Pulsed and continuous shortwave therapy

Therapy manual

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1 Preface

This book is primarily intended to provide basic information on the use of Enraf-Nonius shortwave therapy equipment. However, in view of the great demand for more information on this subject, we have gone into the principles of shortwave therapy in somewhat more depth.

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2 Physical principles of shortwave therapy

2.1 Introduction

High-frequency electrotherapy
High-frequency electrotherapy may be defined as the therapeutic use of electromagnetic oscillations with frequencies higher than 300 kHz. Electromagnetic oscillations at such high frequencies do not cause depolarization of the nerve fibres. However, the electromagnetic energy can be converted into thermal energy in the body tissue.

Shortwave therapy is a form of high-frequency electrotherapy using oscillations with a frequency of 27.12×10^6 Hz. This corresponds to a wavelength of 11.06 metres in a vacuum.
Waves with a length of between 10 and 100 meters are now referred to as 'short waves'. The more traditional name of 'ultra-short waves' is, in fact, incorrect. The most appropriate term for the waves used in this type of therapy would be '1 1 -meter waves'. The frequency of the oscillations has been established by international agreement (first reached at Atlantic City in 1947) in order to prevent interference with other forms of RF transmission.

The electromagnetic field
From the research of the physicist and chemist Faraday (1791 - 1867) and the physicist Maxwell (1831 - 1879) it is known that an electrical field gives rise to a magnetic field and that, conversely, a magnetic field will create an electrical field. Maxwell also suspected that electromagnetic energy can propagate in space in the form of electromagnetic waves. Later, in 1878, the existence of these electromagnetic waves was demonstrated by the physicist Hertz (1857 - 1894), who also investigated their properties. One of these properties is that electromagnetic waves propagate with the speed of light which, in a vacuum, is 3 x 1 0^s meters per second.
The relationship between frequency and wavelength for all electromagnetic oscillations is given by the formula:

$$V = \lambda \cdot f$$

where v represents the speed of propagation, X the wavelength and f the frequency.

The electromagnetic spectrum
Electromagnetic waves are classified according to their wavelength and, hence, their frequency. Most of the properties of electromagnetic waves depend on their frequency.

2.2 Transfer of energy to the patient

In shortwave therapy, electromagnetic radiation can be transferred to the patient in two ways:
- using the capacitive method
- using the inductive method.

Frequency range (in Hz)	Technical name	Wavelength range in (m)	Applications
3.10^4 - 3.10^5	Long wave	10^4 - 10^3	}
3.10^5 - 3.10^6	Medium wave	10^3 - 10^2	
3.10^6 - 3.10^7	Short wave	10^2 - 10	Shortwave therapy
3.10^7 - 10^9	Ultra-short wave	10 – $3.\ 10^{-1}$	T.V. 69-cm wave
10^9 - 3.10^{11}	Microwave	$3.\ 10^{-1}$ - 10^{-3}	Radar 12-cm wave

2.2.1 The capacitive method

With this method, the part of the body to be treated is placed in the rapidly changing electric field between two capacitor plates, and acts as the dielectric.
A high-frequency alternating voltage applied to tissue gives rise to two types of current:
• a conduction current (I_R)

This current develops heat in the tissue in accordance with the formula:

$$Q = I_R^2 . R . t$$

where Q is the heat energy in joules, I_R the intensity of the conduction current in amperes, R the resistance in ohms, and t the time in seconds. The peak value of this current is inversely proportional to the resistance in ohms, which in turn is determined by the specific resistance of the tissue. For this reason, a strong conduction current can flow in tissue with a a relatively low specific resistance, such as tissue with a high fluid content.
• a displacement current (I_c)

This is not so much a real current as a displacement of the electrical energy by polarization of the tissue. This current does not lead to the generation of heat, as it only represents a displacement of energy, rather than transfer of energy to the tissue. The extent to which this current occurs depends on the capacitance of the tissue (which is determined by several factors, including the dielectric constant of the tissue) and by the frequency of the alternating voltage.

No tissue behaves like a perfect insulator: all tissues pass conduction current to a greater or lesser extent. The ratio between the conduction current and the displacement current occurring in tissue as the result of an alternating voltage at a given frequency is determined by the extent to which the tissue behaves like an electrical circuit with a capacitor and resistance connected in parallel. This differs for each kind of tissue, and is given by the dielectric constant ε and the specific resistance δ of the tissue. The values of these constants and the ratio between them determine the extent to which a conduction current occurs, or the energy is simply passed through the tissue by the displacement current (Fig. 2.1).

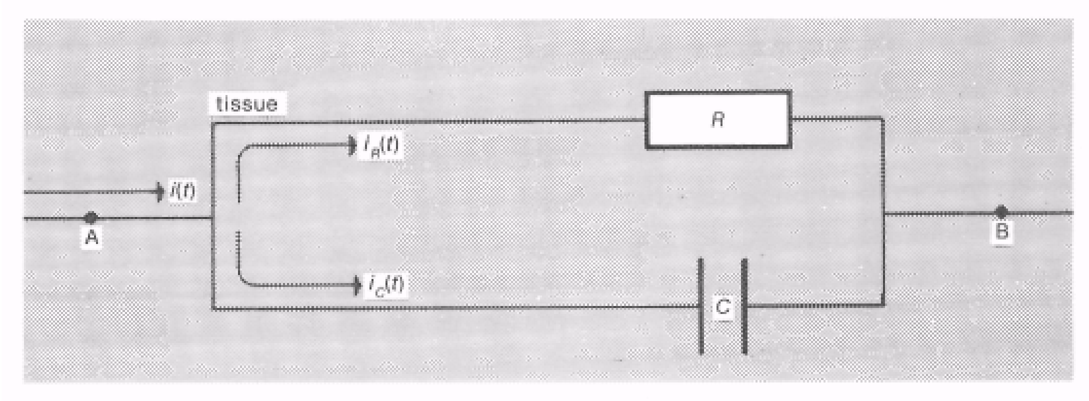

Figure 2.1 Physical model of tissue

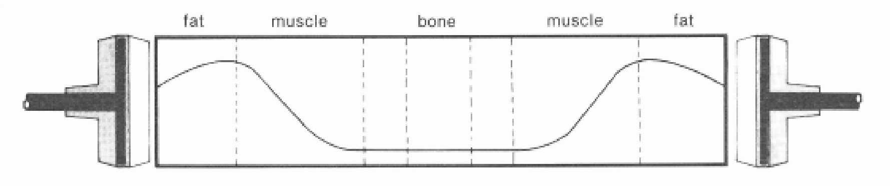

Figure 2.2 Energy dissipation in a phantom with the capacitor method

Thermal load on fat with the capacitive method

Owing to the differences in the dielectric constants and specific resistances of fat and bone marrow on one hand, and muscles and organs on the other, higher displacement currents occur in muscles and organs than in fat and marrow when these are placed in an alternating electrical field with a frequency of 27.12 MHz. It can be calculated that, in transverse treatment, the heat production in muscles and organs and that in fat and marrow are in a ratio of 1:13 to each other. The resultant temperature increases were measured by Kebbel, Krause and Patzold [8] in a tissue model (phantom). The ratio of temperature increases in muscular tissue and those in fat was found to be 1:10 (Fig. 2.2).

The heat generation in fat in vivo is also much greater than that in muscles and organs. There is obviously a very high thermal load on skin and subcutaneous fatty tissue. The differences between the dielectric constants and specific resistances of the various tissues such as muscles, and internal organs with a high fluid and protein content, are very small. It is consequently impossible to effect selective heating of a particular organ.

Since energy absorption in tissue increases quadratically with the field-line density, it is important to localize the highest field-line density accurately in order to obtain the most favourable result possible with treatment. There are several possibilities with regard to the positioning of electrodes for this purpose.

2.2.2 Positioning of electrodes

As far as the behaviour of the electric field lines in relation to the position of the various layers of tissue is concerned, three types of treatment can be distinguished:

A) Transverse application (Figs. 2.3 to 2.7)

The various tissue layers are located one behind the other in relation to the field lines; electrically speaking, they are connected in series. The total current intensity $I_{(t)} = I_C + I_R$ is the same in all tissues. The temperature increase will be greater in fatty tissue than in muscle tissue.

B) Longitudinal application (Fig. 2.8)
The various layers of tissue are now arranged more or less in the same direction as the field lines between the capacitor plates. Electrically speaking, the tissues may be said to be connected in parallel. This means that the voltage across all the tissues is the same and the current will follow the path of least resistance, i.e. through the muscles and other tissues which are rich in water and ions.

C) Co-planar application (Fig. 2.9)
In this case the electrodes are located in the same plane, at one side of the part of the body to be treated. Because of the high thermal load on fatty tissue and since there is no transverse flow through all the layers of tissue, the energy absorb-tion in the deeper layers of tissue will be low. This method of application is consequently superficial. With these three different positionings of electrodes the following factors also affect the location of the highest field-line density:

- the electrode-skin distance
- the sizes of the electrodes in relation to each other and to the part of the body to be treated
- the location of the electrodes in relation to each other and to the body.

With a short electrode-skin distance a high field-line density will occur at the surface of the part of the body being treated (Fig. 1.3). A greater electrode-skin distance results in a more even flow through the tissue and consequently in a 'relatively' larger depth effect. The thermal load on fatty tissue will consequently be smaller than with the surface method (Fig. 2.4).

If different electrode-skin distances are chosen when using electrodes of the same size the effect in tissue at the surface will be greatest on the side with the electrode at the shorter distance from the skin (Fig. 2.5).

When one electrode is smaller than the other and the electrode-skin distances are the same, the energy concentration in both the surface layers and the deep layers will be greater at the side with the smaller electrode (Fig. 2.6). If in this last situation the electrode-skin distance of the smaller electrode is made shorter than that of the larger one, the energy concentration will be located nearer the surface (Fig. 2.7). In the case of longitudinal treatment it should be appreciated that a short electrode-skin distance will produce a relatively high thermal load on fatty tissue, so that the intensity should be kept fairly low and little energy is left for the tissues to be traversed in the longitudinal direction (Fig. 2.8).
If the co-planar method is used, but very superficial treatment is not desired, it is advisable to use a large electrode-skin distance and to keep a distance between the conductive plates of one and a half times their diameter (Fig. 2.9). The size of the electrodes will have to be adapted to the part of the body to be treated.

The use of excessively large electrodes leads to:

- poor localization of energy, so that the optimum effect is not achieved
- energy concentration in the part of the tissue which is closest to the electrode: the 'point effect' (Fig. 2.13).

N.B. In some cases the point effect may be precisely what is required, e.g. in treating a prepatellar bursitis.

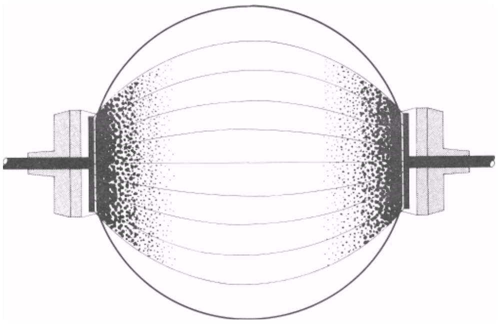

Fig. 2.3 Transverse application with a short electrode-skin distance

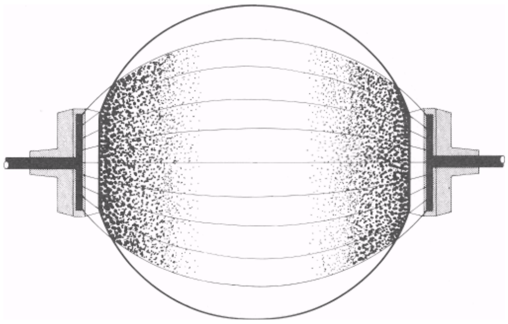

Fig. 2.4 Transverse application with a greater electrode-skin distance

With conically shaped parts of the body the following effects also occur. If the electrodes are located parallel to each other a concentration of field lines, i.e. a region of high energy, occurs where the electrodes are nearest the skin (Fig. 2.10). If the electrodes are located parallel to the surface of the body, they will generally not be parallel to each other and there will be a concentration of field lines where the electrodes are closest to each other (edge effects) (Fig. 2.11). As the dosage is determined by the energy distribution, it is generally desirable to avoid both of these extreme situations. In order to achieve a more even effect, the electrodes should be placed in a position intermediate between being parallel to each other and parallel to the skin (Fig. 2.12). There are several other factors which influence the field line ditribution: when a pointed part of the body is treated, a high energy concentration is obtained at the point closest to the electrode (Fig. 2.13). Similarly, when two adjacent parts of the body are treated simultaneously, e.g. both knees, it is possible that a high field-line concentration will occur at the point of contact between the two parts.

Metals, whether or not in the body, cause a concentration of field lines towards and through the metal. This concentration of field lines is responsible for the very high temperature increase in the tissue around the metal. Recent research has shown that with the capacitive method the metal itself is not heated, but only the surrounding tissue. With the inductive method the metal itself also becomes warm (see Section 2.2.3). Metal objects implanted in the body are a relative contra-indication for shortwave therapy. Where metal is present, shortwave treatment can only be considered if there is a very important indication in its favour. Even then it will be necessary to determine the dose with extreme caution, i.e. it must be kept low (see Section 7.2).

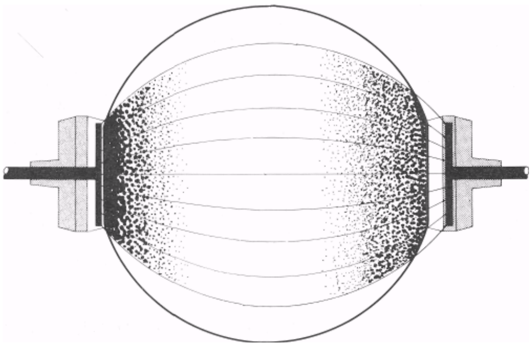

Fig. 2.5 Transverse application with unequal electrode-skin distances

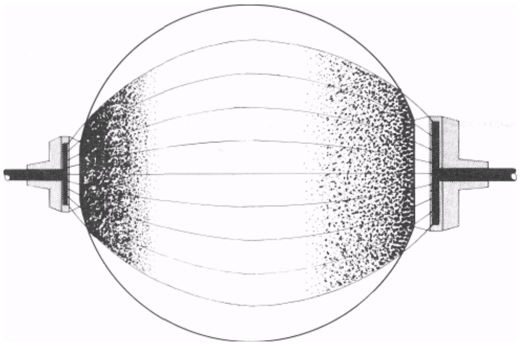

Fig. 2.6 Transverse application with unequal electrodes and equal electrode-skin distances

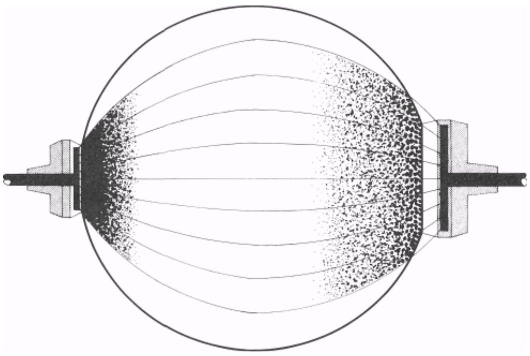

Fig. 2.7 Transverse application with unequal electrodes and unequal electrode-skin distances

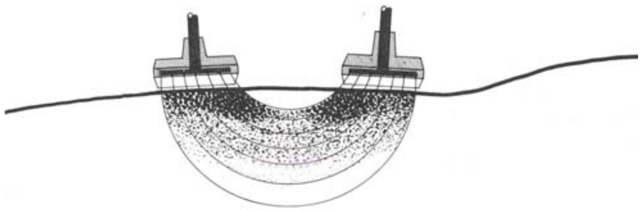

Fig. 2.8 Co-planar application to the back

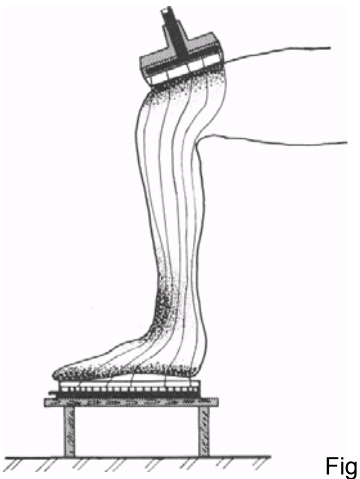

Fig. 2.9 Longitudinal treatment of the lower leg

2.2.3 The inductive method

With the inductive method the therapeutic effect is achieved by placing the part of the body to be treated in a rapidly alternating magnetic field, which is generated by passing a high-frequency alternating current through a coil.

The rapidly changing magnetic flux sets up an induction voltage in the body tissue being treated, which gives rise to induction currents, generally known as eddy currents. These eddy currents generate heat in accordance with the formula:

$$Q = I^2 . t$$

The heat generated using this method depends on the conductivity of the tissue. Tissues which are rich in water and ions will be heated more readily than, for example, fatty tissue. The magnetic permeability constant, which is comparable with the dielectric constant, is approximately the same for all types of tissue. In other words, magnetic energy is passed to the same extent by all tissues.

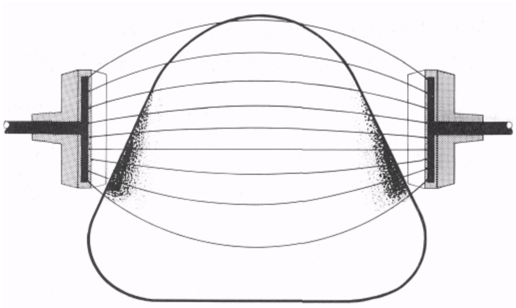

Fig. 2.10 Transverse treatment of a conically shaped part of the body with electrodes placed parallel to each other

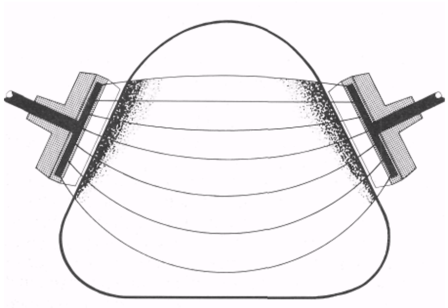

Fig. 2.11 Transverse treatment of a conically shaped part of the body with electrodes placed parallel to the body surface

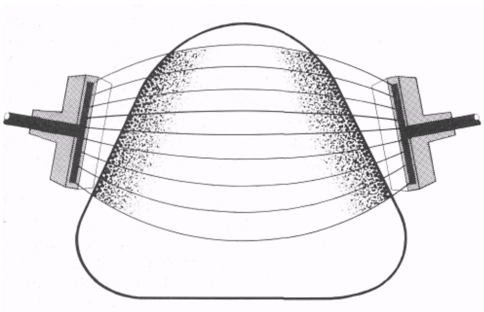

Fig. 2.12 Transverse treatment of a conically shaped part of the body with the electrodes in a position intermeidate between those of Fig. 2.10 and Fig. 2.11

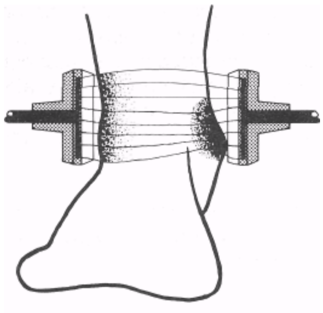

Fig. 2.13 Transverse treatment of a pointed part of the body

2.2.4 Application of coil electrodes

In this method of treatment, a distinction can be made with respect to the passage of field lines through the layers of tissue:
A) The part of the body to be treated is outside the coil.
B) The part of the body to be treated is within the turns of the coil.

A) The part of the body to be treated is outside the coil.
Since the top layers of tissue are closer to the coil, and because of the divergence of the field lines outside the coil, there is a higher concentration of energy in the surface layers than in the deeper layers. The relative heating of the various layers is consequently not precisely as might be expected on the basis of the conductivity differences between fatty tissue and muscular tissue. The inductive method also involves an electrical field component. Although it is small, it causes a thermal load on fatty tissue (Fig. 2.14). Investigation with a tissue phantom, described by Kebbel et al [8], yields the following important information:

- temperature increases in fatty tissue and in muscle are in the ratio of 1:1.
- the half-value thickness (i.e. the thickness of tissue required to reduce the incoming intensity to half its original value) is approximately 2 cm in muscular tissue.
- with a layer of fatty tissue 3 cm thick the muscular layer is still appreciably heated.

In the Circuplode®, developed by Enraf-Nonius, a screen is positioned in front of the coil which stops the electrical field but allows the magnetic field to pass (Fig. 2.15). This screen, which was originally introduced for interference suppression, has the effect of reducing the thermal load on fatty tissue to a minimum. In determining the dose, it is therefore necessary to appreciate that the patient will not feel any heat until the heat developed in the muscular tissue has reached the surface layers of tissue by conduction, and produces an increase of temperature there. This is because there are heat sensors in the skin but, as far as we know, not in the muscles.

B) The part of the body to be treated is within the turns of the coil
By wrapping a 'solenoid cable' (induction cable) around the part of the body to be treated, the area of treatment can be brought within the coil (Fig. 2.16). The field lines of the magnetic fields inside the coil run parallel to the axis of the coil which, in this situation, is also the axis of the part of the body being treated. Small eddy currents can now be set up in all layers of tissue. Here again, the current will be strongest in conductive tissues. Between the turns of the cable, there is an electrical field which becomes more powerful as the turns are closer to each other. If the distance between turns is increased, the total number of turns is decreased and with it the strength of the magnetic field. The distance between turns should be approximately 15 cm.

The potential difference between the cable and the skin also generates an electrical field which is limited by the thickness of the cable sheath. Generally speaking, the electrical field components, even under optimum conditions, will be greater when the solenoid cable is used than with the coil at some distance from the body.

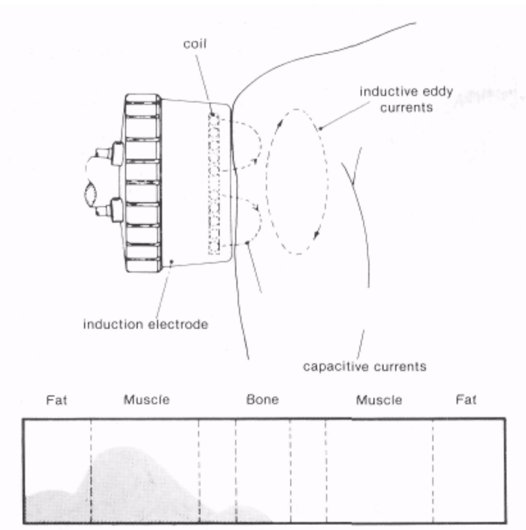

Fig. 2.14 Treatment with a conventional induction electrode

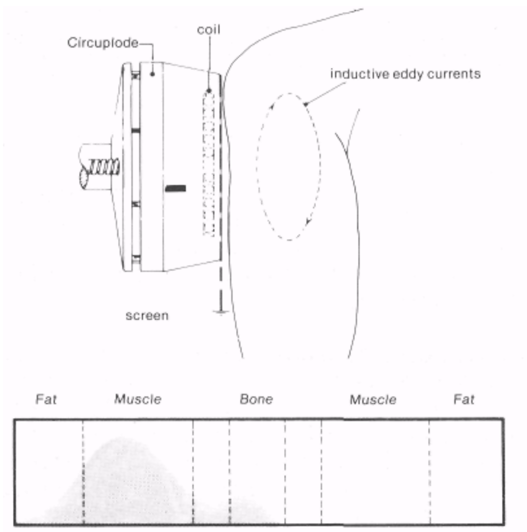

Fig. 2.15 Treatment with the circuplode

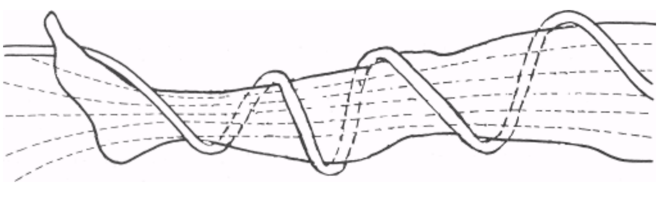

Fig. 2.16 Treatment with the induction cable

3 Physiological effects of continuous shortwave therapy

Thom [16] points out that all research regarding the effects of shortwave therapy shows that the dosage is of decisive importance. Numerous experiments with plants and animals reveal that a temperature increase within certain limits has a beneficial effect on the body processes. On the other hand, excessive application of heat leads to damage.

3.1 Effects on the blood and lymph vessels

Almost all authors who have investigated the effects of continuous shortwave therapy emphasize its circulation-promoting effect. Rentsch [13] states that the arterial part of the circulation in particular (specifically arterioles and capillaries) dilates when subjected to shortwave therapy. This is the reverse of the effect of other forms of thermotherapy.

According to Thom, experiments with animals show that after an initial constriction, a marked dilatation of all vessels, including the veins, occurs. He, too, points out that the dilatation occurs chiefly in the arterial vessels, and that this distinguishes shortwave treatment from more superficial forms of heating. He also observed an enhanced drainage of lymph, which increases the resorptive capacity of the tissue. Barth and Kern [1] emphasize the connection between dosage and effects on the blood vessels. Their research showed that administration of a low intensity for up to ten minutes promotes the blood flow most markedly, and that a higher intensity for a longer treatment time produces the opposite effect, namely vasoconstriction and a slowing-down of the blood flow sometimes even to the point of stasis.

Scott [14] observed an increased blood supply to the tissue, but points out that direct local heat should not be applied in the case of defective arterial circulation. The increased metabolic activity caused by the heat (see Section 3.3) demands more oxygen and nutrients, while the arterial defect makes the (extra) supply of these impossible. Incipient gangrene of the tissues can thus be accelerated. Scott gives preference to treatment of the abdomen (abdominal vessels) on the assumption that the heating of the blood would affect the vasomotor centre, leading to a general dilatation of the surface vessels.

To sum up, it may be stated that a moderate thermal shortwave treatment has a clear circulation-promoting effect, which is reflected in a dilatation of all blood vessels (particularly the arterial vessels) and is accompanied by enhanced drainage of" lymph. An excessive supply of heat can produce opposite effects such as vasoconstriction or stasis of the blood. The use of thermal treatment in the case of arterial defects should be approached with caution. If it is nevertheless decided to employ thermal treatment, segmental treatment or (if appropriate) treatment of the abdominal vessels may be used.

3.2 Effects on the blood

Thom states that experiments on animals have shown that shortwave treatment is first followed by leucopenia, which is immediately followed by leucocytosis (especially of the lymphocytes), the latter persisting 24 hours after the process. Similar changes were also demonstrable in human beings. In addition to these important effects, the following changes in the blood were observed:

- increased possibility of migration of leucocytes from the blood vessels to the surrounding tissue
- increased phagocytosis
- increased BSE
- reduced coagulation time
- changes in the blood sugar level.

Prominent among the changes in the blood sugar level are the phenomena which authors such as Schliephake, Sattler and others observed in the direct shortwave treatment of endocrine glands such as the hypophysis, the gonads and the upper abdomen in the region of the pancreas. After an initial increase of the blood sugar level lasting 35 minutes, this level decreased for several hours until the original value was reached. It is still not clear what direct connection this has with the metabolism [13, 16].

The leucocytosis mentioned above, the increased possibility of leucocyte migration and the increased phagocytary effects of the leucocytes, in conjunction with the local hyperaemia, the increased supply of oxygen, nutrients and antibodies, together with the increased metabolism (see Section 3.3), are of therapeutic importance with regard to the body's defence mechanism against infections[14,16].

Thorn postulates that, on the basis of very extensive clinical experience, there is no doubt about the favourable effect of shortwave therapy on bacterial infections. He considers the direct effect of shortwave therapy on bacteria to be unclear, but tests on animals show that the increased bactericidal effect on the blood gives the body increased resistance against disease. Schliephake treated furuncles with shortwave equipment and Jouard [7] noted its inflammation-inhibiting effects on parana-sal sinusitis, while Jorns [6] recommends treatment with shortwave equipment for patients with greatly reduced resistance after protracted operations.

3.3 Effects on the metabolism

In accordance with Thorn's statement relating to the stimulation of all body processes by a moderately dosed shortwave treatment, Rentsch reports an activation of the metabolic processes. The local vasodilatation results in an increased supply of nutrients and oxygen and an accelerated removal of metabolic products. Edel [2] and Scott also refer to Van't Hoff's law (changes of temperature will cause the equilibirium of a chemical reaction to shift in such a way as to tend to counteract the change), in accordance with which increased cell activity is to be expected. Local applications to endocrine glands have resulted in a revival of their activity [13].

3.4 Effects on the nervous system

Central nervous system
Local applications to the hypophysis have been observed to influence the activity of this gland [16].

Peripheral nervous system
Although other research contradicts him, Thorn states that the irritability of motor nerves increases in response to short-wave treatment. A direct inhibitive effect on sensory (pain) fibres is assumed by some, but greatly doubted by others.

According to Scott, pain is also alleviated by the amplified blood circulation: the metabolic products causing pain can thus be removed more quickly while the tissue pressure caused by the accumulation of fluid is relieved by the increased resorptive power. This eliminates an important pain-causing factor in inflammation, trauma and postoperative situation. The speed of conduction of peripheral nerve fibres increases as a result of the heat [10].

Scott also reports that heating of the tissues causes relaxation of the striated muscles, which, according to Thom, is caused by reduction of the gamma tonus. Rentsch and Edel further point out the indirect effect on internal organs via cutovisceral reflexes.

3.5 General effects

Temperature increase and reduction of blood pressure are named by Scott as general effects, although he adds that these are of too short duration to be of therapeutic benefit for e.g., subnormal temperature and hypertension. Other effects reported by Thom are a striking tiredness and a need for sleep, but in response to total body heating. It is clear that these effects occur when large regions of the body are heated.

Thom does, however, point out the cumulative effect of numerous small dosages which can occur with therapists working extensively with shortwave equipment. Particularly in the first few years after the introduction of shortwave therapy equipment, operators of this equipment showed the same symptoms as those operating powerful shortwave radio transmitters. They complained of anxiety, tiredness, depression, headaches and insomnia. Although modern shortwave equipment produces fewer undesirable radiation effects, a certain amount of care seems appropriate, and it is advisable to locate shortwave equipment as far as possible from places where people stay frequently or for long periods of time.

4 Pulsed shortwave therapy

4.1 Introduction

During the application of shortwave therapy, heat is generated in the tissue treated. As shown in Chapter 2, this heat can produce therapeutic effects. Physiological effects also occur with shortwave therapy, but researchers differ considerably in their opinions as to whether they occur in addition to or as a result of the heat. This discussion is important in the present chapter, since little or no perceptible heat is generated during the application of pulsed shortwave energy (see Section 4.3).

4.2 Heat in shortwave therapy

For many years, heat development in tissue during shortwave treatment was regarded as most important. A patient had to experience heat during the treatment. Researchers such as Nicola Tesla (1891), Nagelschmidt (1907) and Schliephake (1928) for instance, assumed that the most important effects during shortwave treatment are produced by heat.

For some considerable time now there has been a perceptible reduction in the use of any form of physiotherapeutic treatment in which heat is the active agent. The reason for this is that the tissue treated often has poor circulation and is not properly able to get rid of the heat produced during the treatment, so that the temperature might rise to an excessive level. The dosage when using shortwave therapy has therefore been reduced from 'normal' to 'mitis' or 'submitis', i.e. from 'readily perceptible' to 'perceptible' or 'only just imperceptible'.

There is also a growing preference for the use of low-frequency therapies, in which heat is never an issue. Even in ultrasound therapy no attempt is made nowadays to produce perceptible heat during treatment; for some considerable time now it has been possible to apply pulsed ultrasound therapy. Similarly, it is also possible to employ pulsed shortwave therapy.

4.3 Investigation and discussion

The first appliance for pulsed shortwave therapy was developed around 1940. Much research was done into the effects of pulsed shortwave therapy on the body. The data which resulted from this can be divided into two groups:

- Data relating to the influence of pulsed shortwaves on various disorders in order to determine their therapeutic effect and/or to devise the best method with which to achieve them (these therapeutic effects will be examined in greater detail in the following section).
- Data which may be used to answer the question of whether pulsed shortwaves have specific hysiological effects which are not the result of heat and which do not occur with the continuous form or occur only occasionally. The remainder of this section deals with the latter group of data.

Liebesny (1937) and others investigated the effects of pulsed and continuous shortwaves on diluted milk. This showed that the fat molecules in the milk form themselves into a chain. These 'pearl-necklace formations' occurred particularly upon exposure to pulsed shortwaves. During exposure to continuous shortwaves this phenomenon only occurred at very low dosages. At higher dosages a coagulation occurred which, unlike the pearl-necklace phenomenon, was irreversible. Tests with blood, lymph and protein also show that pearl-necklace formations occur when pulsed shortwaves are used. It may well be that with pulsed shortwaves for which scarcely any demonstrable temperature change occurs, the ultimate therapeutic effect is nevertheless caused by tiny temperature rises within the tissue. No specific physiological effect has been proved.

In the remainder of this publication, as in most of the literature consulted, a distinction will be made between temperature increase (thermal effect) on one hand and other physiological (non-thermal) effects on the other.

4.4 Therapeutic effects

Remarkable results have been recorded with pulsed short-waves. Research has shown that the following therapeutic effects occur:

- rapid healing of wounds [9]
- rapid reduction of pain [17]
- rapid resorption of hematomas and oedema [19]
- powerful stimulation of the peripheral circulation
- rapid healing of fractures [18].

Many researchers suggest that in order to obtain the best therapeutic results a local application should also be accompanied by treatment of the liver and/or adrenal cortex. They believe that the reticulo-endothelial system and the reticulo-histiocytic system, which are important for the defence mechanism of the body, are stimulated. The liver and adrenal cortex have high concentrations of cells belonging to the reticulo-endothelial system. The nature of this stimulation, however, has not been described by any researcher. During tests for peripheral vasomotor reactions a temperature rise of 2°C and a vasodilation in the feet, measured at the second toe, was observed after treatment of the epigastric region with pulsed shortwaves.

4.5 Summation

An acceptable theory for the effect of pulsed shortwaves is the summation theory, which is also applied to pulsed ultrasound. As described in Section 3.3, heat and other physiological effects in the tissue treated originate as a result of pulsed shortwaves. Figures.1 illustrates the behaviour of these effects for a low pulse-repetition frequency. It is noticeable that the non-thermal effects persist longer than the heat occurring in the tissue, but since the pulse-repetition frequency is low and the interval between pulses is therefore long, both reactions have been reduced to zero before the arrival of the next pulse. The temperature in the tissue therefore does not increase and the patient will not feel any heat (Fig. 4.1).

If the pulse-repetition frequency is increased and the interval between pulses consequently shortened, the heat generated in the tissue will drop to zero but the other, more persistent, physiological effects will not. Therefore, when the next pulse comes, there is still a residual non-thermal effect to which the effect of the second pulse will be added. As in the case of a lower pulse repetition frequency, the heat generated will not accumulate: no temperature increase occurs in the tissue ('submitis' dose; Fig. 4.2).

As the pulse repetition frequency is increased still further, the heat generated will also summate. The resultant temperature increase in the tissue will now cause the patient to have a sensation of heat (dose 'mitis' to normal; Fig. 4.3).

In most treatments with pulsed shortwaves the situation illustrated in Figure 4.2 is almost ideal: no temperature increase and a summating non-thermal effect. As a direct result of the combination of a high pulse power and the absence of temperature increase, the number of indications for pulsed shortwave therapy is greater and the number of centra-indications smaller than for continuous shortwave therapy [15].

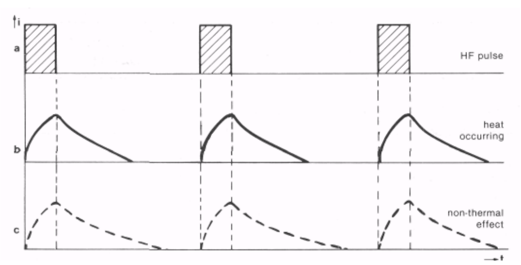

Fig. 4.1 Effects of pulsed shortwave therapy
- a) Three pulses of a given intensity (i), a given duration (t) and a reletively *long interval*
- b) Thermal effect
- c) Increasing non-thermal effect

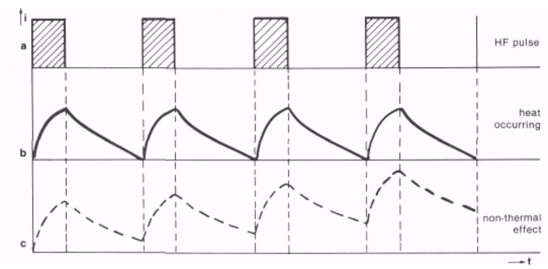

Fig. 4.2 Effects of pulsed shortwave therapy
- a) Four pulses of a given intensity (i), a given duration (t) and a relatively *short interval*
- b) Increasing thermal effect
- c) Powerfully increasing non-thermal effect

4.6 Mean power

The Curapuls 670 supplies a rectangular pulse with a duration of 0.4 ms. The pulse power (the peak power of the pulse) can be set over a range of up to 1000 W. When capacitive electrodes are used the power is generally set to its maximum (see Section 5.3.1). The interval between pulses will depend on the pulse-repetition frequency set (Fig. 4.4).

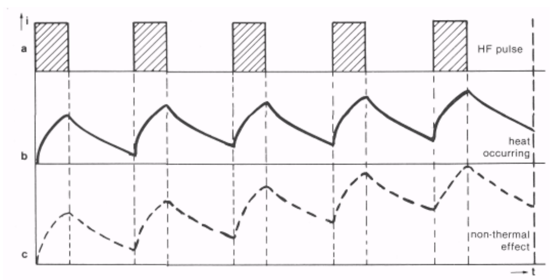

Fig. 4.3 Effects of pulsed shortwave therapy
- a) Five pulses of a given intesity (i), a given duration (t) and a *very short interval*
- b) Increasing thermal effect
- c) Powerfully increasing non-thermal effect

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When pulsed shortwave therapy is used, the aim is to select the highest possible pulse power while generating as little heat as possible. A measure for the heat production is the mean power. With a low mean power the heat production during treatment will be low. The mean powercan easily be calculated. If, for example, the pulse repetition frequency is 20 Hz, the cycle time (the pulse duration plus the interval) is 1000 : 20 = 50 ms. The percentage of time during which the shortwave output is present is then 0.4 : 50 = 0.8 per cent. With the intensity control in position 10, the mean power is thus 0.8 per cent of 1000W, i.e.8 W. The mean power for various intensities and pulse-repetition frequencies is shown in Table 1.

It will be observed that the highest mean power (80 W) which can be reached with pulsed energy emission still remains below the usual output in continuous shortwave treatments (80 to120W).

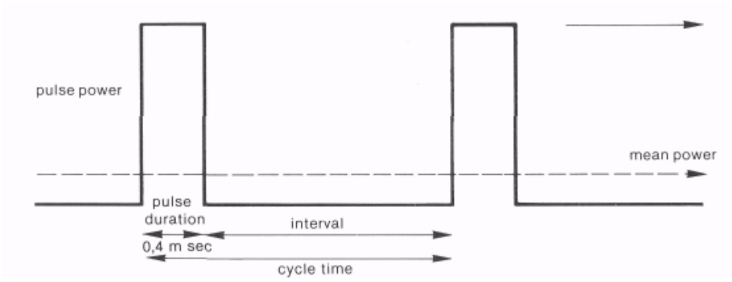

Fig. 4.4 Relationship between pulse interval and pulse repetition frequency

4.7 Specific indications

A) Post-traumatic disorders, e.g. following:

- sprain
- contusion
- rupture
- fracture
- hematoma
- lacerations

It is very important that treatment of these injuries and disorders should begin as soon as possible.

B) Post-operative disorders, e.g. following:

- jaw, foot and hip operations.

Here, the preventive value of the therapy in connection with possible post-operative inflammation is of great importance.

C) *Inflammation*, such as:

- chronic osteitis
- bursitis, possibly with calcification
- sinusitis.

D) Peripheral circulatory disorders

E) Disorders of internal organs

A wide diversity of these disorders are mentioned in the literature.

	1	2	3	4	5	6	7	8	9	10	Position of intensity control
Pulse-repetition frequency	100W	200W	300W	400W	500W	600W	700W	800W	900W	1000W	Pulse Power
15 Hz	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	Mean power
20 Hz	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	
26 Hz	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.4	9.4	10.4	
35 Hz	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.0	
46 Hz	1.8	3.7	5.5	7.4	9.2	11.0	12.9	14.7	16.7	18.4	
62 Hz	2.5	5.0	7.4	9.0	12.4	14.9	17.4	19.8	22.3	24.8	
82 Hz	3.3	6.6	9.9	13.2	16.4	19.7	23.0	26.3	29.6	32.8	
110 Hz	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6	44.0	
150 Hz	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0	
200 Hz	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0	

Table 1:
Mean power at various pulse-repetition frequencies and various pulse powers. The pulse-repetition frequencies have been selected so that the mean power at each step is approximately one third greater than that of the preceding step. The mean power determines the subjective awareness of heat.

5 Dosage

5.1 Introduction

The dose is the total shortwave energy administered to a patient during a single treatment. It depends on the intensity set on the apparatus, the duration of treatment and (if the treatment is with pulsed shortwaves) the pulse-repetition frequency selected.

5.2 Continuous shortwave therapy

5.2.1 Intensity

In continuous shortwave therapy the operator is guided in the choice of the appropriate intensity by the patient's subjective sensation of heat. As already stated, the intensity will be 'only just imperceptible' (a 'submitis' dose). In treating very acute complaints the best choice is the 'submitis' dose because in most cases the generation of heat is undesirable. In the case of subacute complaints, the 'mitis' dose will be chosen since limited heat generation as a result of the high energy supply may be desirable.

The maximum permissible intensity setting for the various electrodes with continuous shortwave therapy is as follows:

Circuplode	: 6
Flexiplode	: 7
Capacitor electrodes	: 10

N.B. When the purpose of treatment is to improve circulation, 'warmer' treatments (normal and 'fortis' dose) are not considered appropriate [1, 16].

5.2.2 Duration of treatment

The duration of treatment will depend on the seriousness and nature of the disorder. When the inductive method is used to promote circulation, Barth and Kern advise against prolonging treatment for more than 10 minutes, since it has no further effect after that time. Edel recommends a treatment duration of 1 - 5 minutes for acute disorders and 10-20 minutes for subacute disorders.

The normal duration of treatment is somewhere between 10 and 20 minutes. Acute disorders are treated for shorter times and subacute disorders for longer times.

5.2.3 Frequency of treatment

Treatments should take place daily if the dosage per treatment is low and the effect of the therapy is therefore not very long lasting. This is the case with the treatment of very acute disorders. Various authors in fact advise a frequency of more than one treatment daily in such cases. In the treatment of subacute disorders the effect will persist longer owing to the higher dosage, and the interval between treatments can therefore be longer. The number of treatments depends on the patient's reactions to the therapy.

5.2.4 Example of treatment (photo 5.1)

A patient has suffered from gonarthritis of both knees for several years; in the last three weeks the disorder has become very acute. The periarticular tissue is painful and there is a slight swelling round both knees. To begin with, a low dosage will have to be administered daily (e.g. a submitis dose for 10 minutes). Depending on the patient's reaction to the treatment it may be possible to change later to a higher dosage (a mitis dose for 15 minutes) with a longer interval between treatments (e.g. three times per week).

N.B.Specific parts of the periarticular tissue of the knee can be treated by using electrodes of different sizes and by varying the electrode-skin distance (Section 2.2.1).

5.3 Pulsed shortwave therapy

Treatment with pulsed shortwaves is particularly indicated if heat is undesirable. The dosage is then 'submitis' (Chapter 4).

5.3.1 Intensity

The intensity setting (the pulse power) will almost always be maximum. The maximum settings for the various electrodes with pulsed shortwave therapy are:

Circuplode : 8
Flexiplode : 7
Capacitor electrodes : 10

N.B. In the case of extremely acute disorders it is sometimes necessary to select a lower intensity in order to make the treatments as mild as possible.

5.3.2 Pulse-repetition frequency

The quantity of energy applied can be influenced by adjusting the pulse-repetition frequency. In cases of recent disorders, a low pulse-repetition frequency (< 82 Hz) is chosen, since the region to be treated is still very sensitive. At a later stage, the treatment can be changed over to a higher pulse repetition frequency (> 82 Hz).

5.3.3 Duration of treatment

The duration of treatment of recent disorders with pulsed shortwave therapy will be relatively short. Treatment times of 10 to 15 minutes are usual.

5.3.4 Frequency of treatment

Depending on the dose per treatment, there will be several treatments per day to start with. During the course of treatment, the dosage may be raised and the frequency of treatment lowered to three times a week. The number of treatments should be adapted to the patient's reactions to the treatment.

5.3.5 Example of treatment (Photo 5.2)

A patient with a traumatic lesion of a medial collateral ligament of the knee. For the first few days, treatment is given twice a day: dose submitis, 10 minutes, pulse-repetition frequency 46 Hz. Subsequently, a 15-minute treatment is given daily with a pulse-repetition frequency up to 110 Hz.

Photo 5.1: Example of treatment of gonarthritis of both knees, using two large capacitor electrodes and one flexible electrode.

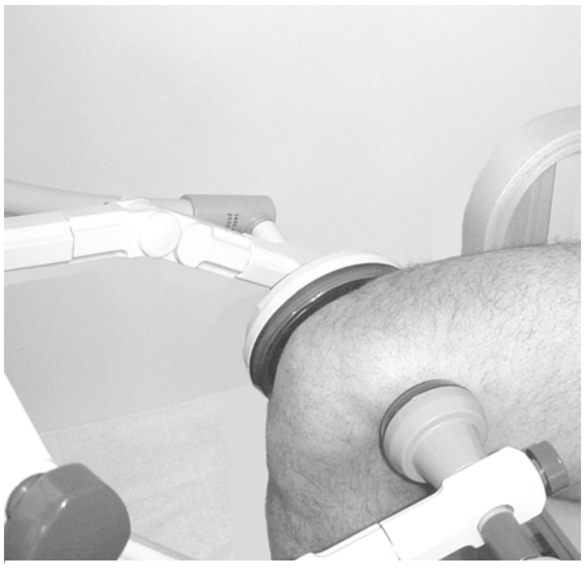

Photo 5.2: Example of treatment of a medial collateral ligament of the knee using unequal electrodes and unequal electrode-skin distances.

6 Indications and methods

The therapeutic application of shortwave therapy is determined by the nature of the symptoms and the placement of the disorder, and is linked to a correct control of dosage. Instead of the usual list of indications, this chapter will present some examples of treatment. It should be pointed out that these are only examples and that other forms of application or methods are not excluded.
For the sake of clarity regarding the electrode localization, the application of a terry cloth between electrodes and skin has been omitted in the photographs.

6.1 Indications

Circulation disorders form a large area of indication. Many disease processes are accompanied by circulation disorders of the tissues concerned. Oedema and vascular affections can also be treated by shortwave therapy (photo 6.1).

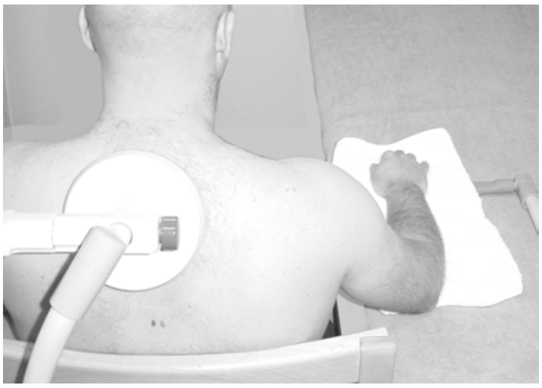

Photo 6.1: Example of treatment of Raynaud´s disease using a flexible electrode under the hand and a large capacitor electrode on the back in the skin segments T1-T10 (orthosympathetic innervation region of the arm).

Inflammation processes can be favourably influenced by the leucocytosing effect of shortwaves combined with the stimulating effect on various defence mechanisms. Examples of these are scapulohumeral periarthritis, humeral epicondylitis (tennis elbow), bursitis, periostitis, etc., and also bacterial inflammations.

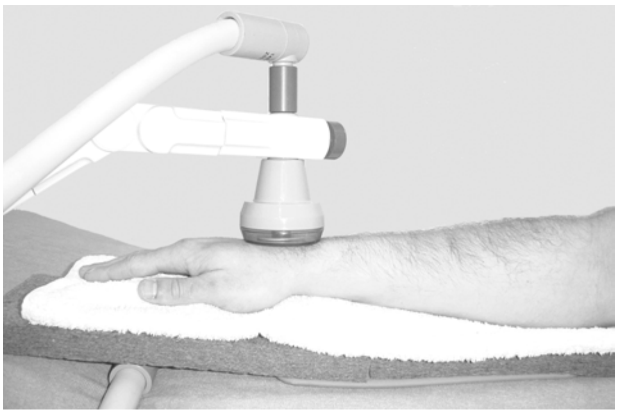

Photo 6.2 Example of treatment of tenoxynovitis using a small capacitor electrode (small electrode-skin distance) and a large flexible electrode.

Photo 6.3 Example of treatment of a sacral decubitus using the Circuplode.

To what extent changes in the blood-sugar level can be used to therapeutic ends has not, to the writer's knowledge, been investigated. It is clear, however, that metabolic processes can be stimulated by local treatment; this is evidenced by more rapid healing of accidental and surgical wounds. The stimulation of the defence mechanisms is also important in this connection, especially in the case of inflamed wounds (photo 6.3).

A pre-operative increase in resistance may also be useful for minimizing post-operative complaints such as oedema and pain (photo 6.4).

Pain is an important indication for shortwave therapy. Its direct effect on the pain mechanisms and the psychological effect of the thermal application, as well as the indirect influence of the resultant hyperaemia, the reduction of the existing hypertonia and the reduction of tissue pressure due to accumulations of fluid have an analgesic effect.

Thus arthrosis, neuralgia, neuritis, vasomotor headache, hypertonia and many other complaints in which pain is a prominent feature can be treated very successfully by shortwave therapy (photo 6.5).

Hypertonia of the striated muscles, e.g. in orthopaedic and neurological disorders, can also be considered for localized treatment, owing to the relaxing effect of shortwave therapy. It is known that relaxation can be achieved by shortwave treatment in cases of hypertonia resulting from arthrosis or neuralgia, reflex hypertonia in the case of internal complaints and hypertonia resulting from psychological stress (Photo 6.6).

Photo 6.4 Pre-operative treatment of the jaw using the Circuplode before surgical operation on the jaw.

Photo 6.5 Example of treatment of a cervical arthrosis using two small capacitor electrodes.

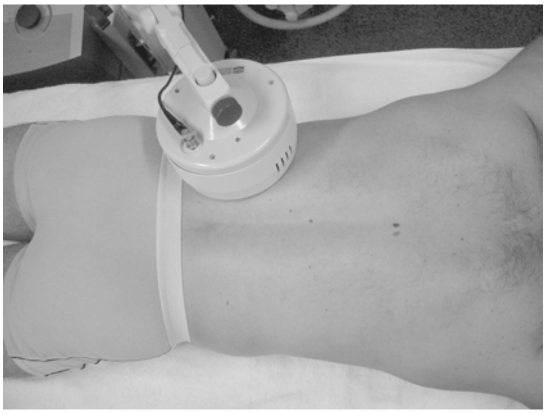

Photo 6.6 Example of treatment of acute unilateral hypertonia of the quadrate muscle (lumbago) using the Circuplode.

6.2 Examples of treatment

Before proceeding to treatment with continuous or pulsed short waves, a choice will have to be made from the various methods of treatment (and application techniques). In Chapter 1 the possibilities are described for effective application of shortwave energy by the appropriate choice of method, electrode-skin distance and the size of the electrodes.

The physiotherapeutic examination is very important, as it determines the kind of tissue affected, the location of the disorder, and the points of application for treatment. Each disorder must be treated on a specific tissue basis. Acute myalgia, and muscle injuries such as whiplash, may be treated by the inductive method or by longitudinal treatment using the capacitive method. Furuncles, and also superficial hematomas in the case of sprains etc., can best be treated by transverse application of short waves (capacitive method).

Treatment of the iliotibial tract
In this example, the lower leg is treated by the inductive method, using the Circuplode electrode (Photo 6.7). The treatment is applied longitudinally, with the patient sitting. A flexible rubber electrode is place under the foot, and the capacitor electrode is place above the knee. It is important to note that the position of the plug connection on the flexible rubber electrode has a marked effect on the concentration of high-frequency energy. This is at its greatest at the plug connection end.

Irritation of the Achilles tendon
For irritation of the Achilles tendon, the lower leg is treated longitudinally, with the plug connection of the flexible rubber electrode at the heel end (Photo 6.8).

Photo 6.7 Example of treatment of constusion of the iliotibial tract using the Circuplode.

Photo 6.8 Example of treatment of an irritation of the Achilles tendon.

Shin splint
A 'shin spl int' may sometimes be located at the front of the lower leg, e.g. in the anterior tibial muscle. In this case the plug connection of the flexible rubber electrode is placed at the toe end (Photo 6.9).

Irritation of the peroneal muscles
For treatment of the lateral part of the lower leg, e.g. for irritation of the peroneal muscles after an ankle sprain, the plug connection is placed at the external side of the foot (Photo 666.10).
In other cases of ankle sprain there are various treatment possibilities, depending on the stage, the severity and the extent of the injury. In a very acute stage, for example, when all tissues around a joint are painful and swollen, treatment using two capacitors of the same size (the size being appropriate to the ankle) will give good results. The electrode-skin distance is set on the basis of the depth effect considered desirable. If there is fluid in the joint a large electrode-skin distance will be chosen; if it is thought that the capsule and ligament are more affected, a shorter distance (2 cm) will be selected. In the case of a serious sprain it is also possible that the muscles of the lower leg will be affected and/or that there is extensive oedema. In such cases a longitudinal treatment of the lower leg will be chosen, as described in the example of treatment for irritation of the peroneal muscles.

In some cases it is necessary to localize the energy in a ligament, e.g. for an injury of the innermost ligament of the ankle joint (the deltoid ligament). Use can now be made of a large capacitor electrode applied to the lateral surface of the foot, and a small capacitor electrode applied to the median surface, over the affected ligament. The energy can be concentrated even more superficially by adapting the electrode-skin distance (short distance for the small electrode and longer distance for the large electrode).

Photo 6.8 Example of treatment of extensive complaints after a lateral ankle sprain.

Photo 6.9 Example of treatment of a shin plint.

Furuncle in the neck
To treat a furuncle in the neck at the level of C7, a small capacitor electrode is placed over the furuncle with a short electrode-skin distance, and a large capacitor electrode is placed elsewhere (Photo 6.11).

6.3 General guidelines

- The patient should be undressed. This prevents undesirable concentrations of energy, e.g. in nylon, leather or damp clothing. Jewellery, hairpins and other metal objects should be removed.
- In shortwave treatment, good blood circulation is important. In many cases, the aim is to increase the circulation. Anything interfering with the circulation, such as constriction of blood vessels by fastening straps, tight items of clothing, rolled up trouser legs or excessively tight fitting of an induction cable should be avoided.
- In order to prevent electrodes and felt sheets from becoming greasy, and to avoid perspiration, a terry cloth should be placed between the electrode and the skin. Perspiration can lead to undesirable concentrations of energy. Parts of the body not being treated should be covered.
- To ensure correct localization of the therapy and to prevent disturbances in the electromagnetic field it is important that the patient should remain as still as possible. This can be facilitated by placing the patient in a relaxed position.

Additional guidelines for treatment using the induction cable.

- To avoid excessive strain on the superficial blood vessels the cable must not pass through the armpit, the bend of the elbow or knee, or the groin. The vessels, with their high fluid content, could be subjected to excessive thermal stress.
- The cable must not trail on the ground. Where cables cross, a minimum distance of 3 cm should be maintained between them to prevent local heating.

Photo 6.11 Example of treatment of a skin disorder: a furuncle in the neck.

7 Contra-indications

Over the years, a number of centra-indications for shortwave therapy have been identified. Some are clearly documented, while others are based on assumptions. Others, again, depend on dosage or location. For these reasons, the contra-indica-tions are divided into three groups.

7.1 Absolute contra-indications

Malignant tumours
Although some publications [16] mention possibilities for shortwave therapy of malignant tumours, it must be stressed that these theories are based on experiments (on animals) and that, until proved otherwise, malignant tumours must be regarded as an absolute contra-indication for shortwave therapy. This is due to the possibility that shortwave radiation increases the activity of tumour cells and promotes their division.

Pacemakers
If subjected to pulsed shortwave radiation, pacemakers may develop rhythm irregularities. People with pacemakers should therefore not remain in the vicinity of working shortwave equipment.

Pregnancy
In view of a probable effect on the rapid division of embryonic tissue and blood supply to the placenta, it is inadvisable to treat pregnant women with shortwave radiation. It is also advised that pregnant women (including therapists!) should not remain in the vicinity of working shortwave equipment.

Tuberculosis
In certain forms of tuberculosis, heating in deep tissue has been observed to cause a marked decrease in the number of leucocytes.

Fever
In cases of fever, shortwave radiation may have the effect of increasing the metabolism even more. This would cause the temperature to rise still further, leading to hyperthermia.

Rheumatoid arthritis
Various researchers such as Harris and McCroskery [3], Hollander and Horvath [4, 5] and others report that deep heating in joints markedly increases the activity of collagenase, a cartilage-destroying enzyme, in the joint. For this reason Mason and Currey [2] also state that arthritis deformans should not be treated with shortwave radiation. Although Mainardi et al. [1] contested the clinical value of the above theories in a paper, in our view it is extremely inadvisable to treat rheumatoid arthritis thermally with shortwave radiation.

7.2 Relative contra-indications

Implanted metals
Metals concentrate electromagnetic energy. To prevent possible accumulations of energy around metal implants, with the resulting dangers (burns), continuous shortwave therapy should only be used if the indication outweighs the possible adverse effects. Thus, treatment after a total hip operation is not advisable, whereas treatment of a jaw with metal fillings in teeth may be acceptable. However, when pulsed short waves are applied, no heat is generated in the tissue, so that this form of therapy can be used in such cases.

Disorders affecting sensitivity to heat
Correct dosage is extremely difficult in these cases. The correct intensity can sometimes be derived from the contralateral side by applying the intensity measured on this side, reduced by one third, to the affected side.

Serious arterial and venous circulatory disorders such as atherosclerosis, thrombosis etc.
Do not apply locally, except submitis, since it is difficult for the affected tissue to deal with the heat.

Heart disorders
The dosage should be kept low in view of possible decompensation.

Acute infectious diseases, acute inflammation
Depending on the nature and the seriousness of the disorder, select a low dosage. With local thermal applications there is a danger that bacteria will be carried away by the blood.

7.3 Unproved, largely traditional contra-indications

Osteoporosis
Shortwave therapy is alleged to promote this process.

Rapidly dividing tissue
Cell division in tissues such as epiphyseal discs, gonads etc. may possibly be promoted by the effect of shortwave radiation.

Hemophilia
It is not clear what adverse effect shortwave radiation may have on this disease.

Use of anticoagulant drugs
Shortwave therapy is not known to have any adverse consequences for patients using anticoagulants.

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