

The Effect of Ultrasound on the Mechanical Pain Threshold of Healthy Subjects

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Key Words

Ultrasound, mechanical pain threshold.

Summary

The purpose of this study was to examine the effect of ultrasound on threshold to pain produced by a pressure dolorimeter. Twenty healthy, pain-free subjects (12 men, 8 women) who were naive to ultrasound received five minutes of continuous 1.1 MHz ultrasound at 1.0 W/cm² on the dorsal aspect of one forearm. The other arm acted as the control and received sham ultrasound. A pressure dolorimeter was used to measure pain threshold on the treated area and on an untreated area of both arms, before and after the ultrasound. A three-way ANOVA revealed an interaction among arm (control versus experimental), site (treated versus untreated) and time (before versus after treatment). Newman-Keuls *post hoc* analysis demonstrated a significant ($p < 0.05$) increase in pain threshold from before (mean = 1.53 kg/cm², SE = 0.08) to after (1.93 ± 0.12 kg/cm²) treatment only on the dorsal aspect of the experimental arm. There were no changes in pain threshold on the treated site of the control arm (1.49 ± 0.07 – 1.56 ± 0.08 kg/cm²) or on the untreated site on the experimental (1.95 ± 0.12 – 1.96 ± 0.13 kg/cm²) or control (1.95 ± 0.13 – 1.94 ± 0.13 kg/cm²) arm. It is concluded that, in healthy subjects, continuous ultrasound can raise the threshold of pressure-induced pain.

Introduction

Ultrasound is one of the modalities frequently used by physiotherapists for the treatment of pain (Partridge, 1987; Holmes and Rudland, 1991), and yet the published research does not provide a clear picture of the efficacy of this treatment or of the mechanism by which ultrasound would affect pain. Falconer *et al* (1990) indicated that most of the literature on ultrasound was old, and the studies were poorly designed. For example, only five out of 35 articles they reviewed used both sham ultrasound and blind evaluation. Although several studies demonstrated that ultrasound decreased pain in osteo-arthritis or acute periarticular inflammatory conditions, most of these were uncontrolled or lacked blind evaluation. Falconer *et al* (1990) concluded that placebo

response and expectation bias of the evaluator could have contributed significantly to the positive results.

Holmes and Rudland (1991) also provided a critical review of the literature on ultrasound. They indicated that many studies that had reported improvement in pain with ultrasound did not include appropriate analyses. Where enough information was available from the article, Holmes and Rudland re-analysed the data, and found no significant results.

Studies on lateral epicondylitis provide examples of the conflicting results on the effect of ultrasound on pain. Binder *et al* (1985) and Haker and Lundeberg (1991) compared groups receiving pulsed (1:4) ultrasound at 1 MHz or sham ultrasound for a series of treatments. Binder *et al* (1985) increased the dose from 1 to 2 W/cm² and five to ten minutes duration over the treatments. He reported greater improvements in pain and strength in the experimental group compared to the control group. Haker and Lundeberg (1991) kept the dose at 1 W/cm² for ten minutes for the entire ten treatments. They found no difference between groups in the change in the grip strength at which pain occurred. Another study (Lundeberg *et al*, 1988) reported significant differences between two ultrasound groups and one receiving no treatment, but no differences in pain between real and placebo ultrasound. All three studies had good designs with random assignment, inclusion of a placebo treatment and blinded observers. The varying results, therefore, could be due to differences in the treatment parameters or differences in the natural history of the condition.

To reduce the problems related to clinical studies, some investigators have studied the effects of ultrasound on experimental pain. Lehmann *et al* (1958) used radiant heat as a pain stimulus and found that 1.5 W/cm² of continuous ultrasound resulted in a higher pain threshold than placebo ultrasound applied to the opposite limb. Williams *et al* (1987) found that continuous ultrasound decreased threshold to pain produced by electrical current. They compared sides and measured the post treatment score only. Both these studies suggest that ultrasound can have a direct effect on pain.

It is not known, however, if mechanically produced pain would respond in a similar manner. Some nociceptors react quite differently to heat and mechanical stimuli (Campbell *et al*, 1989). In addition, it has been demonstrated clinically (Mannheimer and Lampe, 1984) and experimentally (Simmonds *et al*, 1992) that the efficacy of transcutaneous electrical nerve stimulation (TENS) is dependent on the type of pain. Although TENS and ultrasound provide different stimuli, these results suggest that the type of pain may affect response to treatment.

There have been no well controlled studies investigating the effect of ultrasound on mechanically induced pain. The purpose of this study was to examine the effect of ultrasound on pain threshold produced by a pressure dolorimeter.

Methods

Study Design

The study was a within-subject design. One arm received the experimental treatment and the other arm acted as a control. Both arms were tested for pain threshold before and two minutes after the treatment ultrasound or sham ultrasound. The within-subject design was used because there is a great variability in pain threshold in healthy individuals, but no significant differences when pain threshold is measured at the same site bi-laterally (Fischer, 1987; Hogeweg *et al*, 1992).

Pain threshold was also tested on an untreated site on both arms. This was done to increase the validity of the testing situation. If the subjects were going to have a 'placebo' response, the treated areas on both arms would show a change in pain threshold, but the untreated sites would not.

The experimental situation was randomly assigned to the right or left arm by drawing 'right' or 'left' from a hat. The opposite arm then became the control arm. The process was repeated to determine which arm (right or left) was to be treated first. Both the subjects and the tester were blinded to the allocation of the experimental and the control arm.

Subjects

Subjects were 20 healthy volunteers (12 men, eight women) ranging in age from 22 to 51 years. They were recruited from students and support staff in the Faculty of Rehabilitation Medicine at the University of Alberta. The study was approved by the Faculty Ethics Committee, and all subjects signed a consent form before participating in the study. They received no payment for their partic-

ipation. Persons were excluded from the study if they (a) had present pain, (b) had any known or suspected upper extremity or cervical pathology, (c) had previous surgery of upper limbs, (d) were taking any medication, (e) were pregnant, or (f) had any previous experience with ultrasound.

Testing

Pain threshold of a site in the treated area and of an untreated site was measured with a pressure dolorimeter (Pain Diagnostic and Thermography, Italy). It is a force gauge fitted by a rubber disc with a surface area of 1 cm². It has been found to be reliable and valid for the measurement of pain (McCarty *et al*, 1965; Reeves *et al*, 1986; Brennum *et al*, 1989; Keele and Lond, 1954; Harris and Rollman, 1983). The dolorimeter was also used because it produces a dull, aching pain (Simmonds *et al*, 1992) similar to that experienced in many musculoskeletal conditions (Dubuisson and Melzack, 1976) seen by physiotherapists.

The sites for measurement of pain threshold were marked to ensure that the before and after measurements were taken at the same locations. The measurement site on the treated area was over the muscle belly of the wrist extensors 7 cm distal to the lateral epicondyle of the humerus, on a line drawn from the lateral epicondyle of the humerus to the dorsal radial tubercle. This was the centre point of the insonated area (fig 1). The

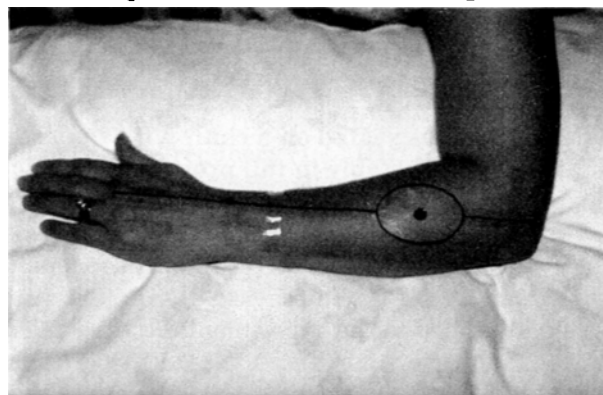


Fig 1: Marking of treatment area (oval on forearm) and test site in centre of treatment area

untreated test site was over the muscle belly of the wrist flexors, 10 cm distal to the medial epicondyle of the humerus, on a line drawn from the epicondyle to the radial styloid process.

The tester applied the dolorimeter to the test site at a right angle to the arm and increased the force through the dolorimeter at the rate of about 1 kg/sec. The subjects were instructed to call 'stop' as soon as they felt discomfort.

The tester removed the dolorimeter at 'stop', and read the maximum applied force from the dial. The subjects were not able to see the amount of pressure applied during the test, and were not told their results. The word 'pain' was not used because in previous work in this laboratory, some subjects reached maximal values on the dolorimeter scale while waiting for pain to occur. These subjects had frequently indicated that it 'hurt' but they would not call it real pain. Pain threshold measurements were only taken once at each test site before and after treatment, because Hogeweg *et al* (1992) found significant effects of repeating measures several times within a short time interval.

Treatment

The ultrasound unit was the Therasonic Mark 3a (Electro Medical Supplies Ltd, Wantage. It had a frequency of 1.1 MHz, a transducer area of 5 cm² and a maximum output of 3 W/cm². The timer and the intensity of output of the unit were tested before, during and after the study and no significant change in output was detected.

Ultrasound was applied over the muscle bellies of the wrist extensors to an area twice the size of the ultrasound head (fig 1). This area was chosen because it was easily accessible, and the ultrasound head could remain in contact with the area because it was fleshy and there were no bony prominences. The area was also quite tender, that is, the pain threshold was low on a number of subjects. Thus there was less danger of a ceiling effect with testing.

The subject was seated on a chair with the arm supported comfortably in full pronation and 90° elbow flexion. The machine was screened behind a curtain so that the subject did not know the intensity of the ultrasound given. The ultrasound was given by a trained research assistant who was not blinded to the experimental/control allocation. However, he did not indicate to the subjects which treatment he was applying. He told them that each arm was being treated with a different intensity, that there was a possibility of feeling some warmth, and that they were to indicate if they felt any pain during the treatment.

Continuous ultrasound at 1.0 W/cm² was applied for five minutes using the direct contact method with ultrasound gel (Aquasonic 100, Parker Laboratories Inc, Orange, NJ 07050, USA). The transducer was moved around at the rate of about 3 cm/sec. The sham ultrasound was given in a similar manner to the treatment protocol, except that the intensity was zero.

Statistical Analysis

A three-way analysis of variance (ANOVA) with repeated measures on all factors (arm × time × site) and Newman-Keul *post hoc* analysis were used to reveal whether the response to treatment was any different between arms and between sites. An alpha level of 0.05 was set for the analysis.

Results

The pain threshold measurements are presented in the table. The ANOVA demonstrated a significant three-way interaction ($p = 0.0002$). The interaction can also be seen in figure 2.

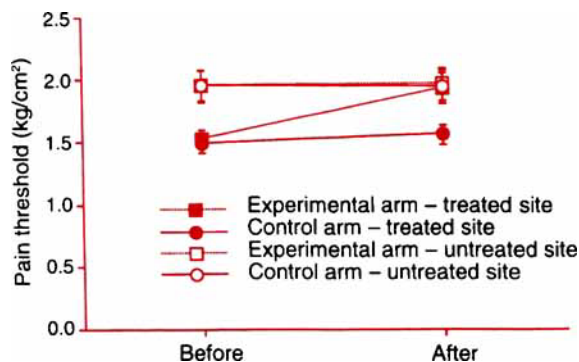


Fig 2: Means and SE of pain threshold measurements demonstrating a three-way interaction of arm, site and time. Only the pain threshold of the treated site on the experimental arm changed following application of real or sham ultrasound

The results of Newman-Keul *post hoc* analysis revealed only one significant change from before to after — an increase in pain threshold on the experimental arm following treatment with real ultrasound. Because of this change, the difference between sides was significant for the treated site only after ultrasound. These differences are noted in the table. There were significant differences in pain threshold between treated and untreated sites except after treatment with real ultrasound.

Eleven subjects reported warmth on the treated site during treatment on the experimental arm.

Means (and standard errors) of pain thresholds (kg/cm²)

	Treated site			Untreated site		
	Pre-test	Post-test	Difference	Pre-test	Post-test	Difference
Experimental arm	1.53 (0.078)	1.93 (0.124)	0.40*	1.95 (0.121)	1.96 (0.128)	0.01
Control arm	1.49 (0.071)	1.56 (0.078)	0.07	1.95 (0.129)	1.94 (0.130)	-0.01
Difference between arms	0.04	0.37*		0.00	0.02	

*Significant difference ($p < 0.05$)

Discussion

This study indicated that ultrasound treatment significantly raised pain threshold of the treated site in healthy subjects, but had no effect on the pain threshold of an untreated adjacent site. Sham ultrasound had no effect on the treated or untreated sites.

The difference in the response to the real and sham ultrasound indicates that the increase in pain threshold was not due to a placebo effect. Others have reported changes in pain with sham ultrasound (Lundeberg *et al*, 1988; Haker and Lundeberg, 1991), but the reduction in pain could have been related to the natural history of the condition or to interventions other than ultrasound (Lundeberg *et al*, 1988). Treatment with sham ultrasound has also resulted in a decrease in inflammation (Hashish *et al*, 1986). Fields and Levine (1984) suggested that both these placebo responses may be related to the release of endorphins. On the other hand, Craig (1989) points out that placebo medication has affected the unpleasantness of pain, but not the sensory aspects. In the present study, only pain threshold was tested and in a controlled situation. Perhaps a response to placebo would have been demonstrated on pain tolerance or unpleasantness, or if there were greater emotion attached to the pain experience.

The lack of a response at the untreated sites is evidence that ultrasound does not decrease the pain threshold through a systemic mechanism, or even by the spread of a local response. However, it is possible that ultrasound could affect the pain of areas remote to the treated site provided they were innervated by the same nerve. The studies of Lehmann *et al* (1958) and Anderson *et al* (1951) support such a pattern of pain reduction distal to the treated area. In the present study, the sonation was over the area supplied by the radial nerve and the lateral cutaneous nerve of the forearm. However, other sites innervated by these nerves were not tested. Inclusion of such a measurement in future studies might help clarify the mechanism by which ultrasound increases pain threshold.

Pain threshold was found to be similar on the same part of the body bi-laterally, but different on the dorsal and ventral aspects of the forearm. These findings are in agreement with those reported by others (Fischer, 1987; Brennum *et al*, 1989; Gerecz-Simon *et al*, 1989; Hogeweg *et al*, 1992), and support the use of the bi-lateral arm for the control condition.

Although the study was designed to eliminate subject and tester bias, there were still some potential sources of error. The warm sensation

experienced by some subjects may have affected their blinded state and suggested to them that the 'warm' treatment was more effective. In future studies, an additional group might receive the treatments with heated ultrasound gel, and the temperature could be monitored at all sites. Downing and Weinstein (1986) heated the gel and demonstrated that ultrasound could be presented in a double-blind fashion if the subjects were naive to ultrasound as in the present study.

Several mechanisms have been postulated to explain the change in pain perception after the application of ultrasound (Hayes, 1992). One theory is that the absorption of ultrasound by the nociceptive fibres (A-delta and C) may block the pain transmission. However, studies on the effects of ultrasound on nerve conduction have only been able to measure changes in the nerve conduction of the large, fastest conducting fibres. It has been shown that the nerve conduction velocity of these large afferents increases with the application of ultrasound, and that this increase is related to the rise in temperature (Kramer, 1984). Since an increase in afferent input from the A-beta fibres can inhibit the effects of painful stimuli at the cord level (Wall, 1989), it is possible that the increase in pain threshold is at least partially due to the effect of the ultrasound on these large fibres. As previously stated, some subjects indicated they felt warmth during the application of the real ultrasound. Unfortunately, neither the temperature nor the nerve conduction were monitored in the present study.

It is unlikely that the reduction in pain threshold was due to direct effects of vibration or a decrease in inflammation. The vibration produced by ultrasound has a frequency (1.1 MHz) too high to excite nerve fibres (Lundeberg *et al*, 1984). Ribot-Ciscar *et al* (1989) indicated that mechanoreceptors can only respond to vibrations up to 280 Hz. None of the subjects had any inflammation of the treated areas.

There is always the question of the relevance of the present results to clinical pain. Experimental pain is considered a model of acute rather than chronic pain (Wolff, 1983) and probably does not elicit emotional and cognitive responses comparable to those occurring in the clinical situation (Chapman, 1983). In addition, measures of pain threshold have not generally been correlated with intensity of clinical pain (Luckhurst *et al*, 1992; Jaeger and Reeves, 1986). On the other hand, the results of this study could be applicable to the sensory aspect of clinical pain of a dull, aching nature. As indicated previously, pain produced by the pressure dolorimeter has a similar quality (Simmonds *et al*, 1992), and both experimental

and acute clinical pain are initiated by the stimulation of nociceptors (Dwarakanath, 1991). In addition, both pain intensity and pain threshold measurements have changed with treatment in persons with myofascial pain (Jaeger and Reeves, 1986).

Additional research is required to clarify the application of the present findings to clinical pain. Future studies should include several post treatment measurements to provide information on the duration of the effects of the ultrasound. Other treatment protocols (eg different intensities, durations, frequencies) could be compared. Finally, the study procedures could be repeated using different types of mechanically induced pain, and subjects with clinical pain.

Conclusion

It is concluded that continuous 1.1 MHz ultrasound applied at 1.0 W/cm² for five minutes can increase the threshold to pressure-produced pain in healthy subjects. The increase in pain threshold occurs only in the area treated by ultrasound, and not at an untreated site or at a site receiving sham ultrasound.

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This work was part of the master's thesis of Mr Mardiman in the MSc programme in physical therapy at the university of Alberta. Dr Wessel was his supervisor and Dr Fisher was a member of the supervising committee. Mr Mardiman was supported by the Canadian International Development Agency.

This article was received on January 17, 1994, and accepted on July 7, 1995.

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