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Physical Therapy 103

Ultrasound – An Underused Modality

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Therapeutic ultrasound has been used in the treatment of musculoskeletal injuries and conditions for years, primarily because it effectively promotes healing in the injured tissue and helps reduce pain. However, in spite of the beneficial healing effects, pain reduction, and the versatility of the process, ultrasound therapy continues to be underutilized or not utilized by many chiropractic providers. Ultrasound may not be the answer for every patient; however, it does offer unique benefits that should be taken into consideration.

Ultrasound: An Underused Modality

Your patient's shoulder has been throbbing for weeks and has severely limited range of motion. Ice, hot packs, counter-irritants, and soft tissue manipulation have all been tried without gaining much relief or healing. Could ultrasound be the treatment that gets her arm and shoulder back into action?

Therapeutic ultrasound (pulsed or continuous) has been used in the treatment of musculoskeletal injuries and conditions for years, primarily because it effectively promotes healing in the injured tissue and helps reduce pain. Its ability to penetrate deeper than other heat-based modalities facilitate a beneficial effect on deep muscle tissue. Unique capabilities that allow either thermal or non-thermal applications make it a valuable option as a therapeutic treatment for a wide range of acute and chronic conditions, such as tendonitis, muscle spasms, bursitis, fasciitis, edema, sprains, contractures, and adhesions. However, in spite of the beneficial healing effects, pain reduction, and the versatility of the process, ultrasound therapy continues to be underutilized or not utilized by many chiropractic providers.

Underutilization tends to result from several factors. One is that chiropractic providers in practice less than 5 years may not have enough information on the benefits of working with ultrasound, so there is less motivation to employ it. Second is the one-on-one nature of this modality versus other types of treatment that are also effective and require less hands-on work. Last, the technique for application is very specific and needs to be performed properly with carefully calibrated equipment to achieve optimum results. Often, the reluctance is due to disappointing outcomes experienced in past attempts, which, in fact, may have been the result of insufficient knowledge or training. With education and a better understanding of the process, these factors can be alleviated as chiropractic providers gain greater confidence in the capabilities of ultrasound and a better grasp of the proper techniques for achieving success.

Therapeutic ultrasound was one of the most commonly used physical agents for the treatment of musculoskeletal injuries by chiropractic providers. It was used as part of an overall treatment program for diagnoses such as temporomandibular joint pain, myofascial pain, lateral epicondylitis, soft-tissue shoulder and ankle disorders, and various other conditions.

Clinical Applications of Ultrasound

Ultrasound is most effectively used to help patients move through and resolve various symptoms associated with the phases of the healing process. Trauma, surgical procedures, and open wounds go through the process of inflammation and repair that consists of three phases: inflammation, proliferation, and maturation. The inflammatory phase begins when injury or disease causes a disruption in the normal physiological function of the tissue, which can last up to 10 days. It is characterized by swelling, heat, redness, pain, and loss of function.

> Michlovitz SL. Thermal Agents in Rehabilitation. 3rd ed. Philadelphia: FA Davis Company; 1996:3-17, 200

During this stage, ultrasound (pulsed) is used primarily for its non-thermal properties to facilitate the process of inflammation and therefore healing. This is attributed to the acoustic streaming of the ultrasound beam in the tissue, which has been shown to increase intracellular calcium, macrophage responsiveness, skin and cell permeability, mast cell degranulation and histamine release. These effects have been attributed to pulsed ultrasound with a duty cycle of 20% at an intensity of 0.5 W/cm^2 or continuous mode at a very low intensity of 0.1 W/cm^2.

> Prentice WE. Therapeutic Modalities for Allied Health Professionals. New York: McGraw-Hill Health Professions Division: 1998:271, 279, 280, 289

The proliferative phase begins around day three and lasts up to 20. This stage is characterized by migration of epithelial cells and fibroblasts to cover and impart strength to the injured area.

> Michlovitz SL. Thermal Agents in Rehabilitation. 3rd ed. Philadelphia: FA Davis Company; 1996:3-17, 200

During this stage, ultrasound has been shown to stimulate fibroblast to produce more collagen and accelerate the development of new blood vessels.

The maturation phase begins around day 9 and may last for years. It is characterized by the gradual disappearance of fibroblasts. Collagen is initially laid down in a random fashion and it is during this phase that the fibers become more organized and mature. Since collagen fibers will orient themselves parallel to lines of stress, the type of tension applied to the scar will affect how it remodels. Scars are inelastic and during this stage clinical techniques are incorporated to avoid the development of short, dense adhesions that would restrict motion. Soft- tissue shortening or adhesion formation can also result from immobilization or chronic inflammation in which healthy tissue is often replaced with scar tissue.

> Michlovitz SL. Thermal Agents in Rehabilitation. 3rd ed. Philadelphia: FA Davis Company; 1996:3-17, 200

The thermal properties of ultrasound (continuous) have been shown to increase elasticity and decrease the viscosity of collagen fibers and soft tissue; allowing for greater residual length gains while reducing the risk of damage through the applied stretching force. The change in viscoelastic properties is transient and in order to get optimal effects, the stretching should be applied during heating or immediately following.

> Prentice WE. Therapeutic Modalities for Allied Health Professionals. New York: McGraw-Hill Health Professions Division: 1998:271, 279, 280, 289.

> Hecox B, Mehreteab TA, Weisberg J. Physical Agents: A Comprehensive Text for Physical Therapists. Norwalk, Conn: Appleton & Lange; 1994:116

Both thermal and non-thermal properties of ultrasound have been shown to decrease pain. The mechanism of pain reduction is still unclear, but it is thought that ultrasound may control pain by altering its transmission or perception due to the stimulation of the cutaneous thermal receptors, altering nerve conduction velocity, and increasing tissue temperature or modulation of the inflammatory process.

Fedorczyk J. The role of physical agents in modulating pain. J Hand Ther. April-June 1997:110-121

Two natural laws need to be taken into consideration when applying ultrasound: ultrasonic energy must be absorbed by the target tissue in order to have an effect, and the right amount of energy needs to be delivered and absorbed by the tissue in order to produce the desired physiological responses. If the energy absorbed is insufficient to stimulate the tissue, no reactions or changes will occur.

Griffin JE, Darselis TC. Physical Agent for Physical Therapists. 2nd ed.. Springfield, IL: Charles C. Thomas; 1982:32-34

With these laws in mind, it is logical to conclude that one favorite or standard intensity and duration for ultrasound cannot and will not be the correct dosage for every diagnosis.

Clinical Fundamentals

Ultrasound delivers sound waves to tissue at a frequency above the range of human hearing, providing a "micro-massage" via mechanical vibrations. Clinical ultrasound is delivered as either a thermal (continuous) or non-thermal (pulsed) application. A topical (coupling) medium, such as water, gel, cream, lotion, or mineral oil, must be applied to the skin surface before treatment. Determination of frequency, duration, and whether to use pulsed or continuous application depends on the equipment being used, as well as the type of injury (eg, adhesion, muscle spasm, tendonitis, contracture, edema, etc).

To ensure correct application and the desired outcome, it is important for chiropractic providers to understand how ultrasound works. Combining knowledge of the physical agent, the pathology of the injury, and the correct technique for delivering it significantly increases the potential for success.

Ultrasound works by delivering acoustic vibrations via a transducer that utilizes a quartz crystal to convert electrical energy to ultrasonic waves, which can then be applied to human tissues for therapeutic purposes. Absorption of this energy takes place at the molecular level with the protein in the tissue acting as the absorbing agent. Muscle, fat, and hemoglobin all absorb ultrasound. Since numerous factors affect absorption and the benefits received, an understanding of the physiology, the delivery process, and any contraindications are key for ensuring that patients' results are maximized.

The basic benefits provided through this treatment include:

- Increased elasticity of collagen in tendons, joint capsules, and scar tissue.
- Increased motor and sensory nerve conduction velocities, which assists in reducing pain.
- Altered contractile activity to skeletal muscle, which reduces muscle spasm.
- Diminished muscle spindle activity, another factor in muscle spasm reduction.
- Increased blood flow.

These factors make ultrasound the modality of choice for conditions involving muscle spasm, pain, scar tissue, and acute and chronic soft tissue inflammation. It can be delivered over smooth, even surfaces such as the lower back, as well as uneven joint surfaces such as the ankle and wrist. For example, for an elderly patient whose muscles are tightening up due to aging or for the shoulder injury discussed earlier, ultrasound's unique characteristics allow the tissue to be stretched more easily and with less trauma, resulting in better gains. Another example would be a case of edema, in which it can be challenging to initiate movement, but the ultrasound's mechanical process helps increase the mobility of the fluid, thus reducing the chances of increasing trauma or injuries to that area.

Ultrasound Basics

Audible sound waves occur at frequencies between 16 kHz and 20 kHz, whereas therapeutic ultrasound waves have frequencies ranging from 75 kHz to 3 MHz.

> Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

Ultrasound is produced via the reverse piezoelectric effect.

> Belanger A-Y. Evidence-Based Guide to Therapeutic Physical Agents. Baltimore: Lippincott, Williams & Wilkins; 2002

Essentially, when an alternating electrical current is passed through a piezoelectric crystal, the crystal expands and contracts at the frequency of the electrical signal.

> Belanger A-Y. Evidence-Based Guide to Therapeutic Physical Agents. Baltimore: Lippincott, Williams & Wilkins; 2002.

> Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

Thus, the oscillations of the crystal create the ultrasound waves that are transmitted to the tissue being treated.

Piezoelectric crystals can be made of quartz (natural or artificial), ceramics, or other types of material,

> Chapelon J-Y, Cathignol D, Cain C, et al. New piezoelectric transducers for therapeutic ultrasound. Ultrasound Med Biol. 2000;26:153-59

and the size and quality of crystals can vary greatly. The effective radiating area (ERA) conducts ultrasound from the transducer to the tissue. The ERA transmits at least 5% of the generated ultrasound waves.

> Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

> Denegar CR. Therapeutic Modalities for Athletic Injuries. Champaign, Ill: Human Kinetics; 2000

The ERA is always smaller than the transducer faceplate, therefore the ERA should be very close to the sound head in size.

> Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

> Draper DO. Don’t disregard ultrasound yet - the jury is still out. Phys Ther. 2002;82:190

This is important when the size of the treatment area is taken into consideration. The treatment area should be no larger than two times the size of the transducer head.

> Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

> Draper DO. Don’t disregard ultrasound yet - the jury is still out. Phys Ther. 2002;82:190

However, some larger sound heads may have only a 5 cm^2 crystal.

Frequency – 1.0 MHz vs 3.0 MHz

Ultrasound can have an effect on the target tissue only if the energy delivered reaches the tissue and is absorbed. The depth of tissue penetration is not intensity dependent, but frequency dependent. Therefore, in order to determine the appropriate frequency, the depth of the target tissue must be ascertained. The 1.0 MHz frequency can heat tissue up to 3-5 cm deep, while the 3.0 MHz can penetrate up to 2 cm. The higher the frequency, the higher the rate of absorption and attenuation. Therefore, most of the ultrasonic energy with a 3.0 MHz frequency will be absorbed in the superficial tissue. In contrast, the slower, 1.0 MHz frequency will have less energy absorbed superficially, allowing for deeper penetration.

Can you compensate for a 1.0 MHz frequency in a superficial structure by lowering the intensity used? Since depth of penetration is not intensity dependent, lowering the intensity may delay periosteal overheating but will not facilitate absorption of energy in the superficial target tissue. Draper et al experimented with the two frequencies applying both to the patellar tendon at 1 W/cm^2. They found that at 4 minutes, the 3.0 MHz ultrasound started to produce heat that was uncomfortable, requiring them to decrease the intensity, while the 1.0 MHz ultrasound caused periosteal aching within 1 minute, resulting in the termination of the treatment. The energy delivered by the 1.0 MHz frequency was not absorbed in the superficial tissue and therefore was able to penetrate and overheat the periosteum, while the energy with the 3.0 MHz was quickly absorbed in the tendon, producing heat.

Draper DO. Ten mistakes commonly made with ultrasound use; current research sheds light on myths. Journal of Athletic Training. 1996;2(2):95-107

https://www.processingmagazine.com/process-control-automation/instrumentation/level-measurement/article/15580471/top-10-mistakes-made-when-applying-ultrasonic-level-sensors accessed 04NOV2022

Another consideration with ultrasound is the type of tissue being treated, or what tissue the ultrasound must travel through to reach the target. Ultrasound energy is absorbed at different rates by different tissues and this is related to both the water and protein content of the tissue.

Denegar CR. Therapeutic Modalities for Athletic Injuries. Champaign, Ill: Human Kinetics; 2000

Denegar CR. Therapeutic Modalities for Musculoskeletal Injuries - 3rd Edition (Athletic Training Education) 3rd Edition

Skin and adipose tissue absorb less acoustic energy than muscle, tendon, and ligament. Nerve tissue and bone absorb the greatest amount of US energy. Therefore, you should consider not only the depth of the tissue to be treated, but also the type of tissue when determining treatment parameters.

In light of this information, substitution of frequencies is not recommended due to the attenuation (decrease in energy of ultrasound as distance traveled increases) and absorption characteristics of ultrasound.

Intensity/Duration

The intensity chosen will be dependent on the treatment goal. The non-thermal effects of ultrasound are desired for the treatment of acute injury, edema, and wound healing. Low-intensity ultrasound at .5 W/cm^2, pulsed mode with a 20% duty cycle are the parameters most frequently cited in related research. The physiological effects associated with thermal applications of ultrasound occur at specific tissue temperature increases. Studies done by Lehman indicate that an increase of 1°C accelerates the metabolic rate of tissue. An increase of 2-3°C reduces muscle spasm and pain, increases blood flow, and reduces chronic inflammation, and greater than 3-4°C tissue temperature rise decreases the viscoelastic properties of collagen.

> Draper DO. Ten mistakes commonly made with ultrasound use; current research sheds light on myths. Journal of Athletic Training. 1996;2(2):95-107

Once the treatment goal has been established, the degree of tissue temperature is chosen and the appropriate treatment at a given intensity is determined. A study done by Draper et al looked at the rates of temperature increase in human muscle during 1.0 MHz and 3.0 MHz continuous ultrasound. From this study, the researchers were able to predict tissue temperature with both frequencies at doses of 0.5, 1.0, 1.5. and 2.0 W/cm^2.

Too often ultrasound treatments are given at a standard duration of 5 minutes. On the basis of the data from this study, the intensity and the frequency used should determine the appropriate duration. In general, the higher the intensity and frequency, the faster the rate of heating. With a 3.0 MHz frequency, we can expect the rate of heating to be 3-4 times faster than at a 1.0 MHz frequency.

> Draper DO, Castel JC, Castel D. Rate of temperature increase in human muscle during 1MHz continuous ultrsound. J Othop Sports Phy Ther. 1995;22:142-149

Suppose I have a patient who is in the subacute stage of healing. My treatment goal is to accelerate the metabolic rate of the tissue and therefore accelerate the rate of healing. In order to obtain this physiologic effect, I need to create a 1°C tissue temperature rise. Using a 1.0 MHz frequency at an intensity of 1.0 W/cm^2, the rate of heating would be 0.2°C per minute for a total treatment time of 5 minutes to reach a 1°C tissue temperature rise. Using the same frequency at an intensity of 0.5 W/cm^2, the rate of heating would be 0.04°C per minute for a total treatment time of 25 minutes.

It is evident that any adjustments in the intensity should be followed by changes in treatment time. It is important to recognize that even though a continuous mode is used for thermal effects, at a 0.5 W/cm^2 intensity with a 1.0 MHz frequency, the rate of heating is very slow and the typical 5 minute treatment time would result in very minimal tissue heating, thus, treatment would be ineffective. With this information in mind, it is important to remember that intensity is ultimately determined by patient tolerance.

Moving the transducer

During the application of ultrasound, it is very easy to inadvertently increase the speed of the movement of the ultrasound head. When this happens, the tissue being treated does not have enough time to absorb the energy.

A frequently recommended rate for the movement of the transducer is 4 cm/second. Castel recommends moving the sound head as slowly as possible without causing pain, while Draper recommends 2 inches per second, lowering the intensity and making appropriate adjustments in treatment time if the patient complains of discomfort.

Enwemeka CS. The effects of therapeutic ultrasound on tendon healing. Am J Phys Med Rehabil. 1998;68:283-286

Lee, CH. World Ultrasonographic evaluation of the effect of extracorporeal shock wave therapy on calcific tendinopathy of the rectus femoris tendon: A case report J Clin Cases. 2019 Nov 26; 7(22): 3772–3777 accessed 04NOV2022

However, the speed at which the transducer should be moved over the treatment area depends on the beam non-uniformity ratio (BNR) identified by the manufacturer on the ultrasound unit.

The most common measure of piezoelectric crystal quality is the beam non-uniformity ratio or BNR. The ultrasound waves created by the crystal are not uniform across the surface of the ultrasound head; there are varying areas of intensity that create peaks and valleys in the ultrasound beam. The BNR is the ratio of the spatial peak intensity to the spatial average intensity.

Denegar CR. Therapeutic Modalities for Athletic Injuries. Champaign, Ill: Human Kinetics; 2000.

Starkey C. Therapeutic Modalities. 2nd ed. Philadelphia: FA Davis Co; 1999

The ultrasound beam is non-uniform in nature and the higher the BNR ratio, the greater the non-uniformity of the beam and potential hot spots. Areas of high intensity increase the likelihood of developing "hot spots" within the treatment area.

Ultrasound units with BNR ratios between 2:1 and 6:1 appear to be clinically acceptable,

Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

Denegar CR. Therapeutic Modalities for Athletic Injuries. Champaign, Ill: Human Kinetics; 2000.

Starkey C. Therapeutic Modalities. 2nd ed. Philadelphia: FA Davis Co; 1999

although some ultrasound units may have a BNR as high as 8:1.

Draper DO. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities for Physical Therapists. 2nd ed. New York: McGraw-Hill; 2002:270-304

For most units, the BNR ratio is usually 5:1 or 6:1, creating peak intensities five to six times greater than that set by the chiropractic provider. This means that at a therapeutic intensity of 1.5 W/cm^2, a machine with a BNR of 6:1 would produce a peak intensity of 9 W/cm^2, exceeding the 8 W/cm^2 safety limit. These high peak intensities are what often cause pain or discomfort associated with ultrasound applications. The lower the BNR, the more uniform the ultrasound beam. A unit with a low BNR will allow for slower movements of the soundhead and less discomfort for the patient. Since BNR is an indication of the quality of the US beam, units with a lower BNR are typically more expensive than units with a greater BNR.

While there are numerous therapy options (eg, electromagnetic radiation, electrical stimulation, hot packs, cryotherapy, massage, manipulation (soft tissue and osseous) and exercise) that can be considered for treatment of musculoskeletal injuries, ultimately the choice depends on an analysis of factors such as the type and location of injury, as well as the condition of the patient and any underlying issues. Once again, the key to determining the most effective method to use is in knowing as much as possible about the treatment options and the injury.

While all modalities have some overlapping qualities, it is important to know the distinctive qualities and contraindications of each option to determine the most appropriate choice. For instance, hot packs provide heat, but do not penetrate as deep as ultrasound. With electromagnetic radiation, the depth of penetration is slightly less compared to ultrasound, in addition to a loss of energy through the surface of the skin during sweating. Ultrasound, which is very deep, produces heat proportional to the heat absorbed in the tissues so there is no loss of energy from the skin, thus having maximal benefit of the diathermy modality.

The only real limitation for ultrasound is in the size of the area that can be treated, which is determined by the size of the transducer head, ie, an acute muscle spasm over a large part of the lower back would be difficult to treat and would tend to make electromagnetic radiation the better choice of diathermy for such cases. The treatment selected also depends on whether the injury being dealt with is acute or chronic. While ultrasound can work effectively for either one because of its thermal and non-thermal qualities, some of the other options do not possess that capability.

Techniques For Optimal Results

To ensure the best possible outcome, ultrasound is typically prescribed in combination with other modalities. For example, in acute injuries (eg, back or neck injury, or knee or ankle sprain), the chiropractic provider may use ice, compression, gentle manipulation and exercise, etc, depending on the severity and location of the injury and the specific symptoms. For chronic injury, treatment might include aggressive stretching and manual therapies in addition to ultrasound, which is useful for allowing muscle spasms to relax, reducing edema, and mobilizing adhered tissues. A combination of ultrasound and electrical stimulation is very effective in treating muscle spasms, controlling pain, and increasing range of motion.

To achieve desired outcomes, it is necessary to pay close attention to these aspects of the procedure:

- Position patient so that the treatment area is easy to reach, and if needed, with enough room for a slight stretch of the target area.
- Set machine to appropriate settings for intensity, duration, and pulsed or continuous application, based on injury type and location, patient condition, etc.
- Explain procedure to patient and that he or she should not feel anything more than a slight vibration or warmth. Ask for feedback if it becomes hot or uncomfortable.

- Keep the application area small.
- Ensure that the skin surface is smooth and free of hair, oil, or lotions that might inhibit the sound waves.
- Spread the topical ultrasound medium smoothly and evenly on the site. Ultrasound gel, which is highly aqueous, is generally considered the preferred medium.
- Use a slow, sweeping, circular motion, slightly overlapping by half as the area is covered. Keep the ultrasound head in contact with and perpendicular to the skin and moving at all times.

When combining ultrasound with certain other forms of treatment such as stretching, it is important to provide the stretching component of the therapy immediately after to take advantage of the increased elasticity and reduced pain achieved in the therapy session.

One example of how proper application can produce desired results would be a typical frozen shoulder, a condition in which external rotation of the shoulder is difficult to achieve. We have had several patients insist that in their experience, ultrasound did not help their condition, yet we have achieved the desired outcome through careful positioning, proper technique, and application of the correct intensity and duration for the specific injury. Typically, the therapy includes providing a gentle stretch during the ultrasound procedure, and afterwards combining other effective therapeutic intervention, such as joint mobilization or specific deep tissue massage and myofascial work, with significantly positive results.

For larger areas, larger heads are available, or the treatment area can be divided into zones. For instance, the chiropractic provider can treat small areas of the distal section of a hamstring first, followed by more proximal sections of the thigh, etc, in 5 minutes increments until all zones have been treated.

Some chiropractic providers find that underwater application can be effective for treating small bony areas such as ankles and wrists, although the technique does demand careful attention to maintain the perpendicular angle of the transducer head and a consistent one-inch distance from the injury site.

Contraindications and Precautions

Certain medical conditions preclude the use of ultrasound therapy, including pregnancy, malignancy, circulatory insufficiency (eg, DVT or occlusive vascular disease), myositis ossificans, acute infection, or severe sepsis infection. In addition, the treatment site must be considered contraindicated if it would require application over the eyes, heart, spinal column, growing bones, testes, epiphyseal plates, carotid sinuses, cervical stellate ganglion, vagus nerve, or a demand pacemaker.

Other important precautions include:

- Diminished or absent sensation to pain and temperature
- Hypersensitivity to ultrasound
- An area of tendon repair
- An area of cemented prosthesis
- Areas of reduced circulation such as a recent scar

In order to make the best clinical decision and achieve the maximum potential results from the treatment, it is critical to weigh the known physiological benefits along with any indications, contraindications, and precautions.

Which Is the Right Ultrasound Unit

A variety of issues come into play when purchasing and using an ultrasound unit. These units come with a variety of options, some that add value to the machine and others that are just bells and whistles. The cost associated with the purchase and upkeep of ultrasound units can be relatively expensive, thus it is important to fully understand the function and use of this modality.

There are many manufacturers of ultrasound units and most of these companies have several different units to choose from. One of the first questions you should consider is in what capacities the unit will be used and what types of conditions you will be treating. This can help simplify the decision-making process when looking for a unit that will best meet your needs and those of your patients.

Since the BNR is an indication of the quality of the piezoelectric crystal, this is an important factor, although recent research suggests that a lower BNR may not always produce better therapeutic effects.

> Holcomb WR, Joyce CJ. A comparison of two commercially available ultrasound units. Journal of Athletic Training. In press

As mentioned previously, machines with lower BNR are typically more expensive, so you need to weigh the value of a lower BNR and more uniform treatment versus the cost of the unit.

The range of frequencies a ultrasound unit can produce is another issue. Units that deliver ultrasound only at one frequency will significantly limit the conditions and tissue that can be treated. Most units can deliver ultrasound at both 1.0 MHz and 3.0 MHz, and newer units may also have 2.0 MHz as a frequency option. Ultimately, the more frequencies the unit can deliver, the greater the flexibility of the machine; however, this usually comes at a higher cost.

A unit's ability to deliver pulsed ultrasound at a variety of duty cycles is another characteristic a chiropractic provider should consider when selecting a model. All units should produce continuous ultrasound; the variety will come in the duty cycle settings that are available. Some units will have fixed duty cycles while others will allow the chiropractic provider to set the duty cycle, typically ranging from 5% and up. As with other options, the greater the flexibility in duty cycle settings, the greater the cost of the unit.

Another consideration is the number of channels available on the unit. Some models have multiple channels, allowing for one machine to administer multiple treatments at the same time. This option may be useful in a busy clinic where patient load is sufficient to justify the need for multiple channels. Otherwise, this option may not be useful to the clinic where multiple ultrasound units with one channel may be more effective for patient needs.

Many newer units have factory-installed software that has pre-selected parameters and also has the ability to read the treatment time and intensity changes. Some units can adjust either time or intensity as the other is manipulated. For instance, if you adjust the treatment time, the machine will automatically adjust the intensity to account for the change. While this is an intriguing function, many chiropractic providers may not be comfortable with the unit manipulating treatment parameters. In many cases, the software can be programmed to save individual treatment parameters and protocols that the chiropractic provider inputs into the software. These options can make treatment setup and delivery easier; however, the chiropractic provider must decide whether such advanced options are worth the cost.

Many chiropractic providers choose to have multiple sound head sizes for their ultrasound units. This increases the number of treatment areas that you can access to utilize ultrasound and it can allow for treatment of larger areas. Sound heads come in sizes ranging from 1 cm^2 to 10 cm^2 . However, the chiropractic provider needs to keep in mind that the sound head size may not be a reflection of the true ERA. A 10 cm^2 sound head may still have only a 5 cm^2 ERA, thus only half of the ultrasound transducer would actually be producing ultrasound waves. The sound head should have an ERA approximately double the size of the treatment area.

> Cameron MH. Physical Agents in Rehabilitation. Philadelphia: WB Saunders Co; 1999

If the sound heads are changed often, carefully inspect the cable connection between the sound head and the cable. Over time, frequent changing of heads may lead to excessive wearing of the cable connections. Furthermore, if the sound head will be used for immersed ultrasound, you should make sure that it is insulated.

Some manufacturers are now making ultrasound heads that have remote controls for treatment time and intensity. This allows chiropractic providers to make changes in parameters without having to direct their focus away from the treatment and patient. If this option is desirable, you should consider placement and fit of the controls on the sound head, and determine ease of use and comfort.

Unit portability is important. Is the unit powered only by AC current or is battery operation an option? If the unit is portable and will be traveling with you, is the external case durable? Does it come with a travel container? Are the cables and plugs sturdy?

The manufacturer warranty is also an essential component of any ultrasound unit purchase. Questions such as warranty duration, parts covered, and who handles repairs or warranty work are crucial. Also, you need to find out how often the unit needs to be calibrated and who can inspect and calibrate the unit without voiding the warranty. Calibration is essential to verify that the dosages of ultrasound are accurate and appropriate. When was the last time you had your ultrasound unit calibrated? Should be done on a yearly basis.

> Artho PA, Thyne JG, Warring BP, Willis CD, Brismee JM, Latman NS. A calibration study of therapeutic ultrasound. Phys Ther. 2002;82:257-63

Perhaps the best way to decide what ultrasound unit may be the best fit is to try several different manufacturers and models. Most manufacturers or vendors will lend ultrasound units to chiropractic providers on a trial basis. Take advantage of such offers to find the unit that best meets your specifications, expectations, and patient needs.

Combining Modalities with Procedures

We believe there are two modalities that, when combined, produce a winning combination when treating musculoskeletal conditions. When the goal is increased range of motion (ROM) in a contracted or frozen joint, the winning combination is deep heat and joint mobilization and/or manipulation. The purpose of this section of the program is twofold: first, to present a case study where ultrasound and joint mobilization and manipulation were effectively used on a frozen joint; and second, to provide a rationale for why this combination is so effective when used together.

Case Study

A 22-year-old man presented to our clinic in April 20XX. When he was 19, a surgeon accidentally severed three extensor tendons in his hand while trying to extract a ganglion cyst. The patient underwent more surgery by another physician to repair the tendons. After prolonged immobilization in a splint, he had extensive physical therapy that included ultrasound and stretching to help gain back lost ROM.

Three years after the injury, however, his wrist movement was still very limited and exhibited a firm, capsular, pathological end-feel. Wrist flexion was 49° out of a possible range of 80° to 90°, while wrist extension was 65° out of a possible 80° measured goniometrically according to the AMA Guide to the Evaluation of Permanent Impairment 5th edition.

Our treatment sessions included ultrasound to heat the tissue, immediately followed by joint mobilization, and manipulation under wrist traction. Ultrasound parameters were frequency (3 MHz), intensity (1.5 W/cm^2), treatment size (twice the size of the sound head faceplate, 5 cm^2), and treatment time (7.5 minutes, anterior wrist; 7.5 minutes, posterior wrist). Standard topical ultrasound gel was used as the coupling medium. As soon as the ultrasound treatment was finished, we started joint mobilizations/manipulations. These lasted for 6 to 8 minutes and consisted of radial-carpal glides in both the anterior and posterior direction to gain back wrist flexion and extension. A total of three treatments were given (Mon, Wed, Fri) over the course of 1 week.

The patient saw immediate improvement of 6° in flexion and 7° in extension after the first treatment session. By the end of the third treatment, the subject had gained 23° flexion and 15° of extension, with near-normal bilateral ROM. Six months after the treatments, he had maintained the ROM that was gained from the ultrasound and mobilization/manipulation under traction regimen.

Thermal effects of Ultrasound

When therapeutic ultrasound is applied to tissue, both thermal and non-thermal effects occur.

> Dyson M. Mechanisms involved in therapeutic ultrasound. Physiotherapy. 1987;73(3):116-120.
>
> Partridge CJ. Evaluation of the efficacy of ultrasound. Physiotherapy. 1987;73(4):166-168.
>
> Haar G. Basic physics of therapeutic ultrasound. Physiotherapy. 1987;73(3):110-113

Ultrasound influences both normal and damaged biologic tissues; however, damaged tissue may be more responsive to ultrasound than normal tissue.

Conventionally, ultrasound has been used for the most part to increase tissue temperature.

Lehmann JF, Guy AW. Ultrasound therapy. In: Reid J, Sikov MR, eds. Interaction of Ultrasound and Biological Tissues. DHEW Publication (FDA) 73-8008. 1971; session 3(8):141.

MacDonald BL, Shipster SB. Temperature changes induced by continuous ultrasound. South African J Phys. 1981;37(1):13-15

The primary advantage of ultrasound over other non-acoustic heating modalities is that tissues high in collagen such as tendons, muscles, ligaments, joint capsules, joint menisci, intramuscular interfaces, nerve roots, periosteum, cortical bone, and other deep tissues may be selectively heated to the therapeutic range without causing a significant increase in tissue temperature in skin or fat.

Lehmann JF, Guy AW. Ultrasound therapy. In: Reid J, Sikov MR, eds. Interaction of Ultrasound and Biological Tissues. DHEW Publication (FDA) 73-8008. 1971; session 3(8):141.

MacDonald BL, Shipster SB. Temperature changes induced by continuous ultrasound. South African J Phys. 1981;37(1):13-15

Ultrasound penetrates skin and fat with very little attenuation.

Haar G, Hopewell JW. Ultrasonic heating of mammalian tissue in vivo. Brit J Cancer. 1982;45(suppl V):65-67

The clinical effects of thermal ultrasound include but are not limited to:

- An increase in the extensibility of collagen fibers found in tendons and joint capsules
- Reduction in viscosity of fluid elements in the tissues
- Decrease in joint stiffness
- Reduction of muscle spasm
- Diminished pain perception
- Slowing of nerve conduction velocity
- Increased metabolism
- Increased blood flow
- Mild inflammatory reaction, which may help in the resolution of chronic inflammation

Draper DO, Sunderland S. Examination of the law of Grotthus-Draper: does ultrasound penetrate subcutaneous fat in humans? J Ath Train. 1993;28:246-250

The first six of these nine properties can have a very positive impact on preparing tissue for the implementation of joint mobilizations.

Scar Tissue, Joint Contracture

During remodeling, collagen fibers are realigned along lines of tensile stresses and strains, forming scar tissue. This process may continue for months or even years. In scar tissue, collagen never attains the same pattern and remains weaker and less elastic than normal tissue prior to injury. Scar tissue in tendons, ligaments, and capsules surrounding joints can produce joint contractures that limit range of motion. It has been theorized that increased tissue temperatures during ultrasound treatment decrease the viscosity of collagen fibers while increasing their elasticity. In this case, ultrasound is the treatment modality of choice, because the deeper tissues surrounding joints that most often restrict range are rich in collagen.

> Draper DO, Prentice WE. Therapeutic ultrasound. In: Prentice WE, ed. Therapeutic Modalities in Sports Medicine. 5th ed. Madison, Wis: WCB McGraw-Hill; 2003;95-128

A number of researchers have investigated the effects of ultrasound treatment on scar tissue and joint contracture. Ultrasound has been demonstrated to increase mobility in a mature scar.

> Lehmann JF. Clinical evaluation of a new approach in the treatment of contracture associated with hip fracture after internal fixation. Arch Phys Med Rehabil. 1961;42:95

A greater residual increase in tissue length with less potential damage is produced through preheating with ultrasound prior to or while stretching.

> Bierman W. Ultrasound in the treatment of scars. Arch Phys Med Rehabil. 1954;35:209

Tissue extensibility increases when continuous ultrasound is applied at higher intensities, causing vigorous heating of tissues.

> Lehmann JF. Effect of therapeutic temperatures on tendon extensibility. Arch Phys Med Rehabil. 1970;51:481

Periarticular structures and scar tissues become significantly more extensible after treatment with ultrasound involving thermal effects at intensities of 1.2 to 2.0 W/cm^2.

> Bierman W. Ultrasound in the treatment of scars. Arch Phys Med Rehabil. 1954;35:209

Scar tissue can be softened if treated with ultrasound at an early stage.

Gersten JW. Effect of ultrasound on tendon extensibility. Am J Phys Med. 1955; 34:662

Early treatment of Dupuytren's contracture with ultrasound shows a beneficial effect on long-standing contracted bands of scar and a decrease in pain.

Patrick MK. Applications of pulsed therapeutic ultrasound. Physiotherapy. 1978;64(4):103-104

Stretching Connective Tissue

Collagenous tissue is fairly rigid when stressed; however, it yields somewhat when heated.

Bierman W. Ultrasound in the treatment of scars. Arch Phys Med Rehabil. 1954;35:209.

Lehmann JF. Effect of therapeutic temperatures on tendon extensibility. Arch Phys Med Rehabil. 1970;51:481

The blend of heat and stretch results in a residual lengthening of connective tissue, which increases according to the force applied.

The period (or window of opportunity) of vigorous heating when tissues will undergo the greatest extensibility and elongation we like to refer to as the "stretching window."

Markham DE, Wood MR. Ultrasound for Dupuytren's contracture. Physiother-apy. 1980;66(2):55-58.

Draper DO, Ricard MD. Rate of temperature decay in human muscle following 3 MHz ultrasound: the stretching window revealed. J Ath Train. 1995;30: 304-307

If tissue is heated vigorously, it becomes more pliable and less resistant to stretch; yet as the tissue cools, it withstands stretching and can actually be damaged if too great a force is applied. Researchers have studied the rate of tissue cooling following continuous ultrasound at both 1.0 MHz and 3.0 MHz frequencies.

Markham DE, Wood MR. Ultrasound for Dupuytren's contracture. Physiother-apy. 1980;66(2):55-58.

Draper DO, Ricard MD. Rate of temperature decay in human muscle following 3 MHz ultrasound: the stretching window revealed. J Ath Train. 1995;30: 304-307

For all intents and purposes here, we suggest that stretching, traction, or joint mobilization or manipulation under traction be performed immediately after ultrasound, since this stretching window of opportunity stays open for only 5 to 10 minutes following an ultrasound treatment. This window varies according to the type and depth of the tissue heated. Since tendon is much less vascular than muscle, tendon heated with ultrasound cools at a slower rate than that for muscle. Also, deeper muscle cools at a slower rate than that for superficial muscle since the added tissue serves as a barrier to escaping heat.

Why Joint Mobilization and/or Manipulation Under Traction?

You might be asking yourself, "Why didn't the ultrasound and stretching treatments the case study patient received 3 years ago result in regaining his ROM?" Possibly the ultrasound treatments were administered with the wrong parameters (too-low intensity or too-short treatment time to result in any significant heating, etc). Another possibility, however, is that passive stretch is inferior to joint mobilizations and manipulation when dealing with contracted scar tissue. The patient in the above case was immobilized in an extension splint while his wrist extensor tendons healed. When the splint was removed, the patient had lost the majority of his wrist flexion, thus passive wrist flexion was applied in an effort to gain back this lost motion. Passive wrist flexion, however, causes the scaphoid, lunate, and triquetrum to roll and then jam against the radius. Conversely, the action of mobilizing and/or manipulating this joint begins with pulling traction on the joint, stabilizing the radius, and then gliding these three carpal bones in a volar (anterior) direction. There is no jamming of the bones together, and what is tight (the capsule embedded with scar tissue) is lengthened.

Ebadi S, Ansari NN, Naghdi S, Jalaei S, Sadat M, Bagheri H, Vantulder MW, Henschke N, Fallah E: The effect of continuous ultrasound on chronic non-specific low back pain: a single blind placebo-controlled randomized trial. BMC Musculoskelet Disord 13:192, 2012 accessed 04NOV2022

Conclusions

Essentially, the key to increased utilization of ultrasound, and the opportunity for more patients to take advantage of its many benefits, lies in chiropractic providers their knowledge and training, dusting off their ultrasound machines and getting them calibrated. Having an understanding of the procedure, its benefits, effects, proper application, and potential outcomes provides a foundation for more effective application of the process. That is important in the health care industry now, because the number of therapies visits a patient is allowed is usually limited by insurance coverage. When determining a therapy plan, it is vital to know as much as possible at the outset about the patient's general condition, the injury to be treated, determining the stage of healing, determining the treatment goal, choosing parameters that will accomplish the desired treatment outcome, as well as any potential modalities that can offer an appropriate solution. Ultrasound may not be the answer for every patient; however, it does offer unique benefits that should be taken into consideration.

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