Introduction to Therapeutic Ultrasound

Table of Contents

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Introduction to Therapeutic Ultrasound

Objectives:

Upon completion of this home-study program, the participant will be able to:

- Explain the physical principles of ultrasound.
- Describe the physiological effects of ultrasound.
- Identify indications, contraindications and precautions for ultrasound.
- List the alterable parameters of ultrasound and how each parameter will affect treatment outcomes.
- Design a treatment plan incorporating ultrasound.
- Explain the rationale for using ultrasound.

Instructions

Please complete this home study course in the following order:

1. Read "*Introduction to Therapeutic Ultrasound"* text.
2. Read and perform the *Lab Exercises.*
3. Read and complete the *Case Studies.*
4. Complete the Test. Your test can be submitted by fax or mail:

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Introduction to Therapeutic Ultrasound

Introduction

Ultrasound, sound waves with frequencies above the range of human hearing, has been utilized in various areas of the field of medicine for many years. Depending on the frequency and intensity utilized, ultrasound has various applications, but is most commonly known for its uses as a diagnostic tool, such as fetal diagnostic imaging. Some of its earliest uses were for the purpose of tissue destruction, using high intensities to eradicate cancerous tumors.

This course, however, will focus on another application, therapeutic 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.

If used properly, therapeutic ultrasound can be a powerful and effective adjunct for facilitating the healing process, alleviating pain, and improving function. It is important to stress the words "if used properly" because appropriate application and parameter selection if imperative for positive clinical results to occur. Unfortunately, many clinicians do not use ultrasound properly, and consequently either do not get the best possible results or get negative results. Over the years, many therapists have used ultrasound too frequently, possibly out of habit or due to the widespread popularity and acceptability of this modality. On the other hand, some therapists, due to lack of understanding, fear, or a history of poor treatment outcomes, have simply abandoned the use of ultrasound all together.

A frequent request from clinicians is for a list of protocols or treatment parameters. Unfortunately, this is difficult to supply because parameters should be tailored specifically for the individual patient and adjusted until the desired results are achieved. Any chart or protocol list is virtually useless without a list of 'ifs, ands, or buts' to explain, at the very least, what the expected outcomes are, and what to do if the actual results are not as expected.

On the bright side, ultrasound units have relatively few alterable parameters. In fact, most ultrasound units have a maximum of three variables: size of sound head, frequency, and intensity. Once a clinician develops a good understanding of these parameters and their effects on human tissues, it will also become clear how each one affects the physiological results and therefore treatment outcomes.

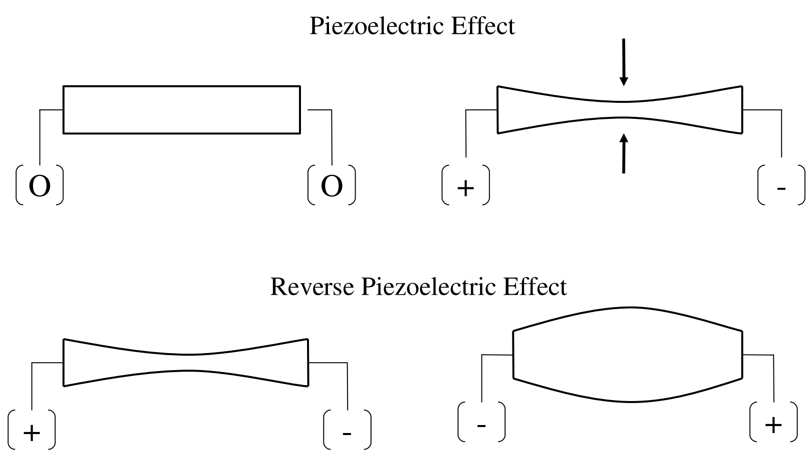
This course will begin with the physical principles of ultrasound and their physiological effects on human tissues, followed by discussion of contraindications and precautions. Clinical applications of ultrasound and designing treatment programs will be covered both in text form and through lab exercises.

Frequency

Sound waves can be distinguished according to their frequency. The unit of measure for frequency is Hertz (Hz) and one Hz equals one cycle per second. Humans are capable of hearing sounds at frequencies within the range of 16-20,000Hz. Frequencies higher than 20,000Hz are considered ultrasound.

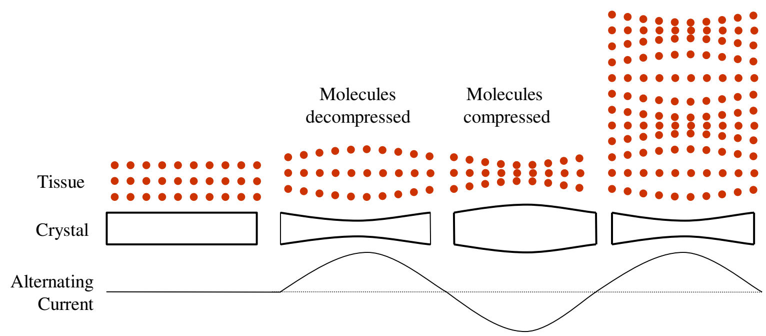
These high frequency sound waves are created using piezoelectric crystals. These crystals have the unique capability of transforming mechanical energy into electrical energy, and this transformation is called the piezoelectric effect. Ultrasound equipment utilizes these crystals by reversing this process, called the reverse piezoelectric effect. When exposed to an alternating current, these crystals will expand and contract with each change in polarity (see figure 1). The crystal is mounted and encased within an applicator, called a transducer or sound head. Piezoelectric crystals occur naturally in our environment, as quartz crystals for example. However, most modern ultrasound manufacturers utilize synthetic crystals, which provide more consistent and predictable output.

Figure 1:
Production of Ultrasound



Sound waves are propagated through matter by mechanical compression and decompression of its molecules. The molecules themselves are not actually permanently displaced, they are simply forced to vibrate, and this vibration is passed on from one molecule to the next like a domino effect. Picture, for example, a common activity in sports arenas called ‘the wave’, where fans stand then sit in succession, creating a visual wave, that progresses around the arena. The people do not actually move around the arena, their ‘energy’ is simply passed from one to another. In this comparison, the people would be the molecules of the tissue, and the ultrasound vibration would be comparable to the wave moving around the arena. Ultrasound energy is passed from one molecule to the next in a series of waves. Each cycle of an ultrasound wave consists of two phases, a compression phase, when the molecules are being pressed together, and a decompression phase called rarefaction, when the molecules are being separated (see figure 2).

Figure 2:
Transmission of Sound



Condensations = molecules compressed
Rarefactions = molecules decompressed
Wavelength = 1 condensation + 1 rarefaction
↑ Density = ↑ speed of conduction
↑ Density = ↓ distance of travel

The high frequencies of ultrasound require a relatively dense medium, such as a liquid or solid, but they are unable to pass through gas and therefore will not travel through air. The type of wave produced and the direction in which it travels is determined by the type of tissue exposed to the ultrasound beam. The soft tissues of the body act as liquids and transmit longitudinal waves, which travel parallel to the ultrasound beam. Bones, however, act as solids and produce both longitudinal and transverse (shear) waves (see figure 3).

The vibrations produced by the ultrasound's crystal are passed from one molecule to the next in the form of kinetic energy. The more dense the tissue, the closer together the molecules are, and therefore, the faster the energy will be transmitted. However, the denser the tissue, the tighter the molecules are held together, and therefore the energy will be used up faster, decreasing the depth of penetration into the tissues.

In addition to density of tissue, depth of ultrasound penetration will also be affected by the frequency used. Higher frequencies force molecules to vibrate at a faster rate, requiring more energy to overcome friction and therefore decreasing penetration. Lower frequencies result in less friction and therefore deeper penetration. As previously mentioned, 1MHz and 3MHz are the most commonly utilized frequencies. A frequency of 3MHz allows for treatment of superficial tissues, up to 2cm deep, while 1MHz should be used to reach tissues between 2 and 5cm deep.

Attenuation

As ultrasound passes through the tissues, there is a continual decrease in the amount of energy left within the beam. This decrease in energy is called attenuation and is a result of reflection, refraction and absorption. As the ultrasound beam encounters a change in tissue density, some or all of the energy may be reflected back, or it may be refracted, allowing it to pass into the next layer, although bending its path and changing the direction in which it is

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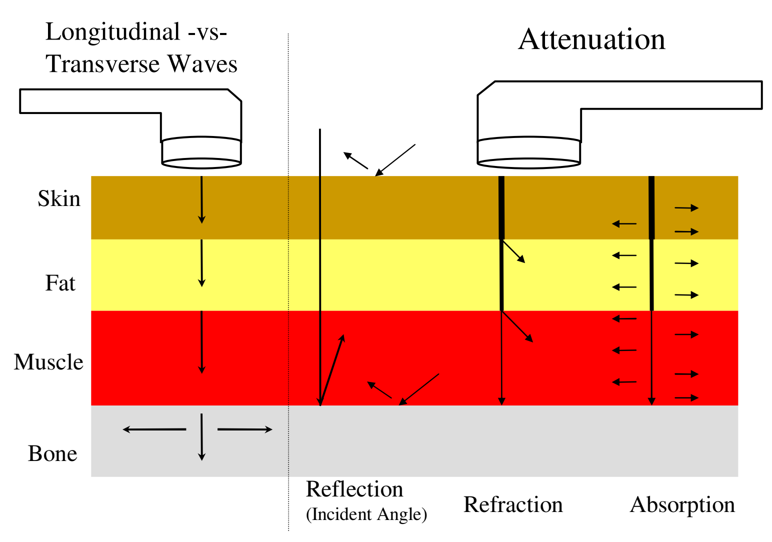
travelling. Reflection is most likely to occur when there is a significant change in density, such as when passing from a coupling medium into skin, or from soft tissue to bone. Sometimes this is unwanted, such as when attempting to deliver ultrasound into dry, thick, callused skin, much of the ultrasound will just reflect off, and never enter the tissue. On the other hand, sometimes reflection can be clinically helpful, such as when ultrasound reflects off of bone and is able to pass through the soft tissue again, meeting incoming waves, and producing a great deal of kinetic energy at the level of the periosteum. Tissues located adjacent to the bone, such as tendons, ligaments and joint capsules can be selectively heated due to their location.

Refraction is more likely to occur when the change in density is not as significant, and rather than the energy reflecting back, it is bent off of its current path. This refraction causes the ultrasound path to scatter and widen. A good comparison is to picture how a flashlight works. If the flashlight is held directly to a surface, the cone of light is small, but as you pull the flashlight away from the surface, the cone of light becomes larger with the increasing distance. Similarly, the deeper ultrasound is able to pass through tissue, the wider the area of treatment becomes, due to refraction.

The third way that energy in an ultrasound beam is decreased is through absorption. Ultrasound is absorbed by the tissues in the form of kinetic energy, resulting in heat build-up. The more dense the tissue, the more energy will be absorbed and therefore, more heat will be produced. Collagen-rich connective tissue, such as tendons, ligaments, and joint capsules are ideal targets for thermal ultrasound as their density allows them to be selectively heated. Therefore, the ability to selectively heat these collagen-rich tissues is two-fold, through increased absorption due to their high density, as well as the availability of high ultrasound energy exposure due to reflection (see figure 3).

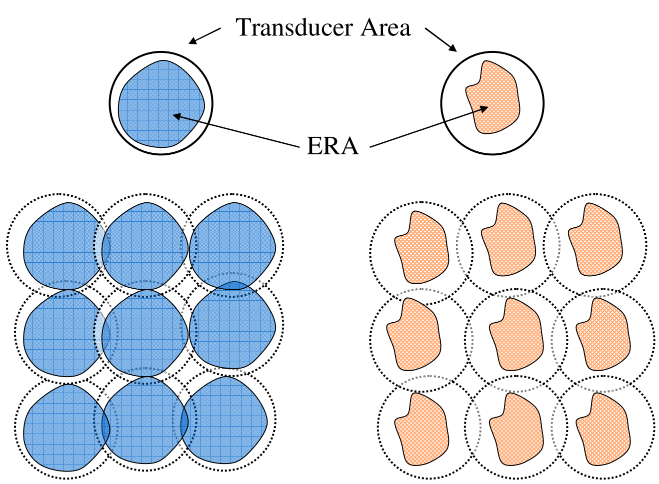
Figure 3:
Propagation Through Tissues



Effective Radiating Area

Sound heads or ultrasound transducers are produced in multiple sizes, the most frequently used size being $5cm^2$, but also commonly available in $2cm^2$, and $10cm^2$. Manufacturers are required to label their ultrasound transducers in terms of their effective radiating area (ERA). The ERA is the size of the transducer face that is producing ultrasound vibration, and this will always be at least a little smaller than the physical size of the transducer surface. When looking at the treatment surface of an ultrasound transducer, it contains a piezoelectric crystal, which is mounted within the sound head. The crystal itself will be slightly smaller than the circumference of the transducer surface, and the physical size of the sound head will be affected by the way the crystal is mounted and stabilized. Therefore, the ERA will be determined by the size and quality of the crystal as well as the way in which it is mounted. A quality ultrasound transducer will have an ERA close to the actual size of the sound head face (see figure 4). If your ultrasound transducer has a poor ERA, it will be important to alter your treatment technique, taking into account that the amount of tissue that is receiving ultrasound energy is less than actually being covered by the sound head. In other words, you may need to imagine that your sound head is smaller than it appears.

Figure 4:
Effective Radiating Area (ERA)

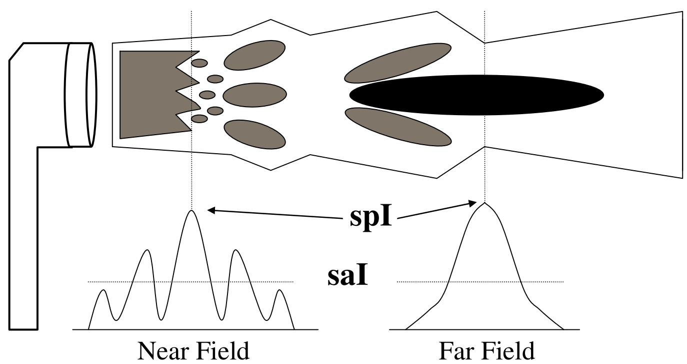


Beam Non-Uniformity Ratio

Manufacturers are also required to label their ultrasound units with the beam non-uniformity ratio (BNR). Because some areas of the crystal produce more energy than others, the overall ultrasound beam will be non-uniform, with certain portions of the beam (usually the central portions) producing higher intensities that others. This is one reason the sound head must be moving continually. By moving the sound head too slowly, or not at all, these points of high intensity will cause small areas of excessive heat build-up, resulting in pain and possible tissue damage. By moving the sound head slowly and continuously throughout the treatment, any potential hot spots may be avoided, creating a more uniform heating of the tissue. The BNR is the ratio of the maximum intensity in the beam, the spatial peak intensity (spI), and the average intensity (saI) (see figure 5). To further illustrate this, if you are delivering ultrasound at 1watt/cm^2 and your BNR is 6:1, then somewhere in the beam is a peak intensity of 6watts/cm^2. A BNR of 6:1 or less is generally considered to be acceptable, and the lower this ratio, the better the quality of the ultrasound.

Figure 5:

Intensity = Power (watts)



saI = Power / ERA

BNR = Maximum Intensity -vs- Average Intensity

6:1 or less

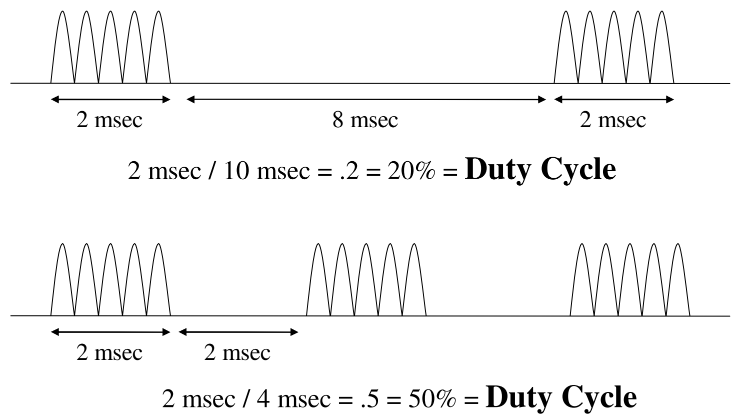
Power and Intensity

The amount of energy contained in an ultrasound beam can be described in terms of power and intensity. The total amount of energy being produced by the sound head is called total power and is measured in watts. Intensity is most commonly described in terms of spatial average intensity (saI) and is measured in watts/cm^2. The spatial average intensity describes the amount of power being delivered per square centimeter and is calculated by dividing the total power by the ERA. So, if the total power being delivered is 5 watts (w), and the ERA of the sound head is 5cm^2, then the saI is 1 w/cm^2.

Temporal Average Intensity

Ultrasound can be delivered as either a continuous or pulsed waveform. When delivered in the pulsed mode, the ultrasound is automatically turned off, or interrupted periodically. When delivered in the pulsed mode, the percentage of time that the ultrasound is actually on is called the duty cycle. For example, if the ultrasound is on for 2 milliseconds, then off for 2 milliseconds, then it is only on for half of the time, or 50%. To calculate the duty cycle, you would divide the on time (2 msec) by the total amount of time in each cycle (on time + off time = 4 msec), which equals a 50% duty cycle (on time / total time = 0.5 = 50%). When utilizing pulsed ultrasound, the intensity can be described as the spatial average intensity with the duty cycle, or you can calculate the temporal average intensity by multiplying the two numbers. So, if you are delivering 1watt/cm^2 at a duty cycle of 50%, your temporal average intensity would be calculated by multiplying the two numbers (1w/cm^2 x 0.5 = 0.5w/cm^2) (see figure 6).

Figure 6:
Pulsed Ultrasound (Duty Cycle)



If you have access to an ultrasound unit, go to Laboratory Exercise #1 now. When you have finished, continue reading from here. Do ***only*** *Laboratory #1, do not continue on with the other labs until you have completed the rest of the reading.*

Physiological Effects of Ultrasound

Therapeutic ultrasound is most traditionally known as a deep-heating modality. More recently, however, the focus of interest has appeared to shift more towards its non-thermal effects. In fact, many of the positive clinical results that ultrasound is known for can be achieved using low intensities and pulsed output, therefore decreasing the possibility of heat production within the tissues.

Thermal Effects

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. When using pulsed ultrasound, the lower the duty cycle, the less chance tissue heating will occur.

As covered previously, higher frequencies force molecules to vibrate at a faster rate, producing more kinetic energy and therefore, more heat. Higher frequencies (3MHz), however, have a decreased depth of penetration, and therefore, if deeper tissues are the target (>2cm), then a lower frequency (1MHz) will be required to reach them.

The type of tissue exposed and the location of the tissue will also affect the amount of heat produced. As discussed under the section on attenuation, the more dense the tissue, the more energy will be absorbed and therefore, the more heat will be produced. Collagen-rich connective tissue, such as tendons, ligaments, and joint capsules are ideal target tissues due to their density and also due to their location, which is generally adjacent to bone. At the tissue-bone interface, much of the energy will be reflected back and will therefore pass through the tissue again, meeting additional incoming waves, resulting in increased heat production at the periosteum and other tissues close to the bone. The thermal effects of ultrasound are outlined in figure 7A.

Figure 7A:

Effects of heat on tissues:

↑ Pain threshold
↑ Nerve conduction velocity
↑ Blood flow
↑ Enzyme activity
↑ Soft tissue extensibility
↓ Muscle spasm

Non-Thermal Effects

Despite the fact that positive clinical results have been achieved at non-thermal intensities, the mechanical effects of ultrasound are not fully understood. It does appear, however, that these physiological effects occur within the tissues on a microscopic level, through mechanical effects on cell membranes.[1-3]

These mechanical effects occur through a combination of cavitation and acoustic streaming. Cavitation is the production of gas-filled bubbles, or cavities, within the tissue by ultrasound. These bubbles are then agitated, expanding and contracting with the compression and decompression of the ultrasound waves. This bubble activity, as well as the mechanical pressures created by the ultrasound waves, result in a flow of tissue fluids, called acoustic streaming, or micro streaming (picture the agitation of a washing machine). This physical agitation within the tissue is believed to affect cell membrane permeability and stimulate cellular activity. The non-thermal effects of ultrasound are outlined in figure 7B. The overall result of these non-thermal effects is enhanced tissue repair.

Figure 7B:

Mechanical/Non-Thermal Effects:

- ↑ cell membrane permeability
- ↑ Histamine release
  - ↑ vascular permeability
  - ↑ inflammatory response
- ↑ macrophage activity
- ↑ fibroblast activity
  - Protein synthesis
- Enhanced angiogenesis
- Enhanced wound contraction

Contraindications

Prior to discussing clinical applications, it is important to discuss possible conditions or scenarios that would make application of ultrasound inadvisable or require special consideration before using.

☹ Therapeutic ultrasound should not be applied over the abdomen or low back during pregnancy due to possible negative effects on the fetus.

☹ Ultrasound should not be applied to the eyes, genitals, or heart.

☹ Ultrasound should not be applied over a pacemaker or its components.

☹ Do not apply ultrasound over malignant tissue or any abnormal growth as ultrasound may promote further growth or increase the rate of growth.

☹ Do not apply ultrasound in the presence of infection or abscess.

☹ Ultrasound should not be applied over ischemic areas as the tissues will not be able to dissipate heat.

☹ Do not apply thermal levels of ultrasound to insensate areas as the patient will not be able to sense heat and could result in burns and tissue damage.

☹ Ultrasound is also contraindicated in the presence of a thrombus or thrombophlebitis due to the risk of dislodging a thrombus.

- ☹ Do not apply ultrasound over epiphyseal plates of growing children.

- ☹ Ultrasound should not be applied in cases of undiagnosed pain, especially in a patient with a history of malignancy.

As will be discussed shortly in clinical applications, ultrasound is a very specific modality, requiring knowledge of the particular tissue being targeted and the physiological effect desired. As with all modalities, ultrasound should not be applied if you feel uncertain or uneasy.

Precautions

Some scenarios, although not absolute contraindications to ultrasound, require strong consideration as to whether or not ultrasound can be safely applied. In these instances, the clinician must consider whether the potential clinical benefits of ultrasound outweigh the risks.

- 😐 Although ultrasound is not contraindicated in the presence of fracture, the clinician should consider possible complications due to the fracture, such as instability, and the presence of adequate vascular supply and sensation.

- 😐 Caution should be exercised when applying ultrasound in the area of artificial joints or metal implants. Although the tissue around the area may potentially benefit from treatment, there must be adequate vascular supply and sensation to ensure safety.

- 😐 Although ultrasound may benefit the healing process, the application of ultrasound on or near open wounds requires knowledge of proper wound treatment and infection control.

- 😐 The presence of impaired but not absent circulation, such as peripheral vascular disease, warrants caution, due to the impaired ability to dissipate heat and the increased risk of tissue damage.

- 😐 Along these same lines, the presence of any bleeding disorders or medication use, which increase the tendency to bleed, such as anticoagulants, warrant consideration.

- 😐 If the patient experiences an increase in symptoms or improvement is not as expected after providing appropriate ultrasound application, ultrasound should be discontinued.

Clinical Application of Ultrasound

Rather than providing a list of diagnoses and conditions that may benefit from ultrasound, it is more appropriate and beneficial to provide problem solving skill for determining when ultrasound is indicated. Ultrasound is a very specific modality, and therefore requires a relatively localized target tissue with a specific goal in mind. If the area to be treated is large (more than two or three times the size of the largest available sound head), or the source of the problem has not been determined, ultrasound may not be an appropriate modality. If, on the other hand, a specific, localized tissue problem has been identified, and all contraindications have been ruled out, ultrasound may be the modality of choice.

Once the target tissue is identified, you must determine the goal of treatment. Do you want to administer a non-thermal treatment to stimulate healing, or a thermal treatment to heat and stretch? Acute and sub-acute conditions of inflammation, such as strains, sprains, muscle tears, dermal wounds and bruises, where the tissue has suffered recent trauma, may benefit from treatment with non-thermal levels of ultrasound to stimulate healing. Chronic conditions, such as contracture, adhesions, chronic edema, muscle spasm and chronic joint pain, where tissue shortening has occurred, thermal levels of ultrasound is indicated for heat and stretch.

Choosing Ultrasound Parameters

As mentioned previously, a frequent request from clinicians is for a list of treatment parameters or protocols. It is not appropriate to simply give a list to clinicians, without the problem solving skills of determining whether thermal or non-thermal settings are required. What will be provided here is a guide that will provide a starting point for choosing a thermal or non-thermal treatment. These settings are based on a combination of published research[4-19] as well as this author's experience, and are summarized in figure 10. Unfortunately, there is a lack of human studies utilizing low intensity non-thermal levels of ultrasound for tissue healing. Therefore, non-thermal parameters are determined theoretically, based on available in vitro and animal studies.

To produce non-thermal levels of ultrasound for tissue healing, use a frequency of 3 MHz for superficial targets of less than 2 cm, and 1 MHz for targets of 2 cm or deeper. An intensity of 0.5 watts/cm^2 delivered at a 20% duty cycle is a good starting point for tissue healing. A low duty cycle allows sufficient time for tissue to cool between pulses, yet 0.5 watts/cm^2 provides intensity high enough to produce the mechanical effects required to stimulate cellular activity. If the desired results are not achieved at this setting, the intensity can be increased to 1.0 watts/cm^2 at 20% duty cycle so long as the patient does not report a sensation of heat.

The tissue healing effects of ultrasound are achieved quickly, and therefore the length of treatment for non-thermal ultrasound is short, lasting two minutes per area the size of the ERA of the sound head being used. In other words, when treating and area 10cm^2 using a 5cm^2 sound head, treatment should last 4 (four) 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.

For thermal levels of ultrasound, you would again utilize a frequency of 3 MHz for superficial targets of less than 2 cm, and 1 MHz for targets of 2 cm or deeper. A setting of 1 MHz is necessary to reach deeper tissues and to produce the desired deep heat due to reflection off of bone; however, it is important to remember that a higher frequency of 3 MHz will produce more aggressive heating at lower intensities. Although not an exact calculation, you can expect

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approximately three times higher amounts of heat production with 3 MHz than with 1 MHz. Therefore, lower intensities will be required to heat superficial tissue utilizing 3 MHz than a comparable type and amount of deeper tissue with 1 MHz.

Parameter choices for thermal effects will also be affected by what type of tissue you are attempting to heat. For example, muscle tissue will require longer treatment sessions at higher intensities than connective tissue such as tendon and ligament. By comparison, tendons and ligaments have a lower vascular supply and higher, denser collagen content than muscle, allowing them to be heated faster and retain heat longer. So, when choosing intensity, you will determine level based on type of tissue as well as depth of tissue. Unlike superficial skin, deep tissue has limited ability to sense warmth. So, it is entirely possible to achieve therapeutic level of warmth in some deeper tissues, yet the patient has no perception of heat. If the patient reports sensation of comfortable heat, this would be desirable but not necessary; however, if the patient reports discomfort, you must turn down the intensity. For superficial muscle, utilizing a frequency of 3 MHz, you will likely produce heat with intensities between 0.5 and 1.5 watts/cm for 5 to 10 minutes, with higher intensities and longer treatments producing more aggressive levels of heat and potential discomfort. For deep muscle, utilizing a frequency of 1 MHz, you will likely produce heat with intensities between 1.0 and 2.0 watts/cm for 5 to 10 minutes, again, with higher intensities and longer treatments producing more aggressive levels of heat and potential discomfort. Connective tissue such as tendon and ligament will require lower intensities and shorter treatments than muscle. For superficial connective tissue, utilizing a frequency of 3 MHz, you will likely produce heat with intensities between 0.5 and 1.0 watts/cm for 2 to 10 minutes, with higher intensities and longer treatments producing more aggressive levels of heat and potential discomfort. For deep connective tissue, utilizing a frequency of 1 MHz, you will likely produce heat with intensities between 0.5 and 1.5 watts/cm for 2 to 10 minutes, again, with higher intensities and longer treatments producing more aggressive levels of heat and potential discomfort. It is important to remember that all of these applications are for an area no larger that two or three times the ERA of the sound head. Covering a larger area would significantly reduce the amount of heat being produced.

When using thermal ultrasound to heat and stretch tissue, it is imperative that the stretch occur before the tissue cools. Ideally, the stretch should occur when the tissue is at the peak heat to take advantage of possible increased collagen extensibility. This is a short window of opportunity and although it is unknown exactly how long it takes for various tissues to cool, ideally, the stretch should occur during treatment and/or immediately after (within 3 minutes), and this stretch should be maintained throughout the cooling period. It is safe to say that the tissue will be cooled, reaching normal temperatures, within 10 to 15 minutes.[20] Therefore, an ideal treatment scenario would be to perform ultrasound over the area with the target tissue in a position of stretch followed by active and or passive stretch immediately following the ultrasound application and maintaining a stretched position or utilizing the available range functionally for the following 10 to 15 minutes.

The recommended frequency of treatments will vary according to the desired outcome, and may be as seldom as once per week or as often as daily.

Treatment should continue as long as benefits are apparent. An overview of parameter selection is provided in Figure 8A and 8B.

Figure 8A:

Choosing Parameters

Non-Thermal - Tissue Healing

- Frequency: 3MHz (1MHz if tissue is 2cm or deeper)
- Intensity: 0.5 W/cm^2 (↑ or ↓ according to tissue specifics)
- Duty Cycle: 20%
- Treatment time: 2 minutes per ERA

Figure 8B:

Choosing Parameters

Thermal - Tissue Heating

		Intensity (Watts/cm^2)	Time (Minutes)
Muscle	3 MHz	0.5 – 1.5	5 - 10
	1 MHz	1.0 – 2.0	5 - 10
Connective Tissue	3 MHz	0.5 – 1.0	2 - 10
	1 MHz	0.5 – 1.5	2 - 10

Coupling and Application Techniques

To assure an effective treatment is achieved, it is important to use proper application techniques. As previously mentioned, ultrasound cannot pass through air. Therefore, a proper coupling medium must be used between the sound head and the skin to eliminate as much air as possible.

Ideally, the ultrasound head should be coupled directly over the skin, using a gel or lotion specifically designed for ultrasound transmission. Using lotions that are not designed for ultrasound transmission is not appropriate as they may contain ingredients that will reflect or absorb ultrasound and therefore will not transmit the ultrasound energy into the tissue effectively. These other products may also contain ingredients that may be driven into the skin, resulting in skin irritation or other undesired side effects.

If ultrasound is applied over an uneven or bony surface, either a small sound head should be used, or an alternative coupling technique may be utilized. Ultrasound can be delivered under water, or by using a water filled bladder or commercially prepared coupling disc. If performing an underwater treatment, a rubber or plastic container will reflect less of the ultrasound, providing a more predictable outcome. The sound head should be held against the skin or within 1-2 cm from the skin and should be moved at the same speed as direct contact. Each time ultrasound encounters and interface, some of the energy will be reflected so, whenever possible, the direct coupling technique should be used. In cases of broken skin, when ultrasound is being used for wound healing, it can be delivered underwater or by direct coupling utilizing individual packets of sterile ultrasound gel.

Ultrasound movement should be applied in slow, overlapping patterns, such as in overlapping circles, or overlapping lines. Moving the sound head too slowly may produce hot spots, resulting in complaints of discomfort, while moving too quickly may decrease the amount of ultrasound that effectively enters the tissue. The sound head should be moved at a speed of approximately 3 to 4 cm/second. If making circles, this would mean making a circle the size of a quarter in 2 seconds to maintain proper speed. If making lines, you would make a 3 to 4 cm line each second.

Care of Equipment

Because ultrasound treatment commonly produces little, if any, sensation, you must depend on your equipment to assure appropriate parameters are being delivered. To ensure that your equipment is in proper working order, you should have it inspected regularly to assure proper calibration. This calibration is technically complex and must be performed by a trained professional, such as a biomedical engineer. If you have questions regarding inspection and calibration, you should refer to the manufacturer of your equipment.

Introduction to Therapeutic Ultrasound
Laboratory Exercise #1

The following exercise is designed to familiarize the participant with their ultrasound unit, as well as with the concepts of beam non-uniformity ratio (BNR) and effective radiating area (ERA). Please note that this is a learning exercise only and cannot replace regular inspections of ultrasound equipment.

a) By inspecting your ultrasound unit, you should be able to determine and record the following information:

Date of last inspection: ______________________________

Available transducer (sound head) sizes: ________________

Effective radiating areas: _____________________________

Beam non-uniformity ratios: ___________________________

Available frequencies: _______________________________

Available duty cycles: ________________________________

b) **Beam Non-Uniformity/Effective Radiating Area**

1) Using transparent tape, form a ring around the edge of your sound head, creating a well deep enough to hold approximately ½ inch of water. Point the sound head up, and fill the surface of the sound head with water to create ½ inch of depth.
2) Turn the ultrasound on, and set the parameters to a frequency of 1 MHz, continuous (CW), and an intensity of 1 W/cm^2.
3) Look down at the surface of the water, and notice how much of the total surface area is creating vibrations in the water. Is the water being disturbed around the edges? This is an indication of the effective radiating area (ERA) of your transducer. A high quality sound head will have an ERA close to the actual size of the external surface of the sound head. Can you see how you may need to alter your treatment application if your ultrasound has a poor ERA?
4) Now look at the water from the side, and notice the distribution of the ultrasound energy across the surface of the water. Peaks in the water represent areas of higher intensities, and troughs represent areas of lower intensities. The number of peaks and troughs and the depth between them are an indication of the beam non-uniformity ratio (BNR). Deep peaks are indicative of a high BNR, and higher risk of significant hot spots. Having a high BNR would require the sound head to be moved more quickly in order to prevent discomfort or burns, and the ultrasound energy delivered will not be as uniform as that delivered from a unit with a low BNR.

Introduction to Therapeutic Ultrasound
Laboratory Exercise #2

The following exercise is meant to familiarize the clinician with proper ultrasound application techniques and will require the use of an ultrasound unit.

- Gather the following items: a quarter, a non-permanent pen, ultrasound transducer (sound head) and ultrasound gel or lotion, and a watch or clock with a second hand.

One common error that is often made is moving the sound head either too fast or too slow. The proper speed of movement is approximately 3-4 cm/second. On your thigh, visualize an area the size of a quarter, or if you wish, you can draw an outline of a quarter on your thigh. At the proper speed, if moving your sound head in a circular motion, you should follow a path in a circle the size of a quarter in two seconds. Looking at the second hand of your watch or clock, make circular motions the size of a quarter in two-second increments. Continue this until you begin to feel comfortable with this speed.

- Step two of this exercise will be for you to perform a non-thermal treatment on yourself.

Another common error that is often made is covering too large an area in too little time. Choose the 5 cm sound head, and visualize an area on your thigh, just above your knee, approximately twice the size of this sound head. If you wish, you can actually draw an area twice the size of the sound head on your thigh. Turn on the ultrasound unit and set your parameters for a non-thermal/tissue healing treatment.

Frequency: 3MHz – This would be the frequency of choice unless the tissue you are treating lies deeper than 2cm. For example, this would be an appropriate setting if you were treating an acute patellar tendon strain.
Intensity: 0.5 W/cm^2
Duty Cycle: 20% pulsed
Treatment Time: 4 minutes (two minutes per ERA). In this case, it is assumed that the ERA of your sound head is approximately 5cm^2 (equal to the actual size of the sound head).

Apply gel or lotion to the area to be treated, and begin moving the sound head at the speed practiced in the previous step. Increase the intensity to 0.5w/cm^2, or press 'Start' if the intensity is pre-set. Be sure to cover only the designated area for treatment. Note how long 4 minutes feels, and how small an area you are actually treating. What do you feel during this treatment? This is what your patients should also feel during a treatment – just the movement of the sound head over the skin. You may explain to your patients that the effects of the treatment occur on a microscopic level, and therefore will not be felt during the actual treatment application. If your unit does not automatically power down, be sure to return the intensity back down to zero.

Laboratory Exercise #2, Cont.

- Step Three of this exercise will be for you to perform a thermal treatment on yourself. An error that is often made is to perform a thermal treatment without performing a stretch prior to the tissue cooling down. If the purpose of administering an ultrasound treatment is to heat and stretch the tissue, and the tissue is not stretched before cooling, then the treatment is a waste of time.

Choose the $5cm^2$ soundhead and visualize an area on your thigh, just above your knee, approximately twice the size of the soundhead, or if you wish, you can actually draw an area twice the size of the soundhead on your thigh. Turn on the ultrasound unit and set your parameters for a thermal/tissue heat and stretch treatment:

Frequency: 1 MHz. This would be the frequency of choice unless the tissue you are treating is very superficial or over a bony prominence. For example, this would be an appropriate setting if you were treating a shortened rectus femoris tendon to heat and stretch to increase ROM. If you feel deep aching (periosteal pain), check your technique. You may be moving too slowly or over too small an area. If you are using proper technique, this is an indication that you are creating too much heat, and you can use 3MHz instead, or turn down your intensity.
Intensity: $1.0W/cm^2$
Duty Cycle: Continuous Wave
Treatment Time: 6 minutes

If you were actually treating a patient with a goal of increasing ROM, you would want to perform the treatment with the tissue on a stretch. In this case, you would place the knee in flexion, with a stretch on the rectus femoris tendon. Because this is a practice exercise, positioning is not an issue. Just sit in a comfortable position such as in short-sitting. Apply gel or lotion to the area to be treated and begin moving the soundhead at the speed practiced in the first step of this exercise. Increase your intensity to $1.0W/cm^2$, or press "Start" if the intensity is pre-set. Be sure to cover only the designated area for treatment. Note how long six minutes feels, and how small an area you are actually treating. What do you feel during this treatment? You may feel mild deep warmth, or mild skin warmth. If you feel comfortable, try slowing the movement of your soundhead until you begin to feel a dull deep ache, then speed back up. This is periosteal pain, and it is important to realize how quickly it can occur. You should always warn your patient that this can occur, and it is **not** a desirable or necessary part of the treatment. Instruct your patient to notify you if any pain or deep ache is felt, and not attempt to endure it. When the six minutes are over, if your unit does not automatically power down be sure to return the intensity back down to zero.

Introduction to Therapeutic Ultrasound
Case Studies

Complete the following case studies on your own, and then refer to the instructor's notes at the end of the syllabus. It is important to remember that there is no single way to treat any condition, and the instructor's notes are meant to give an example of how ultrasound could be incorporated into the treatment of each of the following cases. The notes are not meant to be an all-inclusive treatment plan, and each case would include other therapies; such as education, exercises, etc.

Case Study #1
A 52-year-old patient is referred by her physician with diagnosis of frozen shoulder. She states that her pain began three months ago but she did not seek treatment because she hoped it would get better on its own. She presents with moderate protective muscle spasm of her upper right trapezius and her shoulder is limited in extension and external rotation.

Target tissue ____

Goals ____

____

____

Parameters ____

____

____

____

Position ____

____

____

Justification ____

____

____

____

Case Study #2

A 24-year-old patient referred with diagnosis of patellar ligament strain. The injury was sustained three days ago while playing soccer. Patient presents with moderate edema and pain to palpation. Prior treatment has consisted of rest and ice.

Target tissue ____

Goals ____

____

____

Parameters ____

____

____

____

Position ____

____

____

Justification ____

____

____

____

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Instructor's Notes: Case Study #1

Instructor's Notes: Treatment of this patient could address one or both of the problems including limited extension and external rotation, and/or protective muscle spasm of the upper trapezius.

Target tissue #1: Anterior joint capsule of the right shoulder.

Goals: Increase right shoulder extension and external rotation.

Parameters: Thermal
- Sound head: 5cm^2 (If the patient is very small and thin, you may need to use the 2cm^2 sound head)
- Frequency: 1MHz (If the patient is very thin and experiences periosteal pain, you may need to use 3MHz)
- Intensity: 1.0W/cm^2 (If the patient experiences discomfort, decrease the intensity. If results are not as expected, increase the intensity.)
- Mode: Continuous
- Time: 6 minutes (Time can be increased or decreased according to the size and depth of the target tissue as well as the amount of heat desired)

Position: Sitting or supine, with the shoulder in a position of stretch into extension and external rotation. Other options are to incorporate dynamic stretch such as contract-relax, or have the patient self stretch during the treatment.

Justification: This patient presents with a chronic condition. Limited extension and external rotation are indicative of tightness in the anterior joint capsule. Therefore, treatment could include thermal levels of ultrasound to increase soft tissue extensibility, stretching the tissue while heated, followed by continued stretch through the cool down period.

Target tissue #2: Right upper trapezius, specifically, the portion that presents with palpable muscle spasm. You must be sure to limit the treatment area to no more than twice the size of the sound head/ERA.

Goals: Decrease muscle spasm, decrease pain.

Parameters: Thermal
- Sound head: 5cm^2 (If you have one, you could use the 10cm^2 sound head)
- Frequency: 1MHz (If the patient is very thin and experiences periosteal pain, you may need to use 3MHz)
- Intensity: 1.0W/cm^2 (If the patient experiences discomfort, decrease the intensity. If results are not as expected, increase the intensity.)
- Mode: Continuous
- Time: 10 minutes (Time can be increased or decreased according to the size and depth of the target tissue as well as the amount of heat desired)

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Position: Sitting, with shoulders relaxed and down, with head in a position of rest. Protective muscle spasm of the upper trapezius could also be treated in a position of stretch, and by continuing the stretch during the cool down. Perform stretches however you are comfortable (manual stretch, massage, active stretch, myofascial release, etc.).

Justification: In this case, thermal ultrasound would be indicated to decrease pain and reduce muscle spasm.

Instructor's Notes: Case Study #2

Target tissue: Patellar ligament (just distal to the patella)

Goals: Enhance tissue healing, decrease pain, decrease edema

Parameters: Non-thermal

- Sound head: $2cm^2$ or $5cm^2$ depending on the size of the target.
- Frequency: 3MHz
- Intensity: $0.5W/cm^2$
- Mode: Pulsed - 20% duty cycle
- Time: 2 minutes per ERA (approximately 4-8 minutes depending on the size of the target tissue)

Position: Comfortable position, no stretch (possibly long-sitting with the knee slightly flexed over a bolster)

Justification: This patient presents with an acute condition and therefore, increased heat is unnecessary and unwanted. The injured tissue could benefit from the healing effects of non-thermal ultrasound. Due to the acute injury, the tissue must be protected so the knee should be in a relaxed position without stretch.

Introduction to Therapeutic Ultrasound

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Introduction to Therapeutic Ultrasound
Post Test

Name: ______________________ Credentials/Degree: __________

Address: ______________________

City/State/Zip: ______________________

Daytime Phone: __________ Evening Phone: __________ E-Mail: __________

Read the following questions and circle the most appropriate answer. Be sure to mail or fax this test to JVB Enterprises, Inc., to receive credit and your certificate.

1. 3MHz is:
   a. 3 thousand cycles/second
   b. 3 million cycles/second
   c. 3 thousand cycles/minute
   d. 3 million cycles/minute

2. Ultrasound is transmitted through the soft tissues as:
   a. Longitudinal waves
   b. Transverse waves
   c. Both a and b

3. When delivering ultrasound at a spatial average intensity of 0.5W/cm^2, using an ultrasound unit with a BNR of 5:1, what is the highest intensity in beam?
   a. 1.0W/cm^2
   b. 2.5W/cm^2
   c. 0.5W/cm^2
   d. 25W/cm^2

4. Which of the following does not contribute to attenuation (a decrease in ultrasound energy as it passes through the tissues)?
   a. Absorption
   b. Reflection
   c. Refraction
   d. Condensation

5. When delivering ultrasound at a spatial average intensity of 1.0W/cm^2, using a transducer with an ERA of 5cm^2, what is the total output in watts?
   a. 50 Watts
   b. 0.5 Watts
   c. 5 Watts
   d. 1 Watt

Post-Test, Cont.

6. What is the duty cycle when delivering ultrasound that is pulsed so that it is on for 2 msec, then off for 3 msec?
   a. 40%
   b. 20%
   c. 25%
   d. 50%

7. What is the temporal average intensity when delivering 1.5W/cm^2 at a 50% duty cycle?
   a. 0.75W/cm^2
   b. 3W/cm^2
   c. 2W/cm^2
   d. 1W/cm^2

8. When treating the hip joint, what frequency should be used?
   a. 3MHz
   b. 1MHz

9. Which of the following is a contraindication to ultrasound?
   a. Open wound
   b. Metal implant
   c. Malignant tissue
   d. All of the above

10. In which of the following conditions is thermal ultrasound indicated?
    a. Muscle spasm
    b. Acute ankle sprain
    c. Contracture
    d. Both a and c
    e. All of the above

Introduction to Therapeutic Ultrasound
SEMINAR EVALUATION

A Home Study Course

Please answer questions according to the following scale:

4 – Excellent 3 – Good 2 – Fair 1 – Poor

- **Course Content**
  ____ Did this home study course meet the stated course objectives?
  ____ Was the content of the handouts appropriate?
  ____ Were the visual aids adequate?

  ____ Was the content current and relevant?
  ____ Was the length appropriate?
  ____ Was the cost appropriate?
  ____ Was the information presented in an organized , clear fashion?

  ____ Were the materials delivered promptly and accurately?
  ____ Did the brochure/web site accurately describe the course?
  ____ How do you rate this course overall?

- What did you like best about this course?

____

- What did you like least?

____

- What topics would you like to see covered in the future?

____

- How did you hear about this course?
  ____Advance ad ____Brochure ____Fax ____Web site

- When do you like to attend courses?(Check all that apply)
  ____Evenings (week days) ____Weekdays
  ____2 day weekend courses ____3 day courses (Fri, Sat, Sun)
  ____One day courses (Sat.) ____Home study

- **Additional comments?**

____
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____
____