ULTRASOUND THERAPY

7.2. ULTRASOUND THERAPY

Mechanical waves of a frequency higher than 20 000 Hz are called ultrasound. Application of ultrasound does not generate any electric current in tissues, and is thus classified as mechanotherapy. The frequency usually used in physiotherapy is 0.8 – 3 MHz. When the air gap between the emitter head and the body surface is eliminated, the emitter head vibrations are transmitted deeper through the tissues while propagating in the form of longitudinal waves. All cells in the path of the ultrasonic beam starts to oscillate. This causes micro-massage followed by the transformation of gel into sol (jelly structures become colloid solution), transformation of mechanic energy into thermal, and deep heating of tissues. (heating of deeply seated tissue?) The amount of heat generated depends on the amount of absorbed energy. Other effects of ultrasound (degassing of solutions, formation of cavities in liquids, and local alkalization) are negligible due to ultrasound doses and intensities used in physical therapy. In order to avoid side effects, it is important to keep in mind that molecular oscillation occurs not only in the path of the ultrasonic beam, but also in places that are distant from the area of application as a result of transmission via body fluids. This may lead to recurrence of former epistaxis or acceleration of menstruation. The features of the ultrasound beam and its distance from the emitter head determines the ultrasound field as being either close or distant. Close ultrasound field is characterized by low beam divergence and big intensity variations due to interferential effects. The length of close field is directly proportional to effective radiation area (ERA – see below) of the emitter head and inversely proportional to frequency. For example, the length of close field with 4 cm2 ERA emitter head and 1 MHz frequency is approximately 10 cm, and for the emitter head with 1 cm2 ERA and 1 MHz frequency it is approximately 2 cm. Distant ultrasonic field is characterized by increasing beam divergence, gradual decrease of intensity, and almost no interferential effect. Therapeutic effect takes place mainly in the close field. The ultrasonic beam in the close field has significant interferential effects (interference between(?) applied and reflected waves) - both constructive and destructive. It results in a non-homogenous ultrasonic beam where the peak levels of intensity (local increase of intensity caused by constructive interference) may be many times higher than the pre-set value.

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The beam Non-uniformity Ratio (BNR) states how many times the peaks of intensity exceed the pre-set values. This value characterizes an
ultrasound head with a given frequency. The BNR value of a high quality ultrasound head is lower than 5. It means that if the pre-set
intensity of the unit is 1 W/cm2, the intensity in any part of the ultrasonic beam is not higher than 5 W/cm2.
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The BNR of older ultrasound heads and some new ones (some manufacturers do not mention the BNR value) is often 20 or even more! The Effective Radiating Area (ERA) is always smaller than the actual surface area of the emitter head (the ERA is determined by the size of the piezoelectric crystal or ceramic table that generates ultrasound by oscillation). The ultrasound dose (power emitted to a surface area) is therefore, related to the ERA and not to the actual surface area of the emitter head. These phenomena of ultrasound refraction and reflection are caused by ultrasound wave transmission from one tissue into another and by different transmission speed among tissues. When applying ultrasound, it is necessary to eliminate the air gap between the emitter head and the skin. Therefore, modern ultrasound heads have built-in optic and/or acoustic control mechanisms ensuring insufficient contact. It might have a automatic termination of application time countdown. Due to interference in the close ultrasound field (it reaches the highest level in the place of soft tissue/bone boundary - up to 35%), ultrasonic beam power may increase (constructive interference) or decrease (destructive interference). In order to avoid tissue lesions at the peak levels of intensity, it is necessary to move the emitter head continuously. As a result of reflection and constructive interference, local increase in intensity and temperature may occur, particularly around periosteum/bone boundary. This increase of temperature can lead to pain during ultrasound application. If this occurs, the intensity must be immediately lowered. Ultrasound is primarily absorbed in deeper tissues. Since these tissues usually do not contain thermoreceptors, it is impossible to perceive such local rise in temperature. The patient feels pain only if the local temperature exceeds 45oC and nociceptive receptors are irritated. Most authors agree that a short-term rise in local temperature to 45oC is harmless. In the area of inflammation (edema, erythema, local rise in temperature, pain or dysfunction) additional heat production is contraindicated, and thus only pulsed ultrasound (athermic) should be applied if necessary. During acute phase of post-traumatic conditions (up to 24-36 hours) the pulsed ultrasound application is contraindicated (vibrations hinder capillary proliferation and may cause delayed bleeding).

Local rise in temperature and micro-massage have several physiological effects: • Improvement of local circulation and thus also metabolism because, a rise in temperature enhances vasodilatation (more evident in continuous ultrasound). • Increase in capillary permeability and increase resorption of extravasation fluid. • Improvement of local circulation and decrease orthosympathetic activity resulting in significant muscle relaxation. • Decrease in local ischemic pain. • Transformation of gel into sol (due to transformation of fibrinogen into fibrin, haematomas and edemas change into gel; ultrasound dissolves this gel and speeds up resorption). As the transformation of fibrinogen into fibrin is important in the healing process (scar formation), it is not advisable to apply ultrasound for acute post-traumatic conditions. • Improvement of tissue regeneration capabilities as a result of the above-mentioned effects. Ultrasound has also several non-therapeutic effects that can have negative impact, such as: Tissue lesion - Mechanical and/or thermal tissue lesions can occur when the intensity is too high. Especially sensitive are the peripheral nerves situated on the bone (interference!) below the surface (close field!). Impulse transmission speed in the affected nerve decelerates. This may progress to total (reversible) impulse transmission blockage and finally to irreversible disintegration of the neuron (myelin sheaths are preserved). You should therefore be extremely cautious when applying ultrasound to e.g. paravertebral muscles after laminectomy as nerve structures then loose their natural bone protection. Similarly, bone projections located just under the skin

(ankles, epicondyles, vertebrae, etc.) are also sensitive. • Leukocyte mobility impairment – this can be minimized by sufficient movement of the emitter head. • Other effects (mainly caused by overdoses) are: decrease in glycemia, increased fatigue, nervousness, changes in appetite, constipation, increased tendency to catch colds.

Methods of application

Differs according to: • application area • movement • contact between emitter and body surface

Parameters of application

Ultrasound frequency: 1 MHz frequency is used for deep tissues and 3 MHz frequency for superficial tissues.

Modes of operation: a) continuous - considering the heat generated deeply in tissues. It is contraindicated in inflamed areas and everywhere else where local warming is undesirable. b) pulsed - together with shortening of pulse length there occurs decrease in so called Duty factor. As a result, adverse thermal effects are suppressed and when Duty factor is below 12.5% (1:8), athermic effect can be expected. Duty factor (DF) can be set in pulsed mode of operation. Its value states how many percent the period of duration of the ultrasound signal is being generated. When setting therapy parameters of BTL units, the ratio of ultrasound signal duration to the period length is stated in brackets. This ratio is used in parameters of recommended ultrasound therapies of BTL units. In case of continuous setting of the parameter, only the percentage expression is used.

Emmiter size: The size of the emitter head is determined by the effective radiating area and is usually 1-5 cm2.

Application time:

Application time varies and largely depends on the stage of disease. For acute conditions it is 3 minutes in the beginning, and for chronic conditions, it is usually 5 minutes in the beginning. It is then prolonged using the positive step method. Application time for most therapies does not exceed 10 minutes.

Intensity: For acute conditions we start with the intensity of 0.5 W/cm2, and for chronic conditions 0.8 - 1.0 W/cm2 is used. Later it is increased according to the patient's reaction (the positive step method). The ultrasound intensity must not exceed 2.0 W/cm2 in continuous mode and 3.0 W/cm2 in pulse mode.

Frequency of treatment: Recommended frequency of treatments for acute conditions is 5 times per week and for chronic conditions 3 times per week. The total number of treatments varies according to the individual condition. It can range from a single application before myoskeletal surgery up to 9 applications over a 3-week period for chronic conditions.

Combined therapy is simultaneous application of two or more kinds of energy. (Common diadynamic currents with simultaneous application of galvanic and pulsatile energy. Low frequency currents can also be considered as combined therapy.)

Typical combinations are: - ultrasound + low-frequency currents - ultrasound + amplitude-modulated mid-frequency currents - ultrasound + TENS

Specific contraindications for ultrasound therapy

Absolute contraindications:

1. Epiphyses of growing bones. There is the risk of irreversibly damage the growth zone, causing deformity and permanent impairment. Since older types of ultrasound units employed low intensity (displayed data did not correspond with the actual energy applied), the damage of the growth zone was exceptional and many physicians did not take this contraindication seriously. However, modern effective ultrasounds can cause damage of the growth zone, especially due to insufficient movement of the emitter head. The responsibility lies with the physician who prescribed the therapy as well as with the therapist who performed the contraindicated procedure.

2. gonads. Small doses cause temporary and high doses of permanent spermio / oogenesis impairment.

3. pregnancy

4. eyes. The use of special ophthalmic ultrasound units is restricted to specialized centers. In physiotherapy, it is contraindicated.

5. post-laminectomy conditions. After laminectomy, the spinal cord is not completely covered by the osseous cover, and ultrasound application can cause temporary or even permanent paraparesis of the lower extremities (if the axons of the spinal cord paths becomes disorganized). This is one of the most severe damages in physiotherapy practice ,and the connection between the physiotherapeutic application and the condition is obvious. 6. bleeding with recent onset (any location) Ultrasound waves propagate far via bodily fluids (though with significant energetic decrease). This can cause for example re-occurrence of stubborn epistaxis (e.g., when the ultrasound is applied to a knee).

Relative contraindications:

1. brain, parenchymatous organs, heart. There is no reason to apply ultrasound to these organs (The brain is covered by the cranium). In spite of this, there has been reported a case of a patient who irradiated his sinuses while he applied ultrasound to the knee and after a few hours died of massive bleeding into his frontal lobe (calcified atheroma plate might have been disturbed). The patient must not apply ultrasound to himself/herself under any circumstances, not even to areas easy to reach!

2. peripheral nerves situated on the bone, just below the surface. It mainly concerns n. ulnaris in the elbow area, palmar areas of the wrist, inguinal areas, areas under external and internal malleoli, etc. In all of the above-mentioned areas, the constructive interference (stationary waves) results in local increase in intensity (peaks of intensity) and thus prolongation of impulse transmission and irreversible destruction of nerve fibers without damaging muscular fibers. Myelin sheaths of damaged nerves are usually preserved.

3. Bony projections located under the skin - spinous projections of vertebrae, ankles, condyles, epicondyles. This contraindication is very often ignored. Ultrasound can be used for treatment of epicondylitis, but this is true only in case when one applies ultrasound to a specific muscular group (extensors in lateral epicondylitis, flexors in ulnar epicondylitis). Direct ultrasound application to a painful muscle attachment often causes increased pain, and more often it may lead to chronic manifestation (the same effect as in the case of repeated local application of corticosteroids). Similarly, direct ultrasound application to spine often results in stubborn periosteum pain around spinous processes.

4. Emphysema, bronchiectasis (ultrasound application to the chest area)

5. Menstruation. Ultrasound application is absolutely contraindicated in the lower abdominal area during menstruation. When applying ultrasound to other areas, it is advisable to inform the patient that the menstrual bleeding might increase (more common is acceleration of menstruation than metrorrhagia). If the patient history shows that the ultrasound application might adversely affect menstruation, the therapist should refuse to carry out the treatment and suggest that the patient consult it with her physician. (It is not enough to postpone the ultrasound application until after the menstruating period, when ultrasound indications may not exist anymore.)

6. blood circulation insufficiency

7. pacemaker

8. cardiovascular diseases

9. cochlear implants

10. metal implants

11. tumours

12. acute inflammations

13. vascular and blood diseases (haemophilia)

14. generally poor state of health

15. endocrine glands

16. TB