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THE ANALGESIC AND BONE HEALING EFFECTS OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION

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INTRODUCTION

During the period of fracture immobilization, early rehabilitation program, including exercise, is essential (Kathrins, 1982). This will speeds the rate of reduction of swelling and tenderness, minimizes fibrosis and atrophy and keeps tendons gliding (Schafer, 1983). The appropriate and effective rehabilitation program may be hampered by the presence of post-fracture pain. An ideal analgesic method to be used in orthopaedic surgery would be one that controls pain without having detrimental effects on fracture healing. Non-steroidal anti-inflammatory drugs (NSAIDs) are commonly used

on an empirical basis for pain relief in these patients (Scott et al., 1984). At the same time many other studies proved the deleterious effect of NSAIDs on fracture healing (Allen et al., 1980 El-Batouti et al., 1984 ; Tornkvist , 1985 and Keller et al., 1987).

Alternative methods of pain relief are available but none has been adopted as routine practice. Transcutaneous electrical nerve stimulation (TENS) has none of the side effects of drug therapy and the advantage of continuous admistration (Gilbert et al., 1986). A compact and light TENS apparatus which is convenient and easy

to use has recently been introduced, and if effective, would be of great benefit to the patient. This study described the effects of TENS on the relief of pain and bone healing after experimentally induced fractures in rats. Regarding the analgesic and healing effects, TENS was compared with indomethacin as standard NSAID used for post-fracture pain relief.

MATERIAL AND METHODS

Ninety Albino rats (average weight 129 grams) were used. Under ether anaesthesia, the right forelimb of each animal was manually fractured, using digital pressure over a fulcrum. On the day following the fracture procedure, the rats were divided randomly into three equal groups. The rats in group I underwent transcutaneous electrical nerve stimulation on the antero-posterior sides of the fractured ends. Transcutaneous electrical nerve stimulation was applied from Neuro Pulse (Hirose Electric Co. LTD, Japan) stimulator at a stimulation frequency of 80 Hz, a pulse duration of 0.4 ms and an intensity of 15 mA through conduction rubber silicon electrodes coated with

conducting gell. Electrical stimulation was given for 30 minutes every day. The rats in group II received a daily dose of 0.75 mg of indomethacin/kg administered intragastrically by a special stomach canula (El-Sayed, 1988). The rats in group III were not given any line of treatment and allowed to heal spontaneously. The animals were kept in standard conditions with free supplies of food and water. Ten animals from each of the three groups were sacrificed at 1, 2 and 3 weeks after the fracture.

Assessment of pain threshold using analgesymeter was done on the second day after fracture and immediately before sacrifice of rats. Pressure was applied by an analgesymeter apparatus at the supported site of fracture until the rat either squeaked or attempted to withdraw the limb under a free weight that increased at a constant rate. This force was continuously monitored by a pointer moving along a linear scale (Randal & Selitto, 1957 and Takeusue et al., 1969).

Radiographic assessment for each

fractured forelimb was done for each rat immediately before sacrifice. These films were done without knowledge of the treatment regimen. Points were given for the stage of healing on a scale from one to four for the following: early callus formation, good callus formation, early healing with callus margins well seen and early trabeculation, or healed fracture (Low, 1985).

The rats were anaesthetized with ether and sacrificed for autopsy for the histopathological assessment of each fractured forelimb. Autopsy was limited to removal of the fractured forelimbs by severing at the carpus and cubitus. The tissue was fixed in 10 percent formalin. Decalcification of bone according to Greep et al. (1948) method was performed. The specimens were embedded in paraffin and sections were cut and stained with Haematoxylin and Eosin. All the histologic sections were examined at random sequence without knowledge of the treatment regimen. The degree of fracture healing was determined using a 5 point scale (Allen et al., 1980): Grade 0 = Non union; Grade 1 = in-

complete cartilagenous union, due to retention of fibrous elements in the cartilagenous plate; Grade 2 = complete cartilagenous union (a well formed plate of hyaline cartilage unites the fragments); Grade 3 = incomplete bony union due to the presence of a small amount of cartilage in the callus. Grade 4 = complete bony union.

Comparison between pain threshold, radiological and histological healing scores of the fractures in the different groups and with the same fracture duration, were made using Student's t-test of significance.

RESULTS

- * There was an occurrence of two deaths in the group of rats treated with indomethacin prior to day 21. However, there was no occurrence of any deaths among the rats in the remaining groups.
- * Pain threshold was not a significant point of difference observed among the three groups at the start of the trial (Table 1).

- * One and two weeks after fracture, a significant improvement in pain threshold was observed in the groups treated with TENS and indomethacin, when compared with that before treatment or after the same periods in the control group.

However within the third week of fracture, a significant improvement in pain threshold was observed in the control group. After the third week, no significant difference in pain threshold was observed after comparing that of the control group with either that of the TENS or indomethacin treated group (Table 1, 2).

- * The group of rats that received TENS showed higher degrees of radiological and histological bone healing scores when compared with either of the control or indomethacin treated groups (Table 3, 4 and Fig. 1 - 6).
- * The group of rats treated with indomethacin showed lesser degrees of radiological and

histological bone healing scores when compared with either control or TENS treated groups (Table 3,4 and Fig. 1 - 5).

- * Inflammatory cells and blood vessels were observed at the site of fracture in the group of rats receiving TENS to the same extent as that observed in the control group (Fig. 2,3).
- * Decreased cellular infiltration and vascularization was observed at the site of fracture in the rats subjected to indomethacin treatment, when compared with that of the control or TENS treated groups. (Fig. 1, 2).

DISCUSSION

Pain relief was an important goal for the effective, early rehabilitation program during the period of fracture immobilization (Kathrins, 1982). An ideal analgesic method to be used would be that which controls pain without having detrimental effects on the process of fracture healing. Our

results indicate that transcutaneous electrical nerve stimulation offers satisfactory post-fracture analgesia equal to that of indomethacin. Concomitant to this analgesic effect, TENS was associated with enhancement of the bone healing process in contrast to indomethacin which proved to retard bone healing.

The analgesic effect of TENS was explained by Taub (1974 and Wyke, 1976) who emphasized the blocking mechanism of electrical currents on C-fibre mediated pain which supply the periosteum and cancellous bone. Bloedel and McCreery (1975) observed that large myelinated fibres have a low threshold to electrical stimulation, thus its early stimulation closes the spinal gate and thus prevents painful peripheral stimuli from gaining access to the ascending transmission system. An alternative explanation for the ability of TENS to produce analgesia is based upon the premise that stimulation causes release of endorphins which subsequently attach to receptors and inhibit transmission of noxious stimuli (Snyder, 1977 and

Solomon, 1980). The proved analgesic effect of TENS in our study in agreement with that of Pike (1978) who used TENS following hip surgery.

The mechanism by which electrical current stimulate fracture healing remains obscure. Nannmark et al., (1985) proved that electric current can stimulate osteogenic cells. Roaze and Hinsenkamp (1982 & 1985) found that electrostimulation can increase glycoaminoglycans synthesis and growth of bone rudiments. More recently Cochran et al., (1985) and Grenshaw (1987) demonstrated that bone has natural electric properties which stimulate the process of osteogenesis. When bone is electrically stimulated, the source of the electricity is external, whereas the source in naturally healing bone is internal. The external source of electricity appears to initiate healing in a manner identical to that initiated by the naturally induced electrical current (Friedenberg and Brighton, 1987). The observations made in the present study showed that TENS do not impair cellular infiltration or vascularity at the fracture site. This

cellular infiltration is very important for the initiation of bone healing as these cells begin to produce new cells which differentiate and organize to provide new vessels, fibroblasts, chondroblasts and osteoblasts (Frost, 1989). Our results were in agreement with that of Nannmark et al., (1985) who found that electrical stimulation may give rise to an early inflammatory reaction in bones as well as in soft tissues and that this reaction may be hampered by the administration of indomethacin.

Our results indicate that indomethacin offers satisfactory post-fracture analgesia. This is perhaps due to analgesic, anti-inflammatory and anti-prostaglandin actions, which may exert an effect upon the post-fracture tissue reaction and result in a lesser degree of perceived pain (Yrjola et al., 1988).

The presence of cellular infiltration and prostaglandins at the site of fracture are the most important factors for bone healing (Dekal et al., 1981 and Simmons, 1985). It is therefore not

surprising that indomethacin delays fracture healing in our study. Our results are in agreement with that of Sudmann et al., (1979) and Keller et al., (1987) who proved that indomethacin inhibits bone healing secondary to reduction of blood flow and cellular infiltration.

The use of NSAIDs during the acute phase of fracture is better to be avoided as they can reduce the potential of the normal healing process and thereby actually prolong the phases of rehabilitation. The analgesic effect in these cases can be obtained by the use of TENS which proved to possess an analgesic effect equal to that of indomethacin and at the same time enhance the process of bone healing.

SUMMARY

The effects of TENS on the relief of pain and bone healing was studied after the performance of experimental fractures in rats. With regards to these actions, TENS was compared with indomethacin as a commonly used drug for post-fracture pain relief. The right

forelimb of 90 Albino rats was fractured and divided into three equal treatment groups. The first group received TENS, the second group received indomethacin while the rats in group 3 were left to heal spontaneously without any line of treatment. Pain threshold, radiological and histological healing scores were determined for each rat. TENS offers satisfactory

analgesia equal to that of indomethacin, and at the same time enhances the process of bone healing in contrast to indomethacin which proved to retard the healing process. It is possible to conclude that TENS is a significant adjunct for simultaneous post-fracture analgesia and enhancement of bone healing process and thereby actually shortens the phases of rehabilitation.

Group	Mean Pain Threshold (g)	Mean Radiological Healing Score	Mean Histological Healing Score
TENS	10.5 ± 1.2	2.8 ± 0.3	3.2 ± 0.4
Indomethacin	10.2 ± 1.1	2.5 ± 0.2	2.9 ± 0.3
Spontaneous	10.8 ± 1.3	3.1 ± 0.4	3.5 ± 0.5

Table (1) : The level of significance between analgesimeter pressure at start of treatment and each observation period .

Observation period (days)	Group I (TENS)	Group II (Indomethacin)	Group III (Control)	Statistical Significance between
1	0.901 ± 0.392 (n = 30)	1.103 ± 0.469 (n = 30)	1.096 ± 0.467 (n = 30)	1 - 111 N. S. 1 - 111 N. S. 1 - 111 N. S.
7	2.124 ± 0.458 (n = 30)	2.235 ± 0.539 (n = 29)	1.234 ± 0.432 (n = 30)	1 - 11 N. S. 1 > 111 P < 0.001 11 > 111 P < 0.0001
14	3.013 ± 0.591 (n = 20)	2.924 ± 0.403 (n = 18)	1.301 ± 0.462 (n = 20)	1 - 11 N. S. 1 - 111 P < 0.001 11 - 111 P < 0.001
21	3.062 ± 0.384 (n = 10)	3.031 ± 0.295 (n = 8)	2.961 ± 0.394 (n = 10)	1 - 11 N. S. 1 - 111 N. S. 11 - 111 N. S.

Table (2) : Analgesimeter pressure before and after treatment at each observation period.

Observation Period (days)	Group 1		Group II		Group III	
	n	TENS	n	Indomethacin	n	Control
1	30	0.910 ± 0.392	30	1.103 ± 0.465	30	1.096 ± 0.467
7	30	2.124 ± 0.458 p1 < 0.001	29	2.325 ± 0.539 P1 < 0.001	30	1.234 ± 0.432 N.S.
14	20	3.013 ± 0.591 p2 < 0.001	18	2.924 ± 0.403 p2 < 0.001	20	1.301 ± 0.462 N.S.
21	10	3.062 ± 0.384 p3 < 0.001	8	3.031 ± 0.295 p3 < 0.001	10	2.961 ± 0.394 p3 < 0.001

Table (3) : Radiological fracture healing score at each observation period.

Observation Period (days)	Group 1	Group II		Statistical Significance Between
	TENS	(Indomethacin)	(Control)	
7	2.367 ± 0.595 (n = 30)	0.624 ± 0.793 (n = 29)	1.415 ± 0.681 (n = 30)	I > III P < 0.001 I > III P < 0.001 II < III P < 0.001
14	3.391 ± 0.598 (n = 20)	1.127 ± 0.641 (n = 18)	2.724 ± 0.713 (n = 20)	I > II P < 0.001 I > III P < 0.01 II < III P < 0.001
21	3.714 ± 0.532 (n = 10)	2.056 ± 0.6138 (n = 8)	3.611 ± 0.729 (n = 10)	I > II P < 0.001 I - III N.S. II < III P < 0.001

Table (4) : Histological fracture - healing score at each observation period.

Observation Period (days)	Group 1	Group II		Statistical Significance Between
	TENS	(Indomethacin)	(Control)	
7	2.421 ± 0.643 (n = 10)	0.56 ± 0.83 (n = 9)	1.514 ± 0.792 (n = 10)	I > III P < 0.001 I > III P < 0.001 II < III P < 0.025
14	3.502 ± 0.782 (n = 10)	1.032 ± 0.714 (n = 10)	2.589 ± 0.646 (n = 10)	I > II P < 0.001 I < III N.S. II < III P < 0.001
21	3.789 ± 0.422 (n + 10)	2.097 ± 0.521 (n = 8)	3.613 ± 0.654 (n = 10)	I > II P < 0.001 I - III N.S. II < III P < 0.001

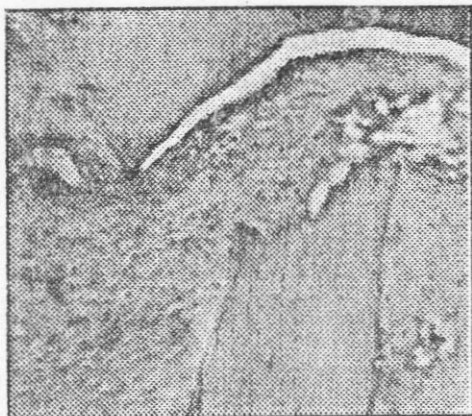


Fig. (1) : Section of the fractured area after two weeks of a rat received Indomethacin, showing non-union with fibrous tissue remnants, decreased cellular infiltration and decreased vascularity (Hx. & E. Stain X 100).

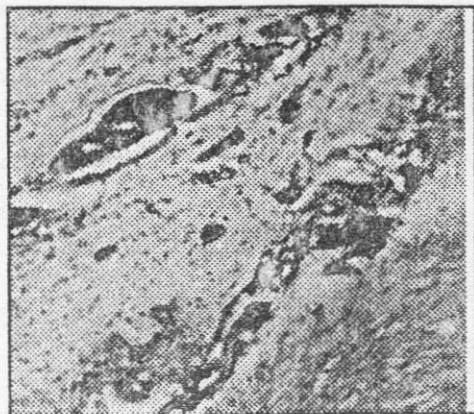


Fig. (3) : Section of the fractured area after two weeks of a rat treated with TENS, showing incomplete bony union (grade 3) with increased cellular infiltration and vascularity (Hx. & E. stain, X 100).



Fig. (2) : Section of the fractured area after two weeks, of a control rat, showing incomplete cartilagenous union (grade 1) with increased vascularity and cellular infiltration (Hx. & E. stain X 100).



Fig. (4) : Section of the fractured area after three weeks of a control rat, showing incomplete bony union (grade 3). (Hx. & E. stain X 100).

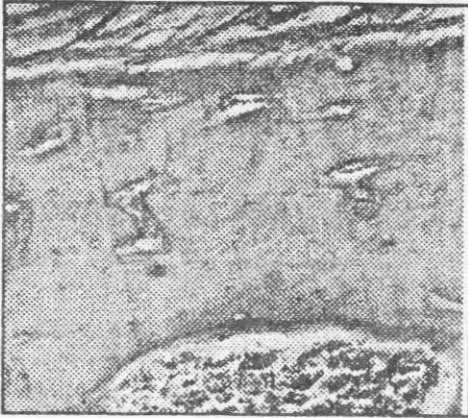


Fig. (5) : Section of the fractured area after three weeks of a rat treated with TENS , showing complete bony union (grade 4), (Hx.& E. stain X 100).

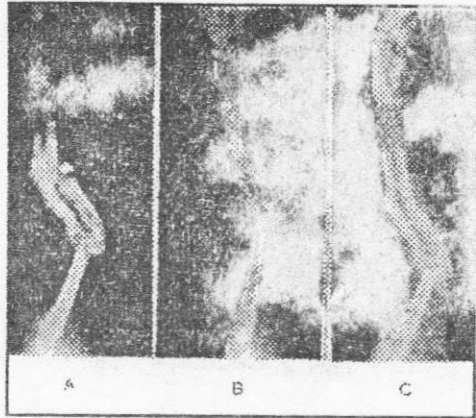


Fig. (6) : Roentgenograms of fractured tibia and fibula in the three groups after 3 weeks

a- Early callus formation (grade 1) in a rat received indomethacin treatment.

b- Early healing with callus margins and early trabeculation (grade 3) in a control rat.

c- Heald fracture (grade 4) in a rat treated with TENS.

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تأثيرات التنبيه الكهربائي خلال الجلد فى تسكين الالم والتثام الكسور

د . / عاطف الغويط
د . / نجبوى هلال
د . / محمد مجدى البطوطى
د . / صبرى الموجى

وجد ان تسكين الألم المصاحب للكسور بواسطة الأدوية الغير أستيرودية المضادة للالتهاب يؤدى الى تأخر التثام الكسور ، ويرجع ذلك الى تأثيرها المثبط على البروستا جلاتدين والتفاعلات المصاحبة للكسر وحيث ان تقليل درجة الألم فى هذه الحالات هامة للمريض ولبرنامج التأهيل الطبى فقد أستهدف هذا البحث دراسة تأثير التنبيه الكهربائى خلال الجلد على درجة الألم والتثام الكسور فى فتران التجارب حيث قورن هذا التأثير بالاندوميثاسين كمثال لاحد الأدوية الغير أستيرودية التى تستعمل لتقليل الألم فى حالات الكسور. وقد تم أحداث كسور بعظمتى الساعد الايمن فى ٩٠ فأر أبيض تحت تأثير المخدر ، ثم قسمت هذه الفتران بطريقة عشوائية الى ثلاث مجموعات : عولجت الاولى بالتنبيه الكهربائى خلال الجلد لمكان الكسر ، والثانية بالاندوميثاسين بينما أعتبرت الثالثة كمجموعة تحكيم حيث ترك الكسر يلتئم بدون أى تأثير خارجى .

وقد تم متابعة الكسر أسبوعيا من حيث درجة الموض ودرجة التثام الكسر بناء على الفحص الاشعاعى والشكلى للاسجة .

وقد أثبتت النتائج أنه لا يوجد فرق ذو دلالة إحصائية بين التأثير المسكن لكل من التنبيه الكهربائى والاندوميثاسين بينما التامت الكسور التى عولجت بالتنبيه الكهربائى بصورة أفضل من التى عولجت بالاندوميثاسين أو التى تركت بدون أى علاج ويستنتج من هذا البحث أن التنبيه الكهربائى خلال الجلد يعتبر وسيلة فعالة لتقليل الالم وفى نفس الوقت تنشيط التثام الكسور مما يساعد على تقليل فترة التأهيل الطبى لحالات الكسور .

Highland County, Ohio

Highland County, Ohio

I, the undersigned, Clerk of the Court of Common Pleas for Highland County, Ohio, do hereby certify that the within and foregoing is a true and correct copy of the original as the same appears from the records of said Court.

In testimony whereof, I have hereunto set my hand and the seal of said Court at Newburg, Ohio, this _____ day of _____, 1890.

 Clerk of the Court of Common Pleas