0.86 MHz AND 3 MHz CONTINUOUS ULTRASOUND EXPOSURES ON ALTERATIONS OF MEDIAN NERVE PROPERTIES

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ABSTRACT

Ultrasound has been extensively used for a variety of treatments. Some researches have shown that it has ability to stimulate the nerve action potential but there have been in vivo no comparison of nerve property alterations between the 0.86 MHz and 3 MHz ultrasound treatments. Consequently, the purpose of this study is to study the effects of ultrasound at various intensities and frequencies on electrical properties of the median nerve. Twenty subjects were randomly selected for 0.86 MHz and 3 MHz ultrasound exposures. The median nerve electrical properties after 10 minutes of both 0.86 MHz and 3 MHz ultrasound exposures at four intensity levels i.e. 0.5, 1.0, 1.5 and 2.0 W/cm^2 were compared with pre-exposure. No significant differences were noted between pre-exposure and immediately post-exposure at all intensity levels of 3 MHz. For 0.86 MHz, median nerve conduction velocity after ultrasound exposure increases approximately 4.5% and 2.7% at 1.5 and 2.0 W/cm^2, respectively. The results show that the 10 minute exposure of 0.86 MHz ultrasound at 1.5 W/cm^2 plays a significant role in affecting the nerve conduction velocity. Although in this study, the nerve conduction velocity increases correspondingly with skin temperature decreases whereas other studies reported that an increase of intramuscular temperature was found. In conclusion, clinicians or physical therapists can take benefits of this result for a guide to select the suitable frequency, intensity and exposure time when using ultrasound therapy for nerve rehabilitation.

KEYWORDS: Median Nerve, Ultrasound Intensity, Ultrasound Frequency, Skin Temperature, Amplitude, Conduction Velocity

1. INTRODUCTION

Ultrasound is a mechanical wave requiring an elastic medium for its propagation. For the application of ultrasound therapy, the electrical energy is converted to mechanical energy by the transducer head. Many ultrasound therapy machines can produce ultrasound waves both continuous mode and pulse mode. The application of a continuous mode is used to heat tissues by its peak intensity whereas the pulse mode reduces the average intensity and produces less heating effects of the tissues. Consequently, a continuous mode of ultrasound therapy has become a common mode for physical therapy [1].

Ultrasound therapy has been extensively used for a variety of conditions such as the decrease of musculoskeletal pain, inflammation, joint stiffness and muscle spasm [2], [3], [4], [5], [6]. Recently, additional usages include the accelerated healing of bone fractures, strength of tendons and thrombolysis [7], [8]. Normally, the effects of ultrasound can be divided into two classes, low intensity applications (0.125-3 W/cm^2) and high intensity applications (over 5 W/cm^2). Typically, the intention of the low intensity ultrasound treatment is to perform for reduction of edema, stimulation of tissue repair and treatment of trigger points for pain management [9], [11]. The purpose of high intensity ultrasound treatment is used for reduction of pain, chronic inflammation, muscle spasm and

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stretching of collagenous tissue in joint and stretching of connective tissue contracture [10], [12], [13].

The baseline of body and muscle temperature is approximately 36-37 °C. Although the increased temperature is required to achieve beneficial effects in tissues, the temperature that higher than 41-42° C has inversely effects such as sympathetic activity inhibition [14].

The mechanical and heating properties of ultrasound therapy have been shown to have an effect on the ability of nerve fibers to propagate the action potential. A previous study reported that applying ultrasound therapy intensity of 1.5 W/cm² for five minutes caused the significant increase in conduction velocity and decrease in latency of sensory nerves at the muscle temperature of about 1.1 °C higher the normal temperature [15]. There have been evidences that ultrasound, at an intensity of 1.27 W/cm² or 1.5 W/cm² for five minutes of exposure, causes a slight increase in the threshold for perception of vibration sensibility and rise up in pain threshold [16]. Basically, there are four different ultrasound therapy intensity levels of 0.5, 1.0, 1.5 and 2.0 W/cm² and two different ultrasound therapy frequencies of 0.86 and 3 MHz. The ultrasound therapy frequency of 3 MHz is generally used to treat the regions where the thickness of the tissue overlying bone is relatively small. The penetration depth of this frequency is 0.8 mm–1.6 mm and, consequently, the rate of energy absorption is greater than that of the 0.86 MHz frequency. The 0.86 MHz frequency is used with deeper lesions as it has greater penetration depth, 2.5 mm – 5.0 mm, in all tissues [14]. To date, there have been no studies on the alterations in properties of nerve during four ultrasound therapy intensities. Moreover, there is still no comparisons of nerve properties at 0.86 MHz and 3 MHz. Thus, the purpose of this study is to investigate the effects of four different ultrasound intensities and two different ultrasound frequencies on the properties of nerve.

2. MATERIALS AND METHODS

2.1 Subjects

Twenty physical active male college students with a mean age of 22.5±1.5 years had volunteered to participate in the investigation. Each participant was informed, signed and consent of possible risks associated with participation in the study. All the subjects were non-smokers and non-alcohol drinkers. The left forearm of each subject was free from ecchymosis, infection, swelling and any injuries. The mean body mass was 62.1±4.3 kg and the mean height was 1.7±0.1 m. A little piece of adipose tissue was taken from each subject using the skinfold technique to prevent ultrasound beam absorption [17]. Twenty subjects were randomly selected for the 0.86 MHz group and the 3 MHz group. The ten subjects of both groups were exposed to four ultrasound intensities in random order at 0.5, 1.0, 1.5 and 2.0 W/cm².

2.2 Instruments

The ultrasonic machine (Diter S3004) was used and calibrated prior to the study. The ultrasound machine provides two frequencies of 0.86 and 3 MHz. The transducer head has a surface area of about 5 cm² and contains a lead zirconate titanate crystal. The effective radiating area is 5 cm² which is related to the acoustic energy of the ultrasound wave.

The Electromyograph (Neuropack Σ MEB-5504F/K) was used to measure the median nerve properties. Temperature transducers were connected with bedside monitor (900RK) to monitor and record skin temperatures in degrees Celsius.

2.3 Procedures

After resting in the 25 °C experimental room, each subject was asked to lie in a supine position and the whole area on the left medial forearm was shaved and cleaned with 70% isopropyl alcohol. A caliper was used to measure the depths of skin where temperature transducers were located. Two temperature transducers were then placed on the center between the medial epicondyle of humerous and the ulnar styloid process of the left forearm. At 3 MHz, the first temperature transducer was placed on the skin at a depth of 0.8 cm and the other at a depth of 1.6 cm whereas, at 0.86 MHz, temperature transducers were placed at a depth of 2.5 cm and another at about 5.0 cm, respectively. Thereafter, temperature transducers were connected to a bedside monitor. Prior to making a measurement procedure, both temperatures were monitored until stable. During each exposure, skin temperature was recorded every minute and the procedure lasted for ten minutes.

Placement of recording and stimulating electrodes on the median nerve was in accord with the standard procedure. A ground electrode was secured to the palmar aspect of the left hand. Two recording electrodes were placed on the second proximal interphalangeal joint and on the second distal interphalangeal joint. The stimulating electrode was stimulated supramaximally at the elbow and the wrist in order to record median nerve electrical properties (nerve conduction velocity, latency and amplitudes of evoked response) before the ultrasound exposure. After determining the pre-exposure of electrical properties, each ultrasound treatment of 0.5, 1.0, 1.5, and 2.0 W/cm² was applied one at a time for 10 minutes to the subjects. Repeating this procedure for other intensities was carried out every three days.

For each intensity, the ultrasound transducer was moved at the rate of about 6 cm/sec in a counterclockwise circular motion and traveled back and forth for a distance of 10 cm of each side depending on the mid forearm of the subjects. The linear rate of movement of the ultrasound transducer was approximately 1-2 cm/sec. For the post-exposure, median nerve electrical properties was done in a similar procedure to the pre-exposure immediately after the end of ultrasound exposures. In order to minimize the error of data between pre-exposure and post-exposure of ultrasound, the recording electrodes were kept in place throughout the procedure. The points of stimulation at the elbow and wrist were marked and were used for other exposures. Therefore, the distance between the stimulating electrode and the recording electrodes was constant.

2.4 Statistical Analysis

Two-way analysis of variance was used to analyze the difference of the skin temperature between pre-exposure and every minute of post-exposure for different intensities and frequencies. Comparisons of the electrical properties of median nerve between pre-exposure and post-exposure were performed by the Mann-Whitney U test at the significant p value less than 0.05.

3. RESULTS AND DISCUSSION

3.1 Results

In overall, there were no significant differences of the mean skin temperature between the two different depths at all intensities of each frequency. For 0.86 MHz, the skin temperature at 2.5 cm depth was not shown. Figure 1 shows the skin temperature at 5.0 cm depth for each minute of 0.86 MHz. At 0.5 W/cm² and 1.0 W/cm² of 0.86 MHz, it didn't show significant differences of the skin temperature between pre-exposure for each minute during exposure. The results of 1.5 W/cm² of 0.86 MHz of two depths showed a significant decrease of the skin temperature from the fifth to seventh minute and then the temperature slightly increased back to the base line. For 0.86 MHz, the patterns of the skin temperature between 1.5 and 2.0 W/cm² were quite similar. When skin temperatures of each minute for four ultrasound intensities of 0.86 MHz were compared, all insignificant differences between them were obtained except at 1.5 W/cm². For 3 MHz, because the differences of skin temperatures at each intensity were not significant, only those at 1.6 cm depth was shown in Figure 2.

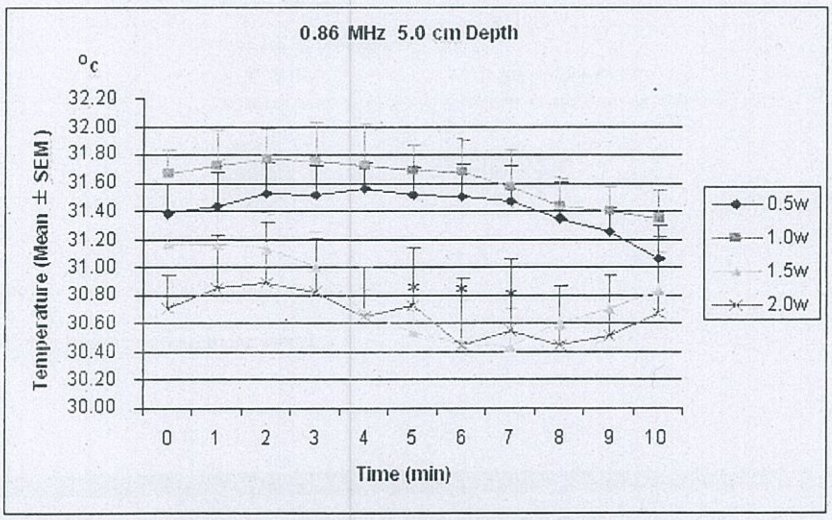

Figure 1. Skin temperature changes per minute at 5.0 cm depth of four intensity levels of0.86 MHz (* p value <0.05).

As shown in Figure 3, nerve conduction velocity after immediately termination of 10 minute ultrasound exposure increased approximately 4.5 and 2.7% at 1.5 and 2.0 W/cm² of 0.86 MHz, respectively, compared to the pre-exposures. A small change of nerve conduction velocity is shown at 0.5 and 1.0 W/cm². All of 3 MHz did not show significant difference of nerve conduction velocities. In addition, a decrease of median nerve latency corresponding to a decrease of the skin temperature at the 1.5 W/cm², 0.86 MHz exposure was shown in Figure 4. A comparison of the amplitude of median nerve action potentials preceding and following ultrasound exposures was also performed. There was no change in action potential amplitudes as shown in Figure 5.

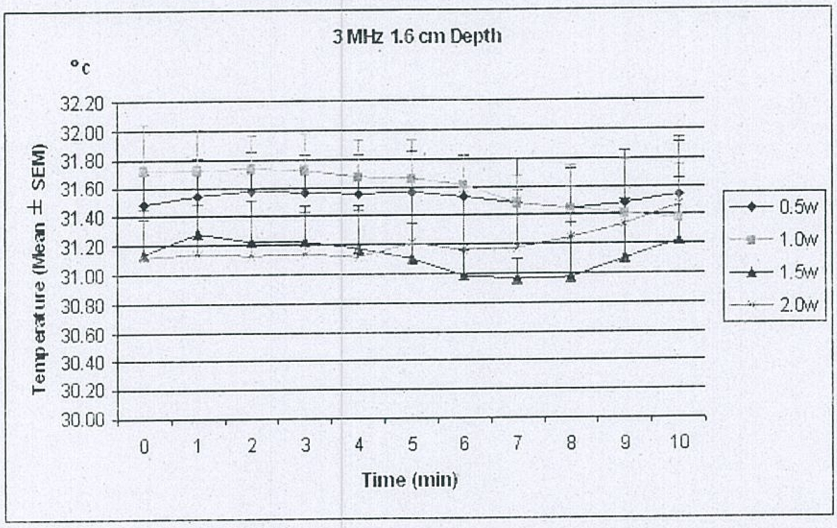

Figure 2. Skin temperature changes per minute at 1.6 cm depth of four intensity levels of 0.86 MHz (* p value <0.05).

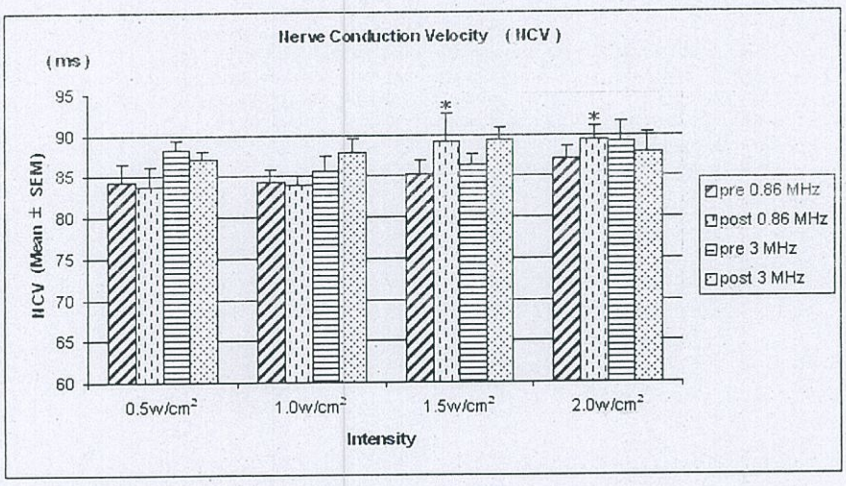

Figure 3. Changes in nerve conduction velocities after four intensity levels and two frequencies of ultrasound exposure to the median nerve(*p < 0.05).

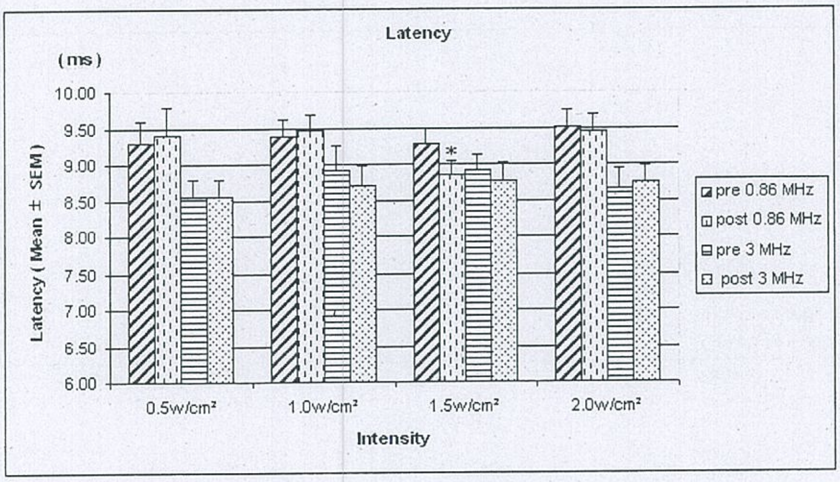

Figure 4. Changes in nerve latencies after four intensity levels and two frequencies of ultrasound exposure to the median nerve(*$p < 0.05$).

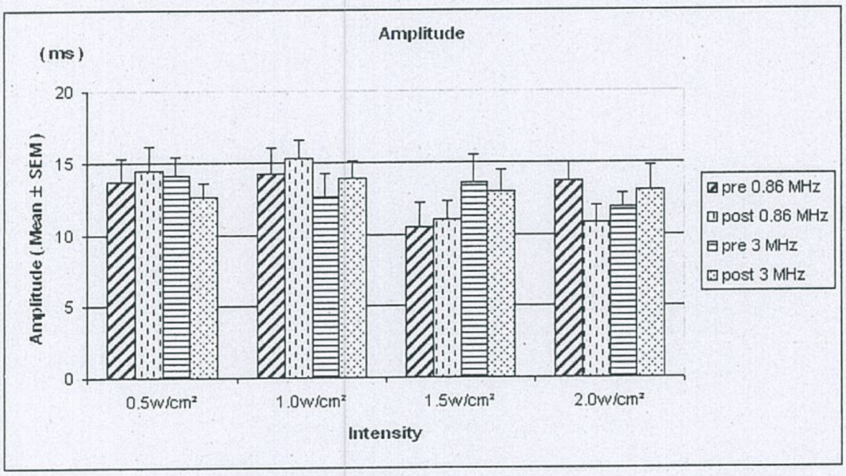

Figure 5. Changes in nerve amplitudes after four intensity levels and two frequencies of ultrasound exposure to the median nerve(*$p < 0.05$).

3.2 Discussion

The treatment goal of therapeutic ultrasound is to increase the tissue temperature. Failure to achieve the desired temperature will affect the outcome of therapy [18]. Thus, the technique of using ultrasound should be taken more carefully than the current practice. Fortunately, the present study has gained attention in the clinical practice of selection factors such as the size of the treatment area, depth of the target tissue, output intensity and treatment time [1]. This research studied the above factors and evaluated the properties of nerve (conduction velocity, latency and amplitude) at various intensity levels and frequencies. Numerous researchers have documented that 0.86 MHz and 3 MHz of ultrasound caused an increase in tissue temperature [14], [19], [20]. As the measurement of the skin temperature is an indirect method, the recorded temperature will be altered by various factors. The skin temperature at 1.5 W/cm² of 0.86 MHz in the present study showed a significant decrease from the fifth to seventh minute during the ultrasound exposure, The author believed that heating effects inside tissues were produced because all subjects felt warm inside of their left forearms. The hypothesis for the mechanism of these results is still has been unclear. Several investigators reported that ultrasound therapy increased the blood flow via vasodilation. Vasodilation causes heat loss from the exposure area [21], [22], [23]. Therefore, a decrease of the skin temperature at 1.5 W/cm² of 0.86 MHz in this study may be due to the vasodilation effect in respond to heat generation in the body. The skin temperatures at 3 MHz for all intensities didn't show any significant change. The explanation of this mechanism is possibly due to the amount of heat generation at 3 MHz ultrasound equal to the amount of heat transfer out by blood flow.

The practical and the clinical applications of ultrasound in term of indications have been established [14]. However, the intensities prescribed for the therapeutic use are empirical. The intensities of ultrasound therapy instruments can be measured accurately but it is still difficult to evaluate the relationship between the intensities and the biological effects especially, nerve conduction velocity, latency and the amplitude of action potential. It is anticipated that movement of the ultrasound head with the large effective radiating area (four times) forth and back in a manner which might be used clinically, would result in changes in conduction velocity. It was shown that an increase in the tissue temperature following ultrasound therapy could produce an increase in nerve conduction velocity [24]. Although skin temperatures in this study decreased during the ultrasound exposure, the subjects felt warm, therefore the muscle temperature may be increased inside the tissue. Previous researches found that propagation velocity of motor nerve increased when ultrasound was administered due to heating effects rather than mechanical effects [25]. Our results showed that, after ultrasound exposure, the median nerve conduction velocity had no significant change at 0.5 and 1.0 W/cm^2 whereas it increased 4.5% and 2.7% at 1.5 and 2.0 W/cm^2 of 0.86 MHz, respectively. It has been reported that an increase of the ultrasound intensity is related to an increase of heat and conduction velocity but its relation would be broken down when the intensity is too high [16], [26]. This is may be the reason why the conduction velocity at 2.0 W/cm^2 exposure of 0.86 MHz is less than that at 1.5 W/cm^2. The exact mechanism is still not cleared. However, the mechanism was proposed that the ultrasound caused a complete block of nerve conduction velocity by myelin degeneration [27]. The studies of other authors using histological examination of nerve following ultrasound exposure and direct heat exposure revealed that the extent of myelin degeneration of ultrasound exposure is more than that of direct heat exposure[24], [25]. In addition, the largest A-nerve fibers, the large myelinated motor neurons destroyed by higher ultrasound intensity, has increased the less conduction velocity than the smallest C-nerve fibers after ultrasound exposure [24], [27]. The median nerve conduction velocity at 3 MHz was also examined but it has no any significant alteration in conduction velocity. Typically, the frequency of the ultrasound beam determines the depth of penetration. The 0.86 MHz ultrasound for the continuous mode is used for heating tissues at 2.5-5.0 cm depth, whereas the 3 MHz is used for heating tissue less than 2.5 cm depth [14]. Actually, the median nerve approximately locates more than 2.5 cm deep in the flexor muscle of the forearm [28], which is the target depth of 0.86 MHz. Therefore, heating effects would be expected to be highest at this half-value layer. Furthermore, the confirmable result indicates that the 1.5 W/cm^2 intensity effect of ultrasound does play a significant decrease in nerve conduction latency. In spite of insignificant difference, the 2.0 W/cm^2 intensity showed a slight decrease in nerve conduction latency.

4. CONCLUSIONS

Although ultrasound has been a modality frequently used in physical therapy for a variety of nerve rehabilitations, the frequency and intensity of ultrasound therapy has not been cleared. This study suggests that the ultrasound treatment with 1.5 W/cm^2 0.86 MHz frequency and exposure time of at least 7 minutes should be another choice for nerve rehabilitation.

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