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TRANSCUTANEOUS ELECTRIC NERVE STIMULATION FOR THORACOTOMY PAIN: A COMPARISON OF CONVENTIONAL AND ACUPUNCTURE-LIKE TENS

BY

LUCINDA LEE FINLAY (C)

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OCTOBER 3, 1990

To Maureen, John, Ryan and Kyle Sanborn. Many thanks for a home away from home and for unfailing support and friendship.

ABSTRACT

The inadequacy of narcotic analgesia alone in managing the complex and pervasive problem of postoperative pain, underscores the need for nonpharmacologic adjunct methods such as transcutaneous electric nerve stimulation (TENS). Clinically two "modes" of TENS have been found to be useful, yet little work has been done to systematically evaluate them. Conventional (CTENS) is administered continuously near the site of pain at a high rate, narrow pulse width and a paraesthesia producing intensity. Pain relief that does not extend much beyond the stimulation period is thought to be produced via a peripheral gating mechanism. Alternatively, acupuncture-like TENS (ALTENS) is delivered at intervals to motor/trigger points distal to the painful area at a low rate, wide pulse width and an intensity sufficient to produce muscle contraction. Longer lasting analgesia may be induced that is mediated by endogenous opiates. In a single blind placebo controlled study, sixty patients undergoing posterolateral thoracotomy were randomly assigned to receive one of three treatments after surgery: CTENS, ALTENS or STENS (placebo TENS). Patients rated their pain on a visual analog scale at 6 and 24 hours after surgery. Measures of operative side shoulder range of motion done prior to surgery served as a baseline for flexion and abduction assessed 24 hours after the operation. All

data pertaining to the prescription and administration of analgesic medication before and after surgery were also collected. The hypotheses of interest were the main effects of time and treatment as well as the interaction of time and treatment. Neither CTENS or ALTENS was found to be significantly different from the placebo with regard to pain ratings and these findings held over time. Time alone significantly affected postoperative pain ratings with lower scores being reported 24 hours after surgery. Shoulder range of motion was also not affected by either mode of TENS. In addition, narcotic analgesic intake was not found to be related to postoperative pain scores 24 hours after surgery. The implications of these findings for nursing and for future research are discussed.

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Transcutaneous Electric Nerve Stimulation For Thoracotomy Pain: A Comparison of Conventional and Acupuncture-like TENS

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Lateral thoracotomy is thought to produce one of the most severe forms of postoperative pain (Benedetti, Bonica & Bellucci, 1984; Tolmie, Comer, Pauca & Parkin, 1979). The etiology of this pain, is in large part related to the extensiveness of the surgical procedure which requires a long incision in the chest wall, division of a large mass of richly innervated muscle and placement of chest drainage tubes. In addition, postoperative factors such as reflex muscle spasm, deep breathing and coughing, and body movements that place tension on the incision all tend to exacerbate the pain (Benedetti et al., 1984). The sequelae of persistent pain include limited range of motion in the shoulder on the operative side which impairs normal muscle metabolism, produces atrophy and prolongs the return of normal muscle function (Benedetti et al., 1984). Further, thoracotomy patients invariably experience some degree of pulmonary dysfunction. While pain per se does not account entirely for this impairment, therapeutic measures used to reverse these deficits such as chest physiotherapy, positioning and incentive spirometry are inherently painful and unlikely to be effective if patients

cannot comply with them. Without adequate pain management, these patients are at risk for atelectasis and/or pneumonia, complications which may be life threatening when imposed on an already compromised respiratory system (Craig, 1981).

Thoracotomy pain is not unlike other types of surgical pain in that it is generally poorly managed. Recent evidence suggests that a large proportion of postoperative patients experience moderate to severe pain (Benedetti et al., 1984) that may continue in some cases beyond the fourth day after surgery (Melzack, Abbott, Zackon, Mulder, & Davis, 1987). While the risk of physiological complications may be sufficient reason to improve postsurgical pain control, the need to minimize the psychological consequences of unrelenting pain is equally compelling. Persistent pain interferes with sleep and produces anxiety which may intensify pain perception and diminish ability to cope with the pain (Craig, 1984). Further, indelible pain memories may be produced that influence the patients' ability to manage subsequent painful encounters (Kleinknecht & Bernstein, 1978; Wardle, 1984).

Traditionally, the first line of management for surgical pain is intramuscular narcotic analgesia. A range of doses is prescribed to be administered within a specified interval on an as required or "PRN" basis. Thus, when, why, and how much analgesic medication a patient

receives is dependent upon what is ordered, the skill of the nurse in pain assessment and the patient's verbalization of the pain. Each of these factors is in turn subject to a multitude of influences including a large variability in narcotic analgesic effectiveness among patients and a general lack of pharmacologic knowledge among nurses and physicians (Benedetti, 1990). When taken together with inadequate pain assessment and fears of addiction and respiratory depression held by patients and health care professionals alike, the result is underprescription and underadministration of narcotic analgesia (Sriwatanakul, et al., 1983; Weiss, Sriwatanakul, Alloza, Weintraub, & Lasagna, 1983). In addition, the benefits of opiate analgesia may be limited by side effects such as sedation, diminished cough reflex, nausea and vomiting.

Potentially superior alternatives to intramuscular analgesia included injection or infusion of local anaesthetics or narcotics into the epidural space, local nerve blocks, and patient controlled intravenous administration of opiates. However, these methods are in some cases technically difficult to administer and may be expensive because specialized equipment and/or close patient surveillance is required. Thus, they are unlikely to be widely available to postoperative patients.

There is little doubt that narcotic analgesia will continue to be the

mainstay of postoperative pain management and as such, the problems associated with its effective use must be addressed. However, an area which has received little attention particularly in the nursing community, are the nonpharmacologic adjunct methods of pain control. One such technique is known as transcutaneous electric nerve stimulation (TENS).

TENS involves the administration of a low voltage electrical stimulus to peripheral afferent fibres through electrodes affixed to the skin (Woolf, 1984). This method is especially attractive for a number of reasons. TENS is noninvasive, does not interfere with medical treatment and the only patients to whom it must be administered with caution are those with cardiac pacemakers (Chen, Philip, Philip, & Monga, 1990). The only complications associated with TENS are a minor incidence of contact dermatitis or neurostimulation rash that resolves when treatment is discontinued (Zugerman, 1982). Further, the units are portable and relatively inexpensive.

From a nursing perspective, TENS provides a means for nurses to intervene independently with postoperative pain. This is particularly salient as nurses spend a great deal of time in contact with patients. Thus, they are in an excellent position to identify those who might benefit from TENS, initiate therapy and assess the effectiveness of treatment. In addition, the administration of TENS requires a minimum

of technical expertise and the ability of most patients to manage their own therapy once adequately instructed, may give them a sense of control over their pain.

TENS would seem to be an ideal method to improve postoperative pain management. However, despite 15 years of clinical application, the analgesic properties of this modality have yet to be adequately investigated.

TENS stimulation is determined by the parameters of pulse width or duration in microseconds (mcs), pulse frequency in Hertz (Hz) and pulse intensity in milliamperes (mA). In addition, TENS may be administered through electrodes of various sizes placed on the skin near or distant from the site of pain. Clinical wisdom suggests that specific variations in the stimulation parameters and electrode placement produce different "modes" of TENS. Two modes in particular seem to be supported by empirical evidence.

Conventional TENS (CTENS) is administered via electrodes placed near the surgical incision at a high rate (50-100 Hz), narrow pulse width (40-75 mcs) and at an intensity which produces a comfortable paraesthesia. Stimulation is continuous except for brief interruptions to prevent neural accommodation. Pain relief is said to be achieved nearly immediately and not to extend much beyond the period of stimulation

(Mannheimer & Lampe, 1984).

Acupuncture-like TENS (ALTENS) on the other hand, is delivered to acupuncture points, motor points or myotomes segmentally related to the surgical area. Stimulation frequency is low (1-4 Hz) with a wide single pulse or short trains of impulses (150-250 mcs) and an intensity sufficient to produce strong, rhythmic muscle contractions. Treatments are administered for 20 to 30 minute periods three or four times a day. The analgesia obtained is delayed 15 to 30 minutes, may be enhanced with subsequent treatments and may persist for up to 12 hours post stimulation (Mannheimer & Lampe, 1984).

Laboratory evidence supports this distinction between modes to the extent that high rate-low intensity and low rate-high intensity stimulation are thought to produce analgesia by different physiologic mechanisms. A detailed description of these mechanisms and their relationship to the Gate Control Theory of Pain is provided in Appendix A. Essentially, (high rate-low intensity) CTENS may act mainly on a segmental level, by stimulating large myelinated afferent fibres and inhibiting transmission of nociceptive input in the dorsal horns of the spinal cord. Thus, analgesia is induced when the ratio of large to small fibre firing is enhanced. Similarly analgesia declines when treatment is stopped and this ratio diminishes.

Alternatively, (low rate-high intensity) ALTENS stimulation of muscle afferents may be relayed to supraspinal centers which exert descending inhibitory control over noxious input mediated by endogenous opiates. The latency associated with the release and metabolism of these substances may account for the delay in onset and prolonged duration of ALTENS analgesia.

These explanations outline the predominant means by which CTENS and ALTENS may exert analgesia. However, it should be noted that these mechanisms are not specific to either type of stimulation. Both modes probably produce analgesia by some combination of these mechanisms and others that have not been fully investigated.

Clinical research regarding the existence of TENS modes and the effectiveness of various electrode placements and stimulation parameters on different types of pain has unfortunately, not kept pace with work in the laboratory. As also outlined in Appendix A, the clinical investigation of TENS has been extraordinarily poorly conducted. A few well controlled studies have been done with patients undergoing abdominal surgery. In this population, CTENS was found to be superior to placebo TENS in relieving pain (Hargreaves, 1987; Smith, Guralnick, Gelfand, & Jeans, 1986) and improving pulmonary function (Ali, Yaffe, & Serrette, 1981). However, studies of ALTENS and investigations

comparing ALTENS with CTENS have been directed toward chronic pain and have been either too poorly controlled to give any indication of analgesic effect or lack statistical analyses.

Among the methodological problems clouding the interpretation of findings in TENS research are inadequate measures of pain and lack of placebo control groups. Typically, postoperative pain is indicated in these studies by narcotic analgesic consumption. The variety of factors influencing the administration of analgesic medication clearly demonstrate that this measure is both unreliable and invalid.

More appropriate pain measurement could be achieved using a tool such as the McGill Pain Questionnaire (Melzack, 1975) which assesses pain on a variety of dimensions. However, for two of the scales patients are required to choose word descriptors. This process may prove too lengthy for postoperative patients who may have limited energy and attention span. It may also be particularly difficult for non English speaking patients to complete appropriately.

Other suitable alternatives include visual analog pain scales and numerical rating scales. Although measurement is reduced to a single dimension, they are easily administered and have been shown to be valid indicators of pain (Scott & Huskisson, 1976; Sriwatanakul, Kelvie, Lasagna, Calimlim, Weis, & Mehta, 1983; Ekblom & Hansson, 1988).

A second methodological difficulty in many of these studies is the absence of a placebo control group. Such control is necessary to ensure that analgesic effects produced are not merely due to the presence of the TENS apparatus and the suggestion that pain is being relieved. This is not an easy control to achieve as TENS stimulation produces a definite physical sensation. In general, three methods have been used to establish the placebo condition in TENS. For all of these procedures it is recommended that subjects be TENS naive or that they be carefully instructed that different types of TENS which may or may not produce sensation are being used.

The first method involves presenting all subjects with a similar looking apparatus but providing no stimulation to the placebo group (VanderArk & McGrath, 1975). Another variation involves raising stimulation intensity to sensory threshold momentarily and then turning it off (Smedley, Taube, & Wastell, 1988). Alternatively, intensity may be raised initially to threshold level and not adjusted further when neural accommodation occurs (Mannheimer, Lund, & Carlson, 1978). This final method is somewhat less preferred, however, as it is unknown whether subthreshold stimulation may have an analgesic effect.

Given the practical acceptability of TENS therapy and laboratory evidence of analgesic effects produced through various physiologic

mechanisms, appropriate clinical evaluation of this modality is long overdue. Research is needed to determine whether modes of TENS can be distinguished by different clinical effects and if so, which mode is most useful for various types of pain.

Postoperative patients are an ideal population for study as many surgical procedures are done in large numbers thus allowing sufficient sample sizes and permitting to some degree, standardization of the pain producing event. Further, hospitalized patients are readily accessible for observation. Therefore, the following study was designed to compare the analgesic effects of conventional and acupuncture-like TENS on post thoracotomy pain as indicated by subjective pain ratings and shoulder range of motion.

METHOD

Sample

A convenience sample of 60 sequential cases undergoing posterolateral thoracotomy participated in the study. The inclusion of 20 subjects in each of three groups was determined by mathematical estimation (Shavelson, 1988) to be the sample size necessary to detect a difference of one standard deviation on the visual analog pain scale (alpha=.05 and beta=.20). Potential subjects were recruited from two large teaching and research hospitals and one affiliated hospital.

Patients were asked to participate if they were able to speak and understand English and had not been previously exposed to TENS treatment. Those with cardiac pacemakers, severely reduced range of motion in the shoulder on the operative side, obviously impaired manual dexterity or previously diagnosed neurologic dysfunction were excluded from the study. Patients were also withdrawn from the protocol if they required admission to an intensive care unit following surgery.

Equipment

TENS stimulation through two channels, was produced by model 6880 3M Tenzcare units. To ensure that the placebo TENS stimulators were similar in weight and appearance to the active TENS units, they were equipped with dead batteries and the indicator lights on all of the units were covered. Stimulation was delivered through either four circular electrodes 3.2 centimetres (cm) in diameter (Red Dot 2258T) or two pairs of rectangular electrodes measuring 3.7 x 15 cm and 3.7 x 12.5 cm (Tenzcare 6231) respectively. Reusable carbon electrodes of similar dimensions were used during preoperative orientation of subjects to TENS therapy.

Instruments

Pain intensity after surgery was measured with a 10 cm horizontal

visual analog scale (VAS) (Appendix C). This tool has been used extensively with adult surgical patients and has been shown to be a valid indicator of pain (Huskisson, 1983; Revill, Robinson, Rosen & Hogg, 1976; Onhaus & Adler, 1975; Kremer, Atkinson & Ignelzi, 1981). Assessment of the reliability of the VAS is precluded, as a single item cannot be tested for internal consistency and changes in scores during retest procedures may as easily be due to variation in pain perception as to unreliability of the instrument. However, in the abscence of a more rigorous means to assess the variable psychological experience of pain, the VAS is considered to be a practical and meaningful measure.

Shoulder range of motion (ROM) was assessed using a large plastic goniometer. Universal goniometers are reported to accurately reflect joint motion (Miller, 1985) and to be highly reliable when administered by the same rater (Riddle, Rothstein, & Lamb, 1987). Two physiotherapists performed range of motion measures during the course of the study. As each rater always measured the same patient both before and after surgery and subjects served as their own controls, consistency between the raters was not assessed. However, intrarater reliability was established by ensuring that each therapist was able to obtain measures on five volunteers that varied by no more than

10 degrees when testing was repeated. The second measurements were conducted in random order and without the rater being reminded of the initial value.

Personnel

Research personnel consisted of a TENS technician and two research assistants. The role of the TENS technician was filled by the researcher who was responsible for administration of all TENS treatments and collection of the completed visual analog pain scales. As noted above, the research assistants were trained raters hired to assess shoulder range of motion before and after surgery.

Procedure

On the evening before surgery, consent to participate was obtained from suitable patients (Appendix B). At this time the procedures of the study were explained to subjects including the different forms of TENS stimulation, use of the pain scale and the measurement of shoulder range of motion. A partial blind was created as group assignments were not made until after this initial explanation had been given.

To ensure that patients were able to adequately comprehend and complete the pain scale, they were asked to rate the amount of pain they perceived to be expressed by four faces from a tool developed by

McGrath, DeVeber, & Hearn (1985) (Appendix C). The faces representing varying degrees of pain distress, were presented along with horizontal visual analog scales (VAS) anchored by the descriptors "no pain" at the left end and "worst pain possible" on the right. Patients were asked to place a mark through the VAS at the point that corresponded to the amount of pain expressed by each face. Comprehension of the scale was considered to be adequate if subjects were able to distinguish the different degrees of pain distress expressed by the faces and were able to properly rank them in order of severity.

Pending successful completion of the VAS, baseline measures of active glenohumeral range of motion in the shoulder on the operative side, were done by a trained rater. For these maneuvers patients were positioned supine with the head of the bed elevated approximately 60 degrees and the knees flexed to flatten the lumbar spine. Using the acromion process as the joint axis and beginning with the shoulder in zero degrees of abduction, adduction and rotation and the forearm neither supinated or pronated, range in the plane of flexion was assessed. Then, with the coracoid process as the joint axis, the shoulder in full lateral rotation and the palm facing anteriorly, the range of abduction was determined. For both measures care was taken to stabilize the spine and the scapula. Range in each plane was assessed

twice and the greater value recorded.

Subjects were then randomly assigned to one of three groups: Conventional TENS (CTENS), Acupuncture-like TENS (ALTENS) or sham TENS (STENS). Gender was balanced to prevent unequal proportions of males and females among the treatment conditions. All subjects were provided with a 30 minute practice session prior to surgery using the assigned type of TENS. This was done in order to familiarize subjects with the equipment and the sensations they would experience during the study, as well as to assess any skin reaction to stimulation or the electrode material.

After surgery, within one hour of admission to the recovery room, TENS treatments began for all groups and continued for 24 hours. As stimulation was provided by six TENS units, to prevent systematic equipment error, these units were used randomly among the groups. Appendix D illustrates the electrode placement protocol. Operating room nurses in each hospital were trained in the application of the sterile CTENS electrodes. These electrodes were affixed to the skin after the incision was closed and were covered, along with the surgical wound, by an occlusive dressing. The two longer rectangular electrodes were applied along the length of the incision 2.5 cm above and below the wound. The shorter electrodes were placed 2.5 cm on either side of

the chest tube(s) sites. These positions were chosen because CTENS administered to sites near the painful area is thought to be the most effective (Mannheimer & Lampe, 1984). Channel I was connected to the incisional electrodes and Channel II was attached to the electrodes surrounding the chest drainage tubes. Stimulation was delivered at a pulse width of 75 microseconds (mcs) and a frequency of 100 Hertz (Hz). The intensity was set initially at two to three times the threshold value established in the practice session. As patients recovered from anaesthesia they adjusted the output so that a comfortable paraesthesia was produced in the painful area. Subjects were instructed to raise or lower the intensity according to the severity of their pain. They were also advised that neural accommodation would necessitate periodic elevations in intensity to maintain the paraesthetic tingling sensation. When the intensity could be raised no further, subjects were instructed to turn the output down for a few minutes and then turn it up until the desired effect was achieved.

Those in the ALTENS group had round electrodes placed on both hands after admission to the recovery room. One electrode was positioned in the web space between the thumb and forefinger which corresponds to the motor/trigger points of the first dorsal interosseous and abductor pollicis muscles. The other was placed on the ulnar

aspect of the hand just proximal to the articulation of the fifth digit which corresponds to the motor point of the abductor digiti minimi. These positions were chosen because stimulation at motor points and/or the superficial aspect of a major mixed peripheral nerve may be the most optimal sites for ALTENS treatment (Andersson & Holmgren, 1976; Sjolund, Terenius, & Ericksson, 1977). Channel I was connected to the electrodes affixed to the right hand and Channel II was connected to those on the left. Trains of impulses with a total pulse duration of 250 mcs were delivered at a frequency of 2 Hz. Impulse trains were used rather than single pulses as the strong rhythmic muscle contractions necessary to this mode of treatment are generated at a lower intensity level and may be better tolerated by subjects (Eriksson, Sjolund, & Nielzen, 1979). All controls were locked off to prevent manipulation. Treatments were administered for thirty minutes immediately following surgery, and at eight and sixteen hours thereafter.

In the STENS group, one half of the subjects had electrodes placed in the CTENS positions and received sham stimulation continuously. The remaining subjects were fitted with electrodes at the ALTENS sites and were administered intermittent sham treatments at the same times as the true ALTENS subjects. To produce a convincing placebo in this group, subjects were attached to identical TENS units

and were given the same instructions as the true TENS subjects except for any indication of the sensations they might experience.

Those in the CTENS and sham CTENS groups were visited at 8 hour intervals following surgery to ensure that they were using their TENS units properly and that equal attention was received by all subjects. Subjects and ward staff were instructed that participation in the study did not prohibit the administration of pain medication and that it should be given in the usual manner.

At six hours after surgery, subjects in all groups rated their pain using the VAS. Patients were asked to made a pencil mark through the line at the point corresponding to the intensity of their pain at that moment. A "pain score" was obtained by measuring the distance from the left end of the scale to where the pencil mark intersected the line. To prevent response bias in pain ratings, subjects were left alone to completed the pain scale. Subjects who were not physically able to mark the scale pointed to the position on the line corresponding to their pain and this rating was recorded for them.

Twenty-four hours after surgery, the VAS was completed once again. TENS treatments were then discontinued and the electrodes were either removed or concealed to ensure that the research assistants would remain blind to the treatment condition. Assessments

of active shoulder range of motion in flexion and abduction were then repeated. The patient record was also reviewed at this time and data including the subjects' age, weight, type of procedure and type of anaesthesia were collected. All information regarding the type of analgesic medication prescribed as well as the dose, route and timing of administration both before and after surgery were recorded.

Design

A 3 x 2 mixed factorial design with placebo control was used in this study. This design included a single blind for subjects and a partial blind for the TENS technician. A complete blind was maintained for the research assistants who were unaware of group assignment throughout the study. The between subject independent variable was TENS treatment administered in three levels: CTENS, ALTENS and STENS/placebo control. Time of measurement (six and 24 hours after surgery) was the within subject independent variable and dependent variables included self-reported pain (at six hours and 24 hours) and shoulder range of motion in the planes of flexion and abduction.

Hypotheses

1. The CTENS group will have the lowest pain scores at 6 hours after surgery whereas those receiving ALTENS will have the lowest pain scores at 24 hours after the operation (interaction effect of time and

treatment).

2. Subjects receiving ALTENS or CTENS will report less pain and will have greater preservation of shoulder range of motion than those in the STENS condition (main effect of treatment).

3. Pain scores will decrease between six and 24 hours after surgery (main effect of time).

RESULTS

Sample Characteristics

A total of 80 patients were approached to participate in the study. Of these, one patient declined to participate. Eighteen patients were withdrawn from the protocol after surgery for the following reasons: admission to an intensive care unit (n=7), administration of continuous epidural analgesia (n=3), deferral of surgery in favour of medical treatment (n=3), an operative procedure other than posterolateral thoracotomy (n=2) or mental confusion (n=3). One patient in the placebo group was dropped from the study because hospital staff provided a TENS treatment for pain management. All of the patients who remained eligible to continue in the study completed the protocol.

The demographic characteristics of the sample broken down by treatment group, are described in Table 1. A total of 60 subjects, 36 males and 24 females, age 24 to 83 years (mean 56.9 standard

Table 1.

Demographic Characteristics By Treatment Group

Variable	Group CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
Age				
Mean	58.4	55.8	56.7	56.9
SD	14.4	12.6	12.3	12.9
Gender				
Male	12 (60%)	12 (60%)	12 (60%)	36 (60%)
Female	8 (40%)	8 (40%)	8 (40%)	24 (40%)
Diagnosis				
Cancer	13 (65%)	15 (75%)	16 (80%)	44 (73.3%)
Pneumothorax	4 (20%)	1 (5%)	3 (15%)	8 (13.3%)
Pleural Effusion	0 (0%)	1 (5%)	0 (0%)	1 (1.7%)
Other	3 (15%)	3 (15%)	1 (5%)	7 (11.7%)
Surgery				
Lobectomy	6 (30%)	5 (25%)	7 (35%)	18 (30.0%)
Lobectomy & Wedge Resection	1 (5%)	1 (5%)	2 (10%)	4 (6.7%)
Lobectomy & Rib Resection	0 (0%)	0 (0%)	1 (5%)	1 (1.7%)
Lobectomy & Aneurysm Resection	1 (5%)	0 (0%)	0 (0%)	1 (1.7%)
Lobectomy & Open Lung Biopsy	0 (0%)	1 (5%)	0 (0%)	1 (1.7%)
Open Lung Biopsy	3 (15%)	4 (20%)	3 (15%)	10 (16.7%)
Wedge Resection	5 (25%)	5 (25%)	3 (15%)	13 (21.7%)
Pleurectomy & Wedge Resection	1 (5%)	1 (5%)	3 (15%)	5 (8.3%)
Decortication & Wedge Resection	0 (0%)	0 (0%)	1 (5%)	1 (1.7%)
Wedge Resection & Pleuredesis	1 (5%)	0 (0%)	0 (0%)	1 (1.7%)
Segmentectomy & Wedge Resection	0 (0%)	1 (5%)	0 (0%)	1 (1.7%)
Segmentectomy	0 (0%)	1 (5%)	0 (0%)	1 (1.7%)
Decortication	1 (5%)	0 (0%)	0 (0%)	1 (1.7%)
Pneumonectomy	1 (5%)	1 (5%)	0 (0%)	2 (3.3%)

deviation 12.9) were included in the study. They were recruited from three local hospitals and all had undergone surgery performed by one of seven surgeons. There were many indications for surgery but the most common were malignant lung lesions and spontaneous pneumothoraces. The types of surgical procedures and operative characteristics are described by treatment group in Tables 1 and 2 respectively.

Postoperative pain and range of motion were not correlated with age and length of surgery nor were they influenced by gender, the type of procedure, the operative side, or intercostal Marcaine injection as determined by analysis of variance. However, post surgical abduction was significantly reduced in those having two chest tubes ($F=4.12$, $df=1,58$ $p=.047$).

When the type of surgery was classified by extensiveness of resection, analysis of variance ($F=9.004$ $df=1,58$ $p=.004$) demonstrated that patients undergoing procedures involving lobectomy, segmentectomy or pneumonectomy experienced more pain six hours after surgery than those undergoing less extensive procedures. However, this difference in pain scores was not evident 24 hours after surgery.

Table 2.

Operative Characteristics By Treatment Group

Variable	Group CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
Operative Side				
Right	12 (60%)	10 (50%)	9 (45%)	31 (51.7%)
Left	8 (40%)	10 (50%)	11 (55%)	29 (48.3%)
Number of Chest Tubes				
One	12 (60%)	18 (90%)	11 (55%)	41 (68.3%)
Two	8 (40%)	2 (10%)	9 (45%)	19 (31.7%)
Length Of Surgery (Hours)				
Mean	1.4	1.5	1.7	1.5
SD	.6	.6	.7	.6
Intercostal Nerve Injection				
Marcaine	14 (70%)	18 (90%)	13 (65%)	45 (75%)
None	6 (30%)	2 (10%)	7 (35%)	15 (25%)

Perioperative Prescription and Administration of Analgesic Drugs

For purposes of comparison, all data regarding analgesic medications were converted to equivalent doses of intramuscular Morphine (Appendix B). Summaries of analgesic medication administered within 24 hours prior to surgery, during the operation and in the recovery room are given in Tables 3, 4 and 5 respectively. Descriptions of analgesic drug prescription and administration practices are also provided for the entire postoperative period (Table 6) as well as the intervals preceding the assessment of outcome variables (Tables 7 and 8).

Before surgery, 22 (33.3%) patients received analgesic medication. These included intramuscular Demerol or Morphine and oral Percocet or Tylenol 3 administered as preparation for anaesthesia and/or to treat pain due to arthritic conditions or chest tubes. During surgery, 54 (90%) patients were given a mean of 2.9 (standard deviation 1.2) doses of narcotic. The remaining six (10%) patients received continuous infusions of analgesic medication throughout the operative period. All intraoperative narcotics were given intravenously and consisted of combinations of Morphine, Demerol, Sublimase, Sufenta or Alfenta. In the recovery room, Morphine and Demerol were administered via intramuscular and/or intravenous routes. While only 6 (10%) patients

Table 3.

Preoperative Analgesic Medication Administration By Treatment Group *

Variable	Group CTENS n= 8	ALTENS n= 6	Placebo n= 8	All ** Subjects n=22
Number of Doses				
Mean	2.38	1.5	1.5	1.8
SD	1.69	.84	1.4	1.4
Amount Given				
Mean	15.76	9.89	14.69	13.7
SD	7.4	3.05	14.48	9.8

* Amounts of analgesic medication reported in milligrams of Morphine equivalents

** Only Subjects receiving medication before surgery are included therefore total n=22

Table 4.

Intraoperative Narcotic Administration By Treatment Group *

Variable	Group			
	CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
Amount Given				
Mean	35.46	46.00	42.26	41.24
SD	16.46	26.90	29.74	24.99
Amount Per Hour of Surgery				
Mean	30.0	37.62	31.93	33.18
SD	20.17	35.10	32.36	29.56

* Amounts of narcotics reported in milligrams of Morphine equivalents

Table 5.

Narcotics Prescribed and Administered in Recovery Room By Treatment Group *

	Group			
Variable	CTENS n=13	ALTENS n=14	Placebo n=11	All ** Subjects n=38
PRESCRIPTION				
Morphine	10 (76.9%)	13 (92.8%)	8 (72.7%)	31 (81.5%)
Demerol	3 (23.1%)	0 (0%)	3 (27.3%)	6 (15.8%)
Both	0 (0%)	1 (.07%)	0 (0%)	1 (2.6%)
ADMINISTRATION				
Number of Doses				
Mean	2.92	2.21	2.91	2.66
SD	1.38	1.19	1.22	1.23
Amount Given				
Mean	10.94	8.07	8.16	9.07
SD	5.01	3.38	2.60	3.98

* Amounts of narcotics reported in milligrams of Morphine equivalents
** Subjects who did not receive medictaion are excluded therefore total n=38

Table 6.
Postoperative Prescription and Administration of Analgesic Medication by Treatment Group *

Variable	Group CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
PRESCRIPTION				
Initial Order				
Demerol	17 (34.7%)	18 (36.7%)	14 (28.6%)	49 (81.7%)
Morphine	3 (27.3%)	2 (18.2%)	6 (54.5%)	11 (18.3%)
Interval for Administration				
3 Hours	14 (70%)	16 (80%)	14 (70%)	44 (73.3%)
3-4 Hours	6 (30%)	3 (15%)	5 (25%)	14 (23.3%)
$\geq$ 4 Hours	0 (0%)	1 (5%)	1 (5%)	2 (3.4%)
Maximum Amount Ordered				
Mean	64.78	63.16	69.17	65.70
SD	22.61	23.31	21.53	22.59
ADMINISTRATION				
Total Number of Doses				
Mean	6.45	6.10	6.30	6.28
SD	2.26	1.80	1.75	1.92
Total Amount Given				
Mean	40.46	40.37	45.99	42.27
SD	20.13	16.735	16.22	17.67
Amount Given per Hour				
Mean	1.68	1.68	1.90	1.75
SD	.83	.69	.67	.73
Percentage of Maximum Given				
Mean	60.33	58.41	60.89	59.88
SD	15.53	21.85	17.28	18.13

* Amounts of narcotics reported in milligrams of Morphine equivalents

had no orders for analgesic drugs, 22 (36.7%) subjects received no pain relieving medication while recovering from anaesthesia.

Within three hours following surgery, patients were transferred to surgical nursing units or wards where they remained for the duration of the study. Initially, intramuscular Demerol or Morphine were ordered on a PRN basis. This regimen was revised for twenty-one (35%) patients due to inadequate pain relief from the agent or dose originally ordered (n=9), attempts to reduce postoperative sedation or respiratory depression (n=3) and provision for a less potent analgesic to be given when the pain became less severe (n=9). These medications were also prescribed PRN and included oral Tylenol 3 in addition to intramuscular Demerol and Morphine.

Prior to the first pain measure at six hours after surgery, five patients (8.3%) received no analgesic medication. The remainder were given an average of 2.25 (standard deviation .99) milligrams of medication per hour. In comparison, all patients received medication in the period between six and 24 hours after surgery, however, the average amount administered was reduced to 1.7 (standard deviation .71) milligrams per hour.

The first postoperative pain rating was correlated with both the number of doses ($r=.24$ $p=.04$) and the amount ($r=.22$ $p=.04$) of

Table 7.
Administration of Analgesic Drugs Prior to First Pain Rating by Treatment Group*

Variable	Group CTENS n=18	ALTENS n=18	Placebo n=19	All ** Subjects n=55
Number of Doses				
Mean	2.78	2.61	2.65	2.68
SD	1.63	1.46	1.57	1.53
Amount				
Mean	14.01	12.80	13.80	13.54
SD	6.95	6.17	5.11	6.02
Amount per Hour				
Mean	2.33	2.13	2.29	2.25
SD	1.15	1.01	.85	.99
Time From Last Dose to Pain Score (Hours)				
Mean	2.89	2.79	2.24	2.64
SD	1.84	1.91	1.53	1.76

* Amounts of narcotics reported in milligrams of Morphine equivalents
** Subjects receiving no analgesic medication excluded therefore total n=55

Table 8.
Analgesic Medication Administered Following First Pain Rating and Prior to Final Outcome Measures by Treatment Group*

	Group			
Variable	CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
Number of Doses				
Mean	4.75	4.55	4.70	4.67
SD	.91	1.23	1.17	1.09
Amount				
Mean	28.10	28.85	32.5	29.82
SD	14.82	14.05	12.35	13.68
Amount per Hour				
Mean	1.80	1.61	1.82	1.74
SD	.67	.78	.68	.71
Time From Last Dose to Pain and ROM Measures (Hours)				
Mean	3.08	2.63	3.04	2.92
SD	2.10	1.69	2.14	1.96

* Amounts of narcotics reported in milligrams of Morphine equivalents

analgesic medication administered in the recovery room as well as the number of doses given in the first six hours post surgery ($r=.25$ $p=.03$). The second pain score was correlated only with the number of doses of pain relieving medication patients received after returning to the ward ($r=.24$ $p=.03$). As indicated in Table 9, the amount of medication given in the initial six hour after surgery was related to postoperative flexion ($r=-.22$ $p=.05$). In addition, the number of doses of pain medication received after returning to the ward influenced post surgical range of motion in both flexion ($r=-.27$ $p=.02$) and abduction ($r=-.28$ $p=.02$).

Postoperative Pain

Pain intensity was rated by subjects at six and 24 hours after surgery. Despite administration of narcotic analgesia, on average, patients reported severe pain at six hours (mean 55.6 standard deviation 25.2). These scores continued to be high at 24 hours (mean 46.47 standard deviation 25.2) and were not related to the amount of analgesic medication consumed in the interval between ratings. Mean pain scores broken down by treatment group over time are illustrated in Figure 1.

Shoulder Range Of Motion

Range of motion in the shoulder on the operative side was

Figure 1. Mean Pain Scores By Treatment Group Over Time

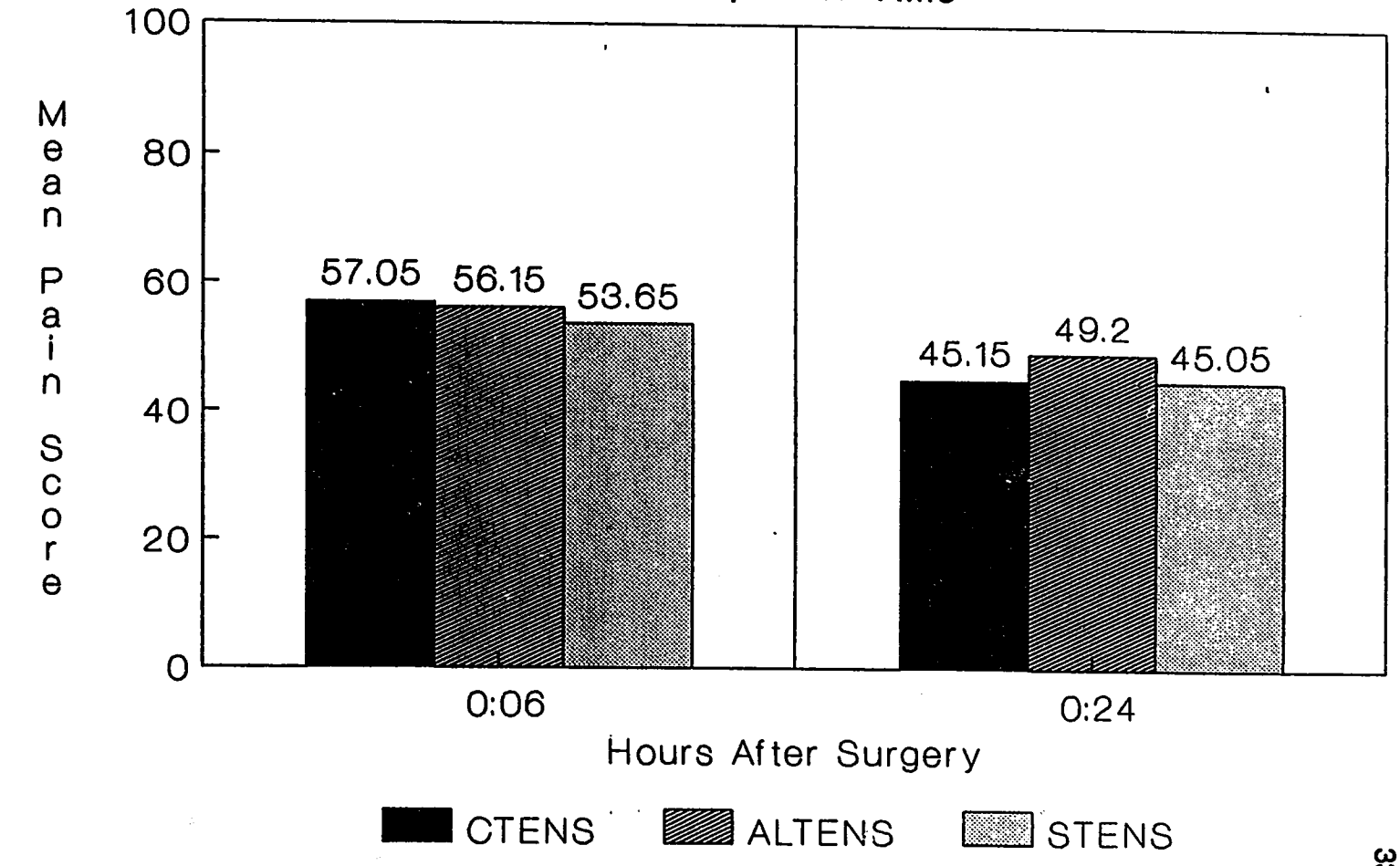

TABLE 9.

PEARSON CORRELATIONS AMONG SHOULDER RANGE OF MOTION, PAIN, WEIGHT AND ANALGESIC MEDICATION ADMINISTRATION

	PREOP FLEXION	PREOP ABDUCTION	DOSES* PREOP	MEDICATION* AMOUNT PREOP	WEIGHT	POSTOP FLEXION	POSTOP ABDUCTION	PAIN AT 24 HOURS	MEDICATION** AMOUNT 6 HOURS POSTOP	DOSES ON WARD
PREOP FLEXION										
PREOP ABDUCTION	.6701 p=<.001									
DOSES* PREOP	-.5166 p=.007	-.6631 p=<.001								
MEDICATION AMOUNT PREOP*	-.6832 p=<.001	-.7421 p=<.001	.6137 p=.001							
WEIGHT	.2221 p=.044									
POSTOP FLEXION	.2638 p=.021	.2309 p=.038								
POSTOP ABDUCTION		.2578 p=.023				.7650 p=<.001				
PAIN AT 24 HOURS POSTOP						-.2645 p=.021	-.2734 p=.017			
MEDICATION** AMOUNT 6 HOURS POSTOP					.4298 p=.001	-.2237 p=.050				
DOSES ON WARD						-.2691 p=.019	-.2775 p=.016	.2405 p=.032	.3799 p=.002	

* n=22
** n=55

measured before surgery to serve as a baseline, and at 24 hours after surgery to assess the effect of treatment. Preoperative flexion ranged from 60 to 180 degrees (mean 148.5 standard deviation 16.4). The range of postoperative flexion was 49 to 165 degrees (mean 112.9 standard deviation 24.7) and averaged 77% (standard deviation 19.3) of the presurgical value. Presurgical abduction ranged from 95 to 190 degrees (mean 157.9 standard deviation 18.5). After surgery, these values fell to between 46 and 190 degrees (mean 103.2 standard deviation 25.4) or an average of 65.9 % (standard deviation 16.6) of the baseline measurement. Significant correlates of shoulder range of motion are provided in Table 9.

Characteristics Of Treatment

According to the study protocol, one half of subjects assigned to the STENS group had electrodes in the CTENS positions while the remainder were fitted with electrodes at the ALTENS sites. Subjects assigned to each of these placebo conditions were compared by analysis of variance and found to be similar in terms of postoperative pain ratings, analgesic medication consumption, the intervals after administration of medication when the outcome variables were assessed and range of motion in both flexion and abduction. Therefore, these cases were combined and treated as a single placebo

Table 10.

Treatment Characteristics By Treatment Group

Variable	Group			
	CTENS n=20	ALTENS n=20	Placebo n=20	All Subjects
Time of Initiation Post Surgery (Hours)				
Mean	.35	.45	.39	.39
SD	.25	.20	.24	.23
Duration (Hours)				
Mean	24.10	23.98	24.15	24.07
SD	.18	.20	.33	.25

group for all analyses. Table 10 describes the time of initiation and the duration of treatment according to group.

Comparison Of Treatment Groups

The treatment groups did not significantly differ in terms of age (Table 1) and surgical time (Table 2) by analysis of variance. The side on which surgery was performed and the incidence of intercostal Marcaine injection also did not differ among groups when chi square tests were applied. Similarly, when diagnoses were categorized according to whether or not cancer was the indication for surgery (Table 1) and when surgical procedures were sorted by extensiveness of excision, the groups were determined to be alike. The only difference among the groups was that those with two chest tubes (X^2=6.62, df=2, p=.036) were significantly under represented in the ALTENS group (Table 2).

Lack of cells with expected frequencies greater than five, prevented comparison of the groups according to the types of postoperative medications ordered as well as the prescribed intervals for drug administration (Table 8). However, analysis of variance determined that the groups were alike in terms of the maximum amount of medication prescribed, the number of doses and total amount of analgesic drugs administered throughout the study period, and the interval following

medication administration when pain ratings were done (Table 6). The groups were also similar with respect to pre and postoperative range of motion and neither the time of initiation nor the duration of treatment (Table 10) was different among the groups by analysis of variance.

Effect Of Treatment On Pain And Shoulder Range Of Motion

Factorial analysis of covariance was used to assess the effects of time and treatment on postoperative pain (Table 11). The amount of analgesic medication administered in the interval preceding each pain rating were held as covariates. It was determined that time alone affected postoperative pain as pain scores diminished significantly between 6 (mean 55.6 standard deviation 25.2) and 24 hours (mean 46.5 standard deviation 23.9) after surgery ($F=6.92$ $df=1,57$ $p=.011$). Neither the CTENS or ALTENS groups varied significantly from each other or the placebo with regard to post surgical pain and no interaction of time and treatment could be demonstrated .

Univariate analysis of covariance was used to examine the effect of treatment on shoulder range of motion on the operative side. In determining treatment effects on post surgical flexion, the correlates preoperative flexion and postoperative abduction were held as covariates. Similarly, postoperative flexion was the covariate entered when the effect of treatment on postoperative abduction was assessed.

Table 11.

FACTORIAL ANCOVA: PAIN RATING BY TIME AND TREATMENT GROUP

Summary Table

Condition	Sum of Squares	DF	Mean Square	F	p
Covariates:					
Amount of Analgesic Medication Given Prior to First Pain Rating and Between First and Second Pain Ratings.					
Main Effect					
Group	377.2	2	188.6	.21	.808
Error		55	883.02		
Time	2511.68	1	2511.68	6.92	.011
Error		57	363.21		
Interaction					
Group x Time	127.05	2	63.53	.17	.840
Error		57	363.21		

However, no effect of treatment on either postoperative flexion or abduction was found.

Factors Influencing Medication Prescription and Administration

How old patients were influenced drug administration throughout the perioperative period. Age was negatively correlated with the amount of analgesic medication given before surgery ($r=-.46$ $p=.02$), in the operating room ($r=-.22$ $p=.05$) and after surgery ($r=-.27$ $p=.02$). Body weight, however, was more of a factor after surgery. Weight was related to the amount of analgesic medication given in the recovery room ($r=.49$ $p=.001$) as well as that both prescribed ($r=.23$ $p=.04$) and administered ($r=.31$ $p=.01$) on the ward. Analysis of variance determined that gender did not influence the amount of analgesic medication received before or during the surgery. However, women received less narcotic than men in the first six hours after surgery ($F=13.67$ $df=1,53$ $p=.0005$). On the nursing unit, although less medication was prescribed for females ($F=5.45$ $df=1,58$ $p=.023$), there was no gender difference in the amount administered. Women in this sample, weighed less than men ($F=6.95$ $df=1,59$ $p=.0107$) but were not significantly older.

DISCUSSION

Effect Of TENS Treatment

The purpose of this study was to assess the effects of CTENS and ALTENS on postoperative pain ratings over time and on preservation of shoulder range of motion after posterolateral thoracotomy. Neither CTENS nor ALTENS produced effects which were significantly different from a placebo treatment and these findings held across time.

Failure to detect a difference among any of the treatment conditions raises the question of whether ALTENS and CTENS have even a placebo effect on pain and/or shoulder range of motion. This hypothesis could not be tested in the present study as a no-treatment control group was not included for comparison. Given the results of previous studies (Hargreaves, 1987; Smith, Guralnick, Gelfand, & Jeans, 1986) indicating that CTENS was superior to placebo TENS in relieving pain after abdominal surgery, it seemed both practical and economical to omit this group from the present investigation. However, failure to demonstrate similar TENS analgesia for thoracotomy pain suggests that TENS may have different effects on different types of surgical pain. Therefore, the inclusion of both placebo and no-treatment control conditions in future research is not only justified but imperative.

The ineffectiveness of TENS for relieving thoracotomy pain might

be related to the quality and intensity of this pain. After thoracic surgery, the pain experienced, is thought to be produced by input from three major sites: the skin, the deep somatic structures, and the involved viscera (Benedetti, 1984). The liberation of local chemical and hormonal irritants from damaged tissue, reduces nociceptive threshold and in combination with peripheral nerve damage, produce localized cutaneous pain. When these algesic substances are added to nerve damage in muscle, fascia, and pleura, diffuse aching pain and muscle spasm result. Pleural irritation is further compounded by the presence of chest drainage tubes. Finally, visceral pain, felt locally or referred to the chest wall, may result from tension and contraction of surgically traumatized smooth muscle. Smith et al.(1986), suggest that CTENS is effective for cutaneous or movement associated pain rather than for pain from visceral or deeper structures. Thus, the penetrating and/or spasmodic pain experienced by patients may not be relieved by CTENS and might also obscure any treatment effect on more superficial pain produced by movement or tension on the incision.

ALTENS stimulation to sites on the chest wall may be more appropriate for somatic and visceral pain as the wider pulse width and higher intensity may penetrate to deeper structures (Mannheimer & Lampe, 1984). However, this hypothesis cannot be addressed in this

study as ALTENS was applied to sites distant from the pain. In addition, the clinical value of administering ALTENS near the incision may be questionable. The muscle contraction produced may be too painful to tolerate and could potentially exacerbate local muscle spasm.

The intensity of thoracotomy pain in the first 24 hours after surgery, may also have caused it to be intractable to TENS therapy in this study. At six hours following surgery, the mean pain rating was 55.6 (standard deviation 25.2). At 24 hours this score was reduced to 46.5 (standard deviation 23.9). Hargreaves (1987) demonstrated an analgesic effect of CTENS for the cleansing and repacking of abdominal wounds. Although CTENS was applied noncontinuously with a narrower pulse width in her study and the treatment took place an average of 42.5 hours after surgery, mean pain scores on a similar scale, were somewhat lower. A study of thoracotomy patients by Liu, Liao & Lien, (1985) also suggests that CTENS may be effective when pain intensity is reduced. In order to assess this hypothesis, future studies might include a longer treatment period following surgery or initiation of TENS therapy after the first postoperative day.

The notion that TENS may be more or less effective with different qualities or intensities of pain also focuses attention on pain assessment. In this study, patients were asked to indicate the point on

the visual analog scale that represented the intensity of their pain at a particular point in time. This rating most likely reflected deep muscular or visceral pain as the majority of patients were resting in bed at the time the pain scores were done and had not been recently turned or ambulated. Also, patients' comments that they especially liked CTENS for periods between medication doses and when they were required to make sudden movements, suggests that assessment of pain at only two intervals after surgery may have been insufficient to capture certain treatment effects.

A more adequate assessment of the effect of TENS on different types of pain could be achieved by documenting activity prior to each rating, and/or separate measurements of muscular, cutaneous and movement associated pain on each occasion. In addition, pain assessments might be done before TENS administration as well as at intervals during and after treatment. These repeated measures over time would assist in determining the relationships among the character of the pain, pain intensity and treatment effect as well as the duration of analgesia obtained.

In this study postoperative pain was indicated only by measures of intensity and did not include assessment of other variables such as pain distress and satisfaction with pain relief that might be affected by

TENS therapy. Pain that is severe and protracted also interferes with sleep and engenders anxiety. As a result patients' coping abilities may be reduced and pain may be perceived to be more intense. Thus, a multidimensional approach to pain measurement as well as assessment of variables such as anxiety may shed more light on the conditions necessary to achieve effective pain relief with TENS.

A tool that may be useful in future research is the McGill Pain Questionnaire (MPQ) which assesses the sensory, affective and evaluative dimensions of pain. However, even the short form of this instrument takes a few minutes to administer and requires ranking of word descriptors. Therefore, non English speaking patients and those who are quite ill or sedated in the immediate postoperative period, may have difficulty completing it appropriately.

The state anxiety scale of the State Trait Anxiety Inventory (Spielberger, Gorusch, Lushene, Vagg, & Jacobs,1983) might be used in conjunction with a measure of pain to assess the influence of anxiety on the painful experience. But again, this instrument is fairly long and may become tedious to subjects if administered repeatedly.

Another alternative may be to use multiple visual analog scales to assess the various dimensions and types of pain as well as situational anxiety. Such scales provide somewhat less detailed information but are

easily understood and may be quickly administered.

The effectiveness of TENS for preserving operative side shoulder range of motion in flexion and abduction were also assessed in this study. Although Liu et al. (1985) report improved postoperative shoulder flexion with TENS therapy, it is unclear whether this is a direct effect on mobility or due to a concurrent reduction in postoperative pain. The results of the present study failed to demonstrate a unique effect of TENS on shoulder range of motion. Postoperative pain was correlated with range of motion in both planes. However, because post surgical pain was not significantly reduced by treatment, any effect on flexion and/or abduction due to TENS analgesia could not be assessed.

The most obvious explanation for inability to detect significant findings, is that the sample size may have been inadequate. The data suggest that any observed effect would be small. Therefore, reduced statistical power due to a small number of subjects would increase the likelihood of failing to detect significant treatment effects (Type II error). However, increasing the sample size to achieve statistical significance is both costly and time consuming, and must be weighed against the practical application of the findings. While detecting even a small difference between treatments may have theoretical value, such minimal effects are unlikely to be of benefit in clinical practice.

For this study, mathematical estimation (Shavelson, 1989) was used to determine the sample size necessary to detect a difference of one standard deviation in pain scores (alpha=.05 beta=.20). The assumption that a difference of this magnitude would be clinically important appears to be reasonable. According to the study data, one standard deviation represents an average change on a 100 mm pain scale of 25.2 mm for the first rating and 23.9 mm for the second.

A final consideration in the failure to demonstrate significant effects among the groups, is the technical administration of TENS treatment. CTENS stimulation is subject to neural accommodation due to the steady application of electrical impulses (Rothman, Davis, & Hay, 1970). Although subjects were instructed to alter stimulation intensity to restore nerve excitability, there is little doubt that habituation occurred to some degree in all cases. Depending on the duration of these accommodation episodes and their proximity to measurement of the outcome variables, the effect of CTENS treatment may have been substantially reduced. This may also explain why significant effects of TENS on abdominal surgical pain (Hargreaves, 1987) and on pulmonary function after thoracotomy (Stratton & Smith, 1980) were demonstrated in studies where CTENS was applied for only short periods.

Effect Of Time

It is not surprising that postoperative pain ratings should be affected by time. Most surgical pain diminishes steadily throughout the postoperative period although Melzack, et al. (1987), report that pain may continue to be moderate to severe in approximately 30% of patients beyond the fourth post surgical day. This rather unpredictable variability in the duration of postoperative pain reinforces the need to include longitudinal measures in future research both to document the course of pain after surgery and to determine the most appropriate timing and type of treatment.

Interaction Effect Of Time And Treatment

Theoretically CTENS is said to relieve pain via a peripheral gating mechanism whereas ALTENS may induce supraspinal centres to produce analgesia mediated by endogenous opiates. Thus, it might be expected that the effects of CTENS would be reduced over time and those of ALTENS enhanced. This hypothesis was not supported by the data. However, tracking the duration and quality of pain relieving effects is necessary to elucidate the physiological basis of TENS.

Analgesic Medication

Although not specifically addressed in this study, some interesting results were found regarding the prescription and administration of

postoperative analgesic medication. As might be expected, the data confirm previous reports of inadequate postoperative analgesia. This is evidenced by the severity of pain reported at both postoperative intervals. It would seem logical that there should be a relationship between pain and analgesic intake. However, there was no correlation between pain rated at 24 hours after surgery and the amount of medication consumed in the previous 18 hours. The mismatch between pain and medication administration could not be accounted for by inadequate prescription of analgesic drugs as patients received only a mean of 59.9% (standard deviation 18.1) of the maximum amount of analgesic medication ordered. This would suggest that either patients were under reporting their pain to the nursing staff or that analgesic medication was being inappropriately administered.

Body weight appeared to be a factor influencing narcotic prescription and administration after surgery with greater amounts being ordered and given to those who weighed more. However, men and women received similar amount of analgesic drugs even though women weighed less. When body weight was held as a covariate there continued to be no gender difference in analgesic administration. This suggests that variables other than body weight are also involved in determining the amount of medication actually administered to men and

women. It is encouraging to find that body weight is not the sole criterion governing the provision of narcotic analgesia. While the patient's weight may be a useful guideline by which to initiate pharmaceutical analgesic therapy, the wide interpersonal variability in effectiveness of these drugs makes body weight an unreliable yardstick for continued administration (Benedetti, 1990).

Age was negatively related to the amount of narcotic administered in the operating room and although older adults weren't prescribed a lesser amount of analgesic medication on the ward, they received less than younger patients. Administration of less medication to older adults cannot be explained by their weight or pain ratings as there were no correlations between these variables. While some studies (Belville, Forest, Miller, & Brown, 1971; Kaiko, Wallenstein, Rogers, Grabinski, & Hoode, 1982) report that older patients require lower doses of narcotic to achieve analgesia, Morgan and Puder (1982), failed to corroborate these findings. Therefore, either the elderly are particularly reluctant to advise the nurses caring for them about their pain, or nurses are using the patient's age as an invalid criterion by which to make decisions about how much medication to administer.

Interestingly, the amount of analgesic medication consumed was negatively related to shoulder range of motion both before and after

surgery. It might be expected that those receiving more analgesic medication would have more pain and thus, reduced range of motion. However, considering the lack of relationship between pain and narcotic analgesic consumption after surgery, it may be that range of motion is reduced because the sedative properties of pain relieving drugs cause patients to be less able to comply with the range assessment procedure.

Practical Consideration In TENS Therapy

Despite the lack of demonstrated analgesic effect from TENS, the treatment was favourably received by most patients. Those in the CTENS group especially, expressed how much they liked having "something to tide them over between shots", being able to "do something about the pain while they were waiting for the nurse to bring their medication" and being able to "turn it up to get through turning over in bed" and other sudden movements. Four CTENS patients continued with the treatment beyond the study period and one study patient who returned for a repeat thoracotomy requested TENS therapy after surgery. The continuous treatment was easily managed by all patients and even those with diminished eyesight and arthritic fingers were able to adjust the intensity controls without difficulty.

The ALTENS patients initially reported that the rhythmic muscle

contractions were annoying but the treatment was well tolerated after they became accustomed to the sensation of "somebody else moving my muscles". None of these patients asked to continue TENS treatment after the study period. Therefore, if there truly is no difference in analgesic effectiveness between the modes, CTENS may be the most preferable treatment from the patients' perspective.

Another consideration when choosing between modes of treatment should be the patient's desire to have some means of personal control over their pain. Patients who cope better when they are able to do something about the pain themselves, may benefit more from continuous stimulation. On the other hand, intermittent therapy was preferred by those who indicated that after surgery they were not that motivated to "be constantly fiddling with that box".

Both modes of therapy were easily incorporated into the usual postoperative routine. The intermittent treatments and verification of proper use of the equipment was conducted during periods when patients were awakened for routine nursing assessments.

The rectangular CTENS electrodes adhered to the skin well and did not hinder dressing changes. The round ALTENS electrodes conformed nicely to the contours of even small hands and posed no interference to manual dexterity. However, some difficulty was

encountered in keeping them adequately affixed to the skin if patients were very diaphoretic. None of the study patients experienced even minor skin irritation at the electrode sites.

NURSING IMPLICATIONS

The results of this study suggest several recommendations for nursing practice. First, it is clear that post thoracotomy pain is severe in the first 24 hours after surgery. Given the potential for life threatening complications related to unrelieved pain in this population, this problem should command particular attention from nurses. Although many factors influence when, why, and how much analgesic medication patients receive, it is important that these decisions be made based on appropriate pain assessment. While the age and weight of a patient may serve as guidelines for the initiation of analgesic drug therapy, effective parenteral analgesia requires individualized assessment and tailoring of administration to the patient's requirements. Of necessity, such titration of medication must also include follow up assessment of analgesic effectiveness after each dose is given.

The results of this study suggest that TENS does not have an independent role in the management of thoracotomy pain. However, if the effectiveness of TENS is dependent on a lower level of pain intensity, then perhaps in combination with appropriate narcotic

analgesia, it may serve as a useful adjunct therapy. TENS may also be more useful later on in the postoperative period when the severity of pain diminishes.

While TENS may not be useful for all thoracotomy cases, individual patients reported that TENS helped them to cope with their pain. Regardless of whether this is a mere placebo effect, patient comfort is enhanced and thus, the quality of postoperative care is improved.

Nurses spend a great deal of time in contact with patients and are therefore, in an excellent position to identify those who might benefit from TENS and administer treatment to them. While in some cases little true analgesia may be obtained, the many positive aspects of this treatment make a trial of TENS a worthwhile effort. TENS is generally well received by patients. In addition, it is convenient to administer as the units are portable, treatments can be incorporated easily into postoperative nursing care routines, and given adequate instruction, most patients can manage their therapy with little supervision. Further, TENS is an independent means for nurses to intervene with postoperative pain that requires a minimum of technical training and is virtually free of side effects.

RECOMMENDATIONS FOR FUTURE RESEARCH

Although TENS has not been shown to be effective in relieving

pain and/or improving range of motion after thoracotomy, the usefulness of TENS treatment for other types of surgical pain warrants investigation. Specifically, information is required about whether TENS induced analgesia varies over the course of surgical pain and whether this is related to changes in the intensity, character, location or affective dimensions of the pain. Further, the effectiveness of TENS treatment needs to be assessed in relation to psychological variables such as anxiety, that affect pain perception.

Different modes of TENS are thought to be defined by particular stimulation parameters, electrode placement and administration schedules. Alterations in the rate and intensity of stimulation may also produce analgesia through different physiologic mechanisms. However, clinical studies that systematically vary these components are needed to determine whether or not distinct TENS modes exist. In addition, the usefulness of various modes of TENS for different types of surgical pain require documentation. Finally, information about the physiologic mechanisms employed by these modes, could be provided by clinical studies documenting the onset and duration of TENS analgesia.

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APPENDIX A

TENS For Postoperative Pain: Basis In Pain Theory And Direction For Clinical Evaluation

ABSTRACT

Transcutaneous electric nerve stimulation (TENS) has been used as an adjunct to narcotic analgesia for over 15 years. It is a means by which nurses can intervene independently with patients in pain thus, potentially reducing the problem of inadequate postoperative pain management. However, this treatment has yet to be adequately studied. As appropriate evaluation requires knowledge of pain theory, the evolution of the most widely accepted pain theory (the gate control theory) is described as well as the influence of this theory on pain research and therapy. Factors influencing pain perception and their implications for pain research methodology are also addressed. Finally, the proposed analgesic mechanisms of TENS and the clinical evaluation of this modality to date are discussed along with directions for further research.

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TENS For Postoperative pain: Basis In Theory And Direction For Clinical Evaluation

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Despite advances in the understanding of pain mechanisms and the development of treatment strategies over the past 100 years, postoperative pain continues to rank among the most poorly managed conditions experienced by hospitalized patients. Recent evidence suggests a large proportion of surgical patients experience moderate to severe pain (Benedetti et al., 1984) which in many cases persists beyond the fourth postoperative day (Melzack, Abbott, Zackon, Mulder, & Davis, 1987). Further, the sequelae of unrelieved surgical pain have been shown to be both severe and protracted (Benedetti, Bonica, & Bellucci, 1984).

Typically, postoperative pain is managed by intermittent parenteral doses of narcotics on an "as required" or PRN basis. When administered appropriately, the analgesic effects of this therapy cannot be denied. Unfortunately, there is a wide range of variability in analgesic requirements among patients (Benedetti, et al., 1984) and a general lack of pharmacologic knowledge among nurses and physicians. When taken together with inadequate pain assessment and fears of

oversedation, respiratory depression and/or addiction held by patients and health care professionals alike, the result is underprescription and under-administration of analgesia (Cohen, 1980; Sriwatanakul, et al., 1983; Weiss, Sriwatanakul, Alloza, Weintraub & Lasagna, 1983).

While the role of nurses on the front lines of pain management implicates them as part of the problem of inadequate treatment, it also provides an excellent opportunity for them to contribute to the solution of that problem. Undoubtedly, nurses need to be aware of the most appropriate use of pain relieving drugs. However, an area which has largely been ignored by both nursing practice and nursing research are the nonpharmacologic adjunct methods of pain control. These interventions are generally quite simple to perform and may be administered by nurses independently. Further, because of the large amount of time that nurses spend in contact with patients, they are in the best position to identify individuals who might benefit from these interventions, administer and assess the effectiveness of treatment and perhaps most importantly, to investigate the analgesic properties of these measures in a clinical setting.

One such treatment modality is known as transcutaneous electric nerve stimulation (TENS). Although TENS has been used as an adjuvant to analgesic medication for over 15 years, the extent of its

pain relieving capabilities, the mechanisms by which analgesia is produced and the types of pain most amenable to this treatment remain unknown.

The study of any pain relieving modality requires an understanding of the broader pain literature. Therefore, this paper presents an overview of the most prominent pain theories with emphasis on the Gate Control Theory (GCT) which is the most widely accepted and influential. The implications of the GCT for the management and study of pain in general are addressed. Attention is also given to the GCT as an explanation for the analgesic properties of TENS and as well as direction for further study of this modality as applied to postoperative pain.

PAIN THEORIES

Specificity Theory

Specificity theory gained wide acceptance near the turn of the century and despite disproving evidence, continues to be the basis of many health care professionals' views of pain. Essentially, this theory holds that pain signals are carried by specific pain fibers from receptors in the skin to a pain center in the brain. This theory evolved from Descartes' (1664) conception of the pain system as a direct channel from the skin to the brain. In Mueller's (1842) "doctrine of specific nerve

energies", the presence of multiple sensory pathways is proposed, but cutaneous sensations are all subsumed under the sense of touch. He further proposed that the various qualities of sensation were due to properties in the area of the brain where the nerves terminated rather than characteristics of the nerves themselves. The concept of distinct sensory pathways was further expanded by Von Frey in 1894. He identified four cutaneous modalities: touch, warmth, cold and pain. Each modality was thought to have its own type of specific nerve ending transmitting impulses to a brain center responsible for the appropriate sensation (Melzack & Wall, 1982).

Perhaps the greatest appeal of this theory was that it opened up new avenues for pain management. Thus, neurosurgical procedures such as cordotomy, rhizotomy, bulbar tractotomy and thalmotomy were designed to interrupt the pain pathway. Ironically, these very treatment strategies served to refute the theory, as surgical lesions in both the peripheral and central nervous systems were unsuccessful in permanently abolishing pain. Other clinical pain phenomena that could not be explained by a "hard-wired" nervous system, were those conditions such as phantom pain, causalgia and neuralgia which may persist or worsen long after the initial cause of the pain has been removed.

A single pathway pain system also presupposes that (a) the psychological experience of pain bears a direct relationship to a specific stimulus, (b) that stimulation of particular receptors must always and only elicit pain and (c) that variations in stimulus perceptions must occur at the receptor level (Melzack & Wall, 1982). However, accounts of painless war wounds (Beecher, 1946) and expressions of ecstasy from men suspended from hooks imbedded in their back muscles during a religious ritual (Kosambi,1967), provide evidence that the quality and intensity of pain may be modulated by a variety of psychological variables. Further, as noted by Melzack & Wall (1982), although there is evidence that physiologic specialization of skin receptors exists, there is none to indicate that stimulation of one type of receptor or nerve pathway produces a single psychological experience.

In light of these deficiencies, opponents of specificity theory, proposed a number of rival theories. This body of work is known collectively as "pattern theory".

Pattern Theory

Rather than direct transmission of pain impulses along a single pathway, pattern theory proposes that pain is evoked by spatial and temporal patterns of nerve impulses produced when sensory impulses are summated at the spinal cord. Thus, pain results when stimulation of

receptors is excessive or when pathological conditions enhance summation.

Although Goldscheider suggested as early as 1894 (cited in Melzack & Wall, 1982) that the critical determinants of pain are the intensity of the stimulus and summation of impulses within the central nervous system, later theorists explored these issues separately. Weddell (1955) and Sinclair (1955) focused mainly on peripheral patterning produced by intense stimulation of nonspecific receptors. However, as evidence supporting the physiological specialization of receptor fibers grew, this conceptualization was called into question.

Livingston's (1943) theory dealt primarily with central summation. He proposed a mechanism by which peripheral noxious stimulation initiates abnormal circuits within the spinal cord that are interpreted by the brain as pain. The potential for these reverberating circuits to become self-sustaining, to be triggered by non-noxious stimuli and persist after the peripheral stimulus has been removed, was thought to be a good explanation for clinical pain syndromes such as phantom pain. However, this theory also fails to account for the fact that surgical lesions of the spinal cord are often unsuccessful in permanently relieving pain.

Noordenboos (1959) extended Goldschieder's original work. He

proposed a sensory interaction system wherein the transmission of pain producing impulses carried by slow conducting small fibers, can be blocked by the stimulation of rapidly conducting large fibers. Thus, if more small than large fibers are stimulated, the result is increased transmission, summation and perception of pain. Alternatively, a predominance of large fiber stimulation would tend to reduce summation and subsequently the perception of pain. Noordenboos also conceptualized a multisynaptic afferent system within the spinal cord whereby impulses may enter the ascending sensory system at any level, be transmitted to the brain, and interpretted as pain.

This theory is particularly useful in explaining why surgical lesions of the central and peripheral nervous systems often fail to abolish pain. It also explains the pain of conditions such as post herpetic neuralgia in which there is a relative loss of large fibers. Similarly, it accounts for the success of sympathectomy for relieving pain as the procedure selectively destroys small fibers. However, like specificity theory, no mechanism for psychological modulation of pain is described.

Despite its explanatory power, pattern theory failed to provide new direction for pain management and therefore, was largely abandoned in favor of specificity theory. However, the contributions of the pattern theorists were not forgotten. In fact, components of both pattern and

specficity theory have been integrated into the most influential and comprehensive theory to date; the gate control theory.

Gate Control Theory

The gate control theory grew out of a need for a holistic conceptualization that incorporated the influence of both physiological and psychological processes on pain perception and response. Simply stated, the theory proposes that the transmission of nerve impulses from peripheral receptors to the central nervous system, may be increased or decreased by way of a neural mechanism or "gate" in the dorsal horns of the spinal cord. Thus, the gate known as the substantia gelatinosa, is able to modify sensory impulses before pain perception and response are evoked.

The extent to which the gate increases or decreases the flow of sensory input, is determined by both the ratio of activity in the small diameter (A delta and C) and large diameter (A beta) fibers as well as descending influences from the brain. Rapidly conducting, large fiber activity is said to close the gate, thereby reducing transmission of somatic input to the central nervous system, whereas activity in the more slowly conducting small diameter fibers, opens the gate and facilitates transmission.

To account for the influence of cognitive processes on pain

perception, it is proposed that afferent stimulation also activates a special system of large diameter fibers called the Central Control Trigger. This mechanism selectively activates cognitive processes in the cerebral cortex which, by way of fibers descending from the brain to the substantia gelatinosa, modulate the perception of pain.

When the amount of information passing through the gate exceeds a critical level, the neural areas known as the Action System are activated to produce pain perception and response. The authors emphasize that the perception of pain is not a static or linear event. The organism is in continuous interaction with the environment thus, painful stimuli are received by an active nervous system and may be influenced by ongoing activity as well as events which preceded the stimulus. Therefore, they postulate that interactions between the gate control system, the action system and the influences of cognitive activities on sensory input, may occur at virtually any level of the central nervous system. Further, the gate may be set and reset as temporal and spatial patterning of sensory impulses are interpreted and acted on by the brain (Melzack & Wall, 1965).

Melzack and Casey (1966) proposed that the psychological influences on pain could be classified into sensory-discriminative, motivational-affective and cognitive-evaluative dimensions. Each

dimension was said to be subserved by a different neural mechanism that could be incorporated within the gate control theory. They further suggested that the interaction of these ascending and descending pathways determine the individual nature of responses to a given painful stimulus.

An updated version of the gate control theory (Melzack & Wall, 1982) included a new dimension which could explain slow changes and plasticity in neural connections. This revision is based on evidence that along with nerve impulses, nerve fibers slowly transport and release chemical substances. Both small (unmyelinated) afferent fibers and the substantia gelatinosa have been found to be rich in peptides including enkephalin. Therefore, the routing of impulses into the central nervous system may depend both on the slow transport and release of chemicals as well as the rapid action of nerve impulses. In addition, portions of the neural network may be rendered inactive by these slowly changing processes.

The gate control concept generally meets the requirements of an adequate theory (Kim, 1980) in that it describes pain as a phenomena of multiple dimensions and proposes relationships among them. It permits explanation of atypical pain syndromes such as phantom limb pain, neuralgia, and causalgia as well as allowing prediction of an

individual's response to a stimulus as being painful. Further, the theory's potential for generating strategies designed to control of pain is perhaps its strongest feature.

Although the anatomic and physiologic evidence of the gate control mechanisms is mixed (Nathan, 1976), the theory has revolutionized both the treatment and study of pain. New hope for relief was offered to patients who, in the absence of a clear organic cause for their pain, were previously considered to have thought disorders (Engel, 1958). A further result of this multidimensional conceptualization, was that pain management was no longer the sole province of the physician. Thus, a variety of disciplines began to develop approaches to pain control. Many new strategies designed to alter the sensory, motivational and cognitive influences on pain were developed. In addition, credibility was provided for some older methods of pain control such as heat, ice, physical manipulation, acupuncture and electrotherapy.

Pain research has also been influenced by the GCT in that it too, has become a multidisciplinary endeavour. Basic scientists have been lead to investigate new areas and mechanisms within the nervous system. In addition, clinical investigators have grown more cognizant of the factors that influence pain and the impact of these variables on pain research methodology. These issues will be addressed briefly in the

following sections.

FACTORS INFLUENCING PAIN PERCEPTION

As noted above, the gate control theory proposes that physiological and psychological factors interact to determine pain perception and response. Knowledge of the effects of these variables on pain is necessary to facilitate pain management as well appropriate design and interpretation of pain research.

A review of psychosocial influences on pain reveals that early experience (Hebb, 1949) plays a role in the development of pain responses that, at critical stages of development, may have a lasting effect on pain behaviour (Scott, Frederickson, & Fuller, 1951). While it is unclear just how accurately past experiences with pain are remembered (Hunter, Philips, & Rachman, 1978; Kent, 1985; Linton & Melin, 1982; Eich, Reeves, Jaeger, & Graff-Radford, 1985), dental researchers report that these memories are rather indelible and that even repeated painless treatments fail to remove dental anxiety and expectations of pain (Kleinknecht & Bernstein, 1978; Wardle, 1984).

Pain and anxiety invariably occur together in the clinical setting. However, the nature of this relationship is more reciprocal than causal in that, just as anxiety heightens pain perception (Johnson, Dabbs, & Leventhal, 1970; Taenzer, Melzack, & Jeans, 1986), protracted pain that

is perceived to be "unbearable and uncontrollable" produces anxiety (Craig, 1984 p. 156).

Anxiety may also be engendered by uncertainty about the painful situation. Unfortunately even accurate expectations of pain have not been consistently associated with a reduction in reported clinical pain (Kleinknecht & Bernstein, 1978; Wardle, 1984; Wallace, 1985; Kent, 1984). Laboratory data indicate that perceptions of control over the pain may attenuate the experience (Bowers, 1986; Staub, Tursky, & Schwartz, 1971; Jones, Bentler, & Petry, 1966). However, clinical findings suggest that control strategies are only useful if they are meaningful to the patient and consistent with their coping style (Andrew, 1970; Scott & Clum, 1984).

Laboratory studies also demonstrate effects on willingness to report pain (though not necessarily in pain perception) produced by social modelling and group affiliation (Craig, Best, & Reith, 1974; Buss & Portnoy, 1967). Group affiliation raises the question of cultural influences on pain. However, although ethnic differences in pain behaviour have been documented (Zborowski, 1952), there is no convincing evidence of cultural variation in pain perception (Sternbach & Tursky, 1965; Tursky & Sternbach, 1967; Chapman & Jones, 1944; Weisenberg, Kriendler, Schachat & Werboff, 1975; Woodrow, Friedman,

Siegelaub, & Collen, 1972; Winsberg & Greenlick, 1967). Further, the multiethnicity of North American society renders these influences nearly impossible to investigate and largely irrelevant to both the treatment and study of pain on this continent.

Age is another variable that is reported to influence pain perception. However, these data are extremely inconsistent. Various laboratory studies have reported pain threshold and tolerance to be increased (Schluderman & Zubeck, 1966; Sherman & Robillard, 1960), decreased (Collins & Stone, 1965; Woodrow et al., 1972), or unchanged (Harkins & Chapman, 1977; Clark & Mehl, 1971) with increasing age in adults depending on the stimulus used. The effects of age on pain in the clinical setting has yet to be investigated.

Gender differences in pain perception are also found in the laboratory setting. Women are said to report more pain (Dubreuil & Kohn, 1986) and have a lower threshold and tolerance (Leon, 1974) to pain than men. Recent clinical evidence suggests that there is no sex difference in reported pain among children aged 4 1/2 to 6 1/2 years, abdominal surgical patients or patients with arthritic conditions of the knee (Lander, Fowler-Kerry, & Hargreaves, 1989).

In relation to surgical patients in particular, a number of variables can be expected to influence the occurrence, intensity, quality and

duration of postoperative pain. At present there is a lack of epidemiologic data documenting the relationships among these factors. Nevertheless, Benedetti et al., (1984) in an extensive review of clinical reports, identify a number of influences that must be considered in both the management and study of postoperative pain. These include: (a) the site, nature and duration of the operation including the type of incision and amount of intraoperative trauma, (b) the physiologic and psychologic makeup of the patient, (c) preoperative physiologic psychologic and pharmacologic preparation of the patient, (e) the presence of serious complications related to the operation (f) anesthetic management throughout the perioperative period and (g) the quality of postoperative care.

METHODOLOGICAL CONSIDERATIONS

Measurement

The individual and multidimensional nature of the pain experience as well as the many factors influencing its perception and response, pose a considerable challenge for clinical pain assessment. In general, three approaches have been taken: (1) behavioral methods, (2) subjective pain reports and, (3) scaling according to word descriptors.

Behavioral methods involve recording the frequency of behaviors thought to be indicative of pain either through observation (Keefe &

Block,1982; Richards, Nepomuceno, Riles, & Suer, 1982), electronic monitoring (Sanders, 1980), or coding of videotaped facial expressions (Craig & Prkachin, 1983). The advantages are that clinically relevant data are generated which may be particularly useful in assessing treatment effects. However, the validity of such measures has been questioned because behaviour does not quantify pain directly and cannot be separated from the context in which it occurs. A case in point is the use of analgesic consumption as an indicator of pain. Reasons mentioned in the introduction to this paper, illustrate that (particularly among hospitalized patients) this measure is both invalid and unreliable.

Subjective pain reports are the most commonly employed indices because they are easily understood and simple to administer. They are used to measure both pain and pain relief. Although the scales are unidimensional in nature, multiple scales have been used by some investigators to concomittantly assess several dimensions of clinical pain at one or more points in time (Gracely, 1980; Johnson & Rice, 1974). Instruments consist mainly of continuous visual analog scales or categorical scales. Pain categories have proven problematic in that it is difficult to specify whether categories are of equal size and spacing and therefore, scores may be artificially raised or lowered (Heft & Parker,

1984; Onhaus & Adler, 1975). Subjective measures have been criticized in that they simplify the complex experience of pain, are subject to response bias and may be confounded by affective states thus rendering them somewhat insensitive to treatment effects (Chapman, Casey, Dubner, Foley, Gracely, & Reading, 1985).

Scaling according to word descriptors has been based on the work of Melzack & Torgerson (1971) and the McGill Pain Questionnaire (MPQ)(Melzack, 1975) is the most widely used instrument of this kind. It consists of 20 sets of word descriptors designed to quantify the sensory, affective and evaluative components of pain. Patients are asked to choose the most relevant word(s) from each set. Scores are computed on the number and/or ranking of descriptors within each dimension and suplemented by information about medication, pain location and past pain experiences. The overall structure, reliability and validity of the MPQ has received considerable support (Reading, 1979; Reading, Everitt, & Sledmere, 1982; Graham, Bond, Gerkousch, & Cook, 1980). However, this tool is semantically difficult and may prove problematic for non-English speaking cultures, or patients who are quite ill (Chapman et al., 1985).

Design

Beecher (1955), was among the first to acknowledge the power of

placebo effects on pain. He noted that placebo effects accounted for up to 30% of the pain relief attributed to morphine. That is not to say that patients who experience relief from placebos do not have "real pain" but rather, that even the suggestion that strategies are being employed to relieve pain can have a profound psychological effect on pain perception. Therefore, appropriate design in pain research must provide for comparison of the treatment with a placebo control group as well as a no-treatment control group. As withholding treatment from patients in pain is not an ethically viable alternative, "no-treatment" is taken to mean baseline or usual treatment.

Beecher also advocated the use of a double-blind technique when feasible or at least a partial blind. Such measures enhance internal validity by controlling for differential expectations of treatment due to cues from the experimenter or the nature of the treatment condition (Oyster, Hanten & Llorens, 1987).

The individual nature of pain perception and the multitude of factors affecting it, make random assignment to treatment conditions imperative. Further, sample sizes must be large enough so that the power of statistical analyses is sufficient to detect theoretically and/or clinically significant effects. When the available population is small, repeated measures or crossover designs may be a means to improve

statistical power. If possible, the course of painful conditions and the duration of treatment effects should also be assessed. Thus, factorial designs or planned followup may be used to assess treatment effects over time.

Having reviewed some of the implications of the gate control theory for pain research in general, attention is now turned to an examination of TENS therapy. An explanation of its analgesic properties according to the GCT will be addressed, as well as a synopsis of clinical research to date and directions for further study.

ANALGESIC MECHANISMS IN TENS

TENS consists of the administration of a low-voltage electrical stimulus to peripheral nerves via electrodes affixed to the skin (Woolf, 1984). This treatment is noninvasive and the only reported side effect is a minor incidence of contact dermatitis (Zugerman, 1982). The potential for interference with cardiac pacemaker function has been considered a contraindication to TENS therapy. However. recent evidence suggests that under appropriately monitored conditions, TENS can safely be administered even to these patients (Chen, Philip, Philip, & Monga, 1990).

Clinical wisdom suggests that by altering the parameters of pulse width, frequency and intensity that different "modes" of stimulation may

be produced. In many cases the particular parameters said to define the modes are not clearly established. However, two modes in particular, seem to be supported by empirical evidence.

Conventional TENS (CTENS) is administered continuously via electrodes placed near the painful area at a high rate (50-100 Hertz), narrow pulse width (40 - 75 microseconds) and an intensity sufficient to produce a comfortable paresthesia. Pain relief is said to be achieved nearly immediately and in most cases not to extend beyond the period of stimulation (Mannheimer & Lampe, 1984).

Acupuncture-like TENS (ALTENS) is delivered to acupuncture points or muscle motor/trigger points segmentally related to the site of pain. Stimulation frequency is low (1 - 4 Hertz) with a wide single pulse or short trains of impulses (150 - 250 microseconds) at an intensity producing strong rhythmic muscle contractions. Treatments are administered for 20 - 30 minute periods three or four times a day. The analgesia obtained is said to be delayed 15 to 30 minutes, may be enhanced by subsequent treatments and may persist for several hours post stimulation (Mannheimer & Lampe, 1984).

This distinction between modes is supported in that high rate - low intensity CTENS, and low rate - high intensity ALTENS may produce analgesia through different physiologic mechanisms. These arguments

are well outlined by Favale and Leandri (1984) and may be summarized as follows. CTENS has been linked from beginning with the gate control theory as it was this hypothesis that led early investigators to consider electrical stimulation as a possible means of temporarily relieving pain. Support for the gate control mechanisms is demonstrated in that low intensity stimulation predominantly activates low threshold peripheral fibers. The discharge of these large myelinated fibers is thought to produce the tingling sensation induced by TENS. Further, segmental inhibition of nociceptive responses of the posterior horn cells can be induced by stimulating both the peripheral nerves and the dorsal columns of the spinal cord. Finally, selective peripheral blockade of small fibers may account for the improvement in somatic sensation [illegible] along with a reduction in clinical pain during CTENS [illegible].

The gate control theory cannot however, account for several other findings. Recent evidence regarding the gradual onset and recovery of dorsal horn inhibition due to large fiber stimulation, is inconsistent with the rapid changes in pain sensitivity associated with CTENS. Also, the fact that CTENS may be effective even when electrodes are not placed near the site of pain and the partial reversal of CTENS analgesia by a serotonin antagonist, suggest that the effects of TENS are not due

entirely to segmental mechanisms.

On the other hand, several lines of evidence indicate that low rate - high intensity stimulation involves the activation of a descending system. ALTENS analgesia may be similar to a mechanism known as diffuse noxious inhibitory controls (DNIC). This mechanism differs from the gate control in that spinal inhibition is induced by the activation of small fibers by a painful stimulus and can be produced by noxious stimulation to areas other than those anatomically related to the pain. Other support for the involvement of supraspinal mechanisms comes from evidence that this type of analgesia is mediated by serotonin and endorphins.

The similarity between DNIC and ALTENS is not complete however, as the neuronal inhibition of DNIC is induced almost immediately whereas, ALTENS inhibition occurs gradually. Further, recent findings that ALTENS analgesia could not be reversed by opiate antagonists suggests that mechanisms other than those mediated by endogenous opiates are involved.

Given the fascinating link between TENS technology and pain theory, questions arise regarding the effectiveness of TENS for clinical pain and whether there are difference between modes.

CLINICAL EVALUATION OF TENS

Unfortunately, the clinical benefits of TENS are not well understood largely because most research to date has been conducted in an uncontrolled manner. These studies often lack random assignment, adequate sample sizes and placebo control groups. In addition, inadequate documentation of stimulation parameters, poor or absent statistical analyses and invalid dependent measures hamper appropriate evaluation of outcomes. Thus, impressions of TENS therapy are often based on erroneous interpretations of research findings.

CTENS was originally used for chronic pain as a means to screen patients who might benefit from having dorsal column stimulators implanted (Burton, 1975). More recently it has been applied to surgical pain and it is in this area that the better controlled trials have been undertaken. These studies investigate the use of CTENS after thoracotomy, cholecystectomy, cesarean section, inguinal hernia repair and total hip or knee replacements. CTENS has also been used during the cleansing and repacking of open abdominal wounds. The few studies that use self-report measures, demonstrate that CTENS is superior to placebo TENS in reducing postoperative pain (Hargreaves & Lander, 1989; Lui, Liao, & Lien, 1985; Warfield, Stein, & Frank, 1985; Smith, Guralnick, Gelfand & Jeans, 1986). Of these, only Hargreaves

and Lander (1989) and Smith et. al. (1986), control for the effect of analgesic intake on pain scores. Smith et al. (1986), also suggest that CTENS may be more effective against cutaneous pain than deep visceral pain. Other investigators, report that CTENS preserves pulmonary function after thoracic and abdominal surgery (Lui et al., 1985; Rooney, Jain, & Goldiner, 1983 ; Stratton & Smith, 1980; Ali, Yaffe, & Serrette, 1981), and enhances shoulder range of motion after thoracotomy (Lui et al., 1985). Presumably these effects may be the result of improved pain relief but the relationship between these variables and pain is not specified. Reduction of analgesia required by patients treated with CTENS has not been consistently reported. However, as previously mentioned, this is both an invalid and unreliable indicator of pain.

ALTENS has been used mainly as a means to improve analgesia in patients with chronic intractable pain who obtain little or no relief from CTENS (Eriksson & Sjolund, 1978; Eriksson & Sjolund, 1979; Deyo, Walsh, Martin, Schoenfeld, & Ramamurthy, 1990). Some of these studies employ a combination of CTENS and ALTENS as the treatment, thus obscuring the effects of either mode alone. In addition, many of these results are merely descriptive and give little indication of the overall effect of ALTENS.

Studies comparing ALTENS and CTENS have used patients with acute orofacial pain (Hansson & Ekblom, 1983), chronic back pain (Andersson, Hansson, Holmgren, & Renberg, 1976) and rheumatoid arthritis (Mannheimer & Carlsson, 1979). Although these authors report either no difference between the modes or superior pain relief with CTENS, no statistical comparison of groups is made.

The analgesic effectiveness of both ALTENS and CTENS may be limited by accomodation or reduced nerve fiber excitability due to the steady application of electrical impulses (Rothman, Davis, & Hay, 1970). This adaptation is thought to be more pronounced when predominantly large fibers are stimulated and therefore, CTENS may be affected somewhat more than ALTENS. In an effort to reduce this problem, antihabituation technology designed to restore nerve excitability by changing one or more of the stimulation parameters has been developed. These include systematically varying or "modulating" the intensity, pulse duration and/or frequency of continuous stimulation (Mannheimer & Lampe, 1984) or random activation of multiple electrodes (Pomeranz & Niznick, 1987). The implications of these modifications on the analgesic effects of TENS therapy have also not been adequately investigated.

From this brief review, it is evident that much work needs to be

done before we can say that TENS has been properly evaluated and determine whether or not it is useful for clinical pain.

DIRECTIONS FOR FURTHER STUDY

Although more data is required to assess the value of TENS for all types of pain, surgical patients provide an ideal population for study. Large numbers of patients undergo surgery each year and the pain producing event can be somewhat standardized according to the type of surgical procedure. Also, hospitalized patients are readily accessible for observation throughout the period when the pain is most intense.

In terms of the appropriateness of TENS therapy, the indications for adjunct methods of pain control for surgical patients are clear. Postoperative pain is severe, may be protracted, and if not adequately controlled, may predispose patients to life threatening complications (Benedetti et al., 1984). Traditional management with analgesic medication alone is inadequate, and may be further hampered by side effects such as nausea, constipation and sedation. Alternative pain relieving measures such as nerve blocks, epidural analgesia and patient controlled analgesia are expensive and/or technically difficult to administer as well as requiring the order of a physician. Thus, TENS therapy that is easily and independently administered, noninvasive and virtually free of side effects may be an attractive means to improve

postoperative pain control.

However, the analgesic effectiveness of TENS will ultimately determine its usefulness for surgical pain. Therefore, well controlled trials with appropriate analyses need to be done. Specifically, research is needed to identify the best electrode placement and stimulation parameters for various types of pain as well as what types of patients and/or painful conditions are likely to benefit from this treatment. In addition, the duration of pain relief and the effectiveness of TENS over the course of postoperative pain require documentation.

CONCLUSION

The evolution of the gate control theory emphasizes that pain is a multidimensional phenomena that requires an interdisciplinary approach to research and therapy. Nurses function on the front lines of pain management and as such, have the opportunity to make a substantial contribution to the understanding and treatment of pain both in their daily practice and through research activities. However, in order to achieve these ends, nurses need to be aware of the factors that influence pain perception, appropriate pain assessment and research methodology necessary to evaluate pain relieving measures. Further, nursing care must extend beyond the administration of analgesic medication to include adjunct methods of pain control such as TENS.

Only by employing these strategies and systematically evaluating them can we hope to improve the care of patients in pain.

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APPENDIX B

Consent Form

CONSENT FORM

PROJECT TITLE: TENS for Thoracotomy Pain

Investigator:

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Pager No. : 445-2799

Supervisor:

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PURPOSE OF THE STUDY:

TENS is a treatment for pain that has been used a lot for patients having your kind of surgery. One type of TENS uses sticky patches placed on the chest around where the operation was. In another type of TENS the patches are placed on the hands. We want to know if one kind of TENS is better than the other for relieving pain.

PROCEDURES:

There is an equal chance that you will get patches on either your hands or your chest. Some patients will get TENS continuously, some will get TENS intermittently and others will not get TENS. **Regardless of which of these groups you are assigned to, if you have pain, you can still have pain medication.**

At 6 and 24 hours after your operation you will be asked to make a mark on a scale that tells us the amount of pain you are having. Also, before surgery and at 24 hours after the operation, we will measure the amount you are able to move the arm on the side of the surgery in front of your body and to the side. This is done with a type of plastic ruler.

I will read your chart and write down information about your age, weight, type of surgery and the medications you were given.

Altogether, you will be in the study for about 25 hours (one hour before surgery and 24 hours after). Within that time, the arm measurements will be done twice and will take about 10 minutes to

complete each time. The pain scales, which take about 5 minutes to fill out, will also be done at two different times.

BENEFITS AND RISKS:

TENS is a very safe method of treatment that your doctor has given us permission to use. The only risk to you is a 3-5% chance of minor skin rash from the patches. This rash usually goes away when the treatment is stopped.

VOLUNTARY PARTICIPATION:

You do not have to be in this study if you don't want to. You can drop out of the study at any time just by telling your nurse, your doctor or the researcher. If anything is learned from this study that may make you change your mind about being in it, you will be told right away. If you decide not to be in the study the care doctors and nurses give you won't change. If you have questions about the study, the researcher will try to answer them now. You may also call the researcher or her supervisor at the telephone numbers given.

CONFIDENTIALITY:

The records from this study will be marked only with a number and not your name. Your name will not be used in any articles or talks given about the study results.

CONSENT:

I AGREE TO PARTICIPATE IN THIS STUDY. MY QUESTIONS ABOUT THE STUDY HAVE BEEN ANSWERED. I HAVE BEEN GIVEN A COPY OF THIS FORM TO KEEP.

_____	_____
Name	Date
_____	_____
Signature of Subject	Signature of Investigator

APPENDIX C

Samples of the Visual Analog Pain Scale and Affective Pain Faces

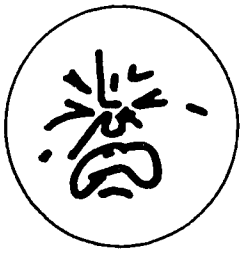
VISUAL ANALOG PAIN SCALE

NO PAIN

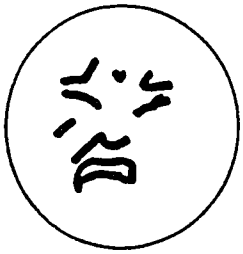
WORST PAIN POSSIBLE

AFFECTIVE PAIN FACES

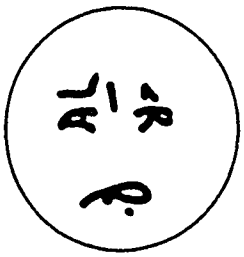
NO PAIN — WORST PAIN POSSIBLE



NO PAIN — WORST PAIN POSSIBLE



NO PAIN — WORST PAIN POSSIBLE



NO PAIN — WORST PAIN POSSIBLE

APPENDIX D

Electrode Placement Protocol

Figure 2. Electrode Placement For Conventional TENS (CTENS) and Placebo Conventional TENS (STENS)

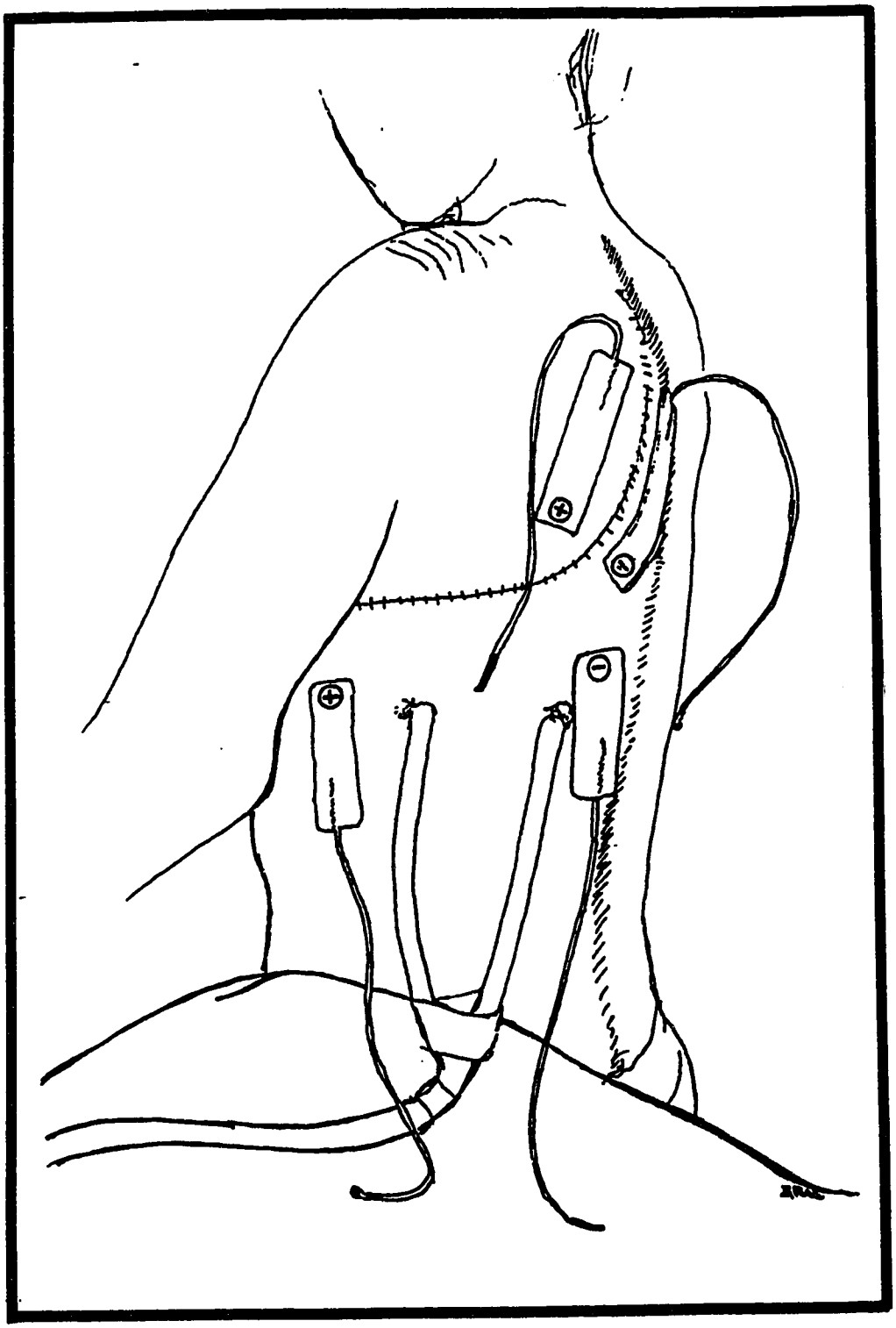
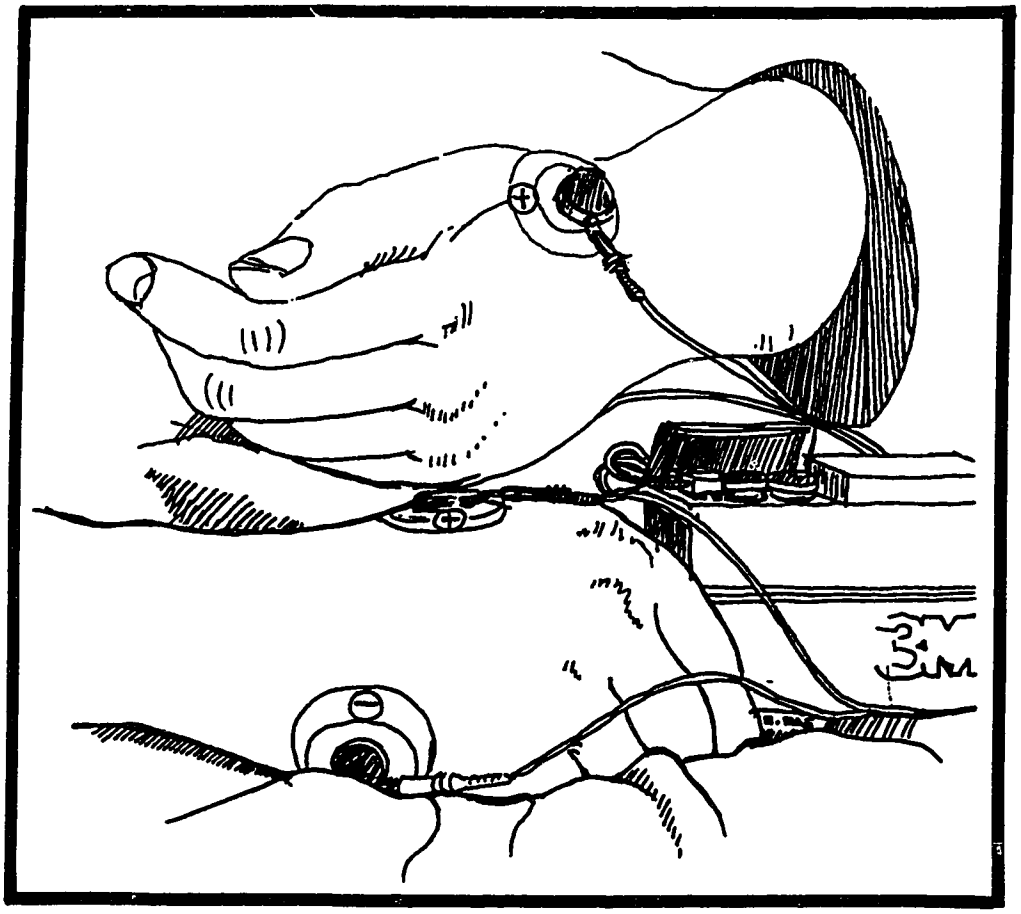


Figure 3. Electrode Placement For Acupuncture-like TENS (ALTENS) and Placebo Acupuncture-like TENS (STENS)



APPENDIX E

Equilanalgesic Drug Conversions

EQUILANALGESIC DRUG CONVERSIONS

Generic Name	Trade Name	Route	Equilanalgesic Dose
Morphine	Morphine	IM/IV	1.000 mg
Meperidine	Demerol	IM/IV	10.000 mg
Fentanyl	Sublimase	IM/IV	.010 mg
Sufentanyl	Sufenta	IM/IV	.002 mg
Alfentanyl	Alfenta	IM/IV	.060 mg
Acetaminophen & Codeine Compound	Tylenol 3	PO	.45 tablets
Acetaminophen & Oxycodone Compound	Percocet	PO	.40 tablets

Sources:

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