On the Safe Use of Microwave and Shortwave Diathermy Units

Diathermy is a common treatment modality used to relieve pain through localized heating. This paper briefly discusses the mechanisms through which heat is generated in tissue and the absorption characteristics of the applied electromagnetic radiation. The adverse effects of this radiation are reviewed with particular emphasis on the current exposure limits for operators and non-patients in the vicinity of diathermy devices.

The newly introduced codes of practice for the 'Safe Use of Shortwave (Radiofrequency) and Microwave Diathermy' are also discussed.

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Diathermy is a form of therapy which utilizes electromagnetic radiation to induce heat inside the patient's body. This leads to increased blood circulation which is believed to induce faster healing. Diathermy is used in a variety of conditions including sprains and strains, muscle and tendon tears, chronic rheumatoid arthritis, tenosynovitis, bursitis and synovitis.

The medical efficacy of this treatment has been the subject of some controversy, while the potential hazards posed by the high power (> 200W) electromagnetic radiation emitted by a diathermy machine are certainly not to be neglected.

In a Canadian survey of shortwave and microwave medical devices (DHW 1980) only 54.3 per cent of the shortwave diathermy operators were described as trained (38.5 per cent of the respondents provided no reply while 7.3 per cent admitted being untrained). The same survey indicated that 8 per cent of the treatments involved irradiation of the pelvis (including treatment of the reproductive and urinary systems) and a similar percentage involved irradiation of the head.

Although similar data is not available for Australia, reports of unwise and potentially hazardous practices in the use of diathermy have caused disquiet among health regulatory authorities and have prompted the National Health and Medical Research Council to issue a uniform code of practice for the safe use of diathermy machines. The code was produced in two slightly different versions, one for microwave and one for shortwave (radiofrequency) units. Both codes are included in Appendices A and B of this article. A similar code has been established in Canada (DHW 1983).

Shortwaves and Microwaves

Technically, the term rediofrequency radiation refers to that portion of the frequency spectrum useful for radiocommunications *ie* 10 kHz to 300 GHz. However, it is not uncommon to further divide this frequency range into radiofrequency (10 kHz to 300 MHz) and microwave (300 MHz to 300 GHz) regions. This latter convention has been adopted for this paper and the codes. Because of the competing demands of various microwave and radiofrequency users, specific bands have been allocated by the International Telecommunication Union for industrial, scientific and medical (ISM) applications. In Australia diathermy units are allowed to operate in only two of the ISM bands, namely the microwave band of 2450 MHz (wavelength = 122 mm) and the shortwave band of 27.12 MHz (wavelength = 11.1 m).

The absorption properties and the methods of application associated with these two frequencies are considerably different and therefore the heating mechanisms and, more importantly, the resulting heating patterns vary.

The interactions of electromagnetic fields with tissue can be considered on a macroscopic or microscopic level. On the microscopic level, three basic machanisms underlie the interactions. These include:

(1) the orientation of electric dipoles that already exist in the atoms and molecules in the tissue;
(2) polarization of atoms and molecules to produce electric dipoles; and

(3) displacement or drift of conduction ('free') electrons and ions in tissue.

Heat can be generated in tissue in each of these three interactions. In the first two cases the heat is generated through friction associated with the movement of atoms and molecules following the time variation of the electric field. In the case of displacement of conduction charges, the collision of electrons and ions with atoms and molecules of the tissue produce heat. Note that it is only the internal electric field that transfers energy to the tissue. However, magnetic fields will induce electric fields in tissues thereby generating heat. Thus both electric and magnetic fields produced by the diathermy applicator are important with respect to the generation of heat.

All three of the above interactions are described by the macroscopic property of tissue, called the 'complex permittivity', which represents the dielectric constant and loss factor of the tissue. The complex permittivity of tissue is a function of frequency and, as a result, the propagation and attenuation of electromagnetic waves are also dependent on the frequency (Schwan 1954, Schwan 1970).

In shortwave diathermy the patient is made part of the electrical circuit of the generator by using either an inductive coil (Figure 1a) or a capacitor type applicator (Figure 1b). A variable capacitor in the unit is tuned to match the generator with the patient-applicator circuit, thus achieving maximum power transfer.

If a capacitive applicator is used, the patient is subjected to an oscillating electric field which causes molecules in the tissue to vibrate and produce heat. In the case of the inductive applicator, primary heating is due to eddy currents induced by the oscillating magnetic field. The heating pattern is determined by the type of applicator, by its size and by its position relative to the patient.

For a microwave unit, the wavelength of the radiation (122 mm) is much smaller than the overall dimensions of the patient and therefore the directional properties of the radiation are important to its operation. The microwave radiation is emitted by a small antenna and directed towards the area of treatment by a suitably shaped reflector. The antenna and the reflector constitute the applicator. Different types of applicators can be used with the same unit to obtain different heating patterns.

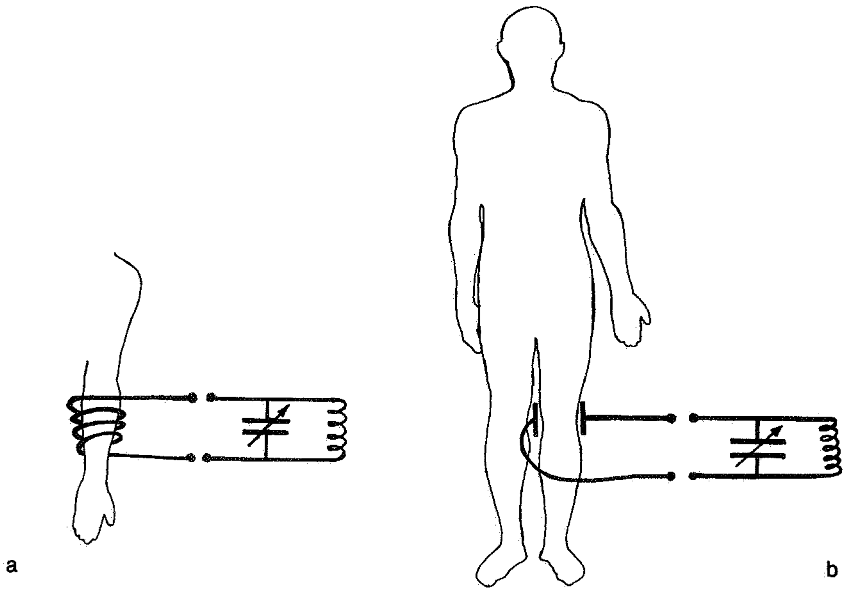

Figure 1: Inductive (a) and capacitive (b) applicators

The heating effect of microwaves is due to energy dissipated by the water molecules in the tissues as they vibrate to follow the oscillations of the electric field. The heating pattern is determined by the penetration characteristics of the radiation and by the type of applicator. Like light, microwaves can be transmitted, reflected, refracted and absorbed by different media. Reflection occurs at the interface between two media through which the radiation propagates at differing velocities (*eg* air and skin, muscle and fat) (Schwan 1954).

Absorption is the transfer of energy from the electromagnetic wave to the medium which it is penetrating. Tissues having a high water content absorb more than tissues such as fat or bone. Within a given medium absorption depends on the electrical properties of the medium, on the frequency of the radiation and the distance travelled by the wave. In general, in the radiofrequency range, absorption increases with increasing frequency. At the frequency of 2450 MHz, the amplitude of the electric field falls by approximately two-thirds after propagating for 20 mm into tissues of high water content. As the power of the radiation is proportional to the square of the electric field, only about 10 per cent of the power is transmitted past that distance.

The rate at which energy is imparted to a given mass of tissue is expressed by the specific absorption rate (SAR) which is measured in W/kg. The SAR is calculated by the relationship (Witters *et al* 1979):

$$SAR = \frac{4.19 \times 10^3\ C\ T}{t}$$

where
C = specific heat of tissue
T = temperature rise in tissue
t = time of energy deposition in the tissue.

The SAR can also be expressed in terms of the electrical properties of the absorbing tissue (Osepchuk 1979):

$$SAR = \frac{1}{2\rho} W\epsilon_o \epsilon \tan \delta E_{in}^2$$

Where
ρ is the mass density of the body, in kg/m^3
ϵ_o is the permittivity of free space, in farads/m
ϵ is the relative dielectric constant
$\tan \delta$ is the loss tangent
ω is the radian frequency given by $\omega = 2\pi f$
E_{in} is the electric field in volts/m at the point in the body.

Experimental and clinical research indicates that therapeutic responses will occur as a result of elevating tissue temperatures in the range 41° to 45°C requiring SARs from 50 to 235 W/kg (U.S.A. Federal Register 1980) in the treatment area (Guy *et al* 1974).

Because of the presence of different layers of tissue with different physical properties and because of the resulting combined effects of absorption and reflection, it is exceedingly difficult to accurately estimate the dose of radiation delivered to a specific organ. In practice the only indicator available to the therapist is the thermal sensation experienced by the patient and even this may not reflect accurately the possible presence, for example, of 'hot spots' in an area which does not possess an adequate number of thermal receptors. The power meter incorporated in the unit's console indicates only the power emitted by the generator, not that delivered to the patient.

Personnel Exposure

Exposure Limits

Like many sources of electromagnetic radiations, diathermy devices are potentially hazardous, not only to the direct user, but also to other persons who may be unintentionally exposed (WHO 1981).

At the Warsaw International Symposium on biological effects and health hazards of microwave radiation in 1973 it was agreed that, from the point of view of the biological effects, microwave power densities could be divided into the following ranges:

- High power densities, greater than 10 mW/cm^2 at which distinct thermal effects predominate.
- Medium power densities, between 1 mW/cm^2 and 10 mW/cm^2, where weak but noticeable thermal effects exist.
- Low power densities, below 1m W/cm^2, where thermal effects do not appear to exist but other effects have been reported. The exact nature of these non-thermal effects continues to be the subject of much controversy as they are subjective in nature and difficult to quantify (see, for example: Symposium on Health Aspects of Non-ionising Radiation 1979, Steneck 1984).

Although no formal agreement has been reached, a similar classification may be applied to the shortwave frequency of 27.12 MHz.

The thermal effect of electromagnetic radiation which has already been discussed may lead to a number of detrimental effects from lesions in specific organs to gross thermal stress from hyperthermia. The severity of the effect depends on many factors including the nature of the organ exposed, the intensity and duration of the exposure, on the size and the health condition of the subject exposed (SAA 1985).

For the operators and members of the public, including other patients, receptionists *etc.*, any effect induced in them is unwanted and therefore the exposure must be limited to the levels prescribed by the Australian Standard AS2772 (SAA 1985) and reported in Table 1. Occupationally exposed individuals are persons exposed to radiation as a direct consequence of their employment, which in this case means the operators of diathermy units.

Surveys of shortwave diathermy devices in the USA (Ruggera 1980) and Canada (Stuchly *et al* 1982) and results of measurements performed by the authors have shown that, in general, if the operator remains approximately 1m from the applicator and, in particular, 0.5 m from the cables his or her exposure will be within the recommended limits.

However, exceptions to this rule have been reported. It was shown in the USA survey (Ruggera 1980) that one shortwave diathermy device produced unwanted power densities well in excess of the recommended limit at a distance of 1 m from the applicator. Although the authors of that survey did not comment on that result, other diathermy devices surveyed, of the same model and used for the same treatment modality, produced much lower power

Table 1:
Maximum permissible exposure limits

Frequency (MHz)	*Occupationally exposed**	*General*
27.12	1.22 mW/cm^2	0.24 mW/cm^2
2450	1 mW/cm^2	0.2 mW/cm^2

* *ie* persons exposed as a consequence of their occupation, in this case the operator.

densities at a distance of 1 m from the applicator. It would appear that the shortwave diathermy device in question may have had either faulty cables, connectors, or applicator. There were other devices in this survey that exceeded the limits at a distance of 1 m.

We have tried to replicate this result using a Siemens Model 808 device with a wing applicator. An experienced physiotherapist was asked to administer shortwave treatment to the thigh of a patient using a normal therapeutic irradiation level. The environmental radiation level was measured at several points at a distance of 1 m from the applicator, using a Holaday HI3002 monitor fitted with a E-field probe. We were able to obtain a level in excess of the standard limit only if the cables were positioned so that they were within 0.5 m of the detector.

Also in the Canadian survey (Stuchly *et al* 1982) high power densities were measured at, we assume, the console of a shortwave diathermy device. This result was attributed, in part, to the treatment regime which consisted of treating both knees using large diameter air spaced electrodes. Again, the only way we could replicate this result was to be within 0.5 m of the cable.

In order to help ensure that operators are not exposed in excess of the recommended limit, the codes prescribe the minimum distances that the operator should maintain from the applicators and leads:

- for shortwaves: 1 m from the applicators and 0.5 m from the leads; short excursions closer to the electrodes are permitted but only when necessary (DHW 1983).
- for microwaves: 2 m from the applicators, but remaining outside the direct beam.

The distance of 2 m should ensure that if reflections occur (it can be shown that, due to the possible formation of standing waves, power densities may increase by a factor of four in this case) the operator exposure will be within the recommended limits.

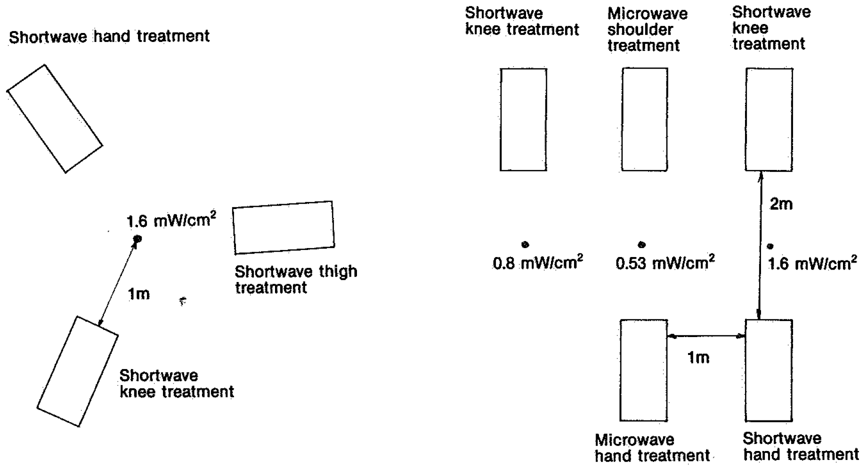

Figure 2: Simultaneous use of more than one unit increases the chance of overexposure of the operator. The radiation levels reported in the figures were obtained during normal therapeutic use of the machines.

The occupational exposure limit may also be exceeded if more than one diathermy unit is operating within 2 m of each other (Figure 2). We have measured the field existing in the space between a number of diathermy units (both microwave and shortwave), during the administration of common treatment modalities. The recommended limit was exceeded between the shortwave devices, but not between two microwave devices, presumably due to the greater directionality of the microwave applicators.

Planning of Patient Treatment Area

Over-exposure to persons other than the patient may result from inadequate planning. To illustrate this we have recreated in our laboratory two examples of badly planned treatment areas and surveyed the radiation levels in positions which could conceivably be occupied by the operator and/or members of the public.

Figure 3 illustrates how reflections from a filing cabinet and a wall-mounted, metallic instrument panel may produce, within one metre from a microwave applicator, local fields in excess of those recommended for occupational exposure.

It is not impossible that persons not directly involved in the use of the machine will be subjected to doses in excess of the recommended limit (Figure 4). It must be remembered that for these persons the recommended limit is five times lower than that applicable to the operator. Normally however this situation is unlikely to occur because the power density varies inversely as the square of the distance.

Careful planning of the patient treatment area can minimize these risks. Advice on the matter can be obtained from the relevant state authorities listed in Appendix C.

Hazards to the Patient

Obviously these 'safe' limits do not apply to the patient as the induction of thermal effects in the patient's body is the purpose of diathermy; however, the line between therapeutic and harmful dose can be uncomfortably thin.

In the specific case of diathermy the detrimental effects of electromagnetic radiation may appear in a number of instances as a consequence of inappropriate practice or because of a particu-

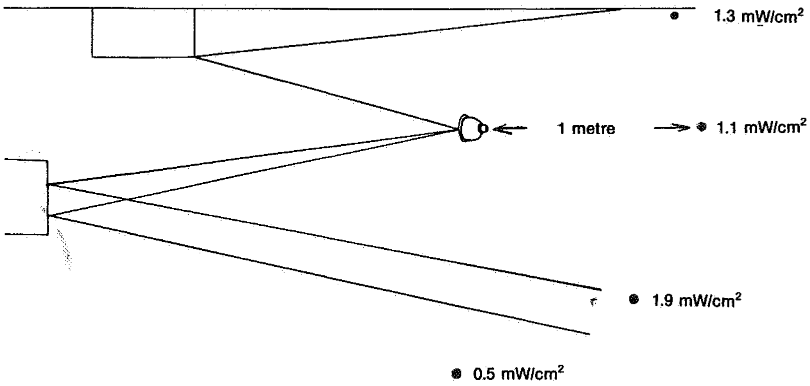

Figure 3: The presence of reflecting objects may cause hazardous radiation levels even behind a microwave applicator.

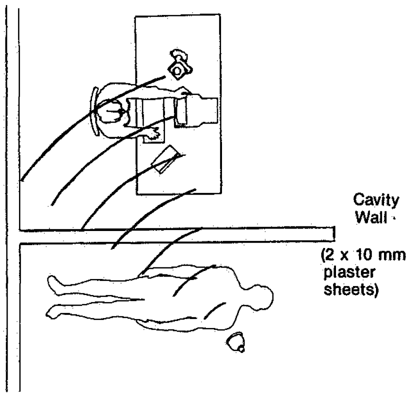

Figure 4: Persons other than the operator can also be exposed to radiation. In this example, the microwave power density at the receptionist's waist level was measured to be ≅0.5 mW/cm², which is 2.5 times the recommended limit. The distances between the receptionist and the applicator was 2.1 m. The microwave output was 180 W.

lar susceptibility of the patient to injury.

In a recent Canadian survey (DHW 1980) a small number (~4%) of respondents have reported the incidence of adverse effects, including increased pain, burns and pacemaker interference, in some of their patients.

Burns and Scalds

Beside the obvious case of a burn or scald resulting from an excessive dose of radiation there are some situations where they can be caused even by normal therapeutic doses.

The subcutaneous fat layer is more easily heated than the muscle tissue during shortwave treatment using capacitor type applicators. This effect, beside being a consequence of the paucity of blood flow in the fat, is also due to the different intensities of the electric field in the two layers (Guy *et al* 1974). This can be explained using an idealized plane wave (Christensen *et al* 1981). When an electric field E_o is applied to a dielectric, such as fat or muscle, it causes a realignment of the electric charges associated with its molecules (Figure 5). The charges thus realigned create an induced field (E_i) which opposes the applied field. As a result, the field (E_d) within the dielectric is less than E_o.

We can write $E_o/E_d = k$, where k is the relative dielectric constant of the medium.

At the boundary between fat and muscle we must have

$$k_f E_f = k_m E_m = E_o$$

(boundary condition for the electric field perpendicular to the fat and muscle layers)

ie $$E_f = \frac{k_m}{k_f} E_m$$

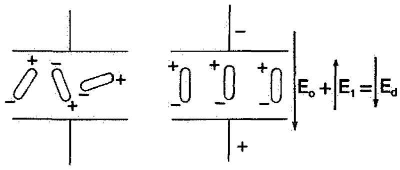

Figure 5: Alignment of polar molecules in the dielectric reduces the electric field between the capacitor's plates.

At the frequency of operation of shortwave diathermy, the ratio between the two coefficients is such that the electric field in the fat layer is considerably larger than in the muscle. Consequently as the power absorbed is proportional to the square of the electric field, the power absorbed in the fat is almost eight times that absorbed in muscle.

When the fat layer is not too thick, capacitive applicators may still be used with care, but they should be avoided with obese patients (*ie* persons 20 per cent or more over the normal weight range).

However, if the electric field is parallel to the interface between muscle and fat, as is the case for microwave treatment (Figure 6), the boundary condition requires that $E_f = E_m$. In this case muscle absorbs more power than fat, although the efficacy of the

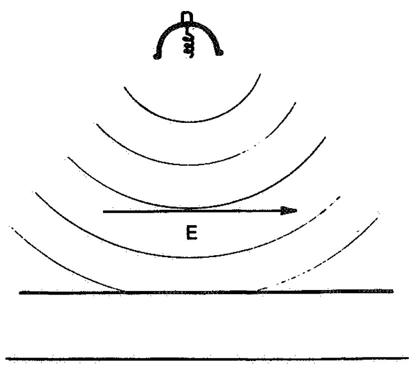

Figure 6: The electric field of the microwave radiation emitted by diathermy applicator is parallel to the fat-muscle interface.

treatment is reduced, as there is no therapeutic value in heating the fat layer. For instance, it can be shown that less than half of the incident power reaches the muscle if the fat layer is 2 cm thick.

An accurate estimate of the rate of temperature increase in fat and muscle tissue is very difficult to obtain because of the many variables involved. The ultimate decision on the use of diathermy units with overweight patients must be left to the professional judgement of the therapist. Shortwave applicators that have predominantly a magnetic field output (*eg* coil, monode, diplode) are the most suitable to produce deep tissue heating without much risk of burns to the fat layer (Kloth 1984).

Perspiration must be allowed to evaporate freely not only to help dissipate body heat but also because water is heated by the electromagnetic radiation. In the case of microwaves this is the major heating mechanism. Droplets of perspiration on the skin can rapidly reach a very high temperature (Kloth 1984). Only dry towelling should be used when this is necessary to support the induction coil used with some shortwave therapy regimes, otherwise all clothing, bandages and coverings should be removed. Nylon and other synthetic fibres are particularly unsuitable because they retain the moisture against the skin. If, in the course of a microwave or shortwave treatment, perspiration appears on the patient's skin, the treatment should be interrupted and the skin dried. For this reason and to make sure that the patient remains in the proper position and most importantly, does not look towards the applicator, it is necessary that the patient not be left alone during the microwave treatment.

Teratogenic Effects

Teratogenic effects following maternal hyperthermia have been experimentally demonstrated in a number of animal species, notably the guinea pig (Edwards 1967, 1978). It has been shown that elevations of core temperature in excess of 2.5°C during the organogenesis stage of pregnancy result in increased resorption of fetuses and in congenital birth defects of the central nervous system. The latter, and the associated clinical disorders in animals, have been reviewed extensively by Edwards (1978, 1981).

While experimental data is lacking for primates, retrospective and prospective studies of mothers with febrile illnesses in the first trimester indicate that hyperthermia has similar teratogenic effects on the developing human fetus (Smith 1978, Clarren 1979).

A recent epidemiological study of birth outcomes among physiotherapists in Sweden has found a higher than normal incidence of dead or malformed infants born to those operating shortwave diathermy units (Kallen *et al* 1982). Rubin and Erdman (1983) reported four cases of patients being treated with microwave diathermy for chronic pelvic inflamation who became pregnant during the course of the treatment and therefore received microwave exposure to the pelvis just prior to and during early pregnancy. In one case the pregnancy resulted in a miscarriage. Three similar cases, this time involving shortwave diathermy, were reported by Imrie (1971). One of the pregnancies terminated in a miscarriage. Ghietti (1955) reported the birth of a malformed, immature, convulsive infant whose mother had been treated with shortwaves during the first two months of pregnancy. Although no direct link can be established between these adverse pregnancy outcomes and the diathermy treatments, these cases, together with the results obtained from animal experimentation, suggest that it is wise to avoid microwave and/or shortwave exposure during pregnancy.

Specific Precautions

Apart from the normal contraindications such as open wounds, haemorrhage or acute infections, the following are more specific risks.

If the irradiated region contains a cancerous growth, temperature tends to develop in the tumor higher than that in surrounding normal tissue (Babbs 1981). This increase in the temperature leads to the destruction of cancerous cells and therefore, diathermy is sometimes used as a therapy for cancer patients. However, if the temperature is between 40 and 41.5°C, the growth rate of tumors is accelerated (Burr 1974). The use of diathermy is therefore contraindicated in patients with evidence of cancer, unless it is part of a specific cancer therapy regime.

Metal intensifies the electromagnetic fields, potentially leading to hazardous temperature increases. Therefore the treatment of patients having metallic implants in the treatment area is contraindicated. For the same reason all metal such as rings and watches should be removed from the area of treatment.

The presence of a cardiac pacemaker in a patient also constitutes a contraindication. The risk, obviously, depends on the treatment regime, being minimal for treatment of the extremities.

Diathermy is also contraindicated with patients who do not possess normal pain and thermal sensation in the area to be treated.

Adverse Effects on the Eye

Acute exposure may cause injury to the eye, particularly using frequencies ranging from 1 GHz to 10 GHz (and therefore including the frequency of operation of microwave diathermy units). Cataract formation may be induced in animals by exposure for 1 hour to power densities in the 150 to 200 mW/cm^2 range (Ruggera 1980). These levels are similar to those produced by microwave diathermy units. Retinal lesions may also occur (Cleary 1980).

Unintentional irradiation of the eyes is a real possibility due to the limited directionality of the applicators. Bassen *et al* (1978) have reported that most non-contact applicators exhibit a high level of radiation 'leakage', that is radiation delivered to the environment rather than to the target tissue. Levels up to 44 mW/cm^2 were measured at 5 cm from the applicator.

The danger that microwaves pose to the eyes, cannot be overcome easily. Goggles do not offer adequate protection because, as the dimensions of the eyepieces are comparable to the wavelength of the radiation, the diffraction around the edges is significant. It has also been shown (Griffin 1983) that metal rimmed spectacles enhance the field near the eye. Therefore it is recommended that the head never be irradiated with microwaves except in the course of cancer therapy.

Effects on the Gonads

The testes are also particularly sensitive to hyperthemia. Exposure of the scrotal area to microwaves at 2450 MHz and at power densities greater than 50 mW/cm^2 resulted in varying degrees of testicular damage (such as oedema, atrophy, fibrosis and coagulation necrosis of seminiferous tubules) in laboratory animals (Leach 1980, WHO 1982, Manikowska-Czerska 1985). The overies are also susceptible to hyperthermia; however, being located deep in the pelvic cavity they are not normally affected by microwave diathermy (Elder 1984). Shortwaves, on the other hand, can penetrate many centimetres of tissue and may put the ovaries at risk.

Conclusion

We have reviewed the hazards presented by the high radiation level associated with shortwave and microwave diathermy.

We have pointed out the possibility for the operator to be exposed to levels exceeding those prescribed by the appropriate standard.

Patients may also be at risk if the operator is untrained and/or careless or if the patient is unco-operative *eg* unable to understand and follow the instructions and appreciate the potential risks.

It is therefore concluded that these units can only be operated by registered health professionals as defined in the Codes (Appendices A and B).

Acknowledgement

We wish to thank Mrs Joan McMeeken and Mr Alex Ward for useful discussions and for allowing us to carry out measurements on the diathermy units at the Lincoln Institute of Health Sciences, Victoria.

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Appendix A

Code of Practice for the Safe Use of Microwave Diathermy Units (1985)*

Introduction

The therapeutic use of heat produced by microwave radiation absorbed in the body is called microwave diathermy. The heat increases the flow of blood in the tissues through dilation of the blood vessels. This in turn increases capillary pressure, cellular membrane permeability, and metabolic rate, causing a more rapid transfer of nutrients from the blood across cell membranes. These actions may reduce pain and promote quicker healing.

A microwave diathermy unit is a device designed to generate microwave radiation and transfer it, via a coaxial cable and a radiating antenna, to the area to be treated. The antenna is incorporated in an applicator which has the function of directing the radiation towards the area to be treated.

These devices are capable of generating a sufficiently high level of radiation that there may be cause for concern for the safety of the eyes, the gonads and, in the case of pregnant patients, the foetus. It is claimed that radiation from microwave diathermy applicators has caused cataracts in patients being treated for sinus conditions. The eyes of patients being treated for a neck or shoulder injury could also be inadvertently subjected to stray radiation. Improper use of the machine may result in burns and/or scalds and tissue or organ damage. Care must also be taken to avoid subjecting the operator and/or the public to radiation levels exceeding those prescribed in the Australian standard AS 2772 (Maximum Exposure Levels — Radiofrequency Radiation — 300 kHz to 300 GHz). It must be noted that the level of radiation present in the vicinity of a diathermy unit may be increased by reflections.

Care must be taken to ensure that the microwave radiation does not cause interference with other equipment.

This Code sets down appropriate rules and procedures to avoid excessive and/or unnecessary exposure to microwave radiation but should be read in conjunction with any State/Territory regulations covering their use.

Definitions

Microwave diathermy unit means a device using electromagnetic energy in the microwave frequency range (300 MHz to 300 GHz) for therapeutic purposes. The unit includes applicators, the microwave generator, and all associated electronics, controls and enclosures. In Australia the only approved frequency for microwave diathermy treatments is 2450 MHz.

Treatment means the use of a microwave diathermy unit on a human being to treat a symptom, disease or disability.

Applicator means any device designed to conduct, transmit or transfer electromagnetic energy from a microwave diathermy unit to a patient undergoing treatment.

Control means any control used during opertion of a microwave diathermy unit which affects the microwave radiation emitted by the applicator.

Health professional means a registered person who has satisfactorily completed an appropriate course of training approved by the relevant registration board and the State/Territory health authority.

User means the person having administrative responsibility for use of a particular microwave diathermy unit. This person shall be the owner or hirer of the unit or his agent or, if the unit is owned or hired by an institution or organization, the agent of that body.

Operator means the health professional given the responsibility, by the user, to treat the patient using a microwave diathermy unit.

Shall indicates that the particular requirement is considered necessary to ensure protection from radiation.

Should indicates a procedure or precaution which is to be applied, whenever practicable, in the interests of minimizing radiation hazards.

Hazards of High Level Exposure to Microwave Radiation

Burns

These may result as a consequence of excessive irradiances or may be due to preferential absorption of microwave radiation (as in the case of a wet dressing over a wound) or to reduced heat dissipation mechanisms (as in the case of the subcutaneous fat layer). In some cases deep tissue and organ damage may ensue.

Ocular effects

Lens opacities may be induced by microwave radiation. Single exposure to intense (> 100 mW/cm^2) electromagnetic radiation at 2450 MHz for an hour or longer has resulted in cataract formation in experimental animals. The power density in the therapeutic beam is of a similar level, but the treatment time is generally somewhat shorter. However, repeated direct irradiation of the eye at such levels and for such treatment times does approach the power-time threshold required for cataract production. Goggles *do not* offer reliable protection.

Effects on the Gonads

Exposure to microwave radiation may increase the temperature of the testes to the point where temporary sterility is induced. Very high specific absorption rates may cause permanent damage. The ovaries may also be at risk.

Teratogenic Effects

Abnormalities in offspring have been reported in several animal species after exposure to intense microwave radiation. Intense fields resulting in significant temperature increase of the foetus could result in teratogenic effects in humans.

Examination and Interview

Microwave treatment shall not be administered unless prescribed by a health professional (as previously defined). At the examination and interview, when treatment is being prescribed, the health professional shall determine the suitability of the patient for treatment. This should not be prescribed if:

- The patient does not understand the potential risks,
- the patient is not able to co-operate with the operator in maintaining the proper position and in reporting the presence of a heating sensation which is the only indication of an adequate or excessive dose.
- the patient does not have normal sensation in the treatment area,
- the patient has metallic implants within the treatment area,
- the patient is pregnant,
- the patient wears a pacemaker,
- the patient has undergone ionizing radiation therapy to the treatment area in the three months prior to the diathermy being administered, as skin sensation and blood circulation may be diminished,
- there is evidence or known history of vascular insufficiency,
- the patient has any evidence of cancer, unless the microwave treatment is carried out as part of a hyperthermia treatment regime. (The metastasis of a cancerous growth may be accelerated by a moderate increase in temperature, such as can be caused by a microwave treatment not specifically intended to treat a malignancy.),
- there are open wounds, haemorrhage, ischaemic tissue, tuberculous joints, or acute infections within the treatment area.

In the cases where the health professional, after due risk/benefit consideration, sees it necessary to prescribe microwave diathermy

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treatment outside the guidelines given above, adequate advice shall be given to the patient, to the user and to the operator of the microwave diathermy unit.

The head shall not be directly irradiated as there is a significant risk of irradiating the eyes. Most applicators are not sufficiently directional to restrict irradiation to the targeted area. Microwave irradiation of the head may only be carried out as part of a cancer therapy.

User Responsibilities

The user shall ensure, by administrative controls or otherwise, that:

- the microwave apparatus complies with all relevant Australian Standards and is maintained in accordance with the relevant State requirements,
- the unit is operated only by health professionals,
- the unit operator is not exposed to a radiation level exceeding the standard for occupational exposure specified by the appropriate authority,
- the general public (including waiting patients, receptionist etc.) is not exposed to a radiation level exceeding that recommended by the appropriate authority,
- a range of applicators suitable for treating different areas of the body is available (the use of modern applicators which reduce scattered radiation and concentrate the energy to the treatment area is encouraged),
- a visible and/or audible signal is installed, to indicate that the unit is operating,
- the unit is not the cause of electric interference with other equipment (This may require the use of a screened cubicle and a mains filter.),
- non metallic chairs and/or beds are available to patients undergoing microwave diathermy treatments.

Treatment

Before administering the treatment the operator shall:

- ensure that the thermal sensitivity of the patients is not impaired by analgesics,
- ensure that the patient has removed all metallic objects (rings, watches metal rimmed glasses, etc.) from the treatment area,
- ensure that the treatment area is not covered by a wet dressing or adhesive tape,
- remove bandages or clothing from the treatment area,
- ensure that the skin is dry,
- ensure that if the patient is wearing a hearing aid, it is removed,
- ask the patient to immediately report any symptoms experienced during the treatment except "a mild, comfortable warmth",
- ensure that the testes are not directly irradiated and that care is taken to minimize indirect irradiation,
- ensure that the coaxial cable is correctly connected to both the machine and the applicator,
- not rest the applicator or cable over metal surfaces,
- align the applicator accurately to ensure an appropriate pattern of heating,
- direct the applicator away from the unit's controls,
- use care in handling the applicator (damage may result in an alteration of its directional properties),
- ensure that the chair or other patient support is not metallic.

After activating the unit the operator shall:

- remain outside the field of emission of microwaves and at least 2 metres from the patient,
- not leave the patient alone in the room during the treatment,
- ensure that the patient maintains the correct position and remains co-operative,
- interrupt the treatment if perspiration appears on the patient's skin,
- not allow the patient to touch the unit,
- ensure that no other person is in the vicinity of the unit or of the applicator during the treatment, in accordance with the administrative controls established by the user.

Appendix B

Code of Practice for the Safe Use of Shortwave* (Radiofrequency) Diathermy Units (1985)

Introduction

The therapeutic use of heat produced in deep tissue by electromagnetic radiation absorbed in the body is called diathermy. The heat increases the flow of blood in the tissues through dilation of the blood vessels. This in turn increases capillary pressure, cellular membrane permeability, and metabolic rate, causing a more rapid transfer of nutrients from the blood across cell membranes. These actions may reduce pain and promote quicker healing.

A shortwave diathermy unit is a device designed to generate radiofrequency radiation and transfer it, via cables and electrodes, to the area to be treated. The units can be operated in either a continuous wave or pulsed mode, but both produce heat in deep tissue. Two basic types of electrodes (applicators) are in use, the capacitor type and the inductor type. In the first case tissue heating is basically due to the radiofrequency electric field, while for the inductive electrodes (coils), heating occurs by a combination of electric field effects and currents induced in the tissue by a magnetic field, the heating profile of the two mechanisms is somewhat different.

These devices are capable of generating a sufficiently high level of radiation that there may be cause for concern for the safety of the gonads and, in the case of pregnant patients, the foetus. Improper use of the machine may result in burns and/or scalds and deep tissue or organ damage. Care must also be taken to avoid subjecting the operator and/or the public to radiation levels exceeding those prescribed in the Australian standard AS 2772 (maximum exposure levels — radio-frequency radiation — 300 kHz to 300 GHz). It must be noted that the level of radiation present in the vicinity of a diathermy unit may be increased by the presence of nearby metallic objects or other units or by reflection from the wall.

Care must be taken to ensure that the shortwave radiation does not cause interference with other equipment.

This Code sets down appropriate rules and procedures to avoid excessive and/or unnecessary exposure to shortwave radiation but should be read in conjunction with any State/Territory regulations covering their use.

Definitions

Shortwave diathermy unit means a device using electromagnetic energy in the shortwave frequency range (3-30 MHz) for therapeutic purposes. The unit includes electrodes, the shortwave generator, and all associated electronics, controls and enclosures. In Australia the only approved frequency for shortwave diathermy is 27.12 MHz.

Treatment means the use of a shortwave diathermy unit on a human being to treat a symptom, disease or disability.

Applicator means any device designed to conduct, transmit or transfer electromagnetic energy from a shortwave diathermy unit to a patient undergoing treatment.

Control means any control used during opertion of a shortwave diathermy unit which affects the radiation emitted by the applicator.

Health professional means a registered person who has satisfactorily completed an ap-

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propriate course of training approved by the relevant registration board and the State/Territory health authority.
User means the person having administrative responsibility for use of a particular shortwave diathermy unit. This person shall be the owner or hirer of the unit or his agent or, if the unit is owned or hired by an institution or organization, the agent of that body.

Operator means the health professional given the responsibility, by the user, to treat the patient using a shortwave diathermy unit.
Shall indicates that the particular requirement is considered necessary to ensure protection from radiation.
Should indicates a procedure or precaution which is to be applied, whenever practicable, in the interests of minimizing radiation hazards.

Hazards of High Level Exposure to Microwave Radiation
Burns
These may result as a consequence of excessive exposures or may be due to non-uniform heating of different tissue layers or to reduced heat dissipation mechanisms (as in the case of the subcutaneous fat layer). In some cases deep tissue and organ damage may ensue because heating is induced at a depth where thermal sensation is reduced.

Teratogenic Effects
Abnormalities in offspring have been reported in several animal species after exposure to intense shortwave radiation. Intense fields resulting in significant temperature increase of the foetus could result in teratogenic effects in humans.

Effects on the Gonads
Exposure to shortwave radiation may increase the temperature of the testes to the point where temporary sterility is induced. Very high specific absorption rates may cause permanent damage. The ovaries may also be at risk.

Examination and Interview
Shortwave treatment shall not be administered unless prescribed by a health professional (as previously defined). At the examination and interview, when treatment is being prescribed, the health professional shall determine the suitability of the patient for treatment. This should not be prescribed if:
— The patient does not understand the potential risks,
— the patient is not able to co-operate with the operator in maintaining the proper position and in reporting the presence of a heating sensation which is the only indication of an adequate or excessive dose.
— the patient does not have normal sensation in the treatment area,
— the patient has metallic implants within the treatment area,
— the patient is pregnant,
— the patient wears a pacemaker,
— the patient has undergone ionizing radiation therapy to the treatment area in the three months prior to the diathermy being administered, as skin sensation and blood circulation may be diminished,
— there is evidence or known history of vascular insufficiency in the treatment area,
— the patient has any evidence of cancer, unless the shortwave treatment is carried out as part of a hyperthermia treatment regime. (The metastasis of a cancerous growth may be accelerated by a moderate increase in temperature, such as can be caused by a shortwave treatment not specifically intended to treat a malignancy.),
— there are open wounds, haemorrhage, ischaemic tissue, tuberculous joints, or acute infections within the treatment area.

In the cases where the clinician, after due risk/benefit consideration, deems it necessary to prescribe shortwave diathermy treatment outside the guidelines given above, adequate advice shall be given to the patient, to the user and to the operator of the shortwave diathermy unit.

User Responsibilities
The user shall ensure, by administrative control or otherwise, that:
— the shortwave diathermy unit complies with all relevant Australian Standards and is maintained in accordance with the relevant State requirements,
— the unit is operated only by health professionals,
— the unit operator is not exposed to a radiation level exceeding the standard for occupational exposure specified by the appropriate authority,
— the general public (including waiting patients, receptionist etc.) is not exposed to a radiation level exceeding that recommended by the appropriate authority,
— a range of applicators suitable for treating different areas of the body is available,
— a visible and/or audible signal is installed, to indicate that the unit is operating,
— the unit is not the cause of electric interference with other equipment (This may require the use of a screened cubicle and a mains filter.),
— non metallic chairs and/or beds are available to patients undergoing shortwave diathermy treatments.

Treatment
Before administering the treatment the operator shall:
— ensure that the thermal sensitivity of the patient is not impaired by analgesics,
— ensure that the patient has removed all metallic objects (rings, watches, metal rimmed glasses, etc.) from the treatment area.
— remove bandages or clothing from the treatment area,
— ensure that the skin is dry,
— ensure that if the patient is wearing a hearing aid, it is removed,
— ask the patient to report immediately any symptoms experienced during treatment except "a mild, comfortable warmth",
— ensure that the cables are correctly connected to both the machine and the applicator,
— not rest the applicator or cables over metal surfaces,
— align the applicator accurately to ensure an appropriate pattern of heating,
— ensure that the testes are not directly irradiated and that care is taken to minimize indirect irradiation,
— ensure that the cables leading to the applicator are not placed in the vicinity of the patient's non targeted tissue,
— ensure that the chair or other patient support is not metallic and that other large metallic objects are kept at least three metres from the electrodes and cables.

After activating the unit the operator shall:
— remain at least 1 m from the electrodes and 0.5 m from the cables during treatment,
— ensure that the patient maintains the correct position and remains co-operative,
— not leave the patient during the treatment, unless the patient has been supplied with an emergency cut-off switch and the patient is reliable,
— not allow the patient to touch the unit,
— ensure that no other person is in the vicinity of the unit or of the applicator during the treatment, in accordance with the administrative controls established by the user.

Appendix C

Advisory Authorities

Australia:
Australian Capital Territory
Consultant, Radiation Safety
ACT Health Authority
PO Box 825
CANBERRA CITY ACT 2601
Telephone: (062) 47 2899

New South Wales
Officer-in-Charge
Radiation Health Services
Department of Health
PO Box 163
LIDCOMBE NSW 2141
Telephone: (02) 646 0327

Northern Territory
Director
Occupational and Environmental Health
NT Department of Health
PO Box 1701
DARWIN NT 5794
Telephone: (089) 80 2601

Queensland
Director
Division of Health and Medical Physics
Department of Health
535 Wickham Terrace
BRISBANE QLD 4000
Telephone: (07) 224 5611

South Australia
Senior Health Physicist
Occupational Health and Radiation Control Branch
South Australian Health Commission
GPO Box 1313
ADELAIDE SA 5001
Telephone: (08) 218 3473

Tasmania
Health Physicist
Division of Public Health
Department of Health Services
PO Box 191B
HOBART TAS 7001
Telephone: (002) 30 6421

Victoria
Chief Radiation Officer
Radiation Safety Section
Health Department of Victoria
555 Collins Street
MELBOURNE VIC 3000
Telephone: (03) 616 7084

Western Australia
The Director
Radiation Health Branch
Health Department of Western Australia
Verdun Street
NEDLANDS WA 6009
Telephone: (09) 389 2713

Commonwealth
Director
Australian Radiation Laboratory
Lower Plenty Road
YALLAMBIE VIC 3085
Telephone: (03) 433 2211

New Zealand:
The Director
National Radiation Laboratory
PO Box 25-009
CHRISTCHURCH
Telephone: Christchurch 65 059