Comparative Study of Thermal and Non-Thermal Ultrasound Waves Effects on the Upper Shoulder Joint Therapeutic Response in the Range of 1-3 MHz

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دراسة مقارنة لتاثير الموجات فوق الصوتية الحرارية وغير الحرارية في معالجة مفصل الكتف ضمن المديات 1-3 ميكاهيرتز. العلوي

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Abstract

Therapeutic ultrasound is one of the most common treatment used in the management of soft tissue lesions. The scientific basis for the use of therapeutic ultrasound waves among soft tissue lesions and the existing evidence related to its clinical effect are detailed. Two kinds of therapeutic ultrasound waves were taking in to account on treating anterior joint capsule of the right shoulder disorders of human being: Thermal and non-thermal ultrasound waves. Thermal ultrasound was applied at 1 MHz with an

intensity of 1.0 W/cm^2 and a 50% duty cycle for 5-10 minutes. The effect of the ultrasound for three cases were found evident from the results obtained. It is found that patient with a younger age has responded to a shorter period of treatment, so that the soft tissues of a 24-year old patient responded faster than that of a 50 years old patient, who needs longer treatment sessions and consequently longer time.

Ultrasound waves of non-thermal was applied at 3 MHz with an intensity of 0.5 W/cm^2 and a 20% duty cycle for 2-8 minutes. The effect of ultrasound for three cases aged (20,35 and 52) years old, were found evident from the results obtained. It is found that patient with a younger age has responded to a shorter period of treatment, which showed that the soft tissues of the 20-year-old patient responded faster than that of a 52-years old patient, who needs longer treatment time.

Results obtained for the six cases selected were cured, although the duration of treatment was varied on using thermal ultrasound which is less than the duration of treatment using non-thermal ultrasound for the same area of injury. The procedure carried out without any sign of pain.

Keywords: Medical Physics: Thermal and Non-Thermal Ultrasound: Comparative Study.

المستخلص

العلاج بواسطة الموجات فوق الصوتية هي واحدة من العلاجات الرئيسية التي تستخدم في التعامل مع الانسجة الرخوة للجسم. الجانب العلمي والقواعد الاساسية للمعالجة بواسطة الموجات فوق

الصوتية قد تم ذكرها تفصيلا. هنالك نوعان من العلاج بالموجات الصوتية قد تم اعتمادها لمعالجة مفصل الكتف الايمن للانسان باستخدام الموجات فوق الصوتية الحرارية وغير الحرارية. تم استخدام الموجات الحرارية النبضية (1 ميكاهيرتز) وبشدة (1 واط لكل سم^2) بواقع 50% للدورة وبمدة تتراوح بين 5-10 دقيقة. تم التطبيق على ثلاثة مرضى اعمارهم 24، 35 و 50 سنة، وقد وجد بان الاعمار الصغيرة تستجيب للعلاج بوقت اسرع من الاعمار المتقدمة، لذلك فان الانسجة الرخوة لمريض عمره 24 سنة استجابت للعلاج اسرع من مريض عمره 50 سنة، والذي احتاج الى جلسات علاجية اكثر و وقتا اطول في العلاج.

تم استخدام الموجات غير الحرارية النبضية (3 ميكاهيرتز) وبشدة (0.5 واط لكل سم^2) بواقع 20% للدورة وبمدة تتراوح بين 2-8 دقيقة. تم التطبيق على ثلاثة مرضى اعمارهم 20، 33، و 52 سنة، وقد وجد بان الاعمار الفتية تستجيب للعلاج اسرع من الاعمار المتقدمة. النتائج اظهرت شفاء الحالات الستة بالرغم من تفاوت مدة العلاج.

الكلمات المفتاحية : الفيزياء الطبية, الموجات فوق الصوتية الحرارية وغير الحرارية, دراسة مقارنة.

Introduction:

Ultrasound waves with frequencies exceed the normal hearing range (> 20,000 Hz) used to evaluate patient's internal organs are transmitted into the body with various internal structures, and these waves are reflected and scattered through tissue then after returning echoes can be collected and used to form an image of a certain part of the body (Noureddin , 2014).

These ultrasound waves are mechanical processes containing compressions and rarefactions transmitted through a medium (1). It is measured in Hertz in the range of 1 to 20 MHz (Alvarenga , 2010).

These waves can be generated by a device known as ultrasonic transducer which consist of piezoelectric materials that convert electric pulses into mechanical vibration waves that passes through tissues of the body (Desmeules *et.al* , 2015) . There are many applications of these waves in curing and healing different parts of the body where problems are existing, such as pain in shoulders or joints by applying thermal or non-thermal ultrasound waves to a specific area under treatment in the range of 1 – 3 MHz (Uhlemann *et.al* , 2003).

Ultrasound waves are interacting with tissues concerning the atomic boundaries, which is based on the acoustic impedance of the bordering tissues. Also the difference between incident angle of the waves and reflected angle. Knowing that some waves continue to pass through body and therefore, no interaction with tissue or transducer takes place (Munich & Duck , 2002 & MacIntyre *et.al* , 2013).

Physiological Effects of Ultrasound:

Therapeutic ultrasound, commonly used in the therapy industry, utilizes both the thermal and non-thermal effects of ultrasound for heating and healing soft tissues, reducing pain, and restoring function (Hussein & Donatelli , 2016).

Thermal Effects

As ultrasound travels through body tissue some percentage is absorbed, resulting in the generation of heat. The degree of absorption depends on the

nature of the tissue, the extent of vascularization and the frequency of the sound waves. Thermal diffusion and local blood flow then dissipate the heat created by the ultrasound. Complications can occur if the ultrasound beam hits bone or a metal prosthesis. These structures will reflect the ultrasound waves, and further heat is created during the beam's return journey. It is therefore important to know the local anatomy and the patient's medical and surgical history when using ultrasound (Draper , 2010).

Non-Thermal Effects

This describes a number of physical mechanisms known as cavitation, acoustic streaming and standing waves . Cavitation is the formation by ultrasound of small bubbles or cavities in gas-containing fluids. These bubbles vibrate to cause changes to the permeability of cell membranes. Acoustic streaming is the unidirectional movement of a fluid in an ultrasound field. It can stimulate cell activity if it occurs at the boundary of the cell membrane and the surrounding fluid. Standing waves occur when an ultrasound wave hits the interface between two different tissues, such as muscle and bone, resulting in reflection of a percentage of the wave. The increased pressure produced in standing wave fields can cause transient cavitation and consequently free radical formation (Lovric *et.al* , 2013) . To prevent this, it is important that therapists move the applicator continuously throughout treatment and use the lowest intensity required to have a therapeutic effect. The technique of treatment is shown in Fig.1.

Figure 1. Shows the technique of treatment using ultrasound wave machine (8).

Objective:

To determine the therapeutic effect of ultrasound, wave in term of thermal and non-thermal energies procedure among patients who were complaining of anterior joint capsule of the right shoulder.

Materials and Methods

Data Collection and Manipulation:

Data were collected from Al-Khalid Physiotherapy Center in Baghdad (Al-khalid , 2018).

Six patients were chosen of different ages, who went through procedures of treatment with thermal and non-thermal therapy. These were demonstrated in table (1) below.

The table classified in columns, so that first column is the target tissue, which is chosen as Anterior joint capsule of the right shoulder; the second is for the type of treatment whether thermal or non-thermal; the third is for the mode of treatment; the fourth is for the frequency chosen for each treatment; the fifth is for the intensity used; the sixth is for the time for each session; the seventh is for the duration of treatment for each case; and the eighth is for the age of each patient.

Table (1) Target Tissue Chosen for Thermal and Non-Thermal Ultrasound Wave Therapy Parameters.

Group	Target tissue	Parameters	Mode	Frequency	Intensity	Time	Duration of treatment	Age (year)
Group A	Anterior joint capsule of the right shoulder.	Thermal	Pulsed 50%	1MHz	1.0W/cm2	10 min	1 week	24
	Anterior joint capsule of the right shoulder.	Thermal	Pulsed 50%	1MHz	1.0W/cm2	8 min	2 weeks	35
	Anterior joint capsule of the right shoulder.	Thermal	Pulsed 50%	1MHz	1.0W/cm2	5 min	3 weeks	50
Group B	Anterior joint capsule of the right shoulder	Non-thermal	Pulsed 20%	3MHz	0.5W/cm2	8 min	2 weeks	20
	Anterior joint capsule of the right shoulder	Non-thermal	Pulsed 20%	3MHz	0.5W/cm2	4 min	4 weeks	33
	Anterior joint capsule of the right shoulder	Non-thermal	Pulsed 20%	3MHz	0.5W/cm2	2 min	6 weeks	52

Tissue heating is a result of absorption of kinetic energy produced by ultrasound. The amount of heat produced will be affected by the intensity and frequency used as well as the type of tissues exposed. As would be expected, as the intensity increases, so does the amount of heat produced, with continuous (constant wave) ultrasound producing more heat than pulsed.

To produce non-thermal levels of ultrasound for tissue healing, use a frequency of 3 MHz for targets of 2 cm. An intensity of 0.5 watts/cm^2 delivered at a 20% duty cycle was a good starting point for tissue healing. A low duty cycle allows sufficient time for tissue to cool between pulses and produce thermal levels of ultrasound for tissue healing, use a frequency of 1MHz for targets of 2 cm. An intensity of 0.1 watts/cm^2 delivered at a 50% duty cycle is a good starting point for tissue healing.

Taking into account that the most frequently available treatment frequencies are 1 and 3MHz, the option between them relates primarily to the effective treatment depth that is required. To treat the six cases in the above table, the pathological cases were divided into two groups (A) and (B) to determine the ultrasound waves best suited for treatment in this depth. His boundary between superficial and deep lesions is in some ways arbitrary, but somewhere around the 2cm depth is often taken as a useful boundary. Hence, if the target tissue is within 2cm (or just under an inch) of the skin surface, 3MHz ultrasound is absorbed more rapidly in the tissues, and therefore is considered to be most appropriate for superficial lesions less

than 2 cm, whilst the 1MHz energy is absorbed less rapidly with progression through the tissues, and can therefore be more effective at greater depth 2 cm.

3MHz treatments will be effective whilst treatments to tissues will be Less effectively achieved with 1MHz ultrasound.

Through the results obtained, it has been noted that tissue healing effects of ultrasound are achieved quickly, and therefore the length of treatment for non-thermal ultrasound is short, Therefore, when the six cases of groups (A, B) are observed, the duration of the treatment varies from one patient to another when treating Anterior joint capsule of the right shoulder, treatment should last (2-10) minutes. Extending the length of treatment has not been shown to improve tissue healing and in fact, may result in unwanted tissue heating. Treatment should be given daily and should continue as long as benefits are apparent.

The use of ultrasound waves in this paper gave results comparable with a number of work done by many authors (Srbely & Dickey , 2007 : Unalan *et.al , 2011 :* Schandelmaier *et.al , 2017 and* Ottenheijm *et.al ,* 2015).

Procedure of Treatment:

The study sample was six cases selected from outpatient clinic divided randomly into two groups:

Group (1):

Three cases aged 24,35, and 50 years old were exposed to thermal therapy in intensity of 1.0 W/cm^2 and frequency of 1MHz with times of 10, 8, and 5 minutes respectively, with duration of 1, 2, and 3 weeks respectively on average of two sessions per week.

Group (2):

Three cases aged 20, 33, and 52 years old were exposed to non-thermal therapy in intensity of 0.5 W/cm^2 and frequency of 3 MHz with time of 8, 4, and 2 minutes respectively with densities of 2, 4, and 6 weeks respectively.

The instrument used for treatment of anterior joint capsule of the right shoulder is ultrasound machine in the interval range of 1 – 3 MHz pulsed frequencies, both thermal and non-thermal modes.

During the week in two forms of treatment exposure is two sessions.

Results and Discussion:

Thermal Technique

It is found that younger age (24 years old) requires one-week period of treatment, with 2 sessions. Each session last for 10 minutes. While age (35 years old) requires two-week treatment, with 4 sessions. Each session last for 8 minutes. For older age (50 years old) requires three-week treatment, with 6 sessions. Each session last for 5 minutes.

This means that older ages patients require more sessions and more duration with less time of exposure for complete treatment.

The intensity power of ultrasound used for this technique is 1.0 w/cm^2 and frequency of 1MHz.

2- Non-Thermal Technique:

Meanwhile in non-thermal therapy, younger age group such as 20 years old requires 4 sessions for 8 minutes each, for two weeks' time of treatment. While patient aged 33 years old require 8 sessions of duration for 4 minutes each, for four weeks' time of treatment.

For older age of 52 years old and older, require 12 sessions for duration of 2 minutes each, for six weeks.

This means that older ages patients require more sessions and more duration with less time of exposure for complete treatment.

The intensity power of ultrasound used for this technique is 0.5 w/cm^2 and frequency of 3MHz.

It can be concluded that older ages require low power with longer time sessions, probably interpreted due to comorbidity accompanying this age group, and to prevent above effects of ultrasound therapy.

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