

Continuous short-wave (radio-frequency) diathermy

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Introduction

When radio-frequency (RF) electromagnetic energy of sufficient intensity is directed at biological tissue it will cause heating. This effect was recognised many years ago¹ and has been used therapeutically since 1928. Commercial units generate RF energy with a frequency of 27.12MHz and a wavelength of 11.06m. This is an international standard and lies within the shortwave radio bands.

Shortwave diathermy (SWD) equipment is designed to emit either a constant or a pulsed output and sometimes provides both. Constant output units are used primarily to achieve deep heating of tissues. Pulsed output allows cooling between pulses, heats less strongly and enhances the non-thermal influences of RF energy. Many studies have shown a beneficial therapeutic effect with pulsed output, although the mode of action remains obscure.

Continuous SWD is widely used clinically but remains poorly researched. Practical details of SWD use are not included here and the reader is referred to some of the excellent texts that are currently available²⁻⁴. This equipment can cause serious burns if used incorrectly.

Apparatus

The design of shortwave diathermy units will vary between the manufacturers, as does the maximum power output and range of compatible applicators. The specifications of some units used widely and readily available in the UK are given in *Table 1*.

Each unit consists of a signal generator and amplifier designed to deliver an output at a single frequency and with an intensity capable of producing therapeutic effects. The amplified signal is fed through a transformer to a second circuit that delivers the energy via various types of applicator to the patient. These two systems are tuned into resonance manually or automatically to allow the maximum amount of energy to be delivered.

The applicators convey energy either by acting as a capacitor, in which the tissues of the patient behave as a dielectric within the electric field, by means of rigid or flexible air- or felt-spaced electrodes, or by acting as an inductor. The latter technique employs an insulated cable that is either pre-formed into a flat spiral and contained within an insulated casing, or is wound by hand to enclose or lie adjacent to the target tissue which then behaves primarily as a conductor within a

Table 1. Specifications of continuous output shortwave (radio-frequency) diathermy units

<i>Manufacturer</i>	<i>Model</i>	<i>Modes of operation</i>	<i>Maximum continuous power output</i>	<i>Coupling</i>	<i>Applicators</i>
Enraf-Nonius Delft	Curapulse 419	Continuous/ pulsed	450W	Automatic	Rigid plates Flexible plates Free cable Cable in drum case Cable in hinged case
EMS (Greenham) Ltd	Megatherm Senior 6	Continuous	400W	Manual/ automatic	Rigid plates Flexible plates Free cable
Siemens Ltd	Ultratherm 808i	Continuous/ pulsed	410W	Automatic	Rigid plates Flexible plates Free cable Cable in drum case Cable in hinged case

magnetic field⁵. The ability of these applicators to heat the musculature whilst retaining a low temperature in the subcutaneous fat varies considerably⁶.

Biophysics

Oscillating electric and magnetic fields produce heat in biological tissues by inducing a rapidly alternating movement of ions, rotation of dipolar molecules and the distortion of non-polar molecules. A movement of ions represents a real flow of current and occurs readily in tissues rich in electrolytes such as blood vessels and muscle. Resistance to this flow leads to heat production. By contrast, in fatty tissue the main effect of an alternating electromagnetic field is to produce rotation and distortion of molecules which does not constitute a real flow of current, hence little heat is generated.

This activity of the SWD field at molecular level should cause blood vessels and muscle to heat strongly and adipose tissue to heat poorly. Experience reveals, however, that adipose tissue is also heated vigorously because it is permeated by small blood vessels that contain a solution of electrolytes. The heat generated is then retained due to the insulating properties of fat allowing a high temperature to develop. Fibrous tissue is not particularly rich in either blood vessels or fat and usually shows a moderate elevation of temperature⁵.

Assessment of heating

Any assessment by the therapist of the rate of heating is necessarily qualitative because neither field strength nor real current flow can be measured easily and thus neither heat production nor dissipation can be estimated. An appropriate intensity of heating is achieved by a process more akin to an art than a science in which the therapist integrates a knowledge of anatomy, the effects of output intensity, electrode placement and the relative rates of heating of different tissues, together with verbal reports of heating from the patient. Differential heating of tissues is enhanced or reduced, according to the aims of treatment, by the choice of applicator, its subsequent alignment and proximity to the skin^{7,8}.

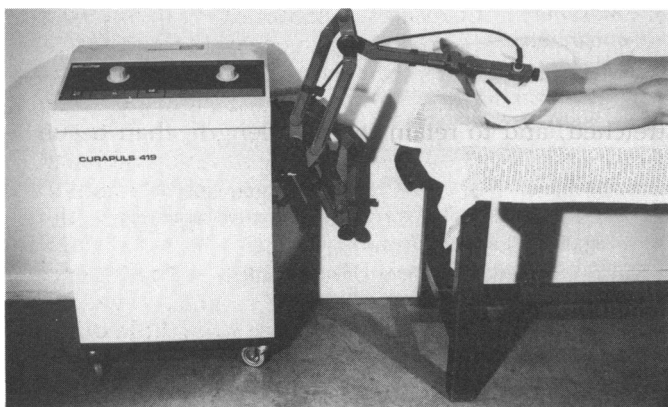


Figure 1. SWD unit fitted with a cable applicator held in a drum case

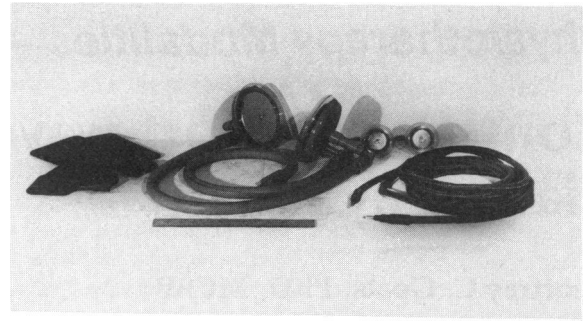


Figure 2. SWD applicators: flexible and rigid plate applicators and a free cable (from L to R)

Therapeutic changes only occur when the temperature of the tissue rises to 40–45°C². Below this there is little demonstrable effect. At higher temperatures the rate at which proteins denature proceeds more rapidly than repair, resulting in irreparable cell damage and acute pain⁹.

Physiological and therapeutic effects

In general, the tissue response to SWD compares closely with that from other methods of heating, and the common indications and contraindications are similar to those for superficial heating. Those differences which do however exist originate in the patterns of heating generated by the diathermies, which are unlike those produced by more superficial heating. Diathermy heats both the deep and superficial layers of tissue whilst the effect of superficial heating is most marked in the skin and subcutaneous tissues⁹. The physiological response also depends upon the magnitude of the rise in temperature, rate of rise, volume of tissue heated and the efficiency of the homeostatic mechanisms active in dissipating heat¹⁰.

Enzyme activity, metabolic rate and growth

Van't Hoff's Law observes that the rate of a chemical reaction increases two or three fold for each 10°C rise in temperature. Thus, elevating the temperature of a tissue from the norm of 37°C to 40–45°C will speed cellular metabolism, oxygen consumption and energy expenditure by a factor of 1.5. Increases in metabolic rate caused by diathermy will accelerate the processes of inflammation and repair and, together with local vasodilation and improved tissue drainage, should help deeply seated lesions to resolve more rapidly^{2,3}.

A muscle heated by shortwave diathermy shows an increased capacity for muscular work. This has been demonstrated in quadriceps femoris over a two hour period post-treatment¹¹, but others dispute this and claim that heating causes both strength and endurance to fall¹².

Heating of the epiphyseal plates in the long bones of children may affect growth¹³, hence injudicious application of SWD to a child may lead to deformity. Collagenases implicated in the destruction of articular cartilage become increasingly active as temperature

rises¹⁴ and the deep heating of SWD may exacerbate the acutely inflamed rheumatoid joint.

Inflammation and blood flow

Tissue heated to 40–45°C exhibits a mild inflammatory reaction mediated primarily by the release of histamine and the prostaglandins¹⁰. These alter directly vascular smooth muscle tone and the contractility of the endothelial cells, thus raising the hydrostatic pressure of blood within the capillaries. This in turn increases the rate at which fluid filters into the extravascular space to cause swelling.

Heat reinforces acute inflammation, promoting further oedema with exacerbation of pain and loss of function. Pulsed shortwave diathermy is used more appropriately in this situation. Sub-acute or chronic conditions respond favourably to heating, SWD being reported effective in conditions such as chronic sinusitis, bicipital and supraspinatus tendinitis and epicondylitis when applied by inductance¹⁵ and as lessening symptoms of traumatic arthritis².

Local heating clearly provokes vasodilation^{10,17}. Deep heating causes arterioles, capillaries and venules to dilate either by direct action or in response to decreased oxygen tension and increasing metabolite concentration in surrounding tissue¹⁸. Lymph vessels also respond to heating and the rate of interstitial fluid drainage increases with temperature¹⁹. Generally, blood flow to active organs rises during heating whilst that to inactive organ falls². This effect is more marked in some tissues than in others.

Blood flow in skeletal muscle is primarily under metabolic regulation²⁰ and is less affected by heating than skin blood flow. Blood flow in muscles heated by diathermy during cooling to 5°C of the overlying skin increased from the resting level of 2.61ml/min/100g to 32ml/min/100g²¹. Muscles exercised whilst heated deeply show higher perfusion rates than those exercised or heated separately²². Experimentally induced haematomas labelled with Cr⁵¹ disperse more quickly when heated to 42–45°C by diathermy⁶.

Blood flow to skin increases promptly in response to SWD heating due to the effect on the cutaneous vessels mentioned above and also the local axon reflexes served by the cutaneous thermoreceptors²³. Spinal reflexes produce a more complex vascular response to heating that is often remote from the treated site and may, for instance, occur in the opposite limb or in some other region²⁴. Heating the proximal segment of a limb can cause vessels lying distally to dilate. Some propose that this mechanism be harnessed to relieve the ischaemia present in peripheral vascular disease, although research has yet to confirm that the deep collateral vessels dilate to the same extent as the superficial networks²⁵.

Pain and muscle spasm

Pain and muscle spasm often coexist and in a variety of musculoskeletal disorders are mutually reinforcing. Empirical evidence justifies the use of heat to reduce pain although the physiological basis for this observation is poorly understood.

Shortwave diathermy increases pain threshold experimentally. This response is apparently mediated by a direct action of heat upon free nerve endings²⁶ or on the nerve trunk that supplies the affected area²⁷. Heat may also stimulate the cutaneous thermoreceptors sufficiently to block the transmission of pain as it enters the spinal cord via the 'pain-gate' mechanism²⁸. Some suggested that heat applied at sufficient intensity to cause pain acts as a 'counter-irritant' that closes the 'pain-gate' and reduces a more severe pain elsewhere²⁹ but this approach is now considered inappropriate. The increase in conduction velocity observed when peripheral nerves are heated by SWD would facilitate this mechanism³⁰. Heating also eases pain by promoting vasodilation² and efflux from the affected tissue of chemicals implicated as mediators of pain e.g. bradykinin, serotonin and the prostaglandins.

Muscle spasm secondary to pain from musculoskeletal disorders is often reduced by heat and this in turn will contribute to the lessening of pain. Heat has a therapeutic effect on muscle spasm by acting directly upon the muscle spindles. These deep structures will be most effectively heated by SWD. As the temperature of the muscle spindle rises the activity of the mechanisms conveying information about static stretch to the spinal cord decreases. At the same time Golgi tendon organ output increases, helping to prevent muscle over-stretch³¹. The sum of these influences on the anterior horn cells in the spinal cord is inhibitory and results in the relaxation of the affected muscle. Furthermore, the output of muscle spindles is reduced and relaxation facilitated by a reduction in gamma efferent activity caused by a reflex response to skin warming²⁴.

SWD is often used successfully in conditions in which pain and muscle spasm are prominent including degenerative joint disease^{32,33}, ankylosing spondylitis⁷, low back pain³⁴, and soft tissue injuries such as inversion sprains of the ankle³⁵.

Elasticity of connective tissue and joint range

The viscoelastic properties of connective tissue vary with temperature and the concentration of a common structural component, the glycosaminoglycans, alters after treatment with shortwave diathermy³⁶. As the temperature of the tissues approaches the therapeutic range, the behaviour of collagen becomes more plastic and less elastic. Thus connective tissue heated to 40–45°C will show a greater tendency to elongate when stretched, and to retain the new length, than tissue stretched at 25°C³⁷. A stretch of long duration achieved with minimal force produces the greatest elongation and maximum recovery of joint range with the minimum of tissue damage³⁸.

Pain and loss of function in patients with OA knee was improved by SWD given three times a week⁴⁰. Such results contrast with those reporting little difference between the symptomatic improvements gained using active or disabled shortwave diathermy units⁴¹, shortwave diathermy or superficial heating modalities⁴¹ and shortwave diathermy and exercise versus interferential therapy and exercises given three times a week for two–six weeks⁴³.

Summary

Continuous shortwave diathermy is the technique of choice when uniform marked elevation of temperature is required in the deep tissues. This heating can be targeted accurately by using an appropriate applicator positioned correctly. SWD also allows superficial structures to be heated selectively, although for this the various methods of surface heating are usually preferable.

Sub-acute or chronic conditions respond best to continuous shortwave diathermy which, when used properly, can be as effective as ultrasound. Acute lesions are better treated with pulsed shortwave diathermy.

Continuous shortwave diathermy can help to relieve pain and muscle spasm, resolve inflammatory states and reduce swelling, promote vasodilation, increase the compliance of connective tissue, increase joint range and decrease joint stiffness.

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