced by the ice may not be tolerated.
10. **Peripheral vascular disease:** Patients with mild vascular conditions could develop a histamine reaction. In patients with advanced conditions, it could cause an episode of paroxysmal haemoglobinurea. Even gangrene can be precipitated in advanced cases.

PRINCIPAL INDICATIONS FOR CRYOTHERAPY WITH COLD AIR

Trauma: Within the field of trauma, several factors must be distinguished which vary according to the kind to pathology and the realized orthopedic or surgical treatment. The traumatized tissues are decisive for the type of treatment with cold air: either on a fixed point, semi-stationary and brief treatment, or longer treatment with sweeping motion above the treatment area.

For each kind of pathology, it can be considered that the treatment is divided into the following stages:

- An immobilization stage, possibly following a surgical operation treated with strapping, casting or post-operative bracing.
- A recuperation stage of the articular range of motion and the muscular activities.
- A stage corresponding to resumption of current sports or other activities.

In the case of the traumatic pathologies, we will distinguish the osseous, articular and muscular pathologies; the fracture has general consequences which derive from the immobilization.

Osseous Pathologies

The Venous Risk: As the cold prevents blood stasis and articular or muscular oedema after an operation, it will reduce the post-operative venous risk as application of cold produces a vasoconstriction followed by a vasodilatation.

The Muscular Atrophy: After a surgical operation on an articulation, for example the knee, the most common complication is the loss of the flexibility, possibly accompanied by an inflammatory reaction to the surgical operation.

The use of cold air allows for physiotherapy to be applied sooner by reducing the inflammation and for an avoidance of muscular atrophy.

Depending on the type of pathology, it is not obligatory to obtain a maximal range of motion. Nevertheless, it should be kept at its maximum. Avoiding the development of the oedema will prevent adhesion formation. Cryotherapy is very interesting in this case.

Joint Pathologies

Sprains:

- Non-bedridden immobilization stage treated with strapping:
  In the treatment of oversprain, cryotherapy can prevent pain and inflammation. During the immobilization, the strapped area is treated directly with the treatment tube.
- Non-bedridden immobilization stage treated by casting:
  The use of cryotherapy is limited by the casting materials. Once it is removed, the casted areas often present a post-traumatic, late oedema which can be treated with cryotherapy. It then has an analgesic, trophic and anti-oedematous effect. The combination with low frequency currents will increase the analgesic effects.

Luxations: In the case of luxations, the treatment with cryotherapy will be appreciated for its analgesic and trophic effects.

Muscular and Tendinous Injuries

Muscular accidents without anatomical lesions relative to an intrinsic cause.

	Cramps	Sore Muscles	Contracture
Cryotherapy with Cold Air	No	No	Yes

Muscular accidents with a muscular lesion relative to an intrinsic or extrinsic cause.

	Elongation	Torn Muscle	Rupture	Contusion
Cryotherapy with Cold Air	Yes	Yes	No	Yes

Tendopathy: There is a disproportion between the forces imposed onto the tendon and the resistance of the tedious fibres. Tendopathies are always followed by pain mechanisms rarely associated with inflammatory signs. The last ones are only the late manifestation of a longer developing degeneration.

There are several kinds of tendopathies:

- Pathologies concerning the tendon itself (Tenodynia).
- Pathologies concerning the tendon itself with inflammation (Tendinitis).
- Pathologies concerning the myo-tendinous junction or more often the insertion on the bone (insertion Tendopathy).

Tendo-myositis, the tendoperiostitis and the tendo-enthesis are distinguished as well. Finally, it is also possible to have pathologies of the tendon adnexa, tendobursitis or tenosynovitis. Some of these pathologies may be treated with physiotherapy (tendonitis, tendo-myositis, tenosynovitis), for others, physiotherapy is only a relative indication, or even a contra-indication.

- Treatment of Tendopathies:
  Treatment will aim to solve the endogenous and exogenic problems, the static troubles, the inadapted movement and other muscle-tendinous problems. The symptomatic treatment will aim to break the vicious pain circle. It will follow the evolution course of the tendopathy.
- Treatment of Tendinitis:
  It is well known that the best way to treat pain is to combine several treatment techniques. The tendon should be immobilized with an adhesive or non-elastic form of athletic tape. We can now associate cold air and the conclusive bands with analgesic and anti-inflammatory electrotherapy.

The Periostitis: The physiotherapeutic treatment of periostitis uses manual techniques centered on progressive stretching of the painful muscles. The physiotherapy will include cryotherapy associated with a iontophoresis of anti-inflammatory substances. The treatment over the leg with cold air is done at a distance of 5 to 10 cm for 2 to 3 minutes.

Rheumatology

Cold air provides better treatment of inflammation than other cold sources. At the moment there are very few studies demonstrating the action of cold air on the most significant inflammatory syndromes, however it is presumed that it is the same as for normal inflammation. For the treatment of arthrosis and joint rheumatism, some studies and observations propose treatment with cryotherapy, although the recognized indications for cold treatment were minimal several years ago. Only sub-acute periarthritis and acute supra-acromial bursitis showed positive results by the applications of cold at 0°C.

The range of applications increases with cryotherapy used at lower temperatures as it has a longer analgesic action. Rheumatic pathologies such as pelvis rheumatoid spondylitis or polyarthritis can be treated much more effectively. Cold air also provides for a shorter or more focused treatment of pain areas (Trigger Points, Acupuncture Points).

Arthrosis

The analgesia created with cold air allows for a less painful mobilization of the articulations. The range of motion can be improved by blowing cold air on contracted muscles. Muscle strengthening with isometric contractions is sometimes very painful; it can be made easier by a preliminary treatment with cold air. The oedema and often the hydrarthrosis associated with this pathology are treated more easily.

Because of the anatomical disposition of the periarticular blood circulation, the treatment must be conducted with the treatment tube and without the reduction nozzle in order to avoid a warming-up caused by the incoming blood flow from the non-treated area. The better treatment method is to sweep over a large area. As the thermal shock is important, the cooling of one face is kept during the treatment of the other face. The results last much longer as those with cold packs.

Neurodystrophic Pain

Cyrotherapy improves the resorption of the oedema and reduces the capsular retraction. With a neurodystrophic pain of the shoulder, cold air allows for the liberation of the venous periarticular stasis responsible for the cystitis and reduces the inflammatory process. Manual mobilization is then easier. The quicker liberation of the articulation with this cold air treatment accelerates the healing process. Complete envelopment is difficult due to the presence of the neurovegetative tracks. Cold packs are not practical because of the contours to be treated, whereas cold air adapts perfectly to the area to be treated.

CHAPTER 31

CRYOKINETICS

Cryokinetics, that is cold and exercise, is an integral part of the initial phase of the athlete's rehabilitation. The key to success in this early stage or recovery is the use of cold for pain inhibition to allow greater effort with graded exercise. Cohn and associates studied the effects of cold in the post-operative management of pain in patients undergoing anterior cruciate ligament reconstruction. Pads filled with 50°F fluid formed an ice blanket applied to either side of the operated knee post-operatively and remained in place for the initial 4-day course. Compared to patients in the control group, the treated group performed ROM exercises with greater ease and required less palliative therapy during their post-operative course. Ice massage may increase an individual's tolerance to the noxious sensation that usually accompanies high levels of electric stimulation. Thereby, the patient can continue strength training without unnecessary pain.

Ice is used in cryokinetics to numb the affected area; 10–15 minutes of application is usually necessary to achieve the required analgesia. The use of cryokinetics has a built-in safety valve, unlike the potential dangers involved when pain-alleviating pharmaceutical agents are injected to enable the patient to perform exercises. Although the clinical application of cold produces a degree of analgesia, if an athlete is experiencing pain during analgesia of the injured part during exercises, this alerts the practitioner that the exercise is too vigorous. In order to avoid pain during exercise, the patient's activity level should be decreased.

Fig. 31.1 *The use of ice massage on a thigh contusion to achieve analgesia prior to isometric exercise during the sub-acute stage*

Cold application can cause substantial pain before it moderates the injury-pain but such discomfort will diminish with repeated applications in cryokinetics treatment sessions. They found that this habituation was temperature and body-part specific.

Cryokinetics is easily performed under proper instruction and supervision. Initially, cold is used to numb the injured part by applying ice massage, ice packs, or immersion baths (Fig. 31.2). If the therapist chooses to use an immersion bath, a technique sometimes employed for injuries of the distal joints, the duration of treatment should not exceed 15 minutes, and the clinician should ensure that the patient has intact peripheral circulation. Prolonged local exposure to cold has been reported to result in nerve palsies. Study of peripheral nerve injury via cold applications indicates that motor function is affected first and to a greater degree than sensory functions. However, as warming occurs, sensory function is restored more rapidly than motor function. Physiotherapist must recognize the tremendous variation in the resistance of individual peripheral nerves to injury from cryotherapy. Total motor and sensory loss can occur at 0 to 5°C. The sensitivity of individuals to the duration and intensity of tissue cooling dictated by its method and location of

Fig. 31.2 *Cryokinetics in the management of tennis elbow. Ice massage is being applied to the area of lateral epicondyle to be followed by a slow, gentle stretch of the wrist extensor muscles*

application (degree of relative insulation provided by the thickness of overlying subcutaneous fat) must be evaluated by the practitioner and modifications implemented accordingly.

Cold can be a valuable tool in the early management of rehabilitation of the injured athlete. Therefore, it is important that the therapist knows the specific effects of cold on the body, when to use this agent, where to apply it, and how it can assist in rehabilitation.

Effects of Cryokinetics: There occurs numbing of the part by cold application. Then the part is put through its range of movement actively in controlled fashion. These controlled exercises enhance the healing process by stimulating the circulation. At the same time, inhibitory neural responses are prevented and early activity of surrounding tissues and muscles are allowed.

Method of Application: This can be explained with the following example: In case of a mild second degree sprain involving the lateral ligaments of the ankle, the treatment is given as:

1st day: Ice is applied along with compression. Gentle range of motion exercises are given if there is no pain or uncomfortable feeling.

2nd day onwards: For 10 to 20 mins. ice is applied. Then heel toe (normal gait) walking is done by patient. If without a limp this is achieved then it is continued until the pain begins. It is repeated 5 times.

The other exercises include ankle inversion exercises, toe raising and hopping exercises. The exercise session should always be concluded by ice.

SECTION VII

- Pain
- Shock

CHAPTER

32

PAIN

- Definition
- Pain Perception
- Types of Pain
- Nociceptors
- Pain Modulation
- Quality of Pain
- Pain Terms

DEFINITION

Pain is defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage." It may be protective, defensive or diagnostic.

A foundation for treatment must be based on:

1. Knowledge of the condition
2. Theories of pain control
3. Mechanism of action of treatment modalities.

PAIN PERCEPTION

For pain to be perceived, there must be an unpleasant or noxious stimulus. Free nerve endings are the best examples of a pain receptor. Once activated, the noxious stimulus must be transmitted to the central nervous system where it reaches a higher centre that recognizes the stimulus. There are several classical theories about its transmission:

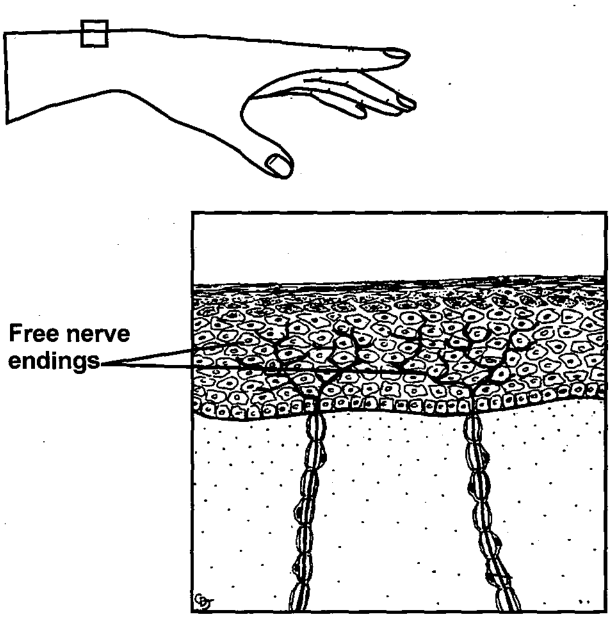

Fig. 32.1 *Free nerve endings are found in abundance in tissue that is pain sensitive*

Specificity Theory

Specific nerve fibres and nerve endings are necessary for noxious stimuli to be transmitted. There are four main classes of cutaneous sensations: warm, cold, touch and pain.

It is clear that there are specialized somatosensory receptors that respond to specific types of stimuli. The central location of the primary afferent neurons and ascending pathways is a critical factor in distinguishing the nature of peripheral stimulus.

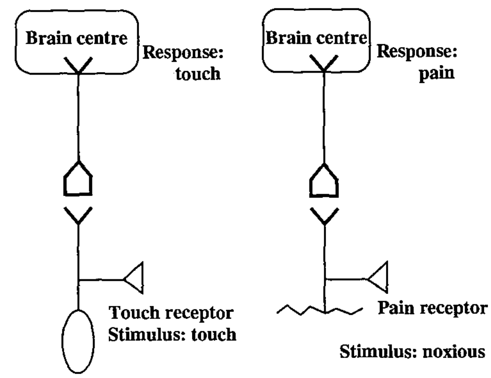

Fig. 32.2 *Specialized somatosensory receptors respond optimally to specific types of stimuli*

Pattern Theory

It's based on the fact that most cutaneous receptors are similar. Many free nerve endings respond non-selectively to mechanical, thermal and chemical stimuli. Most sensory fibres transmit noxious impulses provided the stimulus fits a specific pattern or form. Those fibres that are responsible for transmission of light touch, vibration, deep touch and temperature may send painful messages to the CNS if they are stimulated in an intense or abnormal manner.

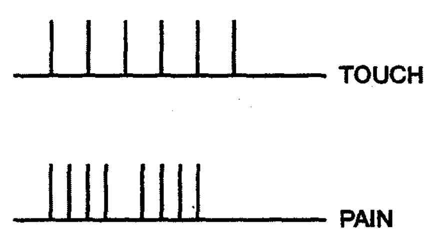

Fig. 32.3 *Most sensory fibres can transmit noxious impulses, provided the stimulus fits a specific pattern or form*

Summation Theory

It has been theorized that excessive stimulation of sensory fibres results in transmission of noxious impulses. Pathological activation of sensory nerves initiates a closed self-exciting loop of neuronal activity. Some nociceptive afferents, especially C polymodal afferents release long-duration neurotransmitters. Slow, temporal summation mechanisms, spatial recruitment mechanisms and after-response mechanisms exist within the dorsal horn.

TYPES OF PAIN

Pain Experience	Characteristics
Acute or Fast Pain	• Short duration. • May last for few minutes to several days. • Defined as pain of recent or sudden onset. • Usually demonstrable etiology and limited course. • Usually localized. • Felt within 0.1 sec. after pain stimulus is applied. • May be sharp, pricking, tingling or electric pain. • Case Example: Patient complains of an acute episode of lower back pain. He points with a finger to the middle of lower back. When questioned about the quality of pain, he describes it as 'like someone sticking an ice pack in his back'. • Protective in nature.
Chronic oF Slow Pain	• Long duration. • Extends months or years beyond the recovery period. • Felt after 1sec. or more than 1 second after pain stimulus is applied. • Defined as 'pain of long duration, associated with anguish, apprehension, depression or hopelessness'. • Often of vague aetiology. • May be burning, aching or throbbing. • Case Example: Patient complains of backache of several months duration. When asked to locate, he is unable to identify any specific area. He places his hand over lower back like a 'toothache in his back'.
Referred Pain	• May be acute or chronic. • Pain felt at a site in the body elsewhere from the source of disease or 'injury'. • It is projected on the same dermatome. • When a trigger point is stimulated, pain is referred to a remote site.

Sensory Interaction Theory

It is stated that a specialized system exists to control sensory input. This system prevents summation to occur. A rapidly conducting system inhibits synoptic transmission in a more slowly conducting nociceptive system. Under certain conditions, the fast conducting system loses its inhibitory control over the slow one, resulting in pathologic pain states.

NOCICEPTORS

Specialized receptors, that are necessary to protect organisms from tissue damage, are labelled as nociceptors. The first characterization of primary nociceptive afferent neurons appeared in the mid 1960s. Since then, considerable evidence has accumulated that a significant portion of cutaneous nerve afferents are uniquely responsive to damaging or potentially damaging stimuli.

Spinal cord neurons that respond exclusively to noxious input are found in high concentrations in the superficial layers of the dorsal horn (laminae I–II) and to a lesser extent in layers IV–V (Fig. 32.4). The major sources of input to these neurons are high-threshold – A delta mechanosensitive fibres, A delta heat sensitive fibres, and C polymodal afferents.

There are two types of sensory fibres that are thought to carry painful impulses to the central nervous system (CNS). The first, the A delta fibres, are fast, finely myelinated fibres that are rapidly accommodating. They appear to be responsible for the transmission of the sharp pain that is characteristic of many acute conditions. This pain is sometimes referred to as **first order pain**. These superficial fibres are found predominantly in the skin and in small numbers in the joints and muscles. They are sensitive to high-intensity mechanical stimuli; a small number are also sensitive to noxious temperatures.

The second fibre types, the C fibres, are slow, small, unmyelinated fibres that are found in the deeper layers of the skin and virtually every other tissue except the nervous system. These fibres are sensitive to mechanical, thermal, and chemical noxious stimuli. C polymodal fibres are the free nerve endings in which the nerve terminals themselves are the receptors. They are commonly silent unless activated by noxious stimulation. Unlike the A delta fibres, the C fibres are slowly accommodating. They are thought to be responsible for the transmission of the dull, aching type of pain that is often characteristic of more chronic conditions. This is sometimes referred to as

second order pain. The transmitter substance for these fibres is probably substance P.

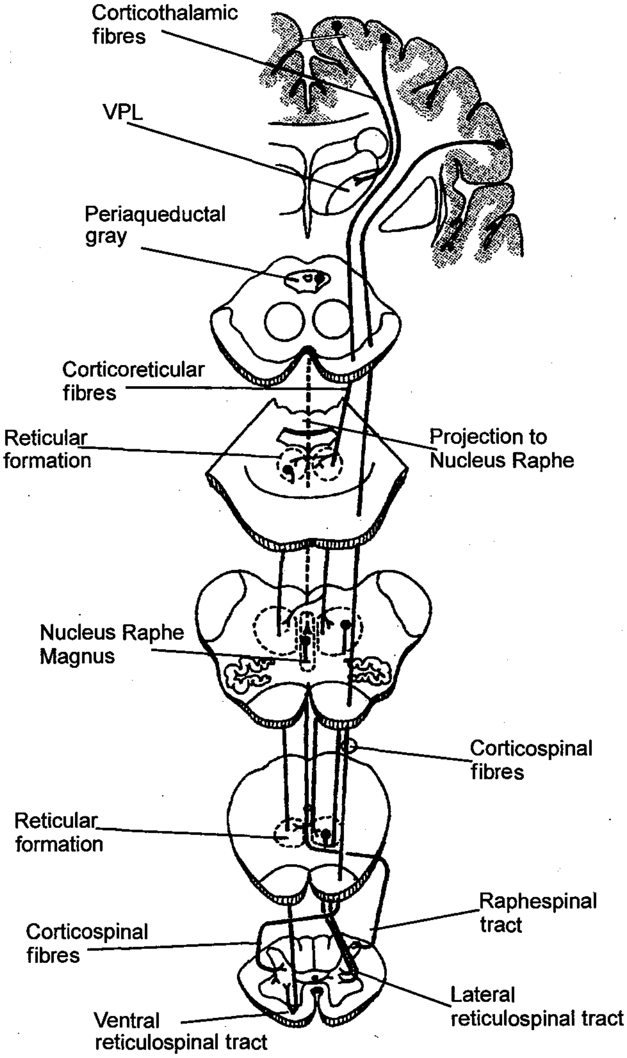

Fig. 32.4 *Diagram demonstrating the components of a pathway involved in the centrifugal control of pain*

Components of the Pain Experience

Aspect	Location
Discrimination	Cortex, thalamus
Affective	Limbic structures, thalamus
Autonomic responses	Reticular formation

PAIN MODULATION

Pain is most important clinical consideration. Pain relief is more important to the patient in early phase of care. Over the years, many theories have been developed to explain how pain is modified or controlled. Some of the more popular are: (1) the gate theory of pain control, (2) the release of endogenous opiates, (3) counter-irritation, (4) the use of exogenous pharmaceuticals, and (5) nerve block (conduction block). Of these theories, the gate theory is probably best known.

Gate Theory of Pain Control

Melzack and Wall, 1965 postulated that there exists a "physiologic gate" in the subtantia gelatinosa of the dorsal horn of the spinal cord. This spinal gate is influenced by the relative amount of activity in the large diameter (A delta) sensory fibres and small diameter fibres. Activity in large fibres tends to inhibit transmission (close the gate), whereas an increase in small-diameter fibre activity tends to facilitate transmission (open the gate). When the gate is opened, the loss of inhibitory activity allows the patient to perceive pain; when closed, however, the sensation of pain is blocked at the cord level. Melzack and Wall stated that the gate could be closed by stimulation of the large, superficial sensory fibres (A delta). This can be achieved via the following: transcutaneous electrical nerve stimulation (TENS), massage, stroking, heat, cold, and vibration.

A modification of the theory includes: (1) stimulation of both mechanoreceptive and nociceptive afferents can evoke inhibition, (2) not all nociceptive neurons of the dorsal horn receive input from both large and small afferents (some nociceptive—specific neurons receive input only from the latter), and (3) not all types of primary nociceptive afferents exert the same central effects. In addition to the changes to the proposed mechanism described above, it has become clear that the transmission of impulses is modulated by descending control systems as well as by local circuit interneurons.

It is fair to state that the gate theory is not an adequate explanation of pain mechanisms. Melzack & Wall theory has served as the basis for a variety of treatment protocols (especially the use of TENS) and subsequent pain theories (Melzack, Wall, 1983).

Release of Endogenous Opiates

It has been observed that, under certain conditions, the body releases a group of chemicals that have been referred to as "naturally occurring morphine-like substances." The most well known of these substances is beta-endorphin, which is said to be approximately 48 times the strength of morphine (others include dynorphin and enkephalin). These chemical pain suppressors are produced in the anterior lobe of the pituitary gland. They exhibit a systemic inhibitory effect and are involved in the degradation of several potent pain-producing chemicals. The production of these endorphins is enhanced by a variety of conditions, including vigorous exercise, deep relaxation, acupuncture, and low frequency — high-intensity electrical stimulation (Low TENS). Manipulation recently has been shown to induce a mild increase in beta-endorphin levels.

Counter-irritation

The counter-irritation phenomena (*i.e.*, the pain-relieving effects of painful stimuli) have been known for centuries. The idea is basically "pain inhibits pain." Consider the individual who is suffering from a headache. This person drops an object and fractures a toe. Temporarily at least, the headache is replaced with pain from the injured toe. Several types of counter-irritants (*e.g.*, cold, heat, mechanical, and electrical) have been used with one of the most effective being the application of painful cold (*i.e.*, ice massage). Painful electrical stimulation is described as "hypalgesia by hyperstimulation," a form of counter-irritant. There is some evidence that electrical acupuncture point stimulation must be as strong as the patient can tolerate for a reliable pain-relieving effect to occur.

Exogenous Pharmaceuticals

There are a variety of exogenous pain-suppressing chemical agents which help to relieve or prevent pain. Many of these chemicals, such as the non-steroidal anti-inflammatory drugs (NSAIDs) block the inflammatory process. Others block the transmission of painful impulses by interfering with the relay of information at the synapse. Some reduce muscle tension and exert a sedating effect on the body. While producing the desired effect, many of these chemicals actually interfere with the healing process and may add to the problems if relied on too heavily.

Nerve Block (Conduction Block)

There is some evidence that high-frequency electrical stimulation may actually block the transmission of sensory stimuli. This may be similar to the muscle fatigue that is known to occur with particular applications of electrical stimulation. The frequency-dependent conduction block theory proposes that a pain-transmission neuron can be rendered inactive or blocked by adjusting the frequency of the impulse so that it is delivered before all the ionic channels in that neuron respond. As no action potential is generated by the neuron, pain sensation is not felt.

QUALITY OF PAIN

(Please see the table on next page.)

PAIN TERMS

1. **Visceral Pain:** Any stimulus that excites pain nerve endings in diffuse area of the viscera causes visceral pain. *E.g.*: Chemical damage to the surface of the viscera, spasm of smooth muscles in hollow viscera.
2. **Causalgia:** A syndrome of sustained burning pain.
3. **General Pain:** Pain associated with a lesion of CNS.
4. **Hyperalgesia:** An increased response to a stimulus which is normally painful.
5. **Hypoalgesia:** A decreased sensitivity to pain stimulation.
6. **Analgesia:** Absence of pain in response to stimulation which is normally painful.
7. **Neuralgia:** Pain in the distribution of nerves.
8. **Myalgia:** Muscle pain.
9. **Noxious Stimulus:** A stimulus which can cause damage to the normal tissue.
10. **Nociceptors:** A receptor preferentially sensitive to a noxious stimulation or to a stimulus which would become noxious if prolonged.
11. **Pain Threshold:** The least experience of pain that a person can recognize.
12. **Pain Tolerance Level:** The greatest level of pain a person can tolerate.
13. **Allodynia:** Pain due to a stimulus which normally do not cause pain.
14. **Paraesthesia:** An abnormal sensation.
15. **Neurogenic Pain:** Pain arising due to nerve injury.
16. **Psychogenic Pain:** Pain felt due to a psychological disorder.

Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Flickering	Jumping	Pricking	Sharp	Pinching
Quivering	Flashing	Boring	Gritting	Pressing
Pulsing	Shooting	Drilling	Lacerating	Gnawing
Throbbing		Stabbing		Cramping
Beating		Lancinating		Crushing
Group 6	**Group 7**	**Group 8**	**Group 9**	**Group 10**
Tugging	Hot	Tingling	Dull	Tender
Pulling	Burning	Itching	Sore	Taut
Wrenching	Scalding	Smarting	Hurting	Rasping
	Searing	Stringing	Aching	Splitting
			Heavy	
Group 11	**Group 12**	**Group 13**	**Group 14**	**Group 15**
Tiring	Sickening	Fearful	Punishing	Wretched
Exhausting	Suffocating	Frightful	Grueling	Blinding
		Terrifying	Cruel	
			Vicious	
			Killing	
Group 16	**Group 17**	**Group 18**	**Group 19**	**Group 20**
Annoying	Spreading	Tight	Cool	Nagging
Troublesome	Radiating	Numb	Cold	Nauseating
Miserable	Penetrating	Drawing	Freezing	Agonizing
Intense	Piercing	Squeezing		Dreadful
Unbearable		Tearing		Torturing

The McGill Pain Questionnaire method of assessing the quality of pain.

CHAPTER

33

SHOCK

- Electric Shock
- Electric Shock and Safety Factors
- Physiological Effects of Shock
- How Electric Shock Occurs
- Other Hazardous Factors
- Safety Factors
- Precautions against Earth Shock

ELECTRIC SHOCK

A shock is a painful stimulation of sensory nerves caused by a sudden flow, cessation or variation in the current passing through the body. It can be caused by poorly designed or badly serviced electro-medical apparatus.

ELECTRIC SHOCK AND SAFETY FACTORS

A seemingly harmless voltage of 20 millivolts can kill a patient under certain conditions. It could be generated by poorly designed or badly serviced electronic apparatus. Most apparatus used in physiotherapy department is plugged into a main supply of 240 V and frequency 50 Hz. Any apparatus plugged into the main represents a hazard—the risk of electric shock. It would seem that a shock of 10,000 volts would be more deadly than 100 volts, but this is not so. Individuals have been electrocuted by appliances using as little as 40 volts direct current in industry, or by using household appliances. The measure of a shock intensity is the amount of current forced through the body. **IT IS NOT THE VOLTAGE BUT THE AMOUNT OF CURRENT WHICH DOES THE DAMAGE.**

After a person receives an electric shock, it is important to give artificial respiration, since it is impossible to state how much current has passed through the vital organs of the body.

PHYSIOLOGICAL EFFECTS OF SHOCK

- up to 20 mA – Laboured breathing, breathing upset, painful.
- up to 100 mA – Cannot let go, muscular paralysis ventricular fibrillation, at higher currents the heart muscle goes into spasm
- 100 to 200 mA – Unconsciousness, death.
- Above 200 mA – Death.

The skin resistance in a person can vary from 1000 Ω in wet skin, to 500,000 Ω in dry skin. If a person contacts the mains supply, the body current can vary from 0.5 mA when the skin is dry to 240 mA when the skin is wet.

Under these circumstances, a current as low as 20 mA will cause fibrillations. A voltage as low as 20V can be fatal when there is faulty earthing of the machine.

HOW ELECTRIC SHOCK OCCURS

In order to receive a shock, the person must become a part of the electrical circuit by touching two terminals of a voltage sources so that a shock current can flow. Two kinds of shock can occur:

1. Micro shock,
2. Macro shock.

Micro Shock: If the current bypasses the surface of the body and enters the heart by way of a myocardial electrode or a transvenous catheter, a minute current can produce a fatal shock without the patient experiencing anything. For example: A physiotherapist may be handling a patient with an electrical monitoring device on the heart. If at the same time he were to connect his hand to a faulty table lamp or some device with a broken ground connection, whilst palpating the patient's chest, then he could give the patient a micro shock, and cause ventricular fibrillation.

Macro Shock: If the current flow is from the body surfaces through the skin into the body, a relatively large amount of current is needed to produce a harmful shock.

A person can obtain a shock without touching the active wire of the power supply by the following mishaps:

a. Many electrical appliances have metal casing. An active voltage can be actually shorted to the casing because of moisture, dust and deterioration of the equipment due to misuse or age. A person touching the casing could get a shock.
b. **The leakage current:** In all electrical equipments the intended current carrying parts are separated from the rest of the equipment by insulators. With high quality insulation materials and good circuit designs, there will be no problem with leakage currents but with poor designs, the leakage currents from the wires carrying the current will be hazardous.
c. **Two-pin connections:** It is important that all electrical equipments should have a three-pin connection with the earth connection to avoid the leakage currents and hazard from metal casings. The three-pin system offers the protection of the fuse blowing if there is a leakage or a metal casing is short-circuit. The three-pin system has the protective ground wire pin always longer than the others, to ensure that the ground connection is the first to be plugged in and the last to be unplugged.

The building itself must carry a good grounding system for the power supply.

d. Faulty components in instrumentation and monitoring devices can causes a shock. Faulty transformers or leaky capacitors in the instrument's power supply can be hazardous.

OTHER HAZARDOUS FACTORS

Short wave machines and microwave machines should not be placed close to an interferential machine as the latter will disrupt the frequencies particularly of the short wave machine.

A microwave machine should not have its antenna in such a direction. That it faces the open end of the room as there is quite a leakage of radiation from the microwave circuits. Patients and therapists with metal rimmed spectacles can also have microwave reflected to their eyes, particularly when treating the neck or shoulder region.

Interferential, short wave, microwave and ultrasound not be applied to any patient with a pacemaker as they will disrupt the operation of the pacemaker. In fact these machines have been shown to disrupt the operation of the pacemaker in a patient in the vicinity of the machine.

SAFETY FACTORS

The following safety precautions should be taken when using electrical equipment for therapeutic purposes.

Equipment use: All equipments which are enclosed with conductive materials must be connected to a three-pin supply plug.

The three-pin plug must be fitted into a power outlet. Do not use the same power outlet for two machines, by including an adapter.

Avoid the use of extension cords as they can increase leakage current flow to the ground, apart from the risk of somebody tripping over the cord.

Never pull the plug out of its socket by pulling on the wire.

Never drag short wave machines or microwave machines by the arms of the machine.

Be careful not to pull the cable connection of the movable angled ultrasound transducer head.

Always check the power plugs and outlet for any loose connections. Never disconnect a machine from the wall power outlet with the power turned up.

PRECAUTIONS AGAINST EARTH SHOCK

Physiotherapy departments should be so arranged that there is minimum danger of anyone making an earth connection while in contact with apparatus. Water and gas pipes should be out of reach of the apparatus and of patients receiving treatment. The floor should be of insulating material and should be kept dry, as water seeping through cracks in linoleum to a stone floor beneath can form an earth connection. If the floor is not of insulating material, a non-conducting mat should be placed under the patient's feet during electrical treatments.

Switches must break the live wire and fuses must be on the live wire, so that if an earth circuit is made and a large current passes, the fuse blows and stops the current flow. The metal casing of all apparatus must be connected to earth. Patients should not be permitted to touch the apparatus during treatment.

SECTION VIII

- Factors that Modify the Inflammation & Repair
- Equipment Selection & Application
- Treatment Planning
- Application of Modalities & Clinical Diagnosis
- Recent Development in Physiotherapy
- Splints, Braces & Orthoses

CHAPTER 34

FACTORS THAT INFLUENCE INFLAMMATION AND REPAIR

Although the process of inflammation and repair is predictable from one person to another, effectiveness and ultimate outcome are variable. Many factors influence the outcome.

A number of factors may modify all or some of the steps in the inflammation and repair processes. Factors such as advanced age, malnutrition, anemia, peripheral vascular disease, and the presence of infection hinder inflammation and repair. A few of these factors will be considered in greater detail.

1. **Age of the Patient:** Typically young people heal faster and more completely than do older individuals.
2. **Nutritional Status:** Healing may be delayed or incomplete in person who are nutritionally deficient or poorly nourished individual. Injury causes physiologic stress, which induces a hypermetabolic state. Wound healing depends on the available supply of amino acids, proteins, vitamins and minerals, and water, as well as sufficient calories from foodstuffs to fuel the inflammation and repair processes. Thus, individuals who are malnourished will not heal well. Major burns are once again a special consideration. Recovery from major burns entails a prolonged hypermetabolic state.
3. **Poor Circulation:** Individuals who are anaemic or have poor peripheral circulation may not heal as readily (example diabetics). Metabolic disorders may also interfere with wound healing. This is especially true for people with diabetes mellitus. People with diabetes are prone to peripheral vascular disease in both macrovessels and microvessels. In addition, peripheral neuropathies are common in diabetes, increasing the probability of traumatic injury to the limbs. Finally, a dampened immune response exists, which compromises the ability to combat infection. For all these reasons, people with diabetes are prone to soft-tissue ulcers that are slow to heal. There is now evidence that with non-insulin-dependent diabetes, excellent control of blood glucose and insulin levels is critical in preventing these secondary effects.
4. **Medication:** Many medications delay or prevent recovery from injury. Certain drugs can inhibit inflammation. Corticosteroids, such as prednisone and cortisol, are powerful anti-inflammatory drugs that stabilize cell membranes, thereby inhibiting production of prostaglandin and related thromboxanes and leukotrienes. These drugs are sometimes used for very severe acute inflammatory conditions or for chronic inflammatory conditions. In the latter case, however, they are not always the first choice because of their strong side effects. Non-steroidal anti-inflammatory drugs, such as aspirin and ibuprofen, also inhibit inflammation by interrupting the production of prostaglandins, but in this case, the mechanism in interruption of the pathway by which prostaglandins are synthesized from arachidonic acid. NSAIDs have fewer side effects than corticosteroids and are often used to reduce inflammation.
5. **Immobilization:** Prolonged immobilization promotes the development of adhesions and limited motion, even after normal healing. In fact, Immobilization aids early inflammation and repair. The need to apply a limb cast to immobilize a bone fracture or to suture a gaping soft-tissue wound seems self-evident, and there is good experimental evidence that immobilization produces faster healing, however, necessarily accompanied by adhesions and stiffness. Studies of animal models have demonstrated that immobilization for up to 9 weeks has caused adhesions in all areas of synovial joints and that the connective tissue has been biochemically altered, having abnormal collagen cross-linking and decreased elasticity. Remobilization is critical to recovery of function after inflammation and repair. For this reason, continuous passive motion (CPM) by machine is often employed as soon as possible after the injured area is stable. This is usually supplemented with active and passive range-of-motion exercises. Studies on dogs with tendon lacerations have demonstrated superior functional outcome with immobilization and early CPM, compared with immobilization only.
6. **Physical Agents:** Some physical agents can also affect wound healing. These include electrical stimulation, total-contact casting, ultraviolet, low-intensity laser, and thermal agents, including therapeutic ultrasound.
7. The extent, type, location of injury.
8. **Stress:** Many individuals exposed to excessive stress may experience difficulty in healing when injured.
9. **Psychological Status:** Some patients may not expect to recover from their injuries, others may not want to improve.

CHAPTER

35

EQUIPMENT SELECTION AND APPLICATION

- Equipment Selection
- Effects of Physical Agents on Mechanism of Pain
- Selection of Physical Agents for Pain
- Guidelines for the Application of Electrotherapy

EQUIPMENT SELECTION

When it time is to purchase electrotherapy equipment, several points should be considered. They are:

1. Avoid going for combined units *i.e.* a single unit that offers all of the modalities needed. This is because it becomes a serious problem when repairs are necessary.
2. Bigger is not always better. Home care conditions, and limited hospital space encourage use of small, portable units, not big ones.
3. Simple parameter controls are better than complex ones. It is commonly seen that complexity often leads to easy complications. You will find many of the staff never touch or change the settings established on the day of delivery.
4. If you put out low bid orders, make certain you request the specific parameters with desired equipment or you may wind up with at least expensive model.
5. Many companies offer rental prior to, or instead of, purchase. This is a useful concept if you are not sure of the need for the particular piece of apparatus.
6. Make sure that operational manuals are present with units.
7. Check serial numbers on delivered models as well as current inspection certification.
8. Having spares on hand for battery-operated units is must.
9. Attending conference and convention exhibit halls is a good way of learning about new equipments.

EFFECTS OF PHYSICAL AGENTS ON MECHANISM OF PAIN

Short Wave Diathermy

These diathermy agents help to relieve pain by producing vigorous heating effect. The physiological process involved is still uncertain. Pain relief obtained by heat is not long lasting.

Ultrasound

The conduction velocity of nerve is reduced if it is insonate with doses of 1–2 W/cm^2 ultrasonic energy. Painful areas sensitive to heat can be treated with pulsed ultrasound, where the micromassage effect blocks the pain pathways by lowering the conduction velocity. If the cause of pain is due to adhesion or contracture, ultrasound is effective in causing depolymerisation of mucopolysaccharide; mucoprotein or glycoprotein ultrasound is also able to alter the distribution of ion concentration at the pain receptor site. It causes increased diffusion of the analgesic plasma peptide and H ion concentration and thus remove the cause of pain.

Cryotherapy

Following effect can be obtained by lowering the temperature of the affected part. A slow down of the rate of conduction and the reduction of size of action potential is seen when the temperature is reduced to at least 10°C. Cooling causes a reduction in Acetyl Choline production and produces an asynchrony of impulses. This asynchrony can break the pain pattern and relieve chronic pain. Cold application with an ice cube massage at 0°C will act as an analgesic and a counter-irritant and relieve pain.

Decreased temperature decreases the activity of fusimotor efferent systems in muscles, thus relieving pain and muscle spasm. The reaction to cold is more lasting than to heat in pain and muscle spasm. This effect is also used for the control of spasticity.

Interferential Therapy, Diadynamic Current, Sinusoidal Currents

Interferential current and Diadynamic currents produce a variety of pulses which can relieve pain by two different mechanisms. A suitable current can be used to reduce pain perception by obtaining a counter-irritant effect. Other pulses can block pain pathways by acting on the large 'A' alpha fibres and inhibiting the pain at the spinal level through the presynaptic inhibitory mechanism.

Sinusoidal currents act as a counter-irritant measure while through-and-through faradism acts on the large A alpha fibres, "opening the gate" according to Melzack's "gate theory".

Patient suffering from partial peripheral nerve lesion, post herpetic neuralgia or causalgia have a loss of conduction of large 'A' alpha fibres. Pain occurs with gentle stimuli and occurs in paroxysms, characteristic of 'C' fibres. Loss of large 'A' alpha fibre may lead to pathologically increased spinal input via 'A' delta and 'C' fibres. If low frequency therapy or diadynamic current are used to activate large 'A' alpha fibre, then pain can be inhibited at spinal level.

Pain occurring from reflex sympathetic dystrophy, osteoporosis, shoulder-hand syndrome and vascular disorder can be treated by using interferential current or diadynamic currents on appropriate sympathetic ganglion, such as the stellate ganglion for shoulder hand syndrome.

Hot Packs, Paraffin Wax, Infrared

Hot packs and paraffin wax produce slow rising temperature and are sedative in action as they reduce nerve conduction velocity of the sensory nerve. As their depth of penetration is only to superficial level, it has been found that they reduce the temperature of underlying superficial joints, and in rheumatoid arthritis, this reduction of temperature in a joint with inflammation can relieve pain.

Infrared causes moderate rise in temperature that goes to the level of superficial muscle and relieves pain.

Use of Exercises with Physical Agents to Relieve Pain: Pain can be due to lack of movement and function of a part. This is because these factors can cause:

A. Aggravation of the bio-chemical situation at pain site, where local factors causing irritation of nerve fibres are unresolved.
B. Disturbance of the normal transmission of various patterns of afferent stimuli from the local area. These afferent stimuli come from stretch receptors present in joint and muscles. Others come from normal thermal, tactile, pressure and vibratory stimuli received on the skin or subcutaneous tissue during activity.
C. Anoxia due to impaired metabolism of muscle circulation increased muscle circulation, but upsets muscle metabolism and the ability of muscle and other soft structures to utilize the nutrition products of circulation.

SELECTION OF PHYSICAL AGENTS FOR PAIN

A. Acting at the pain:

Adhesions	–	Ultrasound
Scars	–	Short wave diathermy
Contracture	–	Microwave
Haematoma	–	Ice
	–	SWD
	–	Ultrasound
Inflammation	–	Short wave diathermy
	–	Microwave
	–	Ultrasound
	–	Wax
Infection	–	Ultraviolet rays
	–	Short wave diathermy
	–	Microwave.

B. Acting at the level of pain receptors:

By removal of pain metabolites and alteration of cell permeability:

Effusion	–	Ultrasound
Oedema	–	Ice

C. Acting at the level of pain perception and interpretation:

A counter-irritant effect produced by:

Interferential currents
Ultraviolet
Diadynamic currents
Sinusoidal currents
Acupuncture
Renotin Ionisation.

D. Acting to block the pathway:

Diadynamic currents
Interferential currents
Acupuncture
Ultrasound
Ice
TENS
Heat.

GUIDELINES FOR THE APPLICATION OF ELECTROTHERAPY

1. Is this treatment effective in producing required results? Many times, the result is known to be effective after having tried for few days or weeks, while in some other cases, effectiveness can be seen at once, *e.g.* relief of pain due to transcutaneous electric nerve stimulation or ice.
2. Whether the treatment is safe or not? *i.e.*, Will the desired results be achieved without undesirable effects? Each modality has its own potential dangers and contra-indications which should be considered thoroughly.
3. Is it the best method of treatment to achieve the required result? Whether it is economical for the patient and the therapist, or not ?

Various other considerations to make the treatment effective:

1. **Preparation of the Patient:** The therapist must explain the method of treatment to the patient prior to application. The type of sensation to be

experienced is explained. Also the patient is informed about the contra-indications and dangers that he can report.

The part to be treated should be thoroughly examined for possible contra-indications and the results should be recorded.

2. **Preparation of Apparatus:** All the apparatus and equipment should be gathered and checked. The electrodes, plugs, leads, power outlets, switches and cables, indicators etc must be properly checked.

   After being checked, the apparatus must be suitably positioned and any other necessary testing required should be performed prior to application.
3. **Preparation of the Part to be Treated:** In this, the part to be treated is washed and positioned comfortably, so that patient is relaxed and unnecessary movements are avoided.
4. **Instructions for the Patient:** Prior to application it is mandatory to instruct the patient about do's and the don'ts *i.e.* what he or she must and must not do.
5. **Application:** The patient must be under observation of therapist during the treatment, to ensure that treatment is progressing satisfactorily, and no adverse effect occurs.
6. **Termination of the Treatment:** At the termination, the part being treated must be observed for any sort of undesirable effect. Patient is instructed of when to come again and what is to be done in between.

   Also, after the treatment is over, the equipment should be carefully switched off and placed back to its place.
7. **Recording:** An accurate record of the treatment given and effects produced must be made for assessment purposes and legal requirements.

CHAPTER

36

TREATMENT PLANNING

INTRODUCTION

Clinical Decision Making in Electrotherapy

One can decide about which modality should be chosen in a particular instance but the real art lies not in selecting the modality but selecting it so that it fetches positive outcome. The questions like what, when and how should the modality be chosen, arise during clinical situations. It should be remembered that whatever is right and suitable for the patient should be followed.

Considerations before deciding treatment:

1. Previous experience of patient if he has taken the physiotherapy treatment
2. Irritability of the patient
3. Underlying pathology
4. Contra-indications
5. Medical condition of the patient
6. Special request by the referring clinician
7. Patient's comfort
8. Treatment time
9. Areas to be treated
10. Depth of penetration
11. Equipment availability
12. Reliability of the equipment
13. Familiarity with equipment
14. Proved outcome
15. Professional suggestions
16. Patient's response
17. Cost of treatment procedure.

Most of the physiotherapists decide about the electrotherapeutic modalities on the basis of their experience with similar kind of case. If their previous patient had responded to a modality, then they prefer the same one for their next patient with similar clinical problem.

Rule out the possibility of the contra-indications for the modality you have decided to use. If it's contra-indicated then think of any other modality that is not contra-indicated for that patient. For instance, you decided to use short wave diathermy but you came to know that your patient has got metal implant in the area of treatment then you can choose a modality like infrared or hot pack instead of short wave diathermy.

Patient Presentation

The primary goal of any form of therapy, whether it is manipulation, medication, electrotherapy, heat and cold, and so forth, is **to stimulate the body to perform a specific function.** In order to select the most appropriate form of therapy, it is imperative that the clinician recognizes the particular physiologic needs of the patient's condition and understand the principles of treatment as they apply to such a condition. Consideration must also be given to the contra-indications for treatment and to patient safety. Finally, in the changing health care environment, clinicians must consider the cost effectiveness of various treatment procedures.

The treatment processes itself the body's reaction to injury (both short and long-term), pain and pain mechanisms. Treatment procedures and protocols are presented in a practical manner with attention given to methods that have been found useful in clinical practice.

Patients present to the doctor with myriad problems and a variety of conditions, both physical and emotional. Some patients present with problems and conditions that are easily identified and provide the doctor with a clear clinical picture. For instance, the patient with a relatively minor ankle sprain does not require any particular diagnosis. Diagnosis is easy and treatment procedures are uncomplicated. Treatment for this patient is usually successful and recovery is quick and complete.

Other patients present with problems that may not be easily identified. The patient with a more severe injury may present with so much inflammation and pain that a complete examination may be difficult to perform. For example, the clinician presented with a patient suffering from an acute episode of lower back pain may be unsure whether the facet joints, the intervertebral disc, or the muscles are the source of pain. The physical and orthopedic tests that ordinarily provide useful information may all be positive owing to the degree of pain and swelling. Consequently, a clear clinical picture may not readily emerge and diagnosis may challenge physiotherapist. Initial treatment may require attention directed at the signs and symptoms.

Patients in this group represent a most difficult and sometimes perplexing clinical situation. Various treatment methods may be attempted with only limited success. When faced with an unresponsive patient, the clinician is challenged to discover the reason for the lack of improvement. Is it due to an inaccurate assessment of the patient's condition, to an inappropriate selection of treatment modalities, to a lack of compliance on the part of the patient, or perhaps to a combination of these factors? Treatment may need to be modified several times to determine the best method of managing the patient's condition.

The choice of which treatment is most accurate for any given condition varies from patient to patient.

Therapy that is effective for one patient may not necessarily be helpful for another who is suffering from a similar disorder. Likewise, the choice of which treatment to use for a given patient varies from physiotherapist to physiotherapist. The general practitioner confronted with a patient who is suffering from an acute episode of low back pain may prescribe moist heat, bed rest, and some form of pain relievers or muscle relaxants. The same patient presenting to physiotherapist undoubtedly will get very different care.

PROCESS OF CLINICAL DECISION MAKING

Step 1. Examine the patient.
Step 2. Evaluate the history and identify problems
Step 3. Determine the diagnosis
Step 4. Determine the prognosis and plan of care
Step 5. Implement the plan of care
Step 6. Re-examine the patient and evaluate treatment outcomes.

Process of Clinical Decision Making

Clinical decision making involves a series of interrelated steps that enable the physiotherapist to plan an effective treatment compatible with the needs and goals of the patient or client and members of the health care team. Important components of skilled decision making include adequate knowledge base and experience, cognitive processing strategies, self-monitoring strategies, and communication and teaching skills. Effective documentation is required for communication among the rehabilitation team members and timely reimbursement of services.

EXAMINE THE PATIENT

This step involves identifying and defining the patient's problem(s) and the resources available to determine appropriate intervention. It consists of three components: patient history, a review of relevant systems, and tests and measures. Assessment begins with patient referral or initial entry, and continues as an ongoing process throughout the course of rehabilitation. Re-examinations allow therapists to evaluate progress and modify interventions as appropriate.

History

Information about the patient's past history and current health status is obtained from the medical record and interviews. The medical record provides detailed reports from members of the health care team; processing these reports requires an understanding of disease processes, medical terminology, differential diagnosis using laboratory and other diagnostic tests, and medical management.

The interview is an important tool used to obtain information directly from the patient, family, significant others, caregivers, and other interested persons. Data that should be obtained include the patient's primary complaint, the history of the present illness or injury, knowledge of the medical condition, personal goals and expectations, and motivation. Information should be obtained about premorbid life style, including health habits, exercise likes and dislikes, and frequency and intensity of regular activity. Pertinent information about the patient's family or caregiver situation and home & work environments also should be gathered. Physiotherapist should be sensitive to differences in culture and ethnicity that may influence how the patient responds during the interview or examination process. For example, different beliefs and attitudes toward health care may influence how cooperative the patient is. During the interview, the therapist should listen carefully to what the patient says. The patient should be observed for any physical manifestations that reveal emotional context (*e.g.*, slumped body posture, grimacing facial expression, poor eye contact, etc.). Patient cooperation serves to make the physiotherapist's observations more valid and becomes crucial to the success of any physiotherapy program.

Systems Review

The use of screening or brief examination allows the physiotherapist to quickly scan the body systems: cardiopulmonary, integumentary, musculoskeletal, and neuromuscular. The data generated relates to specific anatomical and physiological dysfunction. Screening examinations indicate areas of deficit where more detailed assessments and interventions are warranted. They also allow the physiotherapist to determine if the patient's problems are outside the scope of physiotherapy. Thus, the patient, who presents with signs and symptoms of a significant medical condition, would be referred for consultation.

Tests and Measures

More definitive assessments are used to provide objective data to accurately determine the degree of specific function and dysfunction (*e.g.*, manual muscle testing, joint range of motion [ROM], oxygen consumption, etc.). Adequate training and skill in performing specific tests and measures are crucial in ensuring both validity and reliability of the tests. Failure to correctly perform a procedure can lead to the gathering of inaccurate data and the formation of an inappropriate plan of care. The use of a standardized assessment protocol can facilitate the evaluation process but may not always be appropriate for each individual patient. The physiotherapist needs to carefully review the unique problems of the patient to determine the appropriateness and responsiveness of an instrument. Physiotherapists should resist the tendency to gather excessive and extraneous data under the mistaken belief that more information is better. Unnecessary data will only confuse the picture, rendering clinical decision making more difficult and unnecessarily raising the cost of care. If problems arise that are not initially identified in the history or system's review, or if the data obtained are inconsistent, additional tests or measures may be indicated. Consultation with an experienced therapist can provide an important means to clarify inconsistencies and determine the appropriateness of specific tests and measures.

EVALUATE THE HISTORY AND IDENTIFY PROBLEMS

History gathered from the initial examination must then be analyzed and organized. Physiotherapists must consider a number of factors when evaluating data, including the level of impairments, the degree of functional loss, the patient's overall health and physical function, availability of social support systems, living environment, and potential discharge destination. Multisystem involvement, severe impairment or functional loss, extended time of involvement, co-morbid conditions, and overall instability of the patient are important parameters that increase the difficulty and shape the decision making process.

DETERMINE THE DIAGNOSIS

The development of a classification scheme of diagnostic categories unique to physical therapy is a natural outcome of organization, interpretation, and evaluation of data. **Diagnosis** is defined as a "label encompassing a cluster of signs and symptoms, syndromes, or categories." The use of diagnostic categories clarified the body of knowledge in electrotherapy and the role of physiotherapists in the health care system. It assists the physiotherapist in determining an effective plan of care and in selecting appropriate interventions. As the availability of direct access to physiotherapy services continues to expand, use of diagnostic categories can facilitate successful reimbursement, particularly when linked to functional outcomes.

DETERMINE THE PROGNOSIS AND PLAN OF CARE

The term **prognosis** refers to "the predicted optimal level of improvement in function and amount of time needed to reach that level." An accurate prognosis may be determined at the onset of treatment for some patients. For others, more complicated diagnosis such as the patient with severe traumatic injury, a prognosis or prediction of levels of improvement can only be determined at various increments during the course of rehabilitation. Knowledge of recovery patterns (stage of disorder) is sometimes useful to guide decision making. The amount of time needed to reach optimal recovery is an important determination. Predicting optimal levels of recovery and time frames can be very difficult for the inexperienced physiotherapist.

The **plan of care** outlines anticipated patient management. The therapist must integrate data obtained from the patient history and examination to determine the diagnosis, prognosis, and appropriate interventions. It is challenging, requiring skills in the interpretation and integration of data, and clinical reasoning. Essential components of the POC include (1) goals and outcomes, (2) specific interventions to be used, (3) duration and frequency of the interventions, and (4) criteria for discharge.

An important first step in the development of the plan of care is the determination of anticipated goals and outcomes. **Goals** refer to the remediation of impairments, to whatever extent possible; **Outcomes** refer to the remediation of functional limitations and disability, and the optimization of health status and patient satisfaction.

Involving the patient in determining goals and outcomes is critical in ensuring patient compliances. The therapist must follow a mutual planning process by asking the patient such questions as:

- What are your concerns?
- What is your greatest concern?
- What do you want to see happen?
- What would make you feel that you are making progress?
- What are your goals?
- What is your first goal?

The therapist can then use this information to generate goal and outcome statements that truly reflect patient needs and expectations.

Goals define the anticipated remediation of impairments, the outcomes of treatment. The therapist reviews the list of impairments, prioritizes them, and develops goals designed to achieve the anticipated outcomes.

Case management requires that therapists be able to communicate effectively with all members of the rehabilitation team, directly or indirectly. For example, the therapist communicates at case conferences, team meetings, or rounds. Therapists are also responsible for coordinating care at many different levels. For example, for early transfer training to be effective, consistency is important. Thus the therapist needs to communicate effectively with the occupational therapist, nurse, family, and other interested persons about the specifics of the approach being used. Coordinating with the patient and family for discharge planning is another example. The therapist delegates appropriate aspects of treatment to electrotherapy assistances or aids. Decisions must also be made concerning effective time management.

Direct interventions include a wide variety of procedures and techniques practiced by the physiotherapist, including therapeutic exercise, functional training, manual therapy, electrotherapy modalities, and so forth. Many of these interventions are the focus of later chapters of this textbook. Interventions are chosen on the basis of the data obtained, the diagnosis, prognosis, and anticipated goals and outcomes. It is important to identify all possible interventions early in the process, to carefully weigh those alternatives, and then to decide on those interventions that have the best probability of success.

A general outline of the treatment plan is constructed. For example is the frequency intensity-time-type (FITT) **equation** to prescribe exercise. An estimate is made of the:

- Frequency: Number of times per day or week treatment will be given.
- Intensity: Number of repetitions or activities.
- Time: Duration of the treatment session.
- Type of exercise: Specific physical therapy interventions.

IMPLEMENT THE PLAN OF CARE

The patient's pre-treatment level of function or initial state should be carefully assessed. General state organization of the central nervous system and homeostatic balance of the somatic and autonomic systems are important determinants of how a patient may respond to treatment. Patients with altered homeostatic mechanisms can be expected to react to treatment in unpredictable ways. Responses of treatment should be carefully monitored throughout the course of treatments, and treatment modifications implemented as soon as needed to ensure successful performance. Therapists develop the "art of clinical practice" by learning to adjust their input in response to the patient's movements. Treatment thus becomes a dynamic and interactive process between patient and therapist. Shaping of behaviour can be further enhanced by careful orientation to the purpose of the tasks and how they meet the patient's needs, thereby ensuring optimal cooperation and motivation.

RE-EXAMINE THE PATIENT AND EVALUATE TREATMENT OUTCOMES

This last step is ongoing and involves continuous re-examination of the patient and efficacy of treatment. The patient's abilities are evaluated in terms of the specific goals and outcomes set forth in the treatment plan. A determination is made as to whether the goals and outcomes are reasonable, given the patient's diagnosis and progress made. Thus the plan becomes a fluid statement of how the patient is progressing and where he or she is going. Its overall success depends on the therapist's ongoing clinical decision-making skills and on engaging the patient's cooperation and motivation. The level of patient and family satisfaction is an important outcome requiring assessment. Dissatisfaction is frequently the result of failure to fully involve patient and family in the clinical decision making process or to keep them fully informed.

Clinical Decision-Making Expert Versus Novice

Inherent to the physiotherapist's success in clinical decision-making are an appropriate knowledge base and experience, cognitive processing strategies, self-monitoring strategies, communication and teaching skills, and documentation. This information has important implications for novice therapists and for educators involved in teaching clinical decision-making.

DOCUMENTATION

Documentation is an essential requirement for timely reimbursement of services and communication.

Documentation is done both at the time of beginning of treatment and its termination.

Good documentation should include:

1. Patient's full name.
2. The manner in which physical therapy services are initiated.
3. Results of the history and initial examination.
4. Results of evaluation and diagnosis.
5. The plan of care including goals, outcomes and interventions.
6. Results of interventions or services provided, including patient status, progress or regression.
7. Re-examination and re-evaluation.
8. Summation at the conclusion of care (discharge note).

FOLLOWING CARE AND SERVICES PROVIDED BY PHYSIOTHERAPIST

Examining (history systems review, and tests and measures) individuals with impairment, functional limitation, and disability or other health related conditions to determine a diagnosis, prognosis, and intervention; tests and measures may include the following:

- Pain
- Aerobic capacity and endurance
- Anthropometrics characteristics
- Arousal, orientation, and cognition
- Assistive and adaptive devices
- Community and work (jobs/school/play) integration or re-integration
- Environmental, home, and work (job/school/play) barriers
- Cranial nerve integrity
- Ergonomics and body mechanics
- Gait, locomotion, and balance
- Reflex integrity
- Joint integrity and mobility
- Motor function
- Muscle performance
- Integumentary integrity
- Neuromotor development and sensory integration
- Orthotic, protective and supportive devices
- Range of motion
- Posture
- Prosthetic requirements
- Ventilation, respiration, and circulation.

Alleviating impairment and functional limitation by designing, implementing, and modifying therapeutic interventions that may include, but are not limited to:

- Communication, and documentation
- Patient-related instruction
- Therapeutic exercise
- Manual therapy techniques (including mobilization and manipulation)
- Prescription application, fabrication of assistive, adaptive, orthotic, protective, supportive and prosthetic devices and equipment.
- Airway clearance techniques
- Wound management
- Electrotherapeutic modalities
- Physical agents and mechanical modalities.

Preventing injury, impairment, functional limitation, and disability, including the promotion and maintenance of fitness, health and quality of life in all age populations.

Engaging in consultation, education, and research.

CHAPTER 37

APPLICATION OF MODALITIES AND CLINICAL DIAGNOSIS

- Method of Writing Case Sheet
- Special Case Studies
- Modalities Recommended
- Placement of Electrodes

METHOD OF WRITING CASE SHEET

No. 1: Write the case sheet for a man 25 yrs. old who has sustained fracture of Tibia and Fibula in a road traffic accident (RTA).

Name	:	ABC
Age	:	25 years
Sex	:	Male
Occupation	:	Business
Address	:	India.

Chief Complaints

- Pain in right heel while walking
- Pain increases during winter
- Problem in stair climbing
- Swelling at ankle.

History

- He had a fall due to accident leading to Tibia and Fibula fracture.
- POP cast for 6 weeks along with external fixation followed by bed rest for 3 months.

Present medication

- Coming to O.P.D. for physiotherapy treatment.

Observations General

Weight	:	63 kg
Build	:	Average
Heart Rate	:	69/min
Blood Pressure	:	120 mm of Hg
Respiration Rate	:	14/min
Diabetic	:	No
Hypertensive	:	No
Gait	:	Heel strike absent
Posture	:	Normal
Deformity	:	No.

Localised

Scar	:	At medial side of lower leg
Swelling	:	Over the ankle joint
Tenderness	:	At heel
Stiffness	:	Present at ankle joint
Tingling/Numbness	:	Absent
Sensations	:	Normal
Reflexes	:	Plantar normal Ankle jerk diminished.

Range of Motion

- Dorsiflexion : 0–10°
- Plantarflexion : 0–30°
- Inversion : 0–15°
- Eversion : 0–10°.

Manual Muscle Testing

- Dorsiflexors : 4
- Plantarflexors : 4^+
- Invertors : 3^+
- Evertors : 3.

Provisional Diagnosis

- Post fracture stiffness.

Management

- Wax Bath : Over scar and ankle
- Massage : Thumb pad kneading over scars
- Stretching :
  - Dorsiflexors
  - Plantarflexors
  - Evertors
  - Invertors
- Glides :
  - Talocalcaneal
  - Tibiotalar.

Home Advice

- Active movement of ankle
- Bicycling
- Stair climbing.

No. 2: Write the case sheet for a man 40 yrs. old suffering from low back pain (lumbago) since 13 months.

Name	:	ABC
Age	:	40 years
Sex	:	Male
Occupation	:	Gardener
Address	:	India.

Chief Complaints

- Pain at lower back
- Pain increases on coughing
- Forward and backward bending painful
- Pain increases on standing from sitting
- Pain in both legs during walking
- Tingling and numbness.

History

- Pain since last 13 months
- Pain started after lifting heavy box
- Pain increases after doing hard work.

Pain

- Moderate in lower back
- Moderately radiating to both legs.

Past Medical History

- Earlier took treatment at some other clinic, was advised hotpacks and ultrasound, but condition worsened.

Present Medical History

- After 05 months came to physiotherapy deptt. And is now undergoing physiotherapy treatment which includes Traction, I.F.T. exercises.
- Improvement noticeable.

Observations General

Weight	:	65 kg
Build	:	Average
Heart Rate	:	70/min
Blood Pressure	:	130/90 mm of Hg
Respiration Rate	:	13/min
Diabetic	:	No
Hypertensive	:	No
Gait	:	Normal
Posture	:	Erect.

Localised

Swelling	:	Not present
Tenderness	:	At L_5S_1 level
Tingling/Numbness	:	Present
Sensations	:	Present

Palpation

- Tenderness over L_5–S_1 region
- Pain in standing from sitting
- Pain in both legs during walking.

Special Test

- SLR test positive
- Figure of 4 test negative
- Lasegue's test positive.

Range of Motion

- Flexion and extension of back are restricted and painful.
- Lumbar extension – Difference of 1.5 inches
- Flexion – 3 inches
- Lateral flexion – 1 inch
- Rotation – 30°.

Manual Muscle Testing

- Back flexors – 4
- Back extensors – 4.

Radiological Features

- Osteophytes seen at L_5-S_1.

Provisional Diagnosis

- Lumbar spondylosis.

Treatment

- Exercises : Back extensors
  Spinal flexors.

Home Advice

- Spinal flexors exercises
- Back extensors exercise
- Avoid lifting heavy weights.

Prognosis

- Good.

No. 3: Write the case sheet for a woman 56 yrs. who is suffering from right shoulder pain after repeated trauma.

Name	:	XYZ
Age	:	56 years
Sex	:	Female
Occupation	:	Housewife
Address	:	Not available.

Chief Complaints

- Pain and tenderness in right shoulder and upper arm.
- Pain increases during dressing and combing.
- Patient gets awakened due to severe pain during sleep.
- Can't lean on the affected side.
- Can't lift anything by affected arm.
- Restriction of movement due to pain.

History

History of Trauma: Suffered a fall 3 years back but no fracture; sustained a trauma 3 months back at the same site aggravating the condition.

Past Medical History: Analgesics and intra-articular injection of hydrocortisone.

Pain

- Severe type leading to restriction of movements.

Present Medical History: Taking physiotherapy treatment since one month.

Observations (General)

Weight	:	48 kg.
Build	:	Poor
Heart Rate	:	65/min
Blood Pressure	:	140/80 mm of Hg
Respiration Rate	:	15/min
Diabetic	:	Yes
Hypertensive	:	No
Gait	:	Normal
Posture	:	Stooping with shoulder girdle held in elevation.

Localised

Swelling	:	No
Tenderness	:	Over the anterior aspect of shoulder
Tingling/Numbness	:	Absent
Sensation	:	Present
Redness	:	No
Temperature	:	No.

Range of Motion

Active ROM	:	Active range is not complete due to presence of pain at shoulder.
Flexion	:	100° 0–180°
Extension	:	20° 0–60°
Abduction	:	80° 0–90°
Ext. rotation	:	80° but pain during whole range 0–90°.
Int. rotation	:	70° but pain during whole range 0–70°.
Passive ROM	:	Full range of motion but it is very much painful.

Manual Muscle Testing

Flexors	:	3^+
Extensors	:	3
Abductors	:	4^+
Int. rotators	:	3^+
Ext. rotators	:	3.

X-Ray

- Decreased joint space, no other changes.

Provisional Diagnosis

- Frozen shoulder.

Management

- Rest
- Hot water bottle or hotpacks
- Mobilization:
  - Relaxation
  - Glides
  - Relaxed passive movements
- Soft Tissue Manipulation:
  - Kneading
  - Wringing
  - Passive stretching
  - Transverse friction massage
- Codman's exercises
- Free exercises
- Standing and "walking the fingers up the wall"
- Towelling action
- Mariner's wheel
- Overhead pulleys
- Auto-assisted elevation
- SWD
- Ultrasound
- IFT.

Home Advice

- Avoid heavy work
- Exercises.

Prognosis

- Good.

SPECIAL CASE STUDIES

Case Study 1

A 32-year-old graduate student reports to physiotherapy with complaints of right-sided scapular pain, neck pain, and occasional radiating pain to the right arm. There was no history of injury or previous pain in the areas. Over the past 4 months the pain has worsened to such a degree that it interferes with his daily activities and even sleeping.

Complaints

1. Pain with prolonged sitting (more than 30 minutes).
2. Exquisite tenderness to palpation over the levator scapulae on the right.
3. Decreased ROM of neck motions, primarily rotation and side bending.
4. Forward head posture with rounded shoulders in sitting.
5. Limited functional activities and increased difficulty sleeping.

Assessment Techniques

1. Pain quantity, quality, and location
2. ROM measurements
3. Strength measurements of scapular muscles
4. Postural assessment
5. Functional daily activities assessment.

Goals

1. Reduce pain
2. No abnormal tenderness to palpation
3. Increase ROM of the neck
4. Increase strength of the scapular muscles
5. Improve sitting posture.
6. Increase functional activities.

Case Study 2

A 45-year-old woman has had pain in the right cervical and interscapular area for approximately 2 weeks. The onset of pain was caused by repetitive activity in daily routine.

Problems

1. Irritation of right cervical and interscapular pain for about 1 to 2 hours following driving to work.
2. Limited functional activities secondary to limited cervical range of motion and pain.

Assessment Techniques

1. Pain quantity, quality and location
2. Functional daily activities assessment
3. Cervical range of motion assessment.

Goals

1. Reduce pain
2. Increase functional activities
3. Improve range of motion.

Case Study 3

A 26-year-old male patient has a patellar tendinitis. The insidious onset of pain occurred approximately 3 weeks ago. The patient used ice on the area, rest, and performed range of motion exercises.

Problems

1. Persistent pain in affected area
2. Limited functional activities.

Assessment Techniques

1. Pain quality, quantity, and location
2. Functional daily activities assessment.

Goals

1. Reduce pain
2. Increase functional activities.

Case Study 4

A 23-year-old male runner developed left Achilles paratendinitis while running. He was initially treated with ice and high voltage pulsed current and given a ¼-inch heel lift for a period of 72 hours. Swelling and pain subsided. He continued to have intermittent discomfort, however, 5 days post injury. Re-evaluation at that time revealed tightness in the gastrocnemius-soleus muscle complex with mild crepitation within the Achilles tendon.

Problems

1. Swelling in area of left Achilles tendon
2. Pain at left Achilles tendon
3. Mild crepitation within Achilles tendon
4. Limited functional activities.

Assessment Techniques

1. Pain quantity, quality, and location
2. ROM measurements
3. Functional activities assessment, including gait.

Goals

1. Decrease swelling and maintain the reduction
2. Reduce pain
3. Increase ROM of the foot and ankle
4. Increase strength of the foot/ankle musculature
5. Improve gait to normal
6. Increase functional activities.

MODALITIES RECOMMENDED

Modalities are recommended for specific conditions:

1. **Acute Pain:**
   a. Lidocaine iontophoresis or phonophoresis
   b. Tetanizing alternating current stimulation
   c. Cold laser.
2. **Sub-acute Pain:**
   a. Hydrocortisone iontophoresis or phonophoresis
   b. Salicylate iontophoresis
   c. Mecholyl iontophoresis or phonophoresis.
3. **Mild Pain/Discomfort:**
   a. Short wave diathermy
   b. Cold laser
   c. Infrared.
4. **Chronic Pain:**
   a. Hydrocortisone iontophoresis or phonophoresis
   b. Mecholyl iontophoresis or phonophoresis
   c. Salicylate iontophoresis or phonophoresis
   d. Slow-surged alternating current at 100 Hz.
   e. Short wave diathermy
   f. TENS
   g. Interferential current if pain is deep
   h. Transarthral surged alternating current if the pain is arthritic.
5. **Inflammation: General or Specific:**
   a. Hydrocortisone iontophoresis
   b. Hydrocortisone phonophoresis
   c. Cold laser.
6. **Oedema/Hyperemia:**
   a. Salicylate iontophoresis
   b. Mecholyl iontophoresis
   c. Slow surged alternating current stimulation.
7. **Ischaemia:**
   a. Iodex iontophoresis
   b. Short wave diathermy
   c. Mild infrared radiation
   d. Interferential therapy.
8. **Calcified Deposits:**
   a. Ultrasound
   b. Acetic acid iontophoresis
   c. Interferential therapy
   d. Acetic acid iontophoresis for myositis ossificans. Provided treatment is begun early in the condition, the sclerolytic effect of the acetate radical on calcium carbonate depositions may be effective in reducing the density and presence of calcific deposit in muscular pathologies, similar to the efficacy with calcific deposits in the bicipital tendon and subacromial bursae.
9. **Paresthesia: Neurovascular/Neuropraxia:**
   a. Iodex iontophoresis
   b. Cold laser
   c. Mild tetanizing alternating or direct current
   d. Slow surged alternating current
   e. Short wave diathermy.
10. **Weak, Atonic or Atrophied (From Disuse) Musculature:**
    a. Surged alternating current stimulation
    b. Interrupted direct current if RD is present.
11. **Adhesive Joints/Locking Joints (Snapping fingers):**
    a. Calcium chloride iontophoresis
    b. Iodex or salicylate iontophoresis
    c. Surged alternating
    d. Cold laser
    e. Ultrasound.
12. **Myospasm:**
    a. Magnesium sulfate iontophoresis
    b. Mecholyl iontophoresis
    c. Surged alternating current
    d. Interferential currents for deeper muscle groups.
13. **Fracture Healing:**
    a. TENS at a high rate with wide pulse width and lowest intensity is recommended.
14. **Bell's Palsy:**
    a. Treat Bell's palsy with hydrocortisone iontophoresis. Follow this by interrupted direct

current stimulation and, if available, application of cold lasers to the 7th nerve distribution-related acupuncture points.

15. Trigeminal Neuralgia:

For trigeminal neuralgia, administer lidocaine or hydrocortisone iontophoresis, cold laser, and TENS.

16. Reflex Sympathetic Dystrophy:

Treat sympathetic reflex dystrophy with Mecholyl iontophoresis TENS.

17. Prostatism:

For prostatism, administer short wave diathermy and electrical stimulation to the sacral nerve roots and gluteal musculature.

18. Stress Incontinence:

For stress incontinence, administer electrical stimulation, alternating current. Use an active vaginal electrode, followed by 15 min. of pelvic diathermy with surface drum or pad electrodes.

19. Sinusitis, Otitis Media, Bronchitis, Laryngitis:

Short wave diathermy is the treatment for sinusitis, otitis media, bronchitis and laryngitis, offering immediate and considerable relief for the patient either while other procedures are in progress or as interim treatment. In treatment of laryngitis, ultrasound over the anterior throat has proven an effective technique in rapidly returning voice quality to near normal.

20. Psoriasis:

Psoriasis has long been treated with ultraviolet irradiation, using crude coal tar preparations. Current procedures substitute plain white petroleum (vaseline) for the tar product with good results. PUVA techniques are still controversial and should be utilized with care and close cooperation with the attending dermatologist. Resistant, sclerotic plaques can often be softened with 1 minute of ultrasound following the ultraviolet radiation. For open lesions, cold laser is extremely helpful in speeding healing and closure.

21. Herpes Zoster:

The acute pain with intercostals shingles has been modified successfully with cold laser radiation to the appropriate nerve roots. Lasing precedes iontophoresis with lidocaine or hydrocortisone.

22. Pruritus After dialysis:

A single-case study indicated on effective anti pruritic procedure for severe generalized itching following dialysis session:

Ultraviolet radiation.

Various Electro Therapeutic Currents

Continuous galvanic current used in:

- Neuralgia
- Myalgia
- Preliminary treatment of physiotherapy
- Circulation disorders
- Neurotids
- Arthrosis deformities
- Iontophoresis
- Interrupted Galvanic Current
- Used for S-D curve plotting
- Stimulation of denervated muscles.

Faradic Current

Effects: giving tetanic contractions

- Acute pain
- Chronic pain
- Neuralgia
- Post operative pain
- Circulation disorders.

Medium Frequency Currents:

Effects: Muscular contraction, Oedema, Circulation improvement.

- Haematoma
- Flexion contractures
- Isometric and isokinetic training
- Muscular hypotrophy or weakness due to chronic polyarthritis.

Diadynamic Currents:

- Post traumatic conditions
- Neuralgia
- Circulation disorder
- Rheumatoid conditions.

1. Cruciate Ligament Strain:

Electrode type	–	Medium
Frequency	–	4,000 Hz
Base frequency	–	50 Hz
Spectrum	–	50 Hz
Spectrum mode	–	Trapezoid
Treatment time	–	10–15 min
Intensity	–	Slight current perception according to individual's tolerability, the current intensity should be increased with each application.
Sessions	-	6–8.

2. Ankle Distortion:

Electrode type	-	Medium
Frequency	-	4,000 Hz
Base frequency	-	100 Hz
Spectrum	-	50 Hz
Spectrum mode	-	Trapezoid
Treatment time	-	10–15 min

Intensity - Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Sessions - 8 to 10
Remarks - Fast relief can be obtained by interference current therapy in case of distortion.

3. **Tendopathy:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 50 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 10–15 min
Intensity - Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Sessions - 3 to 8.

4. **Herpes Zoster:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 150 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 10–15 min
Intensity - Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Sessions - 6 to 10
Remarks - Fast relief can be obtained by interferential current therapy.

5. **Raynaud's Disease:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 100 Hz
Spectrum - 75 Hz
Spectrum mode - Trapezoid
Treatment time - 10–15 min
Intensity - Slight to pronounced current perception, below motor threshold.
Sessions - 6 to 10.

6. **Lumbago (Low back pain):**
Electrode type - Large/Medium
Frequency - 4,000 Hz
Base frequency - 100 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 15–20 min
Intensity - Slight to pronounced current perception, below motor threshold.
Sessions - 6 to 8
Remarks - After the acute condition has subsided, muscle vibration may be triggered using the frequency range 1–10 Hz to normalize the tonicity.

7. **Spondylosis:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 80 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 20 min
Intensity - Slight current perception according to individual's tolerability.
Sessions - 5–8.

8. **Medial Ligament Strain:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 50 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 10–15 min
Intensity - Slight contraction when the contraction diminishes; increase the intensity to achieve a slight contraction again.
Sessions - 5–8.

9. **Ischialgia:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 120 Hz
Spectrum - 50 Hz
Spectrum mode - Trapezoid
Treatment time - 10–15 min
Intensity - Slight contraction when the contraction diminishes; increase the intensity to achieve slight contraction again.
Sessions - 6–9.

10. **Trigeminal Neuralgia:**
Electrode type - Medium
Frequency - 4,000 Hz
Base frequency - 150 Hz
Spectrum - 100 Hz

Spectrum mode	-	Triangular
Treatment time	-	15 min
Intensity	-	Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Remarks	-	Dose should be given carefully during the first few sessions since severe adverse reaction may be encountered. It is essential to inform the patient that there is reactive pain in most instances. Safer is the 3rd treatment where patient is usually free from pain.

11. Epicondylitis:

Electrode type	-	Medium
Frequency	-	4,000 Hz
Base frequency	-	80 Hz
Spectrum	-	40 Hz
Spectrum mode	-	Triangular
Treatment time	-	15 min
Intensity	-	Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Sessions	-	6–8.

12. Capsulitis:

Electrode type	-	Medium
Frequency	-	4,000 Hz
Base frequency	-	100 Hz
Spectrum	-	50 Hz
Spectrum mode	-	Triangular
Treatment time	-	15 min
Intensity	-	Slight current perception according to individual's tolerance, the current intensity can be increased with each application.
Sessions	-	5–8.

13. Hypertonic Trapezius Muscle:

Electrode type	-	Medium
Frequency	-	4,000 Hz
Base frequency	-	100 Hz
Spectrum	-	10 Hz
Spectrum mode	-	Rectangular
Treatment time	-	2–10 min
Intensity	-	Slight contraction when the contractions diminish, increase the intensity to achieve slight contraction again.
Sessions	-	6–8.

14. Muscles Strengthening:

Electrode type	-	Medium
Frequency	-	2,000 Hz
Base frequency	-	0 Hz
Spectrum	-	40 Hz
Spectrum mode	-	Rectangular
Treatment time	-	30 min
Intensity	-	Increase the intensity until vigorous yet well tolerable muscle contractions are elicited.
Sessions	-	5–10.

PLACEMENT OF ELECTRODES

Correct placement of the electrodes is one of the most important aspects of electrical stimulation. If other aspects of the stimulation protocol are set at the appropriate parameters, but the electrodes are improperly applied, in all probability the therapeutic objective will not be attained.

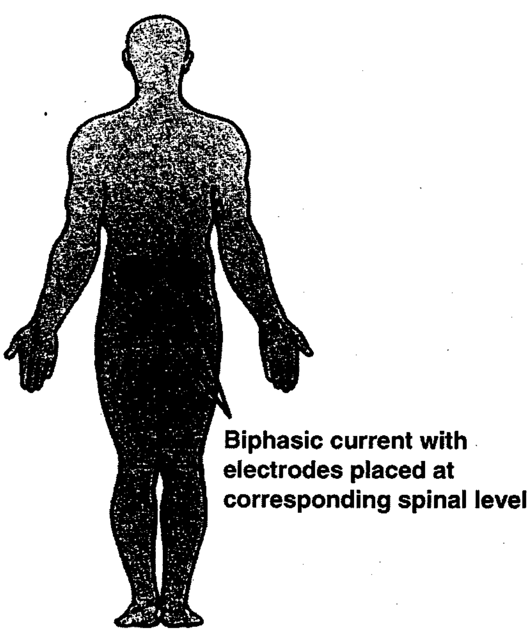

Fig. 37.1 *Electrodes may be placed at the level of the spine that corresponds to the painful area*

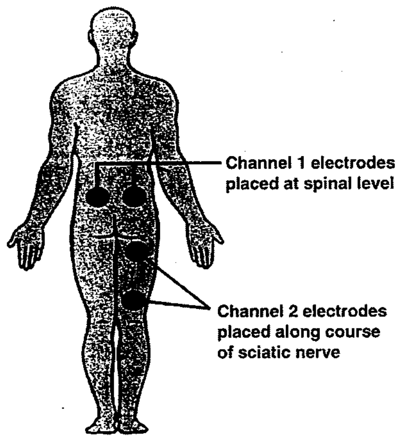

Fig. 37.2 *Electrodes may be placed along the course of an associated peripheral nerve*

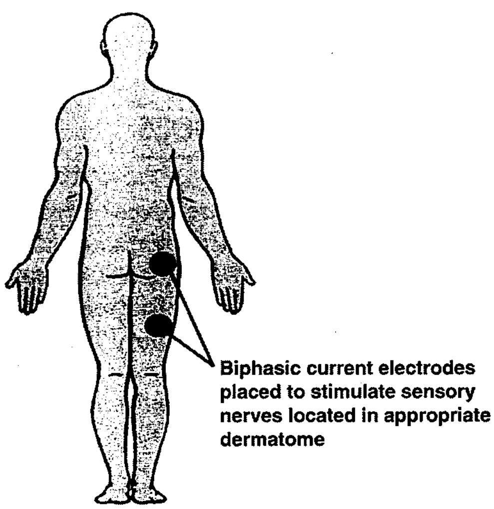

Fig. 37.3 *Electrodes may be placed along the course of an associated dermatome*

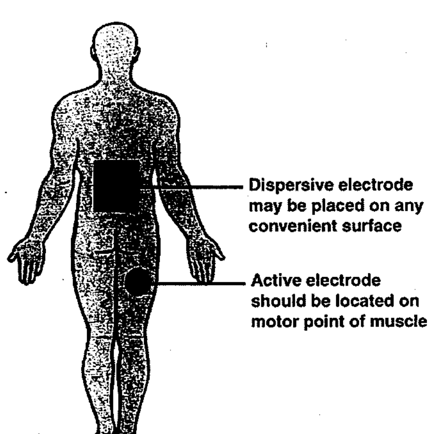

Fig. 37.4 *Electrode placement for muscle stimulation with a DC stimulator*

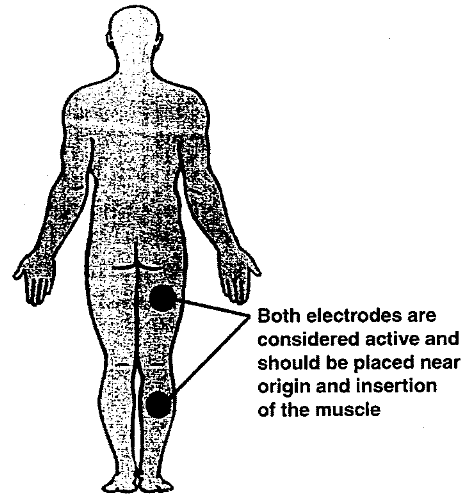

Fig. 37.5 *Electrode placement for muscle stimulation with an AC stimulator*

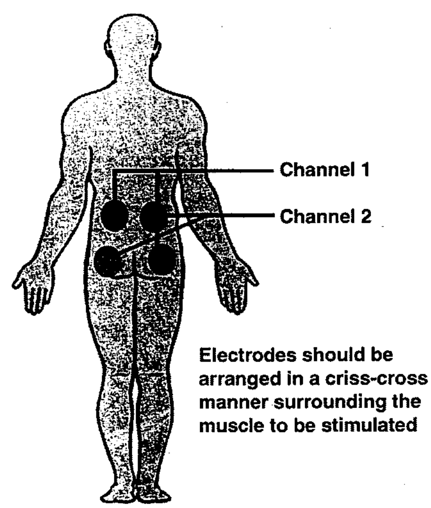

Fig. 37.6 *Electrode placement for an interferential current stimulation technique*

Fig. 37.7 *Traditional interrupted (pulsed) direct current for facial nerve neuropathy (Bell's palsy)*

Fig. 37.8 *The laser is administered intra-orally. Dental surgery had been performed on the previous day with packing in and around the operative site. The patient reported complete pain relief for several hours following lasing*

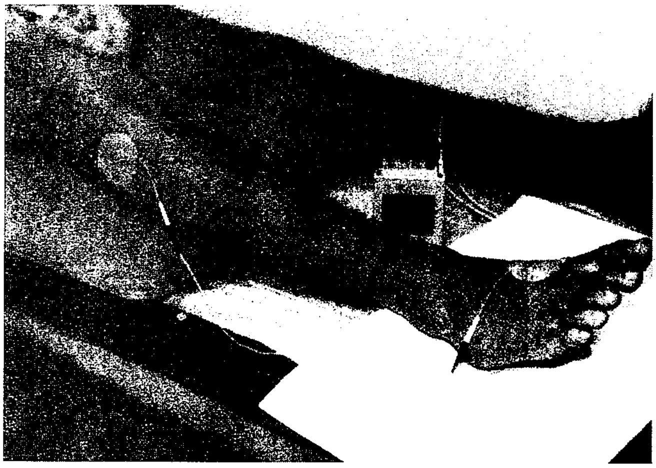

Fig. 37.9 *TENS applied at the fibular head and the dorsum*

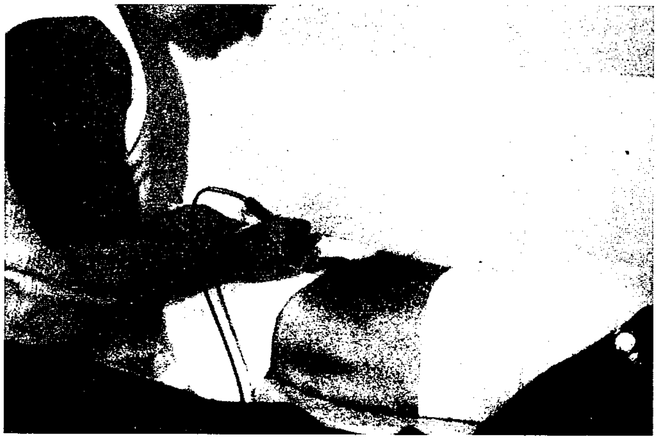

Fig. 37.10 *Cold laser to the fibrotic plaque zone*

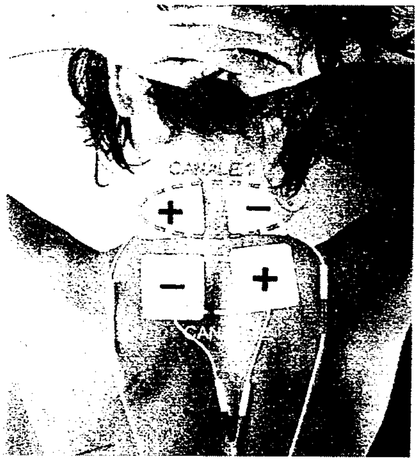

Fig. 37.11 *Cervicalgia*

Fig. 37.12 *Cervico-Brachialgia*

Fig. 37.13 *Cervico-Brachialgia with Diadynamics*

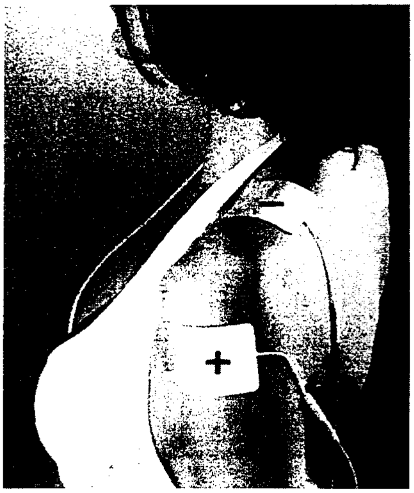

Fig. 37.14 *Shoulder Periarthritis*

Fig. 37.15 *Chronic Epicondylitis*

Fig. 37.16 *Acute Epicon Dylitis*

Fig. 37.17 *Carpal Tunnel Syndrome*

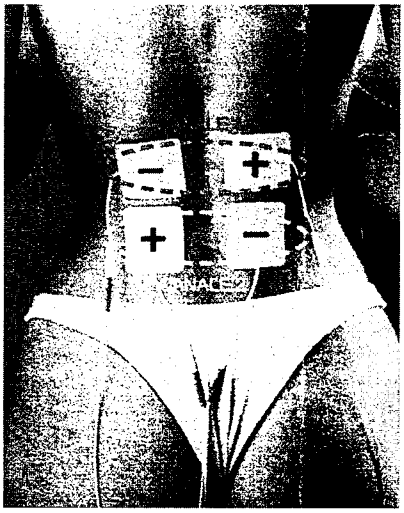

Fig. 37.18 *Lumbago*

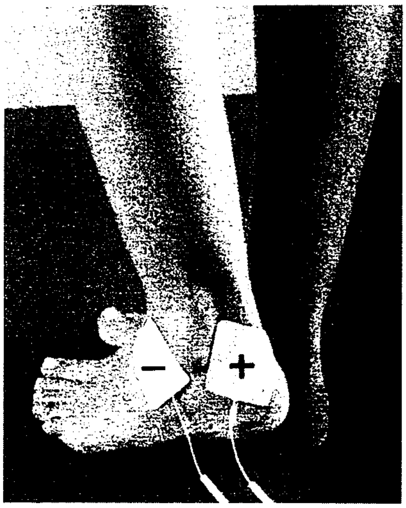

Fig. 37.19 *Ankle Sprain*

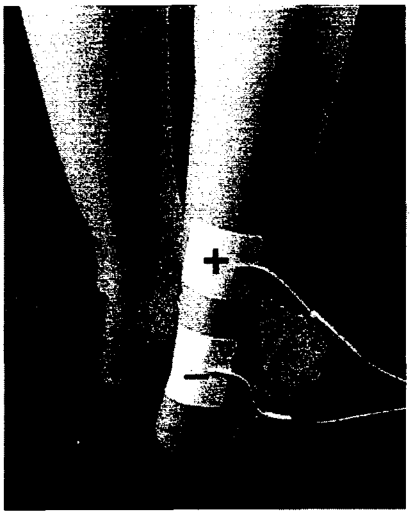

Fig. 37.20 *Acute Tenonitis*

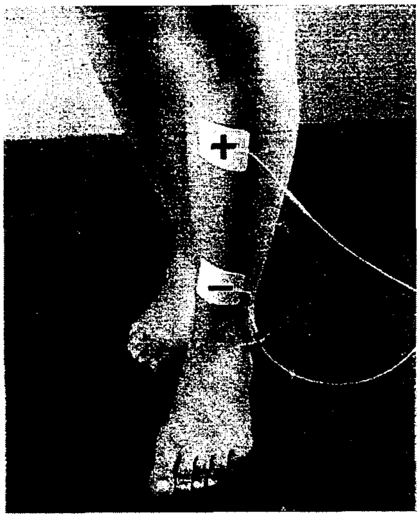

Fig. 37.21 *Periostitis*

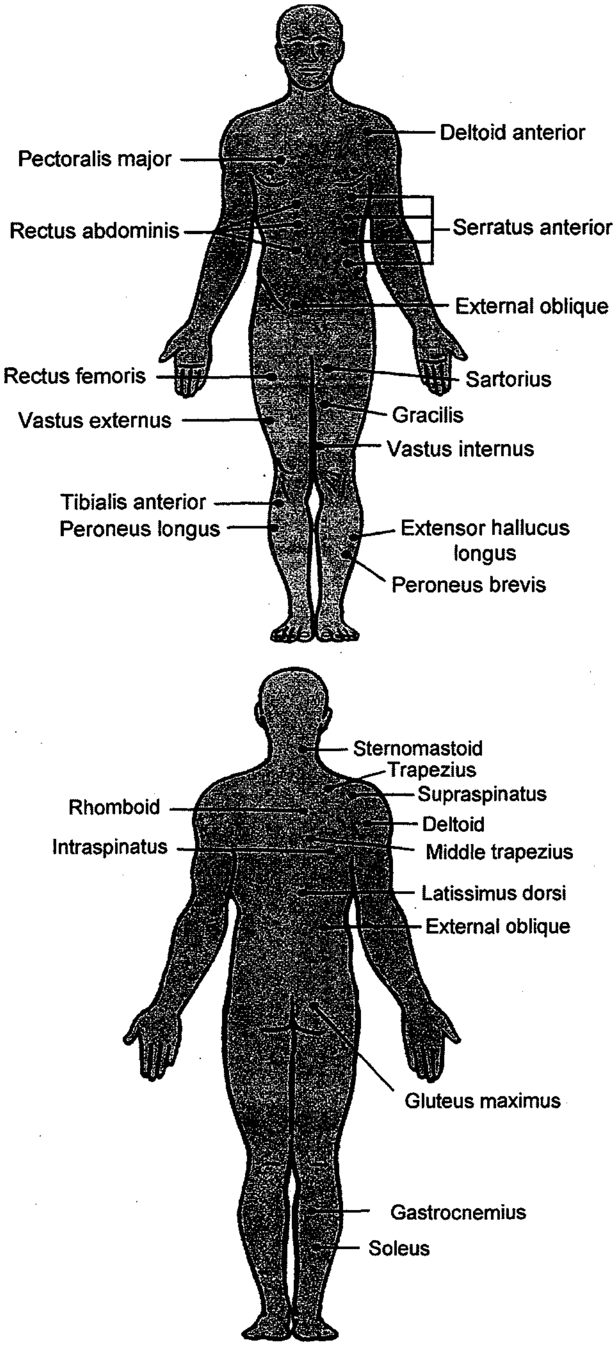

Fig. 37.22 *Motor Points*

CHAPTER

38

RECENT DEVELOPMENTS IN ELECTROTHERAPY

INTRODUCTION

Simultaneous electrical stimulation and ultrasound has yet to be proven more effective than each applied separately. A stimulation treatment lasts considerably longer than an ultrasound treatment. To avoid overdosing with ultrasound, it seems appropriate to utilize the "pulsed" mode of ultrasound, which, in effect, reduces the "on" time.

The main concern with this combined treatment, however, lies in another area: electrical stimulation is designed primarily to obtain muscular **contraction**. One of the characteristics of ultrasound is to increase tendon **extensibility**. It seems improbable that one would elicit maximum contraction or maximum relaxation if both modalities were administered simultaneously! If one were to assume that the relaxation obtained with the ultrasound would enhance the contraction with the electrical stimulation, the time factors for each would necessarily have to be ignored.

The electrical stimulation with cold laser radiation is another combination. The leading manufacturer of the He–Ne cold laser offers a model that includes microampere stimulation separately or combined with the laser. Variable waveforms make this unit useful with several conditions with simplified application techniques, using the laser wand for both modalities. The administration of both, separately, offers physical therapists ample opportunities to evaluate the efficacy of either. Just how necessary or important the combination are, remains to be seen.

A relatively new concept has appeared lately in the form of magnetic field therapy. The part to be treated is placed in a variable magnetic field, which is automatically pulsed by the physiotherapist. Pulse frequency is dependent on the condition, the severity and the goal (*i.e.* plan and healing).

The magnetic properties of the human body, the molecular polarization of the ferrous elements and the phenomenon of "alignment of polarities" of these particles within the magnetic field serve as a basis for this modality. Highly simplified "proper alignment" is associated with healthy tissues, while misalignment represents pathologic changes.

The magnetotherapy represents a step ahead in the field of magnetic therapy. The application of advanced technology makes it possible to use machines which can be constantly updated and integrated, which will be available in the years to come. Magnetic therapy equipment together with their applicators creates a magnetic field, whose intensity and frequency can be adjusted, producing an induction in the surrounding space.

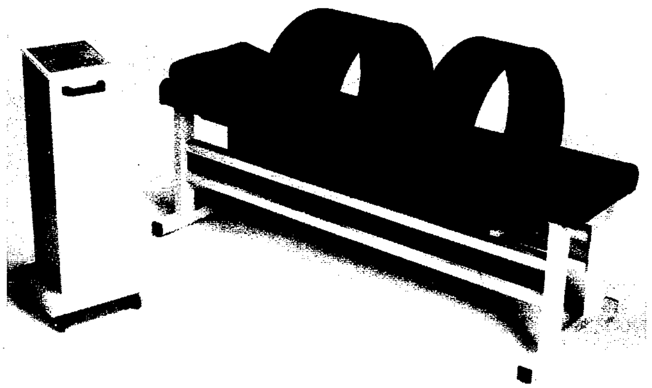

Fig. 38.1 *Available model magnetic therapy unit*

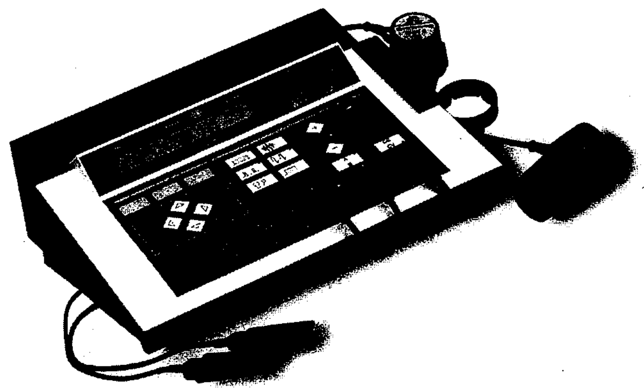

Fig. 38.2 *Combined unit for ultrasound and electrotherapy*

Fig. 38.3 *Electrotherapy ultrasound, laser magnetic therapy combined unit multifunctional equipment contains four apparatus in one unit: 1. Electrotherapy, 2. IR laser, 3. Ultrasound and 4. Magnetic therapy*

PORTABLE LIMB LOAD MONITOR

A versatile light-weight, patient-wearable monitor for use by therapists working in orthopaedics, physiotherapy and rehabilitation, particularly for gait and posture retraining with stroke victims.

This portable limb load monitor and movement sensor system equips therapists with instantaneous electronic feedback for a wide variety of patient load bearing and movement activities, using thin flexible load sensing pads. It gives your patients feedback when walking, in the sit-to-stand manoeuvre, for sitting, and when you are encouraging weight transfer. Patients quickly learn to monitor their own performance.

Audio signalling is provided (through headphones); a wide selection of load and time parameters is easily set and adjusted.

Use it for:

- Walking rehabilitation of stroke patients.
- Gait monitoring, including patient self-monitoring.
- Initiating movement by weight transfer for Parkinson's disease and stroke patients.
- Helping to correct uneven weight distribution in sit-to-stand manoeuvre.
- Working with cerebral palsy victims.
- Signalling incorrect seating position.
- Monitoring weight through leg of patient, after total hip or knee joint replacement.
- Assessing degree of degeneration of hip or knee.
- Helping patients to use crutches as an aid to unloading the foot.
- Monitoring of knee or elbow flexion/extension.

Fig. 38.4 *Set the desired limb loading, using weight scales*

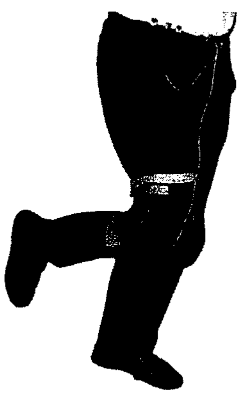

Fig. 38.5 *Movement sensor accessory gives feedback on joint angle*

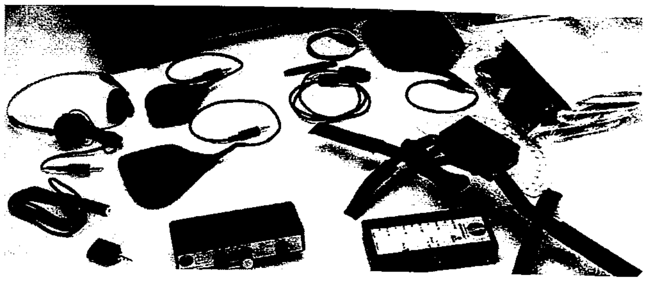

Fig. 38.6 *Complete limb load monitor unit*

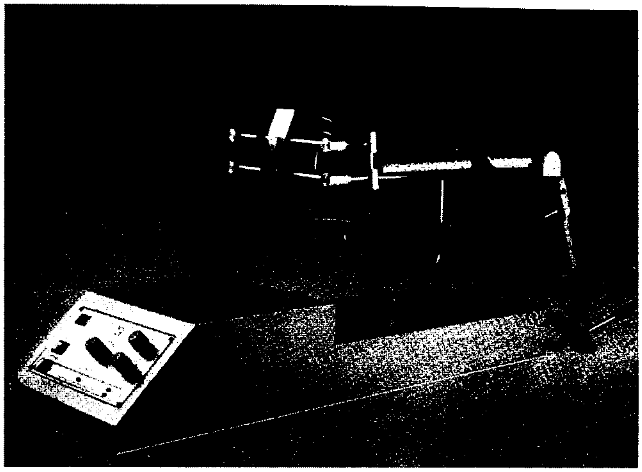

Fig. 38.7 *Continuous passive motion apparatus*

CONTINUOUS PASSIVE MOTION APPARATUS (FIG 38.7)

CPM is useful to treat joints of the lower limb after an injury, disease or following surgery. Based on a concept originated by Salter in 1970, this device has varied applications namely treatment of intra-articular fractures, septic arthritis, ligaments tendon healing and also following total joint replacement to ensure a sufficient range of motion.

To prevent stiffening, the joints have to be moved continuously which result in the following:

a. Minimize swelling and pain after operation.
b. Ensures faster recovery and shortened hospital stay.
c. Prevents extra-articular contractures and adhesions.

- Compact and elegant construction.
- Electronic controls enable all adjustment of angle to be made on the front panel.
- Smooth and silent movement.
- Digital timer with alarm.
- Patient safety switch for stopping and reversing the motion.

Fig. 38.8 *Automatic compression system*

AUTOMATIC COMPRESSION SYSTEM

Improves upper-lower limb lymph oedema, and post-traumatic oedema of the extremities, by promoting venous blood and lymph flow.

Features:

- Effectively designed pulse pressure intensity based on relevant research and experimental findings.
- Very comfortable and no physical irritation.
- Easy attachment and detachment of the air hose.
- Timer for setting the duration of treatment.
- Small, light weight for ease of transport.
- Use of the linear air compressor of low noise, easy maintenance, etc.

Applications:

- Lymph oedema
- Oedema of the legs
- Peripheral oedema
- Venous stasis ulceration
- Stump reduction
- Upper limb oedema
- Post-traumatic oedema of the extremities.

Contra-indications:

- Freshly developed deep vein thrombosis in the lower limb.
- Acute inflammatory and suppurative diseases.

Therapeutic Effects

1. **Improvement in peripheral circulation:** Blood circulation is promoted by repetitive inflation and deflation, as observed on thermography by an increase in skin temperature on the treated side.
2. **Effects on oedema:** The volumetric changes with time of the pressurized part is shown. This effect was observed to persist for at least 3 hours.
3. **Effects on venous blood return:** An increase in venous flow velocity at the inguinal region with repetitive inflation and deflation of the cuff around the lower limb may be confirmed by doppler flow meter measurements.

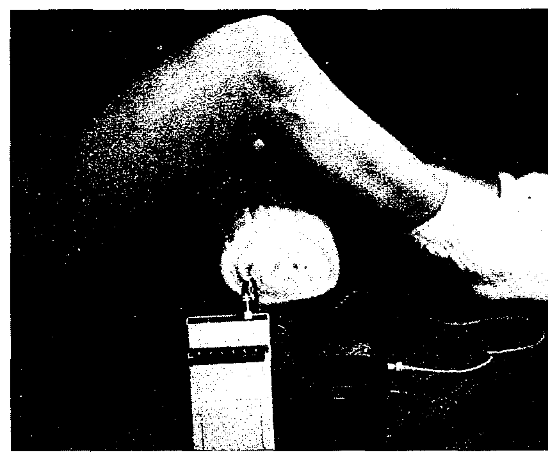

Fig. 38.9 *Compatible biofeedback unit*

COMPATIBLE BIOFEEDBACK UNIT

Patients: The documented results of muscle re-education therapy = Quicker muscle return.

Therapists: The results of using a portable, easy-to-use device = High utilization.

Third Party: Provides the satisfaction of hard copy compliance reports = Verifiable home compliance.

Muscle Stimulation Devices for Enhanced Muscle Re-education: When the patient exceeds the pre-determined EMG threshold, can trigger external muscle stimulation units, and optionally re-direct the NMES current through sensing electrodes.

Alerts the Patient to Undesirable Muscle Activity: They can identify and treat nocturnal brusxism. When excessive muscle EMG activity is detected and remains above a present EMG threshold, the audio can alert the sleeping patient to the undesirable muscle tension.

Home Therapy Performance and Compliance is Verifiable: Verifiable goals can be established for patient home therapy. Compliance and progress can be documented throughout the course of the home therapy program.

Female Urinary Stress Incontinence: Helps Patients Identify and Strengthen the Crucial Muscle: Perineometry at home helps patients with Stress /Mixed Incontinence verify that muscle recruitment exercises are performed correctly and consistently.

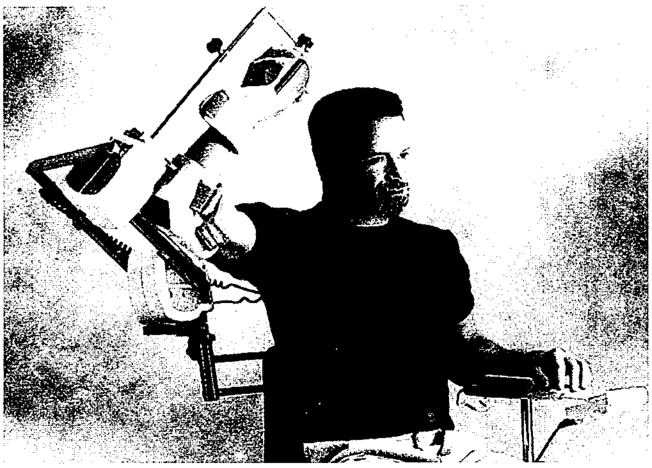

Fig. 38.10 *Anatomical shoulder CPM machine*

ANATOMICAL SHOULDER CPM MACHINE

- **Four functional movements**
  - Abduction/adduction with synchronized rotation.
  - Abduction/adduction with fixed rotation.
  - Rotation with fixed abduction/adduction.
  - Flexion/extension.
- **Maximised ROM and greater patient comfort**
- **Advanced control features, including**
  - The ability to make quick adjustments.
  - Pre-programme multiple protocols.
  - Use visual biofeedback.
  - Employ pauses...and many more.

Using a shoulder CPM for post-operative continuous passive motion therapy

- Breaks the cycle of trauma leading to inflammation and loss of ROM.
- Prevents joint stiffness in the shoulder.
- Speeds the recovery of post-operative ROM.
- Maintains the quality of the articular surface.
- Reduces pain and oedema.
- Diminishes the need for pain medication.
- Reduces hospitalization time.
- Decreases the cost of rehabilitation.

Indications for using a shoulder CPM

- Rotator cuff repair.
- Total shoulder replacement.
- Frozen shoulder.
- Fractures and dislocations requiring reconstructive surgery for:
  - Clavicle
  - Scapula
  - AC joint or glenohumeral joint.
- Capsulotomy
- Acromioplasty
- Burns.

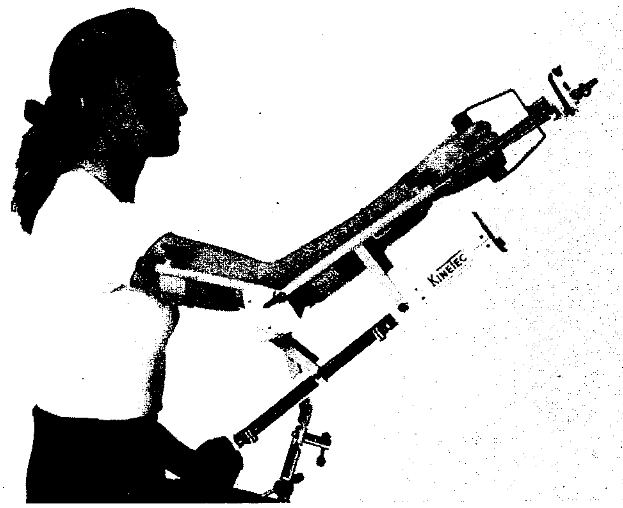

Fig. 38.11 *Elbow CPM machine*

ELBOW CPM MACHINE

- **Anatomical movements:**
  - Extension/flexion.
  - Extension/flexion with synchronized pronation-supination.
- **Easy to use:**
  - In a chair
  - In bed

Clinical benefits:

- Recovery of good range of motion.
- Recovery of physiological movement.
- Prevention of stiffness.
- Maintenance of the quality of the articular surface.

- Reduction of post-operative pain.
- Pronation 90° supination 90° achieved synchronously during flexion.

Indications:

- Intra-articular fractures of the elbow with O.R.I.F.
- Metaphyseal fractures in elbow area with O.R.I.F.
- Arthrolysis for post-traumatic stiffness with limitation of elbow joint motion.
- Release for extra-articular adhesions.
- Prosthetic elbow joint replacement.
- Synovectomy of the elbow.
- Arthrotomy and drainage of acute septic elbow joint.

CHAPTER

39

SPLINTS, BRACES AND ORTHOSES

Fig. 39.1 *Cervical brace*

CERVICAL BRACE

Features: Rigid, two-post, light metal construction with malleable plates for the chin, occiput, chest and back for proper contouring and fit on patient. Three sets of straps provide proper immobilization and secured fit: (a) Chin straps prevent rotation and lateral bending of the neck, (b) Shoulder straps with pads aid in proper immobilization fit, (c) Lateral straps prevent brace migration on usage. Foam padding provides cushioning comfort during extended use.

Fig. 39.2 *Cervical collar*

Applications: Used for post-traction, normal cervical spine alignment support in the case of dislocations and for support and immobilization to the fractured mid and lower cervical spine during pre and post-operative conditions.

CERVICAL COLLAR

Features: Made of high-density polythene sheet. Banian foam padding for comfort. Velcro closures for easy application, removal and adjustment. Holes provided for air circulation.

Applications:

- Cervical disc disease.
- Cervical Spondylolysis.
- Stabilization or hyper-extension of the cervical region.
- Torticollis.

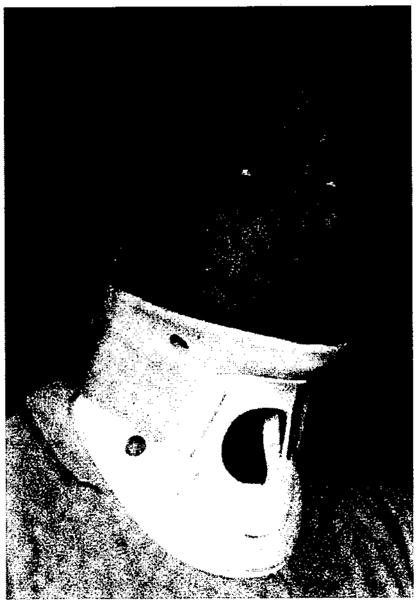

Fig. 39.3 *Providence collar*

PROVIDENCE COLLAR

Features: Two piece designs with padded chin cup. Large opening for tracheostomy, very light, ideal for extended use. Radiolucent allows X-ray while in position. Support strut for mandibular and occipital stability. Contoured shoulder and neck fit. Easy to apply velcro closures.

Applications:

- Can be used in the treatment of spondylosis.
- Spondylolisthesis, rheumatoid arthritis, cervical injuries.
- Fracture and for other conditions requiring support of the neck.

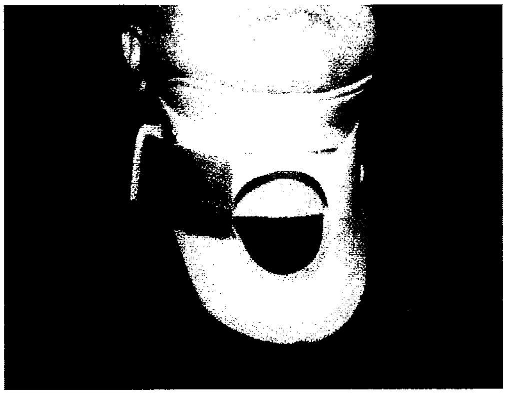

Fig. 39.4 *Ambulance collar*

AMBULANCE COLLAR

Features: Single piece, flat design with easy to form chin cup for quick application and convenient storage. Semi-rigid plastic, padded with sturdy foam, provides comfortable immobilization.

Applications: Temporary cervical immobilization for accident victims during extrication, transportation, diagnostic studies.

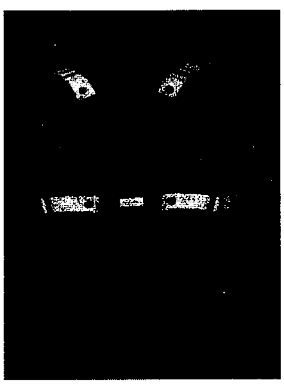

Fig. 39.5 *Spinal brace*

TAYLOR (SPINAL) BRACE

Features: Elastic abdominal panels provide the required compression. Thoracic straps of 4″ elastic provide comfortable fixation of the brace to the body. Two rigid upright para-spinal and lateral bars of lightweight are pre-contoured to keep spine in its natural position. Clavicle straps with cotton stockinet covered foam pads correct shoulder posture.

Applications: Used for post-operative rehabilitation, mild thoraco-lumbar injuries and herniated disc problems.

SACRO LUMBAR BELT

Fig. 39.6 *Sacrolumbar belt*

Features: Made of tempered steel strips, it immobilizes the lumbar and sacral regions effectively.

Since it is fully elasticated, it adds extra pressure and support to the sacral and lumbar regions.

Applications:

- Degenerative lumbar disc disease.
- Osteoporotic pain of the lumbar spine.
- Pot discectomy symptoms of the lumbar spine.
- Lumbosacral strain.
- To relax sacrospinal muscles to modify pelvic inclination and lumbar lordosis.
- To exert constant force on the lumbar spine and make the patient constantly aware of the back pain.

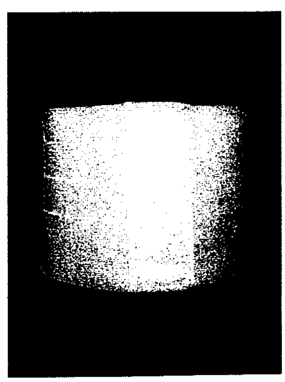

Fig. 39.7 *Abdominal support*

ABDOMINAL SUPPORT

Features: 8″ wide full elastic abdominal belt is ideally suited for patients required. Special stretch construction covers fully the area of incision and firmly holds dressings etc. in proper position. Special stays prevent the belt from rolling up. Elastic made of cotton and imported rubber is an assurance to comfort and durability.

Applications:

- Abdominal support after surgery. After delivery to support abdominal muscles.
- Abdominal hernia support.

WRIST AND ELBOW SPLINTS

Fig. 39.8 *Wrist and elbow splints*

DYNAMIC ELBOW FLEXION EXTENSION ORTHOSIS

Features: The prognosis of correction of deformity can easily be measured in degrees by referring to the measure provided over the spring cover.

Applications: Recovery is faster and better as compared to the conventional methods of elbow exercises.

Patient has liberty to carry out physiotherapy of elbow at any time and at any place.

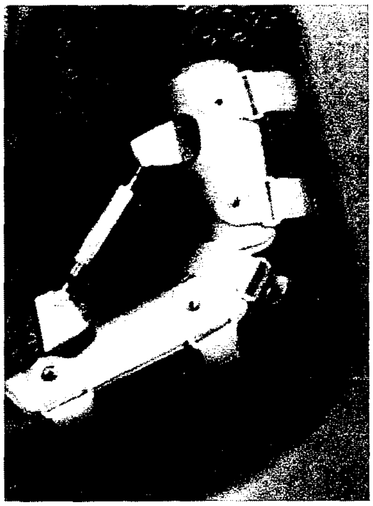

Fig. 39.9 *Elbow turn buckle splint*

ELBOW TURN BUCKLE SPLINT

Features: Innovative splint to correct contracture of elbow. Decreases the rehabilitation time so that muscular atrophy is prevented or lessened. Much better and faster results produced. Works on "three point fixation" mechanism.

Applications:

- Corrects contractures of soft tissues very fast as compared to conventional physiotherapy.
- Better compliance of the patient, as active physiotherapy becomes much easier than otherwise.
- Reverting on plastic material to protect against undue force while correcting (reverting gives way on undue force so that tissues are not damaged).

Fig. 39.10 *Static finger flexion assist*

STATIC FINGER FLEXION ASSIST

Applications: Flexes the PIP joint without interfering with the MCP joint. Distal phalanx is free to allow functional use of the finger pad. Lateral springs can be worn in the radial or ulnar side of the digit. Fits right or left hand.

Features:

- Springs can be bent to adjust tension.
- Can be used for PIP joint tightness.

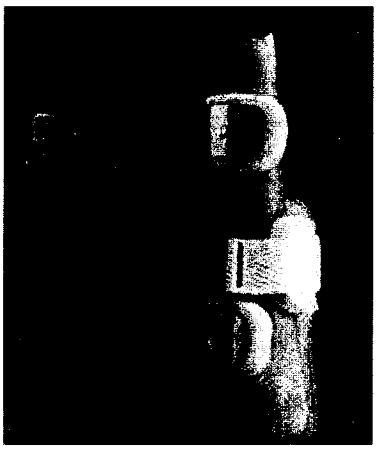

Fig. 39.11 *Finger Baseball splint*

FINGER BASEBALL SPLINT

Features: Best suited for protection and support to tip of finger. It flaps fold to maintain the finger in fixed position.

Applications:

- To prevent contractures due to burns.
- In the case of fractures and sprains.

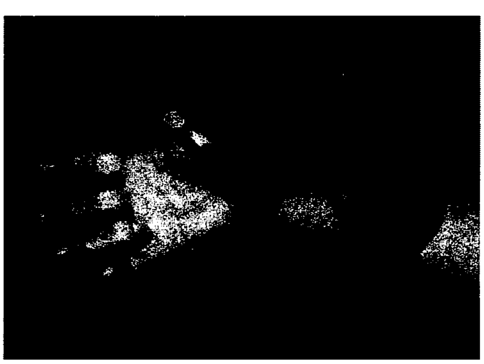

Fig. 39.12 *Thumb abduction splint*

THUMB ABDUCTION SPLINT

Features: Made of quality leather with suede lining for comfort and durability. Allows performance of routine tasks in comfort because it limits extreme motion of the joint of the thumb.

Applications: Designed for patients with painful wrist and thumb tendinitis.

Splint provides light compression to assist in decreasing pain and relieving inflammation.

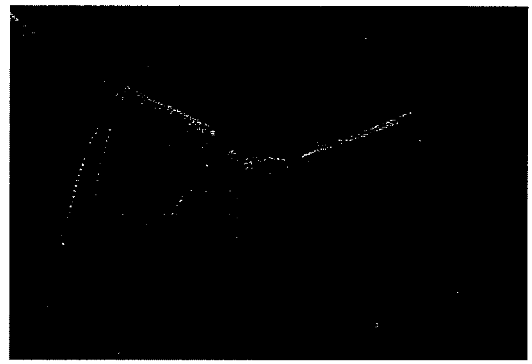

Fig. 39.13 *Elbow wrap*

ELBOW WRAP

Features: Breathable, high quality elastic band offers mild compression over the wrist joint. Velcro closure enables easy application.

Applications:

- Non-surgical care of strained or sprained wrist joint.
- Preventive care for the wrist during activities like sports, driving, household work and assembling jobs.

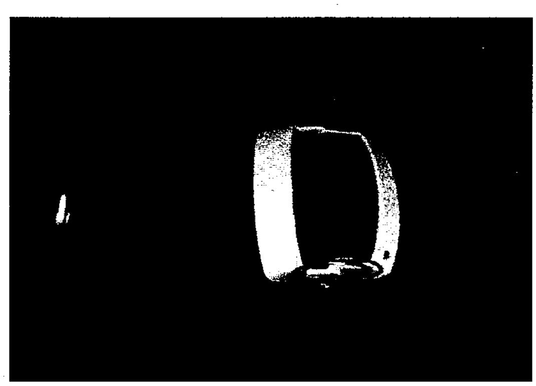

Fig. 39.14 *Knuckle bender*

KNUCKLE BENDER

Features: Concepts of circular stainless steel spring are applied to maintain constant pressure unlike rubber band. It is well padded, unbreakable, washable, reusable and economic.

Applications:

- To flex the metacarpophalangeal joints of the hand.
- The stainless steel springs are detachable to enable the increase and decrease in tension of the apparatus as per the patient's requirement.

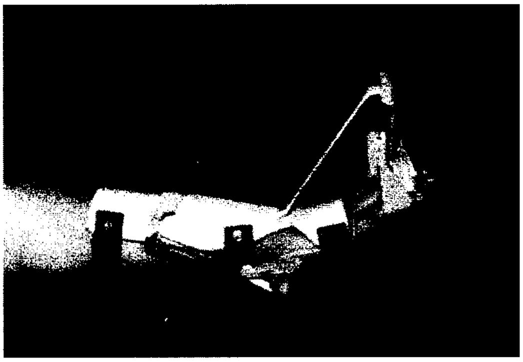

Fig. 39.15 *Dynamic cock up splint*

DYNAMIC COCK UP SPLINT

Features: Made of aluminium sheet, lightweight, easy to apply. It allows exercise against resistant to wrist, fingers and thumbs. Can be applied over plaster cast too.

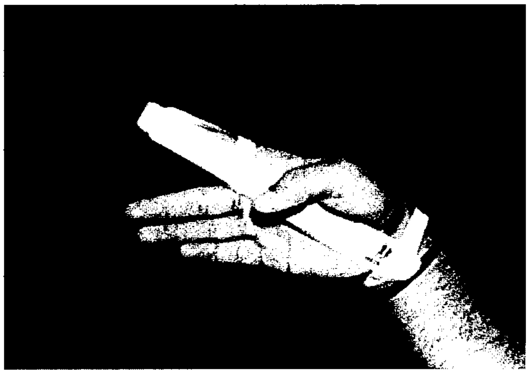

Fig. 39.16 *Finger extension splint*

FINGER EXTENSION SPLINT

Features: Plastic coated malleable aluminium can be molded to keep the interphalangeal joints in required position. Poly foam padding for comfort. Fits any finger. Can be molded by bare hands.

Applications:

- Immobilizes the fingers following reduction of fractures of proximal interphalanges.
- In extensor tendon injuries of the fingers.
- Collateral ligament injuries of the interphalangeal joint.
- Boutonniere's deformity.

KNEE CALF AND ANKLE SPLINTS

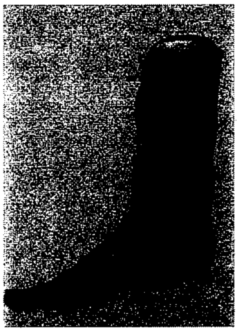

Fig. 39.17 *Knee calf and ankle splints*

ANKLE SUPPORT

Features: Can be fixed firmly to the ankle by Velcro straps. Constructed of semi-rigid outer shell and soft foam padding, provides lateral support, limiting inversion and eversion while allowing normal flexion. Designed to be worn inside laced shoes. Velcro closure allows quick application and proper fit.

Applications:

- Post-operative support.
- Sprains/strains.
- Fractures and cast removal.

Fig. 39.18 *Ankle support*

ELASTIC TUBULAR KNEE SUPPORT (WITH CENTRE HOLE)

Features: Made from soft yarns for comfort and will not loosen after prolonged use as it is made from imported heat resistant rubber.

Applications:

- Gives mild support and warmth.
- Ideal for arthritic conditions.
- Aids stiff, swollen and painful knee caused by weakness or strains.

Fig. 39.19 *Elastic tubular knee support*

ELASTIC TUBULAR ANKLET

Features: Made from soft yarns for comfort and will not loosen after prolonged use as it is made from imported heat resistant rubber.

Applications:

- Gives mild support and warmth.
- Ideal for arthritic conditions.
- Aids stiff, swollen and painful ankle caused by weakness or strains.

Fig. 39.20 *Elastic tubular anklet*

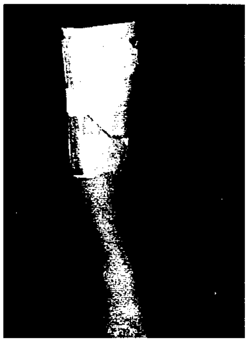

Fig. 39.21 *Knee Brace*

KNEE BRACE

Features: A practical solution to early cast removal. Insertible steel reeves effectively immobilize the knee after surgery. Spring steel stays on dorsal and lateral.

Applications:

- An excellent post-operative knee brace for knee injuries.
- Supportive therapy with maximum bracing.
- Pain relieving support for sprains, strains, muscle or ligament injuries.

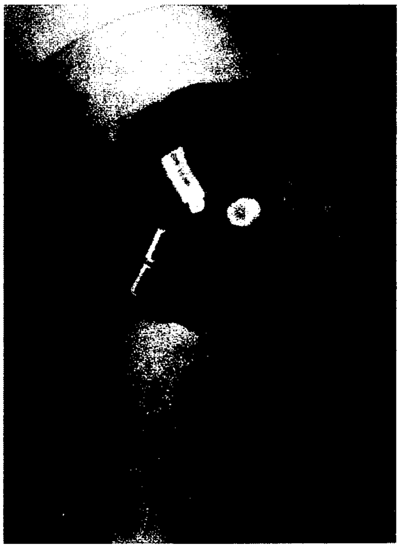

Fig. 39.22 *Functional knee support hinged*

FUNCTIONAL KNEE SUPPORT HINGED

Features: Excellent quality elastic 9″ width forms the main body of the support. Anterior patella hole and posterior cut out are provided to avoid bunching.

Applications:

- Non-surgical management of injured knee.
- Post-surgical rehabilitative support to the healing knee.
- Compression and support to prevent mild strain and sprain that may occur due to activities of daily living.
- To control painful knee movements in the case of arthritis.

Fig. 39.23 *Thigh band*

THIGH BAND

Features: High tenacity strap along the length of product maintains its tubular structure. High quality 8″ elastic band provides compression and support to thigh muscles.

Applications:

- Support in case of hamstring pull, quadriceps muscles strain.

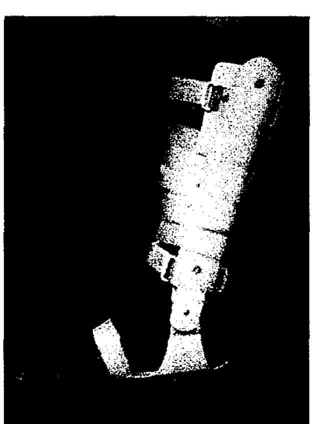

Fig. 39.24 *Tibial functional brace*

TIBIAL FUNCTIONAL BRACE

Features: Light weighted and comfortable. Weight bearing is allowable depending upon the condition of bone/fracture. Cosmetically highly accepted. Removable and hence care of skin is easy.

Applications: Period in plaster cast can be reduced significantly.

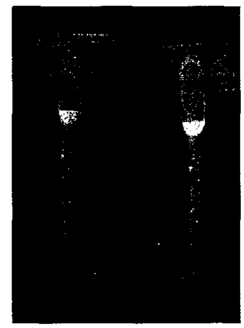

Fig. 39.25 *Fracture bracing joint*

FRACTURE BRACING JOINT

Features: Made of flexible, high-density nylon unbreakable plastic. Allows free motion of the knee. Attaches direct to both above knee and below knee sections to cast. Eliminates hinge misalignment.

Applications:

- Fracture bracing provides functional mobility and early ambulation in post acute fracture care.
- Provides early ambulation with fracture of distal femur and proximal tibia.
- In post acute fracture application, fracture bracing permits joint mobility and increased muscle activity.

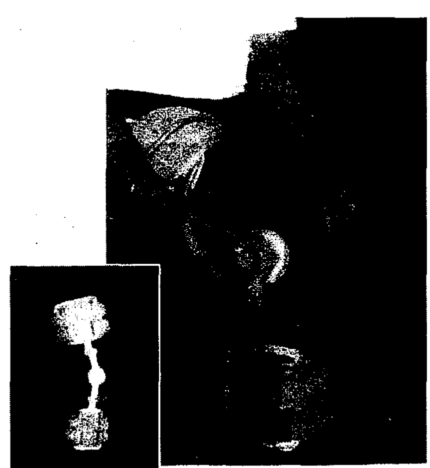

Fig. 39.26 *Functional knee brace*

FUNCTIONAL KNEE BRACE

Brace for protected range of motion for pre-operative, post-operative and rehabilitation management.

Features: Ideal for static, serial or dynamic splinting of knee flexion or extension. Interchangeable velcro straps to determine circumferences for right or left knee. Length adjustable to suite individual patient height by loosening of dial screw. Special padded fabric for comfort.

Applications:

- For controlled range of motion after injury to knee.
- Splint for some stable fractures at physician's discretion.

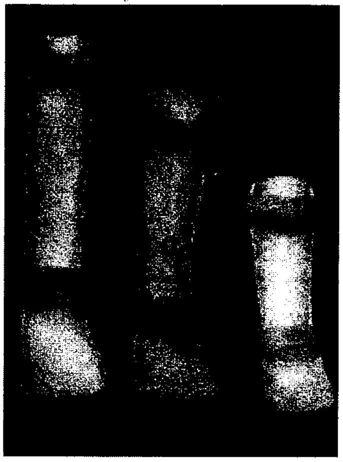

Fig. 39.27 *Foot drop splint*

FOOT DROP SPLINT

Features: Foot portion ends below the metatarsal heads. Can be used as a night splint for foot drop.

Applications: Lightweight, padded posterior leg splints for temporary or short-term immobilization of fractures and sprains.

ARCH SUPPORT

Features: No need to fabricate whole footwear, so saves both time and money. Available in four different sizes suitable to entire range of feet sizes and can be instantaneously fitted to the footwear in use as per the desired size. Better material than conventional materials in use, so better durability.

Applications: Flat foot condition.

Fig. 39.28 *Arch support*

GENERAL AIDS

Fig. 39.29 *Cuff weight belt*

THE CUFF WEIGHT BELT

Features: Four vertically sewn weight pockets permit cuff to bend freely to conform to any wrist or ankle contour. This unique design permits interchangeable use as a wrist of ankle weight cuff.

Applications: The weight cuff is the only weight belt you will need for a complete progressive exercise or therapy program.

UTILITY SPLINTS

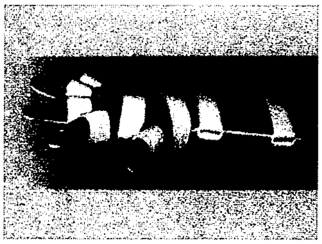

Fig. 39.30 *Volkmann's turn buckle splint*

VOLKMANN'S TURN BUCKLE SPLINT

Features: Innovative splint to correct Volkman's contracture. Much better and faster results produced. Works on "three point fixation" mechanism. Reverting on plastic material to protect against undue force while correcting.

Applications:

- Corrects contractures of soft tissues very fast as compared to conventional physiotherapy and other conventional splints.
- Better compliance of the patient, as active physiotherapy becomes much easier than otherwise.
- Decreases the rehabilitation time, so that muscular atrophy is prevented or lessened.

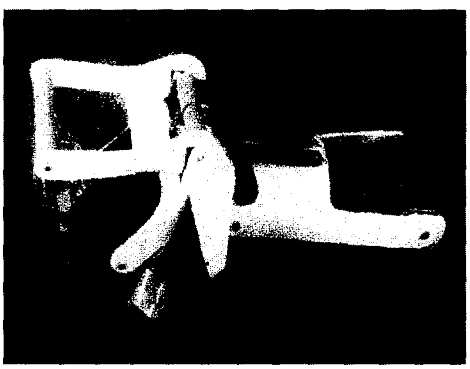

Fig. 39.32 *Dynamic radial palsy splint*

DYNAMIC RADIAL PALSY SPLINT

Features: Well padded, unbreakable, washable, reusable and economic. Finger-thumb attachments are optional. Adjustable wrist-tension by detaching one or two springs.

Applications:

- Used for mobilization exercises of fingers and wrist.
- For physiotherapy after extensor tendon repair.

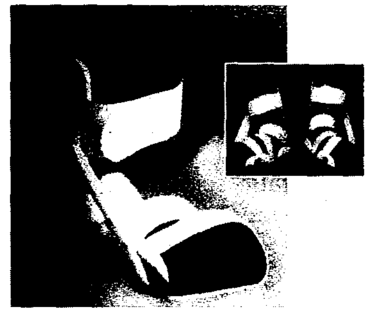

Fig. 39.33 *CTEV splint*

C.T.E.V. SPLINT

Features: The dynamisation is augmented by flexion-extension at the knee, while in use.

Applications:

- It effectively corrects forefoot varus by the molded plastic out flare, which is dynamised by the valgus strap.
- It also assists in correcting the equins as well as the medial rotation of tibia.

FOOT ANKLE LEG SPLINT

Features: It is well padded, unbreakable, washable, reusable and economic.

Applications:

- It is the most ideal alternative to wire splint or cumbersome POP slab, and is very easy to wear.
- It allows dressing to be done without disturbing the splint.

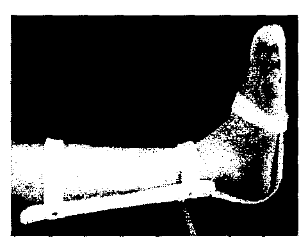

Fig. 39.33 *Foot ankle leg splint*

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Glossary

A

A BETA FIBRES Large, rapidly conducting superficial sensory fibres; they provide the vehicle for TENS applications and the pain-gating mechanism.

ABSOLUTE CONTRA-INDICATION Situation or condition that renders the use of a certain procedure or treatment inadvisable under any circumstances; no exceptions

ACCOMMODATION Adaptation by the sensory receptors to various stimuli over an extended period of time.

ACNE An inflammatory disease of the skin with the formation of an eruption of papules or pustules.

ACTINOTHERAPY Treatment of disease by rays of light.

ACTION POTENTIAL A change in the electrical potential between the inside and outside of a cell, resulting in depolarization.

ACTIVE ELECTRODE The electrode at which the greatest current density occurs.

ACTIVE RANGE OF MOTION That portion of the movement of a body part that a person can voluntarily create.

ACUPRESSURE A technique of using finger pressure over acupuncture points to decrease pain.

ACUPUNCTURE-LIKE TENS Treatment technique that involves electrical stimulation of acupuncture points to achieve pain relief.

ACUTE PAIN A short sharp cutting pain. It is usually associated with acute inflammation.

ACUPUNCTURE Treatment of human ailments by inserting fine needles into the acupuncture points.

A DELTA FIBRES Nociceptors that are mostly distributed throughout the superficial tissues of the body and in small numbers in the joints and muscles; they are sensitive to high-intensity mechanical stimuli.

ADHESION Fibrous band that holds together tissues that are normally separated.

AFFERENT NEURON Nerves that convey information toward the central nervous system (sensory).

ALL-OR-NONE RESPONSE The depolarization of nerve or muscle membranes is always the same; however, once a particular current intensity is reached, depolarization occurs; greater intensities will not produce stronger responses.

ALTERNATING CURRENT Current that periodically change its polarity or direction of flow.

ALTERNATING MODE An electrical stimulation parameter that involves the use of two electrical currents that are not active simultaneously; the current is directed to one channel, then to the other in an alternating manner; also referred to as a reciprocating mode.

AMPERE A unit of measure that indicates the rate at which electrical current is flowing.

AMPLITUDE The intensity of current flow an indicated by the height of the waveforms from baseline.

ANALGESIA The loss of sensibility to pain.

ANAPHORESIS The transmission of positively charged ions into tissues by an electrical current.

ANESTHESIA Partial or complete loss of sensations with or without loss of consciousness as a result of disease, injury or administration of an anesthetic agent usually by an injection or inhalation.

ANGSTROM An international unit used in measuring the wavelength of light.

ANION An ion carrying a negative charge and attracted to a positive pole.

ANODE The positive pole of an electrical source.

APPLICATOR The electrode used to transfer energy in microwave diathermy.

ARNDT-SCHULTZ PRINCIPLE For a reaction to occur in the body, the amount of energy absorbed must be sufficient to stimulate the absorbing tissues; weak stimuli increase physiologic activity and very strong stimuli inhibit or abolish activity.

ATTENUATION The act of thinning or weakening; a decrease in energy due to either absorption or scattering of ultrasound waves.

AVERAGE CURRENT The average amount of current that is delivered during a stimulation; the result of an interaction between the peak current and the pulse with.

B

BETA-ENDORPHIN A neurohormone that is similar in structure to morphine and has similar analgesic properties.

BIPHASIC CURRENT An alternating electrical current in which the direction of flow continually reverses.

BRIEF, INTENSE TENS A form of electrical stimulation with a short stimulus at a strong motor level intensity; a form of counter-irritant.

BURST TENS A current modulation that uses a high frequency current that is divided into a series of bursts or packets.

BURSITIS Inflammation of a bursa especially located between bony prominences and muscle tendon.

C

CABLE ELECTRODES An inductance type of electrode in which the electrodes are coiled around the body part; used in shortwave diathermy.

CATAPHORESIS The process of driving negative ions into tissues by using an electric current.

CATHODE A negatively charged electrode in a direct current system.

CAUSALGIA An extreme burning pain that represents a reflex vasomotor dystrophy.

CAVITATION The vibrational effect on gas bubbles by an ultrasound beam.

CHRONAXIE The time necessary to cause depolarization, given a current of twice the rheobase intensity.

CHRONIC OBSTRUCTIVE PULMONARY DISEASE A degenerative condition affecting the vascular, lymphatic, and pulmonary systems.

CHRONIC PAIN Pain that has been present for at least 6 months.

CIRCUIT The path of current from the generating source through the various components back to the generating source.

CONDENSER ELECTRODES An electrical current conducted back and forth between two electrodes; deep heating occurs between electrodes.

CONDUCTANCE The ease with which a current flows along a conducting medium.

CONDUCTION Heat loss or gain through direct contact (*e.g.*, hydrocollator packs and ice bags).

CONSTANT CURRENT Direct (galvanic) current; continuous non-pulsed current.

CONTINUOUS CURRENT An uninterrupted electrical current; may refer to either a pulsed or non-pulsed (galvanic) current.

CONTINUOUS PASSIVE MOVEMENT (CPM) A mechanical device that is used to improve healing in the synovial joints.

CONTRAST BATH Alternating applications of hot (106°F) and cold (50°F) treatments to stimulate superficial vascular flow.

COLLIMATION The process of making parallel.

CONNECTIVE TISSUE Tissue that supports and connects other tissues and tissues parts.

CONTRA-INDICATIONS Special circumstances or symptoms that render the use of a remedy or procedure inadvisable.

COSINE LAW Optimal radiation occurs when the source of radiation is at right angles to the area being radiated.

CPS An abbreviation for cycles per second; synonymous with Hertz; a measure of frequency.

CRYESTHESIA Abnormal sensitivity to cold.

CRYOKINETICS The combined use of cold and exercise in the treatment of musculoskeletal problems.

CRYOTHERAPY The use of cold in the treatment of pathology and/or disease.

CRYSTAL The part of the ultrasound head that vibrates and changes shape resulting in the emission of ultrasonic waves.

CURRENT The flow of electrons.

CURRENT DENSITY Amount of current flow per cubic area.

CYCLE One period of alternating current.

CRYANESTHESIA Anesthesia produced by the application of cold.

D

DECAY TIME The time required for a waveform to go from peak amplitude to zero volts.

DEPOLARIZATION The process of neutralizing the cell membranes resting potential.

DERMATOME The topographic area of skin that is supplied by afferent cutaneous fibres from a single posterior spinal nerve.

DIAPULSE Pulsed shortwave diathermy.

DIATHERMY The application of high-frequency electromagnetic energy to generate heat in the deeper body tissues.

DIELECTRIC A non-conductor of direct electric current; an insulator between two electrically charged plates.

DIODE A tube that contains two electrodes that pass current in one direction.

DIPLODE A diathermy induction coil drum with flexible hinges.

DIRECT CURRENT (DC) Electrical current that flows continually in one direction.

DISC HERNIATION Any disruption of the annular fibres of the intervertebral disc.

DISC PROLAPSE An intervertebral disc herniation characterized by displacement of the nuclear material; the prolapse is contained by the outermost fibres of the disc.

DISC PROTRUSION A distortion of the anatomic elements of the intervertebral disc without any internal disruption.

DUBOIS-REYMOND LAW It is the variability of current density, not the absolute value of current density at any given moment that acts as a stimulus to a muscle or a motor nerve.

DURATION Also referred to as pulse width; indicates the length of time from the beginning of one pulse of current to the end of the same pulse.

DUTY CYCLE A method of measuring the interruption of current flow in pulsed ultrasound.

E

EDEMA An accumulation of excessive fluid in the cells.

EFFERENT The conduction of a nerve impulse from the central nervous system to the periphery (motor).

ELECTRICAL CURRENT The flow of electrons in an electrical circuit.

ELECTRICAL POTENTIAL The difference in energy between charged particles at a higher and lower potential.

ELECTRICAL STIMULATION The application of electrical current to stimulate or depolarize nerve fibres, usually for therapeutic purposes.

ELECTRICITY A type of energy formed by the interaction of positive and negative charges.

ELECTRODE A surface from which an electrical current is discharged to a part of the body.

ELECTRODIAGNOSIS The determination of functional states of various tissues and organs according to their responses to electrical current.

ELECTROMAGNETIC OR INDUCTION FIELD A magnetic field that is not part of the circuit in which the patient is heated.

ELECTROMAGNETIC SPECTRUM The range of frequencies and wavelengths associated with radiant forms of energy.

ELECTROMOTIVE FORCE (EMF) The result of a difference in electrical potential between two points that causes a flow of electricity, measured in volts.

ELECTROMYOGRAPHY The direction and amplification of electrical signals generated by the muscle as it contracts.

ELECTRON Fundamental particles of matter possessing a negative electrical charge and extremely small mass.

ELECTROTHERAPY The application of electrical current for therapeutic purposes.

ELECTROSTATIC OR CONDENSER FIELD An area between electrodes in which the patient is placed and becomes a part of a series circuit.

ENKEPHALIN A group of pain-relieving neurotransmitters that inhibits the release of substance P.

EPISIOTOMY Surgical excision of the vulvar orifice for obstetric purposes.

ERYTHEMA Redness of the skin caused by capillary dilation.

EXOGENOUS Originating externally; not produced within the body.

EXOSTOSIS Bony outgrowth that arises from the surface of a bone.

F

FACET JOINTS Articular joints of the spine.

FACILITATE To ease or assist.

FARADIC CURRENT An asymmetric alternating current.

FAR ULTRAVIOLET Ultraviolet radiation with a short wavelength, farthest from the visible spectrum.

FIBROBLAST Any cell from which connective tissue is developed.

FIBROSIS Formation of fibrous tissue in the repair process following injury.

FREE NERVE ENDINGS Pain-sensitive nerve endings.

FREQUENCY The number of cycles or pulses per second; also called pulses per second (pps), cycles per second (cps), rate, pulse rate, and hertz (Hz).

FREQUENCY SWEEP A form of current modulation involving a variable or changing frequency.

G

GALVANIC CURRENT A non-pulsed, unidirectional (direct) current.

GATE THEORY OF PAIN CONTROL A theory of pain control that states that stimulation of large, superficial sensory fibres will inhibit the perception of pain.

GATE CONTROL THEORY Assumption which states that painful impulses can be prevented from reaching towards the higher levels of central nervous system by stimulation of large sensory nerve fibres.

GENERAL CONTRA-INDICATION A situation or condition that renders the use of a certain procedure or treatment inadvisable under certain circumstances; treatment may, under some circumstances, continue with caution.

GENERATOR An apparatus that converts mechanical energy into electrical energy.

GROTTHUS-DRAPER LAW Energy not absorbed by the tissues must be transmitted.

H

HAEMATOMA An area of swelling containing clotted blood, which is confined to an organ, tissue or space and caused by a break in blood vessel.

HAEMORRHAGE Tissue reaction to injury.

HAEMARTHROSIS Blood effusion into a cavity of a joint.

HERTZ A unit of frequency equal to one cycle per second.

HIGH VOLTAGE CURRENT Current in which the waveform has an amplitude of greater than 150 volts with a relatively short pulse width.

HIGH VOLTAGE GENERATOR (HVG) An electrical stimulation device that uses a voltage in excess of 150 volts.

HIGH VOLTAGE PULSED STIMULATOR (HVPS) An electrical stimulation device that uses a voltage in excess of 150 volts.

HYDROTHERAPY The application of both cryotherapy and thermotherapy techniques using water as the medium for heat transfer.

HYPALGESIA A diminution or lessening of sensitivity to painful stimuli.

HYPER A state of excess, or more than normal.

HYPERALGESIA An increased sensitivity to painful stimuli.

HYPERPLASIA An increase in the size of a tissue.

HYPERMOBILE A state of excess movement.

HYPERSTIMULATION A state of excess stimulation or excitement.

I

IMPEDANCE The resistance of the tissue to the passage of electrical current, measured in ohms.

INDUCTION The process by which a magnetizable body becomes magnetized when in a magnetic field, or by which an electromotive force is created in a circuit by varying the magnetic field linked with the circuit.

INDUCTION ELECTRODES Electrical current is passed through a coil that in turn gives off eddy currents of electromagnetic energy; this energy is absorbed by the tissues and heat is produced by tissue resistance.

INDICATION The reason to prescribe a remedy or procedure or modality.

INFRARED That portion of the electromagnetic spectrum that is associated with thermal changes.

INSULATOR Substance or the body that interrupts the transmission of electricity to surrounding object by conduction.

INTERFERENTIAL CURRENT (IFC) An electrical stimulator that employs two biphasic sinusoidal waves that are slightly out of phase with each other (medium frequency currents).

INTERMITTENT TRACTION A form of traction involving forces that are alternately applied and released.

INTERNEURONS Neurons contained entirely in the central nervous system; they serve as relay stations.

INTERPULSE INTERVAL The interval from the end of one pulse of current to the beginning of the next pulse, measured in microseconds.

INTERRUPTED CURRENT A flow of electricity that is frequently and regularly turned on and off.

INVERSE SQUARE LAW The intensity of radiation at any distance from the radiating source is directly proportional to the inverse of the square of the distance between the source of energy and the target.

IONIZATION The process by which neutral atoms or molecules become positively or negatively charged.

IONTOPHORESIS The use of constant direct current (galvanic) to drive ions into and through the skin.

ION A positively or negatively charged particle.

IRRADIATION Exposure to some form of radiation.

ISCHEMIA Local anaemia due to some type of functional or mechanical obstruction to circulation.

ISOKINETIC A form of exercise or muscle contraction that involves a constant or steady speed.

K

KIRCHOFF'S LAW The greatest level of heat is produced in the area of greatest current density.

KNEADING A type of therapeutic massage that incorporates pressing, grasping, and wringing of a part of a muscle or muscle group.

KROMAYER LAMP A trade name for a hot quartz ultraviolet lamp.

L

LATENT PERIOD That period of time between the initiation of a stimulus and the body's response.

LASER Acronym for the light amplification of stimulated emission of radiation. A beam of power can also be termed a Laser.

LIDOCAINE A chemical used for analgesia, often used with iontophoresis.

LONGITUDINAL WAVE That portion of the ultrasound wave that travels from the ultrasound head to the patient.

LoTENS Treatment technique that involves electrical stimulation of acupuncture points to achieve pain relief; also referred to as acupuncturelike TENS.

LOW VOLTAGE CURRENT Current in which the waveform has a maximal amplitude of less than 150 volts.

LUMINOUS The property to give off light; those infrared lamps that give off light or glow.

M

MAGNETIC FIELD A technique of heating the tissues seen in shortwave diathermy in which the patient is not part of the electrical circuit.

MAGNETRON A diode vacuum tube used to generate power in microwave diathermy units.

MANIPULATION A form of manual treatment directed at the synovial joints involving a quick thrust that is beyond the patient's ability to resist; specifically used to restore normal joint mobility.

McGILL PAIN QUESTIONNAIRE A pain measurement instrument and quantify, used to qualify pain.

MICROWAVE DIATHERMY A form of deep heating that uses a portion of the radio wave spectrum; sometimes used for tumor eradication.

MILD PAIN Does cause some suffering and rarely interferes with the person's emotional status; any changes are usually temporary.

MILLIAMPERE One-thousandth of an ampere; used in measuring the current intensity of most electrical stimulators.

MINIMAL ERYTHEMAL DOSE (MED) The least amount of ultraviolet radiation necessary to produce erythema.

MINIMAL PAIN Does not cause suffering and does not interfere with the person's emotional status; the injured individual usually does not seek professional help.

MECHANICAL EFFECTS One of the effects of ultrasonic treatment resulting from the vibration of molecules.

MECHANORECEPTOR A sensory nerve that is activated by some form of mechanical stimulus such as pressure, movement, or distortion.

MECHOLYL An ointment with 0.025% methacholine and 10% salicylate; an effective vasodilator that is used with phonophoresis for a variety of vascular conditions and neurovascular deficits.

MODE The method or manner in which something is done.

MODERATE PAIN Causes suffering and may interfere with emotional status; usually prompts a person to seek treatment.

MODULATION Alteration in the parameters of current to prevent accommodation.

MOIST HEAT A superficial thermal agent; usually applied with dampened cloth bags containing silica.

MONOPHASIC CURRENT A current in which the direction of flow remains the same; also known as direct current.

MONOPOLAR Having a single polarity or charge; refers to direct current devices.

MOTOR POINT The point where a motor nerve enters a muscle; identified by a reduction in electrical skin resistance.

MOTOR NEURON A nerve cell body in the central nervous system that is responsible for muscle contraction.

MYELIN A fatty material that surrounds the axons of certain nerve fibres.

MYOFASCIAL TRIGGER POINTS A focus of hyperirritability in a muscle which, when provoked, can refer pain, paraesthesia, and/or autonomic symptoms to an area that is specific for the muscle.

N

NEUROPATHY A disorder affecting a portion of the nervous system.

NOCICEPTOR A neuron that is stimulated by injury; a receptor for pain.

NON-STEROIDAL ANTI-INFLAMMATORY MEDICATIONS (NSAIDs) A type of pharmaceutical used to reduce inflammation.

NOREPINEPHRINE A neurotransmitter that may enhance pain.

NUCLEUS PULPOSUS The central portion of the intervertebral disc.

O

OCCUPATIONAL THERAPY A form of treatment directed at restoring an injured individual's ability to perform work.

OHM'S LAW The current in an electrical circuit is directly proportional to the voltage and inversely proportional to the resistance (*i.e.*, $I = v / r$).

OPEN CIRCUIT An electrical circuit that is not complete or not closed.

OSCILLATING CURRENT An alternating current with either a constant wave amplitude or a gradually diminishing amplitude.

OSTEOMALACIA A softening of the bones associated with progressive deformity.

OSTEOPOROSIS A condition associated with demineralization of the bones.

P

PAD ELECTRODES Capacitor type electrodes used with shortwave diathermy.

PARAFFIN BATH A combination of paraffin and mineral oil (melting temperature 126°F) that is used to increase the temperature of superficial tissue; commonly used in the hands and feet.

PARAESTHESIA Abnormal sensation; a sensation of itching, tingling, or pins and needles.

PASSIVE Being acted upon by external agents; characterized by lack of activity.

PERIOD The time required for one cycle of alternating current to pass through all of its positive and negative cycles.

PHONOPHORESIS The process of driving some type of medication into the subcutaneous tissues by ultrasound.

PHOSPHORESCENCE The induced luminescence that persists after the irradiation causing it has ceased.

PHOTOKERATITIS Inflammation of the eyes caused by exposure to ultraviolet rays.

PHYSICAL THERAPY The application of specific modalities such as heat, light, water, ultrasound, and electricity for the treatment of disease; a specific form of health sciences.

PIEZOELECTRIC EFFECT Generation of electrical charge across the crystal of piezoelectric substance on application of pressure or compression.

POLYMODAL NOCICEPTORS Small unmyelinated sensory fibres that respond to a variety of stimuli such as deep pressure and temperature (C fibres).

POLYPHASIC CURRENT Current that contains three or more grouped phases in a single phase; used in interferential and ``Russia" stimulation.

POTENTIAL In electrotherapy; refers to the difference in electrical energy from one point to another; measured in volts.

PRIME MOVER A muscle or muscle group that is primarily responsible for a given movement; an agonist.

PROPRIOCEPTION The sensation of body awareness.

PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION (PNF) A manual therapeutic procedure that is designed to re-establish coordination.

PULSE CHARGE The total accumulation of electrical current in a tissue.

PULSE DURATION The length of time from the beginning of one phase of an electrical pulse to the end of the same phase; usually measured in microseconds.

PULSED ULTRASOUND A method of administering ultrasound in which the production of sound waves is intermittent.

Q

QUADRIPOLAR An electrode placement technique; refers to the use of two bipolar currents found with interferential current stimulators.

R

RADIATION The process of emitting energy from some source in the form of waves; a method of heat transfer.

RADICULITIS Inflammation of a nerve root.

RECIPROCAL INHIBITION A physiologic principle stating that activation of one muscle or muscle group will produce inhibition of the reciprocal (antagonist) muscle or muscle group.

REFRACTORY PERIOD The period of depolarization of a nerve prior to its return to a normal resting state.

RESISTANCE Opposition to the flow of electrical current, measured in ohms.

RESISTOR A device or substance that inhibits the flow of electrical current.

RESONANCE An inherent state of vibratory activity.

REVERSE PIEZOELECTRIC EFFECT Deformation or oscillations of crystal of piezoelectric substance on application of electricity.

RHEOBASE The minimal amount of electrical current necessary to cause stimulation.

RHEOSTAT A device for regulating a current by means of varying electrical resistance.

RICE Rest, ice, compression, and elevation; the classic or standard treatment for the acute stage of injury.

ROCKER BOARD A therapeutic device that is used to establish balance and coordination.

S

SECOND ORDER PAIN Pain that is sensed or perceived after the acute phase; not first or primary.

SENSITIZATION The process of rendering a cell receptive to stimuli.

SEVERE PAIN A horrible pain that causes intense suffering and, by itself, functionally disables the patient.

SHORTWAVE DIATHERMY A form of deep heating therapy using a particular type of electromagnetic energy.

SLEEVE TEST T procedure used to determine the amount of ultraviolet radiation to be used.

SPASM An involuntary, sustained muscular contraction.

SPASTICITY Increased tone of muscles due to upper motor neuron lesion.

SPECIFICITY THEORY A theory of pain perception that states pain may only be perceived by specific nerve fibres.

SPRAIN An injury of ligament, which is less than complete.

STIMULATED EMISSION When a photon interacts with an atom already in a high energy state and decay of the atomic energy occurs, releasing two photons.

STRAIN An injury of muscle, which is less than complete.

STRENGTH-DURATION CURVE An illustration of the relationship between current intensity and current duration in causing depolarization of nerve fibres.

SUBACUTE The stage of injury that follows the acute or early period; associated with fragile, easily reinjured tissue.

SUBSTANCE P A pain producing neurotransmitter thought to activate the small diameter nociceptors.

SUBSTANTIA GELATINOSA An area in the dorsal horn of the spinal cord associated with the "gate theory of pain control".

SUBTHRESHOLD A stimulus that is inadequate to elicit a response.

SUMMATION PRINCIPLE Sequential stimuli that may be individually inadequate to evoke a response collectively are able to induce a nerve stimulus.

T

T CELL An internuncial (relay) neuron found in lamina V for the spinal cord.

TENDINITIS Inflammation of a tendon of muscle.

THERMAL ENERGY Energy that produces or extracts heat.

THERMOTHERAPY The therapeutic application of heat to treat pathology or disease.

TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) The process of delivering an electrical current through the skin via surface electrodes.

TRANSDUCER A device that changes energy from one form to another.

TRIGGER POINT Any localized area of body that, when stimulated by pressure, causes a sudden pain in a specific area.

U

ULTRASOUND A portion of the acoustic spectrum that is located above the audible sound.

ULTRAVIOLET That portion of the electromagnetic spectrum associated with chemical changes; it is located adjacent to the violet portion of the visible light spectrum.

V

VACUUM ELECTRODE A type of electrode with which suction is used to secure it to the patient; associated with interferential current stimulators.

VASOCONSTRICTION A narrowing of the blood vessels.

VASODILATATION A widening or opening of the blood vessels.

VECTORING The change in direction of electrical current used in interferential current.

VIBRATION A shaking massage technique that incorporates a fine tremulous movement.

VISCOSITY Relative position of fluid particles due to attraction of molecules to each other.

VOLT The electromotive force that produces movement of electrons.

W

WATT A measure of electrical power; watts = volts × amperes.

WAVE One wavelength; a single electrical impulse.

WAVEFORM The shape of an electrical current as displayed on an oscilloscope.

WAVELENGTH The distance from one point in a propagating wave to the same point in the next wave.

WEDENSKY INHIBITION A phenomenon in which the continuous stimulation of a nerve by a medium frequency electrical current leads to inhibition of painful impulses; thought to be due to fatigue of the sensory nerve or some form of nerve block.

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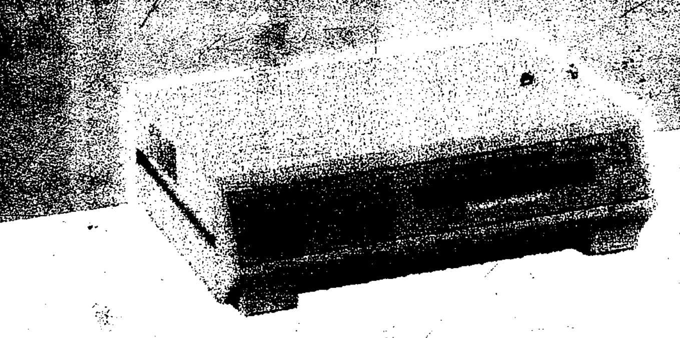

Helpline
Electrotherapy for Physiotherapists

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