Chapter 8

Clinical Application of Therapeutic Ultrasound

Ultrasound application has evolved from what was once a rote "cookbook" approach to a clinical science. Determining if ultrasound is indicated and, if appropriate, the proper output parameters requires knowledge of the type of tissues involved, the depth of the trauma, the nature and inflammatory state of the injury, and consideration of the skin and tissues overlying the treatment area.

Although some treatment parameters have been established, patient feedback and reevaluation of the response to prior treatments form the basis for adjusting the treatment parameters. Inform the patient about the expectations and sensations that are to be expected during the treatment and inform the patient to report any uncomfortable, unusual, or unexpected sensations such as pain or burning.

To ensure safe application of therapeutic ultrasound, units must be calibrated at least once a year (many manufacturers recommend that this be done twice a year). The U.S. Food and Drug Administration (FDA) requires that the output frequency, effective radiating area (ERA), and beam type must be indicated on the generator or the transducer[10] (Fig. 8-1). The date of the last calibration must also be indicated somewhere on the unit. The reported ERA is the average for that make and model; the actual ERA may be significantly different from the reported value.[11] The size of the transducer face may also be included if it is significantly different from the size of the ERA (see Fig. 7.1).[1]

Tissue Treatment Area

Ultrasound can only increase tissue temperatures when the treatment area is approximately two times the size of the ERA.[8] Note that the ERA is approximately half the size of the transducer face. Attempting to heat a larger area will significantly reduce the temperature increase. If the size of the target tissues is larger than three times the ERA, divide the area into two or more treatment zones (Fig. 8-2).

If more than two zones are being treated, stagger the treatment order to prevent contiguous zones from being heated consecutively. However, this method does not increase the collagen elasticity of large body areas sufficiently enough

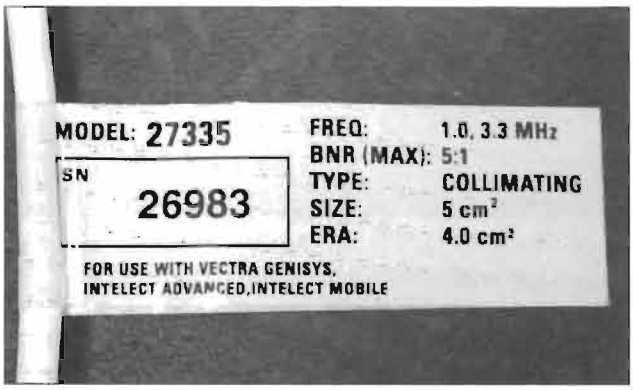


Figure 8-1. **FDA Labeling Requirements for Therapeutic Ultrasound.** The sound head pictured here is capable of producing an output frequency of 1 or 3.3 MHz and has an effective radiating area of 4.0 cm². Note that the BNR is listed as 5:1 for both outputs. The "Max." indicates that this was the maximum BNR found in a sample of sound heads.

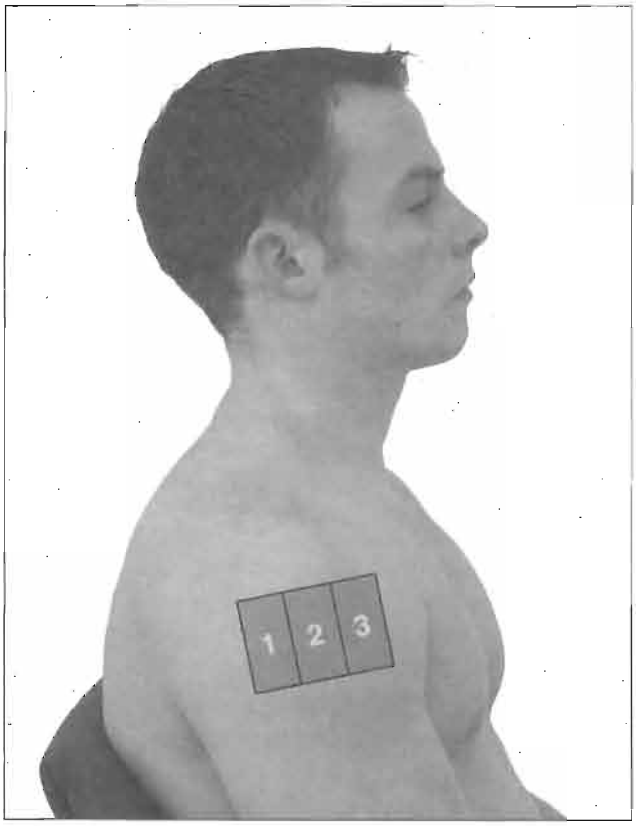


Figure 8-2. **Treatment Zones.** When treating an area more than twice the size of the sound head's ERA, divide the area into two or more "treatment zones." Use caution when treating overlapping areas. In this example treat the two outer zones and then the center zone. As one treatment zone is being heated, the prior treatment areas will cool, thus limiting the ability to effectively heat the muscle mass as a whole.

to promote their elongation. The effectiveness of thermal ultrasound treatment decreases as the area treated increases.

The size of the treatment area for nonthermal treatments may be slightly larger. However, there are no definitive guidelines for this mode of application.

Coupling Methods

Ultrasonic waves cannot pass through the air; a transmission medium is needed to transmit the energy from the transducer into the tissues. A good medium must transmit a significant percentage of the ultrasound; therefore, it should be nonreflective. The optimal medium for transmission is distilled water, which reflects only 0.2% of the energy.[110]

Attempting to pass ultrasound through a nonconductive medium can damage the crystal. Most ultrasound generators automatically shut down if application is attempted without a medium, if an unacceptable medium is used, or if sufficient contact is not made with the skin. Do not attempt to increase the output intensity without the transducer in contact with the body.

When treating large, regularly shaped body areas (such as the quadriceps muscle group), obtaining a good couple is relatively easy. However, irregularly shaped areas decrease the contact area between the transducer and the skin, causing uneven delivery of energy to the tissues, requiring modified coupling methods.

Direct Coupling

In this method of ultrasound application, the transducer is applied directly to the skin, with an approved gel used to transfer the energy between the ultrasound head and the skin. Coupling agents are made of distilled water and an inert, nonreflective material that increases the viscosity of the mixture. Coupling media that contain 1% methyl nicotinate, a superficial vasodilator may increase blood flow and help hydrate the topical skin layer and improve the transmission of energy.[106]

Not all substances efficiently transfer the ultrasonic energy from the transducer to the tissues, and many block the energy altogether (Table 8-1).

Topical counterirritants and analgesics have been used as coupling agents, but these products can decrease the

TABLE 8-1 Coupling Ability of Potential Ultrasound Media

Substance	Transmission Relative to Distilled Water (%)
Saran Wrap	98
Lidex gel, fluocinonide 0.05%	97
Thera-Gesic cream, methyl salicylate	97
Mineral oil	97
Ultrasound transmission gel	96
Ultrasound transmission lotion	90
Chempad-L	68
Hydrocortisone powder (1%) in US gel	29
Hydrocortisone powder (10%) in US gel	7
Eucerin cream	0
Myoflex cream, trolamine salicylate 10%	0
White petrolatum gel	0

US = ultrasound.

effectiveness of the treatment or altogether render the treatment ineffective. Although some analgesic creams are good conductors of ultrasonic energy (e.g., Thera-Gesic), others do not transmit ultrasonic energy (e.g., trolamine salicylate [Myoflex]) (see Table 8-1). The use of counterirritants as an ultrasound transmission agent increases the patient's perception of heat, but the actual amount of intramuscular heating may be less than that obtained from ultrasound gel.[111,112]

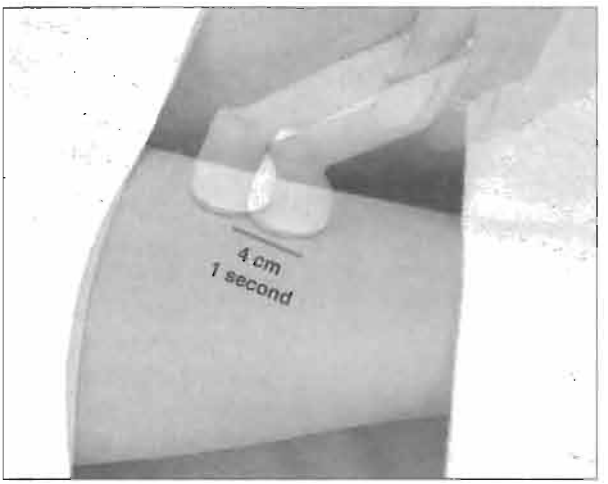
Application Technique

Apply the gel liberally to the area and ensure a consistent thickness and that no large air bubbles are present (Fig. 8-3). Poor conductivity can increase the spatial average intensity by decreasing the contact area between the transducer and the tissues. The effectiveness of ultrasound transmission gel or cream is decreased if the body part is hairy or irregularly shaped. The application of gel causes air bubbles to cling to hair. The greater amount of hair on the body part, the greater the reduction of ultrasound delivered to the tissues. If the body hair is excessive, consider shaving the treatment area.

Use firm, constant pressure to hold the sound head in contact with the skin.[113] Too little pressure creates an insufficient couple. Too much pressure decreases the amount of energy transferred to the tissues by scraping off the transmission medium, and the pressure may cause the patient discomfort. Move the sound head slowly, using approximately 0.44 to 1.32 pounds of pressure.[113]

Figure 8-3. **Direct Coupling Method Using an Ultrasound Gel.** Note that the treatment area is only twice as large as the effective radiating area.

Clinical Techniques: Speed Limit . . . Slow Down When Moving the Sound Head



There is a tendency to move the sound head too rapidly during treatment. When thermal ultrasound is being applied, moving the sound head too quickly can decrease the amount of temperature increase to the point of ineffectiveness. An analogy can be made between the speed that the sound head is moved and ironing a pair of pants. If the iron is moved too quickly across the pant leg, it will not be heated to the point required to remove the wrinkles. Moving the iron too slowly can scorch the cloth.

The same holds true for ultrasound. Slow, precise strokes are recommended to allow the tissues to warm, but moving the sound head too slowly can overheat the tissues. The speed limit for moving the sound head is approximately 4 cm per second, but the slower the better.[113]

If the patient experiences discomfort from the treatment, move the head slightly faster and/or decrease the output intensity. This is related to the spatial peak intensity, creating "hot spots" in the ultrasound output. However, the patient should feel warmth if a thermal treatment is being applied.

In the **stationary head technique,** the sound head is held over the target tissue (e.g., a trigger point or area of muscle spasm). This technique is seldom used because of standing waves overheating the tissue and hot spots associated with the beam.

Heating the skin with a moist heat pack results in a more rapid increase in intramuscular temperature; the use of warm transmission gel does not. Preheating the transmission gel may be done for patient comfort. Overwarming the gel can reduce its density and decrease the efficiency of ultrasonic energy transmission.[114]

Pad (Bladder) Method

This technique originally used a balloon, condom, or plastic bag filled with water or ultrasound transmission gel that was coated with a coupling agent.[115] The bladder is able to conform to irregularly shaped areas such as the acromioclavicular or talocrural joints. The disadvantage is the formation of air pockets within the bladder that prohibit the transmission of sound waves and the difficulty holding the gel-coated bladder in place. The bladder should be made from thin plastic. Rubber products may absorb more energy as the ultrasound wave passes through the bladder on one side and then again on the other, resulting in less energy being available to be delivered to the tissues.[115]

Commercially produced gel pads have become a popular and effective alternative to the bladder method.[115] Gel pads are formed from ultrasound gel in a tight matrix that allows them to hold their shape while also conforming to the contours of the body (Fig. 8-4). Gel pads also limit the treatment area to the size selected, thus focusing the energy on an area approximately twice the size of the sound head.

Application Technique

Fill the bladder with **degassed water** • (see the Immersion Technique section) or ultrasound gel. Remove all air pockets and large bubbles to prevent blockage of the ultrasonic energy. Apply a transmission medium to the skin and the outer surface of the bladder. The bladder is then held against the body part while the sound applicator is moved over its surface. If a gel pad is used, coat both sides with ultrasound gel to improve coupling and to ease motion of the sound head over the pad.[105]

Figure 8-4. **Ultrasound Application Using an Ultrasound Gel Pad.** This method is used to deliver ultrasound to irregularly shaped areas when the underwater area is not practical. These pads also limit the treatment area to an appropriate size.

* Practical Evidence

Gel pads are a convenient method of ultrasound coupling. However, 2-cm-thick gel pads transmit less energy than 1-cm-thick pads. In all cases the use of gel pads reduces the amount of heating relative to direct coupling.[104]

Immersion Technique

When treating irregularly shaped areas such as the distal extremities, a more uniform dose of ultrasound is delivered using water as the transmission medium. The body part is immersed in a tub of water (degassed water is the ideal). Water can be degassed by first boiling it for 30 to 45 minutes and then storing it in an airtight container (sterile or distilled water may be used as well).

Application Technique

A ceramic or metal tub is recommended for underwater ultrasound application.[109,110] The reflective surface creates an "echo chamber" that allows the sound waves to strike the body part from all angles. Plastic tubs are not recommended because they absorb ultrasonic energy.[109] If nondistilled water is being used, the intensity of the ultrasound can be increased by approximately 0.5 W per square centimeter to account for attenuation caused by minerals in the water. Tap water immersion, using 3-MHz ultrasound, is less effective in increasing subcutaneous tissue temperatures than the direct coupling method.[103,115]

Place the transducer in the water with the sound head approximately one-half inch away and facing the body part (Fig. 8-5). The face of the transducer should be parallel with the surface of the skin so that the energy strikes the tissues at a 90-degree angle. Angles of less than 80 degrees significantly reduce the effectiveness of the treatment (see the Cosine Law in Appendix A).[116] The operator's hand should not be continually immersed in the water. Although this is not necessarily dangerous in a single treatment, immersion could unnecessarily expose the hand to ultrasonic energy over repeated exposures.

Air bubbles tend to form along the patient's skin during the treatment, potentially interfering with the transmission of ultrasound and the energy striking the tissues. Using a tongue depressor, wisp away any bubbles that form on the

Degassed water: Water that has been allowed to sit undisturbed for 4 to 24 hours, allowing the gaseous bubbles to escape.

Figure 8-5. **Underwater Application of Ultrasound.** Water is used as a coupling medium to distribute the energy evenly over irregularly shaped areas. The sound head does not come into contact with the body part.

patient's skin or on the transducer face before and during the treatment.

Selecting the Output Parameters

The following sections describe the methodology used to select the various output parameters. This information is described in more detail in Chapter 9.

* Practical Evidence

Although research has identified the parameters needed to maximize the treatment, these recommendations are frequently not used clinically. Even small deviations in the treatment parameters can result in significant decreases in temperature increase. The most common errors in clinical technique are treating too large an area, using too short a treatment duration, and selecting an output intensity that is too low.[36]

Output Frequency

The effective depth of the ultrasonic energy and the rate of heating are based on the output frequency. An output frequency of 1 MHz targets tissues up to at least 5 cm deep. Three-megahertz output has traditionally been thought to target tissues up to 2 cm deep, although there is evidence that indicates that heating may occur up to 2.5 to 3 cm deep.[6,7] Table 8-2 details the differences in 1- and 3-MHz ultrasound application.

Superficial structures such as the patellar tendon, medial collateral ligament, and brachialis require a 3-MHz output. Deep structures such as the rotator cuff, vastus intermedius, and the gastrocnemius call for a 1-MHz output. Keep in mind that subcutaneous adipose tissue is relatively transparent to ultrasonic energy.

Duty Cycle

The duty cycle determines if the treatment effects will be primarily thermal or nonthermal, although the two are never truly separate. Nonthermal effects are always accompanied by thermal effects and vice versa. However, the rate and magnitude of temperature increase are markedly reduced when a low duty cycle is used. Nonthermal effects are used for acute injuries and a continuous output is used when thermal effects are desired.

The duty cycles available on most units range from 20% to 100% (continuous output) with gradations ranging from 5% to 25%. Although it is clear that a 100% duty cycle is used for thermal effects and the lowest duty cycle for the treatment of acute injuries (or when nonthermal effects are desired), it is less clear when, or even if, to use the intermediate duty cycles.

Output Intensity

The effects of the ultrasound treatment depend on the output intensity, the treatment duration, and the duty cycle. The overall amount of energy delivered to the body also depends on the BNR and the ERA.[11] When a continuous output is used, the output meter displays the spatial average temporal peak intensity in watts per square centimeter (W/cm^2) or the total output in watts (W). When the output is pulsed, the overall intensity must be thought of in terms of the spatial average temporal average (SATA) intensity, the average amount of energy per unit of time. Remember that the metered output displays only the average intensity in the near field and does not reflect the peak intensity as represented by the BNR.

TABLE 8-2 Comparison of 1-MHz and 3-MHz Thermal Ultrasound Application

	1 MHz	3 MHz
Beam profile	Relatively divergent	Relatively collimating
Depth of penetration	5 or more cm	0.8 to 3 cm
Maximum rate of heating	0.36°F (0.2°C) per minute per W/cm2	1.1°F (0.6°C) per minute per W/cm2
Heat latency	Retains heat twice as long as 3-MHz ultrasound	Retains heat half as long as 1-MHz ultrasound

Thermal Treatments

For thermal treatments, 1-MHz ultrasound applied at 1.5 W/cm^2 heats at the approximate rate of 0.2°C per W/cm^2; 3 MHz heats at approximately 0.2°C per W/cm^2 (Fig. 8-6).[12] Approximately 10 minutes of treatment time is required to heat tissues to 7.2°F (4°C) using 1-MHz output and a treatment area twice the size of the ERA and an output of 2 W/cm^2. For 3-MHz ultrasound, just under 4 minutes at an output intensity of 1.75 W/cm^2 is required (see Table 8-3). There tends to be a progressive increase in tissue temperature during the first 6 minutes of treatment, after which the rate of increase tapers out. The temperature plateau represents a balance between the energy (heat) applied and blood carrying heat away from the area.[41]

The values presented in Figure 8-6 are estimates of the treatment duration required to reach the target temperature. The body area being treated and the depth of the target tissue, the ultrasound unit's BNR, application techniques, and the coupling medium used influence the rate and degree of temperature increase. Ultimately, heat production varies between manufacturers[34] and even between identical units made by the same manufacturer.[11,41,107]

The patient should describe "warmth" or heat during thermal treatments but not pain or burning. Discomfort could indicate that the sound head is not being moved fast enough, approximately 4 cm per second. Adjust the output intensity to the patient's tolerance and comfort. Uncalibrated units, incomplete contact of the transducer with the skin, and/or too intense a treatment dosage can result in skin burns and blistering.[118] Err on the side of caution, use shorter treatment durations and lower treatment intensities, and make subsequent adjustments based on the patient's response to the treatment. Note that the patient's report of heat may not reflect the actual temperature increase within the muscle.[112]

Nonthermal Treatments

The treatment intensity and duration for nonthermal treatments is largely based on experience and anecdotal evidence. Nonthermal effects are delivered using a low duty cycle (20% to 25%) with an intensity of 0.5 W/cm^2 for treatment of acute injuries.[29,119] Nonthermal effects can also be obtained using a 100% duty cycle with an output intensity less than 0.3 W/cm^2. Superficial skin lesions, such as pressure sores, respond well to 3-MHz ultrasound applied using a 20% duty cycle and an output intensity of 0.1 to 0.5 W/cm^2.[62]

*** Practical Evidence**

The amount of heating depends on the output intensity, treatment duration,[117] and the duty cycle. Increasing each of these variables increases the potential for heat production.

Treatment Duration

The length of the treatment depends on the output frequency, output intensity, duty cycle, and the therapeutic goals of the treatment. In all circumstances, the area for any particular treatment should be no larger than two times the surface area of the sound head's ERA.[1,8]

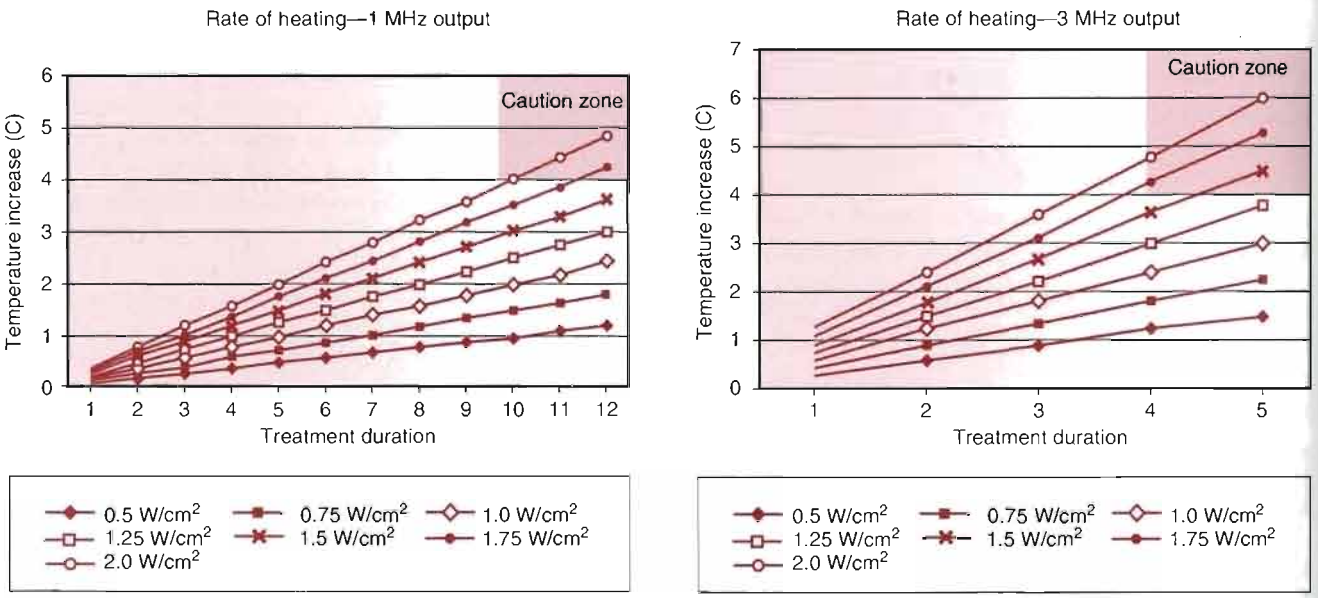


Figure 8-6. **Approximate Treatment Time Based on Target Temperature Increase.** Assuming a continuous output (100% duty cycle), the approximate treatment times (in minutes) required to obtain specific tissue temperatures at different output intensities. The patient should report warmth, but not pain or discomfort, during the treatment.

* Practical Evidence

The treatment duration ultimately determines the amount of intramuscular heating. High intensities applied for a short duration result in less heating than therapeutic ultrasound applied at a lower intensity for a longer duration.[117]

When vigorous heating effects are desired, the treatment duration should be in the range of 10 to 12 minutes for 1-MHz output and 3 to 4 minutes for 3-MHz ultrasound. Table 8-3 should be used as a guide for determining the actual treatment duration based on the frequency of the ultrasound being applied and the goals of the treatment.

Dose-Oriented Treatments

Improvements in the quality of ultrasound generators, microprocessors, and research regarding the heating effects of ultrasound have led to the development of dose-oriented treatment parameters. The desired amount of temperature increase is entered and the unit calculates the output intensity and treatment duration. The clinician may still adjust the treatment intensity, but the treatment duration would change inversely. Decreasing the intensity would increase the duration and vice versa.

Ultrasound and Electrical Stimulation

The combination treatment of ultrasound and electrical stimulation has been used for treatment of trigger points and other superficial painful areas, although research supporting the benefits of this combined treatment approach is lacking. In this technique, the ultrasound head serves as an electrode for an electrical stimulating current (Fig. 8-7). Theoretically, this application method would provide the benefits of ultrasound and electrical stimulation if they were applied separately, namely, improved circulation, reduction of muscle spasm, and decreased adhesion of scar tissue.

Trigger points and other stimulation points display a decreased resistance to electrical current flow (see Chapter 12).

TABLE 8-3 Rate of Ultrasound Heating

Temperature Increase per Minute

Intensity (W/cm^2)	1 MHz	3 MHz
Tissue Depth	5 cm Deep	1.2 cm Deep
0.5	0.04°C	0.3°C
1.0	0.2°C	0.6°C
1.5	0.3°C	0.9°C
2.0	0.4°C	1.4°C

Applied at two to three times the effective radiating area.

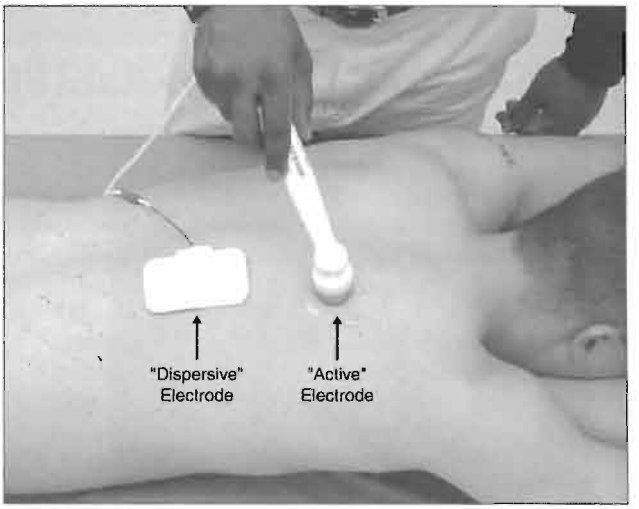


Figure 8-7. **Ultrasound and Electrical Stimulation Combination Therapy.** Using a sound/stimulation combination unit, one electrode is attached to the patient's body while the ultrasound head serves as the active "probe" electrode.

When a moderate pulse duration and moderate pulse frequency are applied at an intensity sufficient to produce a strong muscle contraction, the muscle fibers within the trigger point may fatigue to the point where they no longer have the biochemical ability to spasm. Low-amperage electrical stimulation is capable of increasing adenosine triphosphate activity within the cells, increasing their ability to repair themselves. Increased phagocytosis and increased circulation would assist in the collection and removal of cellular wastes from the treatment area.[120]

A wide range of combined ultrasound and electrical stimulation units are being marketed. The electrical stimulation part of these units delivers a monophasic, biphasic, or alternating current. Each of these parameters would affect the target tissues differently. Likewise, many ultrasound generators in this configuration, especially older ones, deliver only a 1-MHz output. In most instances, a 3-MHz output would be needed to target the stimulation points.

A slowly moving sound head is needed to produce the required amount of subcutaneous tissue temperature increase, approximately 7.2°F (4°C). Placing the target tissues on stretch during treatment could assist the reduction of trigger points and muscle spasm.[53]

Set-Up and Application of Therapeutic Ultrasound

Ultrasound generators are available in a wide range of makes and models. Although most models have unique features, most are capable of delivering ultrasound at different frequencies (1 and 3.3 MHz being the most common), have adjustable duty cycles, and are capable of using sound heads of different effective radiating areas. Many manufacturers produce "combo units" that are both ultrasound generators and electrical stimulators (Fig. 8-8).

At a Glance: Therapeutic Ultrasound

Description

- High-frequency (1 to 3.3 MHz) sound waves applied to the body to produce thermal and nonthermal effects.

Indications

- Chronic inflammatory conditions such as calcific bursitis (pulsed or continuous output)
- Acute inflammatory conditions (pulsed output)
- Pain reduction
- Joint contractures
- Muscle spasm
- Neuroma
- Scar tissue
- Sympathetic nervous system disorders
- Trigger points
- Warts
- Spasticity
- Post-acute reduction of **myositis ossificans**

Primary Effects

THERMAL
- Increased nerve conduction velocity
- Increased extensibility of collagen-rich structures
- Increased blood flow
- Increased macrophage activity

NONTHERMAL
- Increased cell membrane permeability
- Tissue regeneration
- Stimulating phagocytosis
- Synthesis of collagen

Contraindications

- Acute conditions (continuous output)
- Ischemic areas
- Areas of impaired circulation including arterial disease (continuous output)
- Over areas of active deep vein thrombosis or thrombophlebitis
- Anesthetic areas (continuous output)
- Over cancerous tumors
- Over sites of active infection or sepsis
- Exposed metal that penetrates the skin (e.g., **external fixation** devices)
- Over replaced joints using plastic or fixated bone cement.
- Areas around the eyes, heart, skull, carotid sinus, or genitals
- Over the thorax in the presence of an implanted pacemaker
- Pregnancy when used over the pelvic or lumbar areas

- Over breast implants[121]
- Over a fracture site before healing is complete
- Stress fracture sites or sites of osteoporosis
- Over the pelvic or lumbar area in menstruating female patients

Treatment Duration

- The treatment time is from 3 to 12 minutes, depending on the size of the area being treated, the intensity of the treatment, and the goal of the treatment. A minimum of 10 minutes is recommended for thermal treatments.[109]
- Ultrasound is normally given once a day for 10 to 14 days, at which time the efficacy of the treatment protocol should be evaluated.

Precautions

- Use caution when applying ultrasound around the spinal cord, especially after laminectomy. Many manufacturers list this as a contraindication to ultrasound application. The various densities provided by the spinal cord and its covering may result in a rapid temperature rise, causing trauma to the spinal cord.
- Anesthetic areas (pulsed output)
- High treatment doses over the areas of ectopic bone (e.g., heterotopic ossification, myositis ossifications) may stimulate unwanted growth.[109]
- The use of ultrasound over metal implants is not contraindicated as long as the sound head is kept moving and the treatment area has normal sensory function.
- The use of ultrasound over the **epiphyseal plates** of growing bone should be performed with caution.
- Do not apply thermal ultrasound in high doses over the spinal cord, large nerve plexus, or regenerating nerves.
- Symptoms may increase after the first two treatments because of an increase in inflammation in the area. If the symptoms do not improve after the third or fourth treatment, discontinue the use of the modality.[122]

Figure 8-8. **Ultrasound–Electrical Stimulation Combo Unit.** These devices are electrical stimulators and ultrasound generators housed in the same unit. Electrical stimulation and ultrasound can be applied at the same time (see Ultrasound and Electrical Stimulation).

Instrumentation

Duty cycle: Adjusts between continuous and pulsed ultrasound application. Most units display the duty cycle as a percentage, with 100% representing continuous ultrasound. Low duty cycles produce primarily nonthermal effects; with a 100% duty cycle the predominant effect is thermal.

Frequency: Selects the output frequency—and therefore the depth of penetration—of the ultrasound. A 3-MHz frequency should be used for tissues 2.5 cm or less; 1 MHZ is used for greater tissue depths.[6]

Gel warmer: A heating element is used to preheat the transmission gel. This is primarily for patient comfort and has little, if any, additive effect on the treatment. Overwarming (or overcooling) the transmission medium may possibly decrease the thermal effects of ultrasound treatments.[114]

Intensity: Adjusts the intensity of the ultrasound beam. The WATT METER displays the output in either total watts (W) or watts per square centimeter (W/cm^2).

Maximum head temperature: Sets the maximum heat tolerance in the sound head in case the head is not properly coupled.

Pause: Interrupts the treatment but retains the remaining amount of treatment time when the treatment is reinstated.

Power: Allows the source current to flow into the internal components of the generator. On many units, a POWER light goes on, or the WATT METER illuminates.

Start-Stop: Initiates or terminates the production of ultrasound from the transducer.

Timer: Sets the duration of the treatment. The time remaining is displayed on the console, or the timer rotates to display the time remaining.

Watt meter: Displays the output of ultrasound in total watts or watts per square centimeter. Digital meters may require that the user manually switch between the two displays. Most **analog** • meters display the total watts on an upper scale while simultaneously displaying output in watts per square centimeter on the lower scale. These typically have a sound head with a fixed ERA.

Patient Preparation

1. Establish that no contraindications are present.
2. Determine the method and mode of ultrasound application to be used during this treatment.
3. Clean the area to be treated to remove any body oils, dirt, or grime. If necessary, shave excess body hair in the treatment area.
4. For thermal treatments, identify a treatment area that is no larger than two to three times the size of the ERA.
5. Determine the coupling method to be used.

   Direct coupling: Spread the gel over the area to be treated. Use the sound head to evenly distribute the gel.

   Gel pad: Cover both sides of the pad with ultrasound gel.[105]

   Immersion: If possible use degassed water to fill a ceramic or plastic tub deep enough to immerse the target tissue. Place the patient's extremity in the water with the sound head approximately 1 in. from the body part.

6. Explain the sensations to be expected during the treatment. During the application of continuous ultrasound, a sensation of mild to moderate warmth (but not pain or burning) should be expected. No subcutaneous sensations should be felt during the application of pulsed ultrasound. Advise the patient to inform you of any unexpected sensations.
7. For thermal treatments applied using a 1-MHz output, preheating with a moist heat pack will decrease the treatment time required to reach vigorous heating levels.[39]
8. Advise the patient to report any adverse, unusual, or painful sensations during the treatment. Improper application of therapeutic ultrasound can result in skin burns.[118]

Initiation of the Treatment

1. Reduce the INTENSITY to zero before turning on the POWER.
2. Select the appropriate mode for the output. Use CONTINUOUS output to increase the thermal effects of ultrasound application or PULSED output for nonthermal effects. The more acute the injury or the more active the inflammation process, the lower the duty cycle that is used.
3. Ensure that the WATT METER displays the appropriate output for the type of treatment.
4. Set the TIMER to the appropriate treatment duration, but treat an area no larger than two to three times the size of the unit's ERA. The actual duration of the treatment depends on the desired effects of the treatment, the output intensity, and the body area being treated. Nonthermal effects require a shorter treatment duration than thermal effects. Refer to Figure 8-6 for the approximate times required to reach various therapeutic heating levels.
5. Begin slowly moving the sound head over the medium and depress the START button to begin the treatment session. Units having low BNR may be moved at a slower rate than those with a higher BNR.
6. Slowly increase the INTENSITY to the appropriate level while keeping the sound head moving and in contact with the patient's body, immersion bath, or coupling bladder.
7. Move the sound head at a moderate pace (4 cm per second or slower) using firm, yet not strong, overlapping strokes.[113]
8. If periosteal pain is experienced (a sharp pain or ache), move the sound head at a faster rate, use a reduced duty cycle, or lower the intensity. If the pain continues, discontinue the treatment.
9. If the gel begins to wear away or if the sound head begins sticking on the skin, PAUSE the treatment and apply more gel.

Phonophoresis Application

1. Clean and, if necessary, débride and/or shave the treatment area.

Analog: A readout on a continuously variable scale. A clock with hands is a type of analog display

2. Preheating the treatment area is recommended to decrease skin resistance and increase the absorption of the medication.[83]
3. Position the extremity to encourage circulation.
4. Apply the medication directly over the target tissues and apply a liberal amount of ultrasound coupling gel over the medication. Cover the area with an occlusive dressing such as Tegaderm™. If possible, allow the mixture to pre-absorb into the skin for 30 minutes prior to applying ultrasound.[123]
5. Follow the procedures described in Initiation of the Treatment.
6. Ultrasound is delivered using a 50% or 100% duty cycle and at an output intensity ranging from 1.0 to 2.0 W/cm^2.
7. After treatment, allow the occlusive dressing to remain in place.[86]

* Practical Evidence

Applying an occlusive dressing over the medication 30 minutes before the treatment and allowing it to remain in place following the treatment significantly increase the subcutaneous absorption of medication during phonophoresis.[123]

Termination of the Treatment

1. Most units automatically terminate the production of ultrasound when the time expires. If the treatment is terminated prematurely, reduce the intensity before removing the transducer from the medium.
2. Immediately initiate any post-treatment stretching.
3. Remove the remaining gel or water from the patient's skin.
4. To ensure continuity of treatment sessions, record the parameters used for this treatment in the individual's file; specifically, record the output frequency, intensity, duration, and duty cycle. Keep a running count of ultrasound treatments given for this condition.

■ Maintenance

Federal regulations require that therapeutic ultrasound units be recalibrated annually by an authorized service technician. Recalibration of the output intensity is reflected clinically by adjusting the patient's treatment intensity. For example, consider an instance where the metered output was 20% higher than the actual output intensity. The service technician would recalibrate the metered output downward by 20%. In future treatments the treatment output intensity would need to be increased by 20% to obtain the same results.[1]

Daily Maintenance

Clean ultrasound head and transducer face as recommended by the manufacturer.

Monthly Maintenance

1. Check all electrical cords for tears, fraying, or kinks.
2. Check the sound head cable for tears, fraying, or kinks.
3. Clean the transmitter face as recommended by the manufacturer.