BENEFIT OF MICROWAVE DIATHERMIA FOR REHABILITATION

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Abstract

This article deals with benefits of microwave diathermia for rehabilitation and explains how is microwave heating of biological tissue achieved. Furthermore it presents suitable microwave applicator for treatment.

1 Basic principles of microwave diathermia

Diathermia is commonly used treatment method for pain relief in musculoskeletal tissue, rheumatisms, inflammation etc. Whole concept of diathermia is based on fact, that increased temperature in tissue induces and quickens healing process. This fact was observed already by ancient physicians as we can read on prescriptions from Hippocrates of Cos himself. This is one of the first documented uses of diathermia ever.

How does it work? Increased temperature induces better blood perfusion in heated tissue which cause better oxygenation and flushes waste products of metabolism out of the treated tissue. [1] For diathermic therapy we use slight increase of temperature in treated tissue, just to support blood flow and prevent any heat damage to cells, unlike hyperthermia treatment where heat damage is one of the treatment aims. Various methods can be used for heating the tissue like just warm bath of warm wrap, but the most benefit is in deep heating achieved by using microwave sources or shortwave sources and ultrasound.

Shortwave diathermy involves using high-frequency electrical currents. [2] This method is used for large heated areas with primary concentration at the midpoint between electrodes. This method has great penetration, but it is hardly focusable. The electromagnetic field is usually at radio frequency of 27.12 MHz.

Ultrasound diathermia is based on high-frequency acoustic vibrations. For diathermic treatment is used frequency range from 0.8-1.0 MHz . Ultrasound is very useful for heating joints that have a thick layer of overlying soft tissues that both shortwave or microwave diathermy cannot penetrate. It can also be used with caution over metal implants.

Microwave diathermia selectively heats tissue with high concentration of water like muscles. Because applying an electrical field on a molecule of water leads to the polarization, ie rotation in the direction of electric vector of intensity field *E*. If we let alternate current power to take effect on the molecule its field would lead to the alternating polarization from one direction to another. With increasing frequency, the molecule loses its ability to track the rapid changes, the effective dielectric constant decreases, loss angle increases and the energy field is converted to heat. So we can target right the muscle spasms and contractures. In addition we can effectively treat superficial joints of hands, feet and wrist because this structures is close to the body surface and they are overlayed with just thin soft-tissue with high concentration of water. This is very useful with aditional physiotherapy treatment like stretching.

ISM (industrial, scientific, and medical) designated frequencies for microwave heating are 435 MHz, 915 MHz and 2450 MHz. There is no practical use for frequencies higher than 2450 MHz due to their limited penetrations. On the other hand, on lower frequencies field penetration is deeper, but focusing power is difficult and also the applicator has to be much larger. We can determine penetration by equivalent penetration depth this is depth in which intensity of electromagnetic field decreases to cca 37 % of surface value.

2 Applicators for microwave diathermia [3]

For microwave diathermia we can use both planar applicators and waveguides. Both have their advantages and reasons for use in different conditions.

2.1 Waveguide applicators

We can imagine waveguide as conductive tube with any shape of cross-section. Advantages of this applicator result from the fact that it allows transfer the highest power in broadband and has the lowest loss of transferred electromagnetic energy of all kinds of applicators.

Electromagnetic field is in waveguide shaped by the format of tube to mods, on which depends shape of heat profile in treated tissue. There is a critic frequency for every mod. We have to use higher than critical frequency for excitation of chosen mod in waveguide. On the contrary when we use lower than critical frequency, the transmitted energy is exponentially damped through the waveguide, this is so called evanescent mods. Most common shapes of waveguides are rectangle and cylinder. Thickness of waveguide tube material has to be at least quintuple as its effective penetration depth. Constant of cross-section of rectangle waveguide for mod TE_{mn} can be calculated as where a is longer side of

$$k_{c,mn} = \sqrt{\left(\frac{m\pi}{2}\right)^2 + \left(\frac{n\pi}{2}\right)^2}$$

waveguide, b is shorter side and m,n are indexes of mod.

2.2 Planar applicator

Planar applicators differ each other by shape of strip conduit. Most common strip conduit shape is Archimedean double spiral and for slot applicator we use square. We can use this type of applicators with advantage, due their beneficial attributes such as flexibility and easy manufacturing. This applicators are actually created by technology of printed circuit board, so it is very cheap and can be even realized from elastic materials. This is considerable advantage over waveguides, because flexible material can easily adhere to treated area.

Spiral applicator behaves as broadband antenna and is more resistant to dependence of working frequency on permittivity. Wavelength of this applicator can be calculated

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}}$$

where c is speed of light, f is frequency and ε_{eff} is effective permittivity. We consider value of ε_{eff} higher than relative permittivity of used dielectric and lower than relative permittivity of treated tissue.

We consider value of ε_{ff} higher than permittivity of dielectric and lower than permittivity of biological tissue. Radiation of such applicator is circularly polarized and this is very beneficial for prevention of hot spots in treated tissue.

3 Simulation and design

To maximize simplicity and usability we decided for planar applicator of Archimedean double helix shape due to its broadband characteristics and versatility for prevention hotspots . We intended to design an applicator for superficial use, so we chose parameters as shown in Table 1.

Table 1: PARAMETERS OF APPLICATOR

Size	40mm x 40mm
Frequency	2450 MHz
Power	50W

For simulation and design was used CST Microwave studio

4 Evaluation

For evaluation of our applicator we chose agar phantom, because its parameters is close to real muscular tissue. We cared about heat distribution on surface and in depth of heated tissue. It is very good on agar phantom, that we can slice it co see how is the temperature distribution under surface and measure it with thermocamera. Time of heating phantom of 1 kg mass was t = 300 s, where output from generator was 55 W. For evaluating heat profile in phantom we used thermocamera FLIR P25.

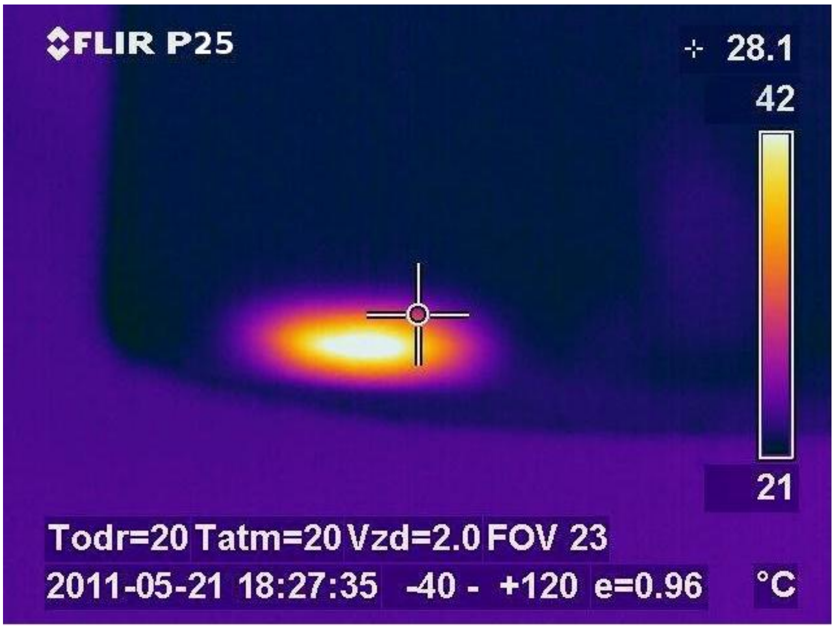

Figure 1: Heat profile in homogenous agar phantom.

Good impedance matching between treated tissue and applicator is crucial. Thanks to fact, that Archimedean double spiral applicator behaves as broadband antenna we avoid strong dependency of frequency on permittivity. We are interested during evaluating reflection coefficient S_{11} how much radiated output is reflected from applicator connector back to generator.

5 Results

The main benefit of microwave diathermia is in selective heating of target tissue (muscles) so we can avoid unwanted heating of other structures such as bones and fat. In our opinion the applicator is suitable for diathermic heating of superficial muscles. Treatment time should be about 25 minutes, with applicator's aperture covered with smooth absorbent cloth to absorb sweat for prevention of creating hot spots on skin surface.

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