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Textbook of
Electrotherapy



Jagmohan Singh

4th Edition

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3

CHAPTER

Low Frequency Currents

FARADIC TYPE CURRENT

Faradic type current is short duration interrupted direct current (DC) with pulse duration of 0.1–1 ms and frequencies between 50 and 100 Hz, used for the stimulation of innervated muscles. The term faradism was previously used to signify the type of current produced by the first faradic coil and was unevenly alternating current (AC) with each cycle consisting of two unequal phases **(Fig. 3.1)**:

1. Low-intensity long duration current
2. High-intensity short duration current

Faradic coils have now been replaced by electronic stimulators **(Figs. 3.2A and B)** which almost have the same physiological effect but differs in the waveform **(Fig. 3.3)**. The features essential for the production of these physiological effects are the impulses with duration of 0.1–1 ms with a frequency of 50–100 Hz.

Modified Faradic Current

For better results in the treatment, faradic current is always surged to produce a near normal tetanic-like contraction and relaxation of the muscle. The apparatus should have sufficient control to surge the current so that the intensity of successive impulses increases gradually with surges varying in waveform to provide satisfactory muscle contraction and relaxation.

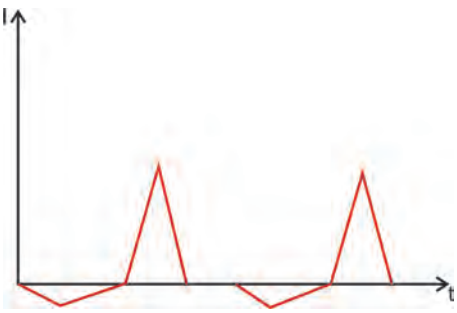

Fig. 3.1: Pure faradic current.

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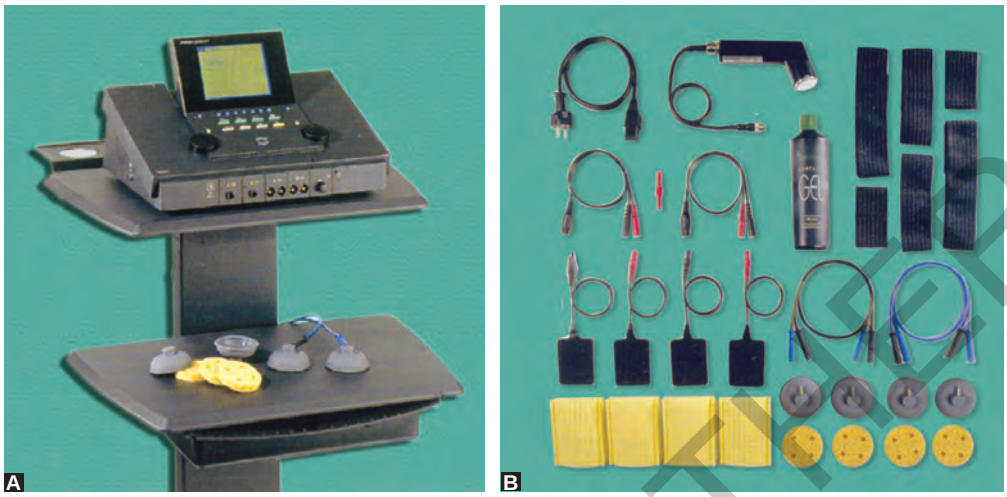

Figs. 3.2A and B: (A) Low frequency current apparatus; (B) Treatment accessories.

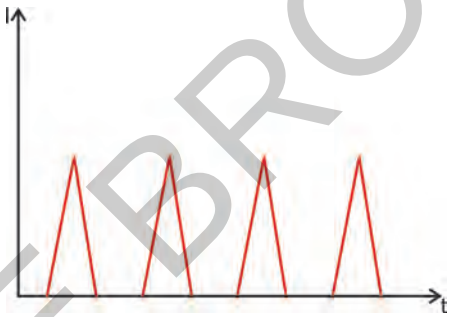

Fig. 3.3: Faradic current from electronic stimulator.

In the original faradic coils, the current was surged by hand but in modern stimulators an electronic device is used. The circuit can be modified to give surges of various durations, frequencies and waveforms. Various forms of surge are available, such as trapezoidal, triangular and saw-tooth impulses, and that most suitable for each patient must be selected **(Fig. 3.4)**.

ELECTROTHERAPEUTIC CURRENTS

Alternating, Direct and Pulsed Currents

Electrotherapeutic currents are basically of three types. These are: (1) *AC,* (2) *DC, or* (3) *pulsed.* Specific therapeutic effects are produced by these electrotherapeutic currents, which are capable of producing specific physiologic changes when introduced into the biological tissues.

Direct current also referred as galvanic current or *constant galvanism* which has a unidirectional flow of electrons toward the positive pole **(Fig. 3.5A)**. In modern devices, the polarity and thus the direction of the flow of current, can also be reversed. The therapeutic use

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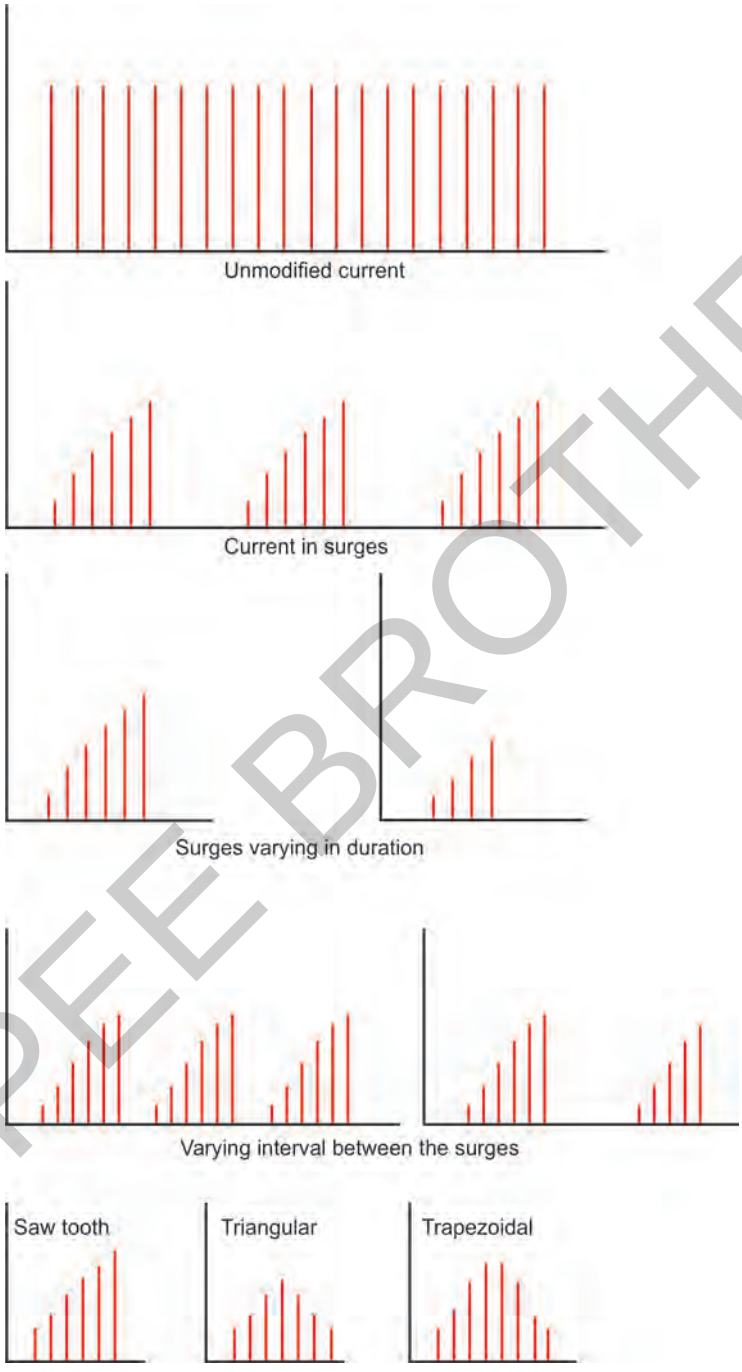

Fig. 3.4: Unmodified and modified (surged) form of faradic current.

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of this unidirectional flow of current is to introduce medication into the body tissues is called as iontophoresis (*LeDuc*, 1903). Some apparatus have the capability of automatically reversing polarity, in which case the physiologic effects will be similar to AC.

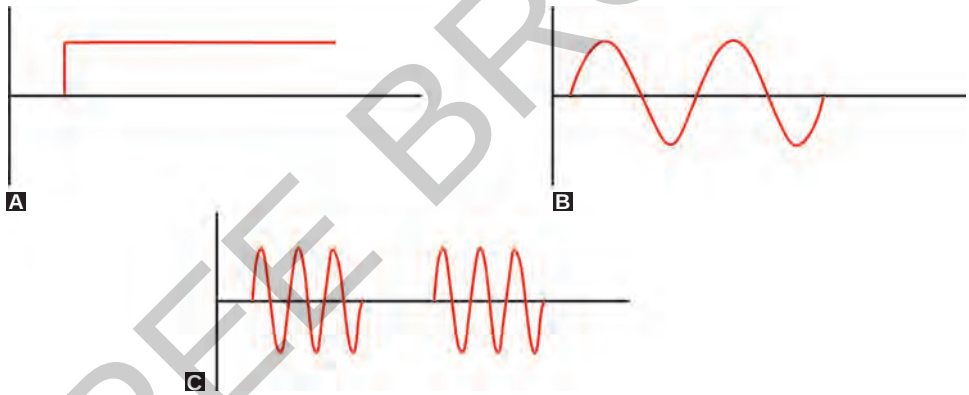
Interrupted Direct Current

If the continuous unidirectional current is interrupted, it gives rise to series of pulses or phases of unidirectional current. A current, which varies sufficiently in magnitude, can stimulate a motor nerve and so produces contraction of the muscles to which it supplies. Suitable current can also stimulate denervated muscle. Intermittent DCs are used in these cases, which ranges from 0.01 to 3 ms. The equipment commonly provides duration of 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30, 100 and 300 ms.

In an AC, the flow of electrons constantly changes direction, or stated differently, reverses its polarity. Electrons flowing in an AC always move from the negative to positive pole, reversing direction, when polarity, if reversed **(Figs. 3.5B and C)**.

Evenly Alternating Currents

Sinusoidal currents: Sinusoidal currents are evenly alternating sine wave currents of 50 Hz. This gives 100 pulses or phases in each second of 10 ms each, 50 in one direction and 50 in another **(Fig. 3.6)**.



Figs. 3.5A to C: (A) Direct monophasic current; (B) Alternating biphasic current; (C) Pulsed polyphasic current.

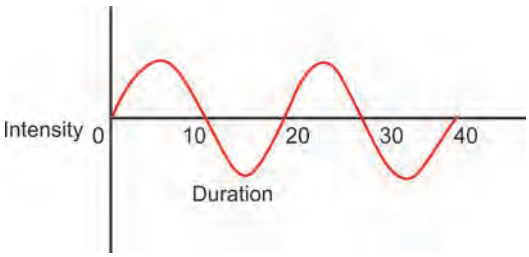


Fig. 3.6: Sinusoidal current.

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It is produced from the mains by reducing the voltage to 60–80 V with a step-down transformer. It is usually surged to cause rhythmical muscle contractions. It relieves pain and reduces edema.

Because of marked sensory stimulation this current is often applied to large areas and rarely used for local muscle stimulation.

Diadynamic currents: Introduced by Pierre Bernard nearly 70 years ago, they are sinusoidal, DCs being rectified mains type currents with frequency of 50–100 Hz. There are six different types of currents, which are each used for different purposes:

1. The *MF (monophase)* is a half-sinusoidal AC, which is created by a one-way DC converter of 50 Hz, with an impulse length and interruption of 10 ms each. The primary effect of this type of current is muscle stimulation **(Fig. 3.7A)**.
2. The *DF (diphase)* type of current is created by an AC of 50 Hz by means of a two-way DC converter, so that a current of 100 Hz is achieved. The patient feels a stabbing sensation in the treated area. The stimulus is less than that of the MF and primarily affects the autonomic nervous system in the sense of lowering the increased sympathetic tone **(Fig. 3.7B)**.
3. The *short-period (SP) current* involves a sudden alternation of MF and DF currents. The patient senses the abrupt change between the tensing MF current and relaxing DF current **(Fig. 3.7C)**.
4. In the *long-period (LP) current*, the MF current is mixed with a second modulated MF. The gradual raising and lowering of the amplitude is experienced by the patient as a more pleasant sensation than that produced by SP **(Fig. 3.7D)**.
5. In the *syncopated rhythm (RS)* the current is interrupted by a pause of 0.9 second after a current flow of 1.1 second. This type of current is used for the electrical stimulus of the muscles **(Fig. 3.7E)**.
6. The *modulated monophase (MM)* current not listed by Bernard is a logical extension of his currents. In the MM the RS is gradually reduced in stepwise fashion. Like the RS, the MM is suited for the treatment of muscular atrophies, but the faradic excitability of the particular muscles must be maintained **(Fig. 3.7F)**.

The therapeutic effects of the diadynamic currents have been researched and established in numerous studies (Bernard).

Therapeutic Effects (Rennie, 1988)

- Pain relief
- Decrease inflammation and swelling
- Muscle reeducation
- Increase local circulation
- Facilitation of tissue healing

Interrupted Galvanic Current

It is called as long duration current having duration of more than 1 ms up to 300 or 600 ms. Interruption is the most usual modification of DC, the flow of current commencing and ceasing at regular intervals. The rise and fall of intensity may be sudden and may be of rectangular, saw-tooth, triangular and trapezoidal type **(Fig. 3.8)**.

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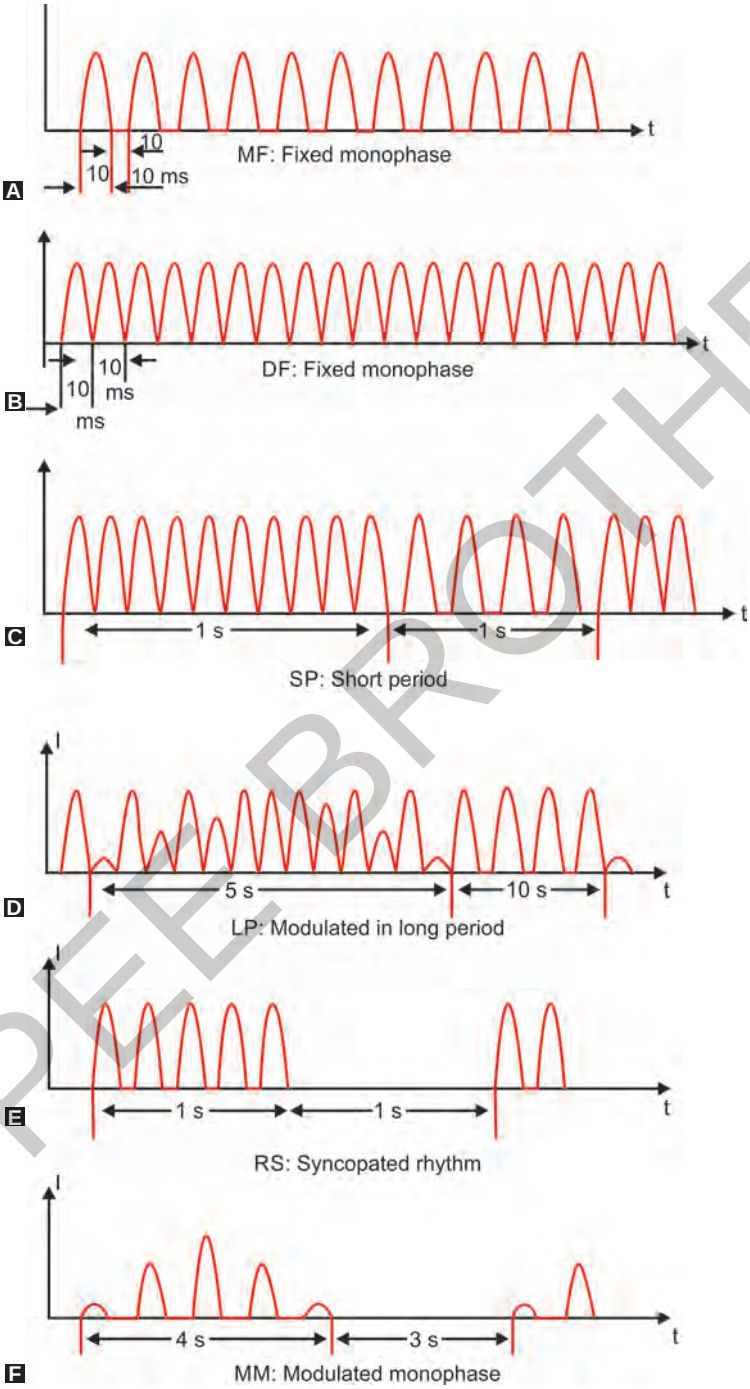

Figs. 3.7A to F: Modulations of various phases of diadynamic currents.

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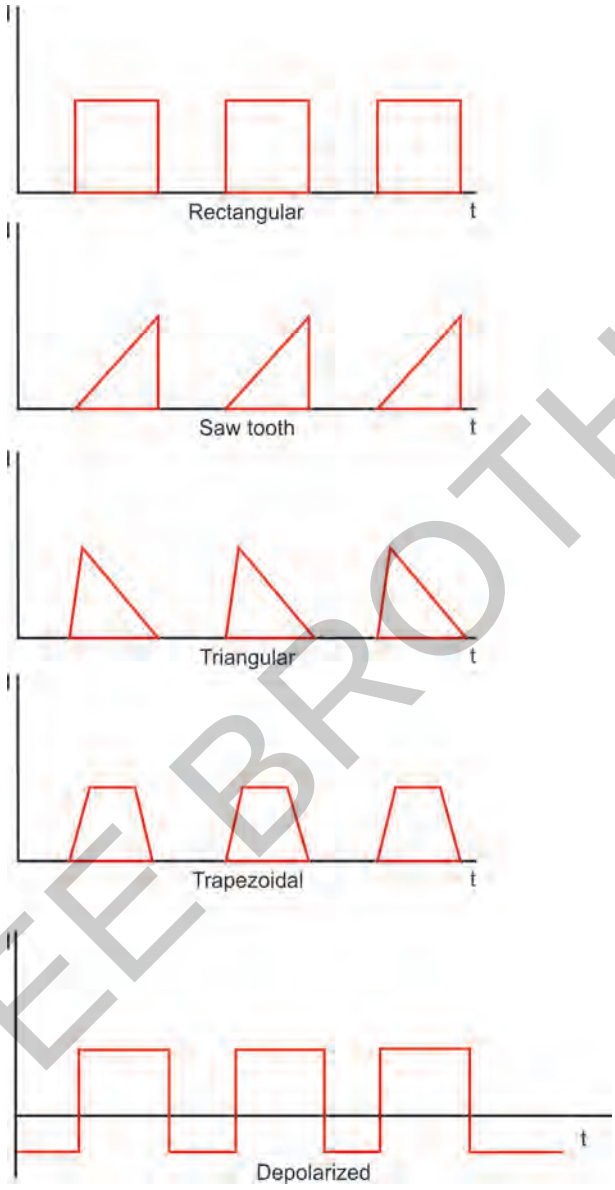

Fig. 3.8: Modified direct current impulses.

The impulse in which the current rises gradually are often termed "selective" because a contraction of denervated muscle can often be produced with an intensity of current that is insufficient to stimulate the motor nerve. This occurs due to accommodation. It is often found that the more long-standing the denervation, the slower the rise in intensity of current that is required.

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An impulse of 100 ms duration is often used which requires frequency of 30 Hz. But as you increase the duration, frequency must be reduced.

To eliminate the danger of chemical burn reverse wave of current, i.e., depolarized impulses should be used, which also reduces the skin irritation.

Production of interrupted DC is usually accomplished in modern apparatus by circuits, which employ transistors and timing devices. Current is always applied to the patient via potentiometer as this allows the intensity of current to be turned up from zero.

NERVE TRANSMISSION

In normal nerve, there is difference of concentration of ions inside and outside the nerve. Due to this there is difference of potential called as potential difference (PD) between inside and outside of the nerve.

Nerve remains in two states:

1. Resting state
2. Stimulated state

In resting state, the nerve is *positive outside* and *negative inside* **(Fig. 3.9)**. At this time, the nerve is not permeable to Na^+ ions, so it is called as polarized state of nerve.

When a nerve is stimulated, it causes fall in PD. When the fall reaches to a certain level, it provides the permeability of sodium ions. This permeability causes the difference in concentration of ions inside and outside the nerve and thus further fall of PD until reversal of polarity occurs. Now the membrane is positive inside and negative outside **(Fig. 3.10)**.

Immediately after this activity the Na^+ ions are pumped again and the stimulated part again comes to resting state.

Now the difference between the active and resting part of the nerve causes the local electron flow between the active and resting part of the nerve. The direction of electron flow through the membrane is opposite to the PD across the fiber.

The fiber acts as a resistance to current so that current flow lowers the PD, this again make the membrane permeable to Na^+ ions and cause the reversal of PD as before. These changes of PD are then propagated along the length of nerve fiber. This change of polarized stage causes the travel of impulse.



Fig. 3.9: Nerve transmission—resting state.

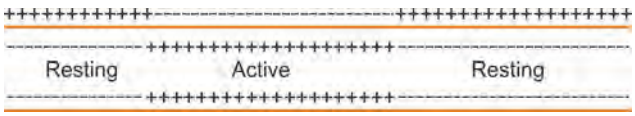

Fig. 3.10: Nerve transmission—stimulated state.

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Electrical Stimulation of Nerves

To initiate the nerve impulse, varying current of adequate intensity must be applied. PD is being formed when current flows in plasma membrane of nerve fibers and resistance lies in series with other tissues. The membrane nearer to cathode will be negative and is denoted by "n", whereas, surface nearer to anode will be positive and is denoted as "p" **(Fig. 3.11)**.

Increase in PD occurs on the nerves nearer to anode, whereas the PD decreases in the membrane nearer to the cathode because of opposite polarity.

When the membrane becomes permeable to Na^+ ions by fall in PD to a certain level, then the ions enter the axon and initiate the nerve impulse.

When cathode is applied to superficial nerve then nearest side will get activated but the anode can only initiate the nerve impulse. Therefore, further aspect of anode is activated. Due to this, the density of current is less in further aspect of nerve fiber than near one. So for initiating impulse cathode is more effective than anode. In some apparatus, polarity of terminals is marked which is beneficial for high peak of current for effective stimulus. To get contraction of innervated muscle in less current, cathode should be connected to active electrode.

Accommodation

When a constant current flows, the nerve adapts itself. This phenomenon is known as *accommodation*.

Effect of Frequency of Stimulation

The muscle responds with a large contraction and then rotates to its resting state. It is called twitch contraction. When single stimulus is applied per second then there is contraction followed by immediate relaxation. Increase in the frequency of stimuli up to 20 Hz shortens the period of relaxation.

If stimuli are given more than 20 Hz then there is no time for complete relaxation between the contraction and another impulse. At more than 60 Hz, there is no relaxation at all and current flows smoothly leading to tetanic contraction.

Strength of Contraction

It depends on:

- Quantity of motor nerve activated
- Rate of change of current

If intensity of current rises suddenly, less intensity is required for muscle contraction as there is no time for accommodation but if current rises slowly greater intensity is required as in trapezoidal, triangular current, etc.

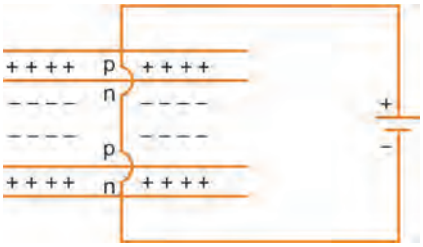

Fig. 3.11: Potential difference across a nerve fiber.

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Pathological Changes in Peripheral Nerve

Peripheral nerves may be damaged by injury or disease in many different ways and the nerve fiber is affected in following ways:

- It can be stopped over a small section of the nerve fiber a local block, so that conduction above and below is normal (in neuropraxia).
- It can be slowed which is usually due to the myelin sheath being affected.
- It can be stopped over a small section of the nerve fiber, a local block. It can be stopped over the whole distal length of nerve from site of injury to the skin and muscle, as in neurotmesis and axonotmesis or damage to nerve cell.

Seddon's Classification

Neuropraxia

Temporary mild compression of the nerve will lead to a conduction block called as *neuropraxia*. It causes displacement of the myelin sheath and local edema of the nerve fiber. The damage is not so severe to cause degeneration of the fiber. As there is no permanent damage so recovery occurs rapidly in a few days or weeks. Since only a section of a nerve fiber is affected, conduction beyond the blockage is normal, thus electrical stimulation of motor nerve fiber beyond the block will cause muscle contraction. Electrical stimulation applied proximal to the block does not result in muscle contraction.

Axonotmesis

More severe compression injury may cause sufficient damage to the nerve axon. This is called *axonotmesis*. Degeneration of the axon takes place including the myelin sheath. Example of this type of lesion is—radial nerve palsy in fractured shaft of humerus. Once the nerve fiber has degenerated, alteration in electrical reaction occurs.

Neurotmesis

Instead of compression if the injury is such as to disrupt all tissues of the nerve fiber such as a cut through the nerve, then the distal segment will degenerate completely. Since the tissue is totally disrupted the axon filament will not readily find correct channels down to regrow, so that recovery is at best imperfect. This is called as *neurotmesis*. Such lesion often requires surgery to ensure that the two cut ends are sufficiently approximated to allow successful growth.

Process of Denervation

Severe injury to the nerve causes damage to the nerve axon so that it is unable to support the metabolic process of its distal part resulting in degeneration of the whole length of the new fiber including the myelin sheath distal to the lesion. This process is called *Wallerian degeneration*. It takes as long as 14 days to degenerate. The distal section of nerve remains excitable and can conduct impulse before degeneration has taken place.

Because of this it may not be possible to make full assessment of the lesion till 3 weeks, after suspected nerve injury.

Regeneration of Nerve

In axonotmesis, the fibrous framework of the bundle of nerve fibers remain intact and fills a chain of Schwann cells so that ultimately nerve fibrils sprouting from the intact

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proximal part of the nerves are guided in their proper channels to reform the complete nerve process.

The duration needed for full recovery will depend on the site of the lesion and the length of nerve that has to regrow. The rate of regrowth is somewhat variable, being more rapid at first, up to 5 mm per day, but is usually considered to be an average 1–2 mm per day.

When there is degeneration of the nerve fiber the normal response is reduced or lost and the changes become evident 3 or 4 days after injury. Changes in the reaction obtained on stimulation over the muscle, may be observed before the end of 1st week.

WAVEFORMS

The term waveform means the graphical representation of the direction, shape, amplitude, duration and pulse frequency of the electrical current produced by the electrotherapeutic device. The instrument which is used to display the electric current is called an oscilloscope.

Pulses, Phases and Direction of Current Flow

The individual waveform as shown by an oscilloscope is referred to as a *pulse*. A pulse may contain either one or two *phases* **(Fig. 3.12)**. It rises above or goes below the baseline for some specific period of time. DC also referred to as monophasic current, produces waveforms that have only a single phase in each pulse. Current flow is unidirectional, always flowing in the same direction toward either the positive or negative pole. Conversely, AC, also referred to as biphasic current, produces waveforms that have two separate phases during each individual pulse. Current flow is bidirectional, reversing direction or polarity once during each pulse.

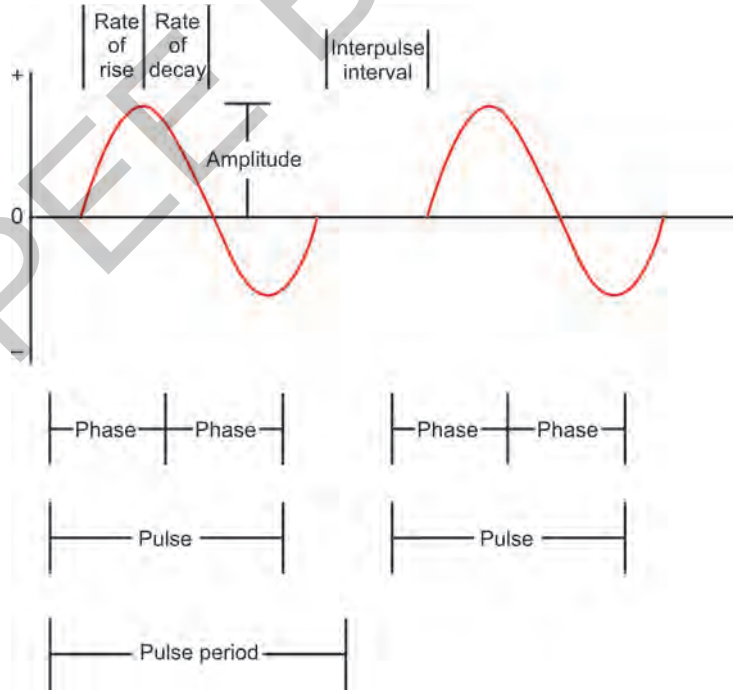

Fig. 3.12: Waveform—biphasic pulse.

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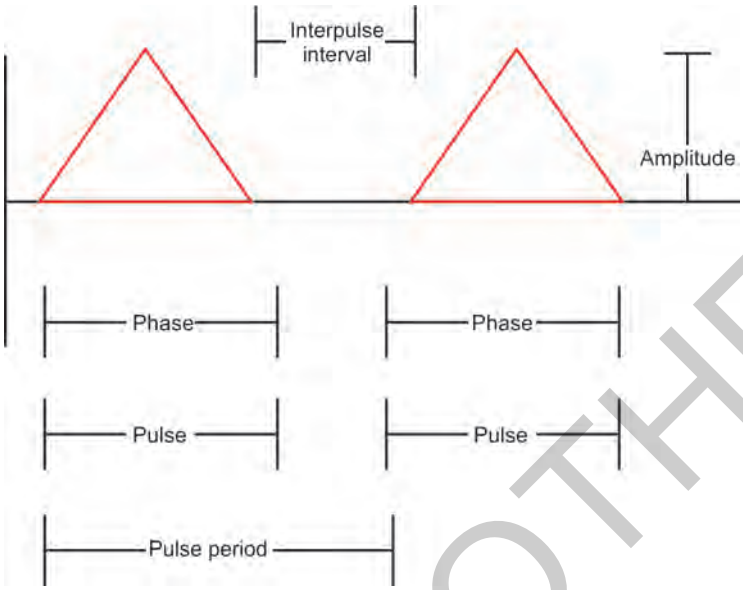

Fig. 3.13: Waveform—monophasic pulse.

Biphasic waveforms may be symmetrical or asymmetrical. If both phases of the waveform may be symmetrical, the shape and size of each phase is identical **(Fig. 3.13)**. Pulsed current waveforms are called polyphasic currents and are representative of electrical current that is conducted as a series of pulses of short duration followed by a SP of time, when current is not flowing called the *interpulse interval*. Single current may flow in one direction as in DC or may reverse direction of flow as in AC. With pulsed currents, there is always some interruption of current flow.

Waveform Shape

It could be of any type like sine, rectangular, or triangular waveform depending on the capabilities of the generator producing the current. Alternating, direct and pulsed currents may be of the following waveform shapes as shown in **Figure 3.14**.

Pulse Amplitude

The maximum amplitude of a pulse can be shown by the tip of highest point of each phase. The amplitude of each pulse reflects the intensity of the current. The term amplitude is synonymous with the terms voltage and current intensity. The higher the amplitude, the greater is the voltage or intensity.

The total current cannot be confused with the tip of highest point of a phase. The total current delivered to the tissues can only be calculated by averaging the current flowing per unit time including the interpulse intervals. The electrical generators that produce short duration pulses, the total current produces (coulomb/s) is low compared to peak current amplitudes due to long interpulse intervals. Thus, the average current or the amount of current flowing per unit of time is relatively low. Average current can be increased by either increasing pulse duration, increasing pulse frequency, or by some combination of the two.

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Salient Features

- This *Textbook of Electrotherapy,* 4th edition has been written as per the latest curriculum of electrotherapy for BPT and MPT Degree courses.
- Chapter on Inflammation and Repair has been added.
- Covers the syllabi of various universities.
- Presents all the necessary aspects of the subject.
- Explains the text in a systematic and lucid manner.
- Includes common as well as updated modalities of treatment.
- Deals with low, medium and high frequency currents, laser therapy, superficial heating modalities, ultrasonic therapy, cryotherapy, electromyography and biofeedback.
- Fulfills the long-felt needs of the students and teachers of physiotherapy.
- Useful for physiotherapists, occupational therapists, electrotherapists, rehabilitation professionals as well as paramedics and public in general.

Jagmohan Singh has acquired International Experience by successfully completing Postdoctoral Fellowship from Department of Physical Therapy, Faculty of Medicine, University of Toronto and Toronto Rehabilitation Institute, Canada.

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