Pain, 52 (1993) 209–216

RCT
pain
TENS
*

PAIN 02210

TENS for children's procedural pain

Janice Lander and Susan Fowler-Kerry

Clinical Sciences (3-106), University of Alberta, Edmonton, Alberta T6G 2G3 (Canada)

(Received 17 April 1992, revision received 9 September 1992, accepted 14 September 1992)

Summary A 3 × 6 factorial design with a double blind and placebo control was employed to investigate the effect of TENS treatment on pain produced by venipuncture. The three treatment groups consisted of TENS, placebo–TENS and control. Subjects were blocked into six 2-year age groups (ages: 5–17 years). During the period of the study, 896 children attending the outpatient laboratory of a general hospital were screened and 514 children completed the study. The data which were collected before venipuncture included expected pain and state anxiety. Following venipuncture, pain intensity was measured with a vertical visual analogue scale (VAS) and pain affect was assessed with McGrath's faces scale. Significant main effects for treatment and age groups were obtained. Pain intensity and affect were lowest for the TENS group and highest for the control group. The pain scores were greatest for lower age groups and lowest for higher age groups. The results of this study support the use of TENS for children's pain and the need for interventions for children's procedural pain.

Key words: TENS; Venipuncture pain; McGrath's Faces scale; (Child)

Introduction

Rather than habituating to uncontrolled and repetitive pain, animals develop conditioned avoidance responses (Domjan and Burkhard 1986). If a similar psychological response occurs with children as a consequence of repeated noxious medical procedures, as suggested by McGrath and Unruh (1987), children may suffer considerable distress when forced to endure procedures for which they have developed a conditioned avoidance response. Further, they may develop into adults who abstain from dental and medical care. Supporting evidence for the notion that medical procedures are distressing is obtained from reports of children who endured moderate or severe post-operative pain to avoid an injection of an analgesic (Mather and Mackie 1983). Other children have related that they became increasingly intolerant of needles given repeatedly during treatment of cancer (Fowler-Kerry 1990).

Correspondence to: Janice Lander, Ph.D., 3-106 Clinical Sciences, University of Alberta, Edmonton, Alberta T6G 2G3, Canada. Tel.: (403) 492-6317; FAX: (403) 492-2551.

In recent years, researchers have investigated psychological and pharmacological interventions which can be useful for children's procedural pain. Research on use of cognitive-behavioural strategies with children is generally favourable. These approaches include: stress management, biofeedback, hypnosis (Katz et al. 1980, 1987), imagery (Brown 1984), relaxation (Richter et al. 1986), providing preparatory information (Wolfner and Visintainer 1975; Harrison 1991) and distraction (Fowler-Kerry and Lander 1987). Pharmacological agents and strategies for administering drugs have been assessed (Eland 1981; Hallen et al. 1984; Maunuksela and Korpela 1986; Woolfson et al. 1990).

One strategy for management of children's pain, which is virtually unexplored, is the use of transcutaneous electrical nerve stimulation (TENS). There are several advantages obtained from using TENS for pain management. It is simple to use. In fact, most people administer TENS treatment to themselves. It is also safe, efficacious and requires very little preparation time for implementation.

Three types of TENS have been described (conventional, acupuncture-like and brief intense) (Mannheimer and Lampe 1984; Ottoson and Lundeberg 1988). The three types of TENS differ according to the stimu-

lation parameters which are employed and the desired clinical outcome. Brief intense TENS consists of high frequency stimulation applied for a short duration. It is used for short-term pain induced by procedures.

Although some studies demonstrate that TENS may not be beneficial for all types of pain (Loeser et al. 1975; Macora et al. 1978; Richardson et al. 1980) a general review of the literature indicates that TENS has a role to play in pain management. In particular, studies investigating the contribution of TENS for post-surgical pain control with adults have reported encouraging results (Cooperman et al. 1977; Rosenberg et al. 1978; Schuster and Infante 1980; Bussey and Jackson 1981; Smith et al. 1986). TENS has also been found to be useful for treating chronic musculo-skeletal pain (Roche et al. 1985; Lehmann et al. 1986; Cheng and Pomeranz 1987; Willer 1988), angina (Mannheimer et al. 1986) and procedural pain among adults (Hargreaves and Lander 1989).

Several reports relate specifically to the use of TENS with children. In all cases, the surgery was for repair of scoliosis or kyphosis and patients ranged in age from 11 to 25 years (Finley and Steward 1983; Issenman et al. 1985; Carmen and Roach 1988). Investigators in two of the studies did not use placebo controls or double blinds. There were validity problems with measurement of pain in all three studies. While these studies do not provide an unequivocal statement about the efficacy of TENS for children's pain, they do indicate that it is possible to use TENS with older children and that no untoward effects resulted from the use of TENS.

TENS has been used effectively with some procedural pain in adults (Hargreaves and Lander 1989) and with experimental pain in the laboratory (Facchinetti et al. 1984; Chan and Tsang 1987). TENS, however, has not been evaluated for suitability or effectiveness regarding children's procedural pain. The purpose of this study was to assess the merit of TENS for procedural pain experienced by children. Venipuncture pain was studied as this is one of the most common causes of procedural pain experienced by children.

Method

Design

A 3×6 between-groups factorial design with double blind and placebo control was used in this study. There were three treatment groups (TENS, placebo–TENS, and control) and six age groups (5–7, > 7–9, > 9–11, > 11–13, > 13–15, and > 15–17 years). The following parameters were established for the power test based on Cohen (1977): $\text{beta}_1 = 0.80$, alpha = 0.05, small effect size (0.20). The sample size was thus determined to be 30 subjects for each age and treatment group combination.

Subjects

Children and adolescents between the ages of 5 and 17 years were included in this study. They were attending pediatric or family medicine out-patient clinics in a tertiary care hospital in western Canada. Patients had been referred to the Outpatient Laboratory to have blood drawn for clinical tests. There were 896 referrals who were assessed to determine if they were suitable for the study. The criteria for selection into the study included: aged 5–17 years; no previous experience with TENS; both arms accessible for electrode placement; accompanied by a parent so that consent could be obtained; and having venipuncture only at the right or left antecubital site.

Instruments

A number of tools were used in this investigation.

Faces Affective Pain Scale. This scale consists of a set of 9 sketched faces which range from happy to sad. The scale was developed in such a way as to produce an interval-ratio measure of pain distress when the numerical scale values are employed (McGrath et al. 1985). The faces of the scale have been presented in random order and in fixed incrementing order (McGrath 1990). There is no evidence to suggest that one approach is more appropriate than the other. The faces were presented in fixed, incrementing order in this study.

Visual Analogue Scale (VAS). The VAS used in this study was a vertical line of 10 cm length. The anchors of the scale were 'no pain' and 'worst pain possible'. The VAS can be used with children over 5 years of age (McGrath et al. 1985). Convergent validity of the VAS has been determined by administering several pain scales to children. Scores on the VAS have strong positive correlations ($r = 0.82$) with frequency of pain indicators (Abu-Saad 1984). Strong positive correlations have also been found among scores of the VAS, Oucher, and Poker-chip scales (Beyer 1989). Discriminant validity for the VAS was determined by the finding of no correlation with the Hospital Fears Rating Scale and the Scare Scale (Beyer 1989).

Children's Anxiety and Pain Scale (CAPS). The scale consists of two sets of five faces. One set are faces in pain. These were used in this study to assess comprehension of the VAS. In the second set are faces experiencing anxiety. As with the pain faces, they range from no anxiety to extreme anxiety. Kuttner and LePage (1989) instruct children to choose a face which shows how afraid they are. CAPS has been assessed for content validity. It has been utilized with children aged 4–10 years.

State-Trait Anxiety Inventory (STAI). The STAI-Y1 is a 20-item test of state anxiety which is used for adolescents and adults (aged 14–15 years and older). There is also the STAI-C1 version which is suitable for children from kindergarten to about grade 8 (Spielberger et al. 1983). The STAI-C must be individually administered for children in kindergarten through grade 2 (Papay and Spielberger 1986). There have been extensive psychometric assessments of the state anxiety scales and the tools are known to be valid and reliable.

Parent questionnaire. A short survey questionnaire for parents was devised for this study. Parents were asked to report age and current health problems of the child.

Equipment

The TENS unit delivered a random pattern of stimulation via six electrodes where only one electrode was active at a time. The electrode pads were 2 cm in diameter. The TENS units were modified and fitted with timers which started and stopped when the machine was turned on and off. Thus, the TENS units permitted accurate recording of duration of TENS treatment. When the brief intense TENS mode of this apparatus was employed, the stimulation parameters which had been built into the equipment were: pulse width, fixed at 1.0 msec; duration of stimulation/channel (electrode), fixed at 10 sec; waveform, balanced biphasic; and recurrence fre-

quency, 200 Hz (5 msec); Further, intensity of stimulation was individually set below pain threshold and adjusted during stimulation to maintain this level (Mannheimer and Lampe 1984; Ottoson and Lundeberg 1988). The duration of stimulation was set at a minimum of 12 min based on prior research (Hargreaves and Lander 1989).

Procedure

The research assistants screened all cases to determine if patients met the inclusion criteria. When the criteria were met, both parent and child were asked to consent to take part in the study.

The pretreatment data collection phase was handled by the data assistant. The child was taken aside for instruction about the VAS while the parent remained nearby in the waiting room, answering the questionnaire. The data assistant described the VAS and assessed comprehension by having the child use the VAS to score the pain depicted by the second, third and fifth CAPS pain faces. These three faces were presented in a fixed random order for all children. The actual rating of the faces was irrelevant; correct ranking was important. If the child was unable to rank the faces correctly, the VAS explanation and assessment procedure was repeated with the remaining CAPS faces. If the data assistant was satisfied that the child was not able to understand the VAS, then the child was excluded from the study.

It was after instruction was successfully concluded that the data assistant asked the child to indicate expected pain from the venipuncture on the VAS. The child was then given the age-correct version of the STAI. Once the pretreatment data were collected, the data assistant took the child to the research room. The data assistant departed from the treatment room and the second assistant, the TENS assistant, began the treatment phase of the study.

The TENS assistant blocked subjects by age group (six groups of 2-year intervals) before making random assignments to treatment group. Individually sealed envelopes contained subjects' group assignments. The randomly assigned treatment was then provided by the TENS assistant. At the end of the treatment phase, the TENS assistant signalled for the laboratory technician to be called to the room to begin the venipuncture. At the conclusion of the venipuncture, the laboratory technician and TENS assistant both left the room. The data assistant returned and obtained the VAS rating of pain intensity and faces rating of affective pain. Neither the TENS assistant nor the laboratory technician was in the room during pain assessment. Similarly, the laboratory technician and the data assistant were not in the room during the assigned study treatment.

TENS treatment. To provide for the possibility that blood could be drawn from either antecubital space, it was necessary that both arms receive TENS stimulation. Therefore, two TENS machines were employed, one for each arm. The six electrodes of one machine were applied as follows: one over the brachial plexus; three 2.5 cm above the venipuncture site over the medial, lateral and ulnar nerves; one 5 cm above the venipuncture site and over the medial nerve; and one over the medial epicondyle. The electrodes of the second machine were placed in precisely the same positions on the other side of the body. The TENS equipment was positioned behind the subject. The equipment was covered to prevent the subject, lab technician and data assistant from discovering the assigned group by using cues such as on/off light switches.

Each of the six channels on both TENS machines was adjusted so that maximum tolerated intensity was attained. The TENS units were then activated and the 12 min treatment period began. The timer and TENS treatment continued until the technician arrived. Both machines were turned off immediately prior to venipuncture. The TENS assistant removed electrodes after venipuncture and before leaving the room with the lab technician.

Placebo–TENS treatment. The electrodes were applied with the same procedure utilized for the TENS group. The subjects were instructed that they may or may not feel a tingle or tickle during the treatment. At the sound of the beep from a timer, the TENS assistant remarked that the TENS machine was running. In reality, no stimulation was actually provided to subjects in the placebo–TENS group. After the timer reached 12 min, the signal was given for the laboratory technician. Other than these differences, the procedure was identical for the placebo–TENS and the TENS groups.

No-treatment control. Control group subjects were placed in the venipuncture chair in the research room and instructed that they were in the control group and would not receive TENS. They remained in the room for 12 min before the lab technician was called. They also remained in the room for the time that would be required to remove electrodes from subjects in the other two groups.

It was hypothesized that subjects who received TENS would have significantly less pain than subjects in both the placebo and control groups. Further, subjects who received placebo–TENS would be found to have significantly less pain than control subjects. Thus, there would be a TENS treatment effect and a placebo effect. It was also hypothesized that venipuncture pain would be greater in younger subject groups compared to older ones.

Results

Data preparation

VAS scores were computed by measuring the length of the line to the point where the subject had made the mark signifying level of pain. The numeric scores assigned to the faces of the affective scale by McGrath et al. (1985) were utilized in analyses of affective pain data.

As the range of scores differs for the two state anxiety scales (one uses three response options and the other four), raw scores were converted to standardized scores. To avoid negative scores, a 50 ± 10 standardized score was set according to Cronbach's (1970) recommendation. Thus, constants were included during the calculation of the standardized scores so that the mean state anxiety was 50 and the standard deviation was 10.

Subject enrollment

Subject enrollment continued for a period of 16 months, at which time four of the six age groups were completed. The two lower age groups were incomplete with 86 of 90 ($>$ 7–9 years old) and 69 of 90 (5–7 years old) enrolled. A decision was made to discontinue subject enrollment and begin data analyses in order to avoid empirical confounding caused by continuing to study subjects who represented only two age groups.

During the period of subject enrollment, 896 children registered in the laboratory. Of these, 517 participated in the study and 514 completed the study. Three children did not complete the study protocol: one adolescent bolted from the room to escape the venipuncture, one child with influenza had to discontinue, and a third child refused to rate pain following venipuncture.

The remaining 378 could not or would not participate in the study. There were 161 children who were

TABLE I

SUBJECT ENROLMENT RATES BY TREATMENT GROUP

	5–7	> 7–9	> 9–11	> 11–13	> 13–15	> 15–17	Total
Referrals	140	127	151	140	147	191	896
Excluded	32	11	18	18	21	61	161
Refused	39	30	42	31	36	39	218
Dropouts	0	0	1	1	0	1	3
Enrolled	69	86	90	90	90	90	514

excluded by study criteria. The most common criterion not met was presence of a parent to provide consent. There were a number of developmentally delayed children across all age groups who were unable to use the pain scales. Eight other children 7 years or younger were also unable to comprehend the VAS. In addition, there were a few children who had casts or skin disorders affecting the arms and one who had venipuncture performed using a vein in the hand.

Another large number (n = 157) could not participate in the study as they lacked the time required to complete the study. Seven parents declined to consent and 54 children, whose parents had given approval, refused consent.

Subject enrollment, exclusion and refusal rates are presented in Table I. The exclusion rates were highest for the youngest and oldest groups. The main reason for the higher exclusion rate among the 5–7-year-old group was a large number of children with developmental delay or inability to understand the VAS. The primary reason for a large number of exclusions in the > 15–17-year-old group was the absence of a parent in the laboratory.

Subject characteristics

Diagnostic information from patient charts or laboratory requisitions was not available for the purposes of this study. The details provided by parents about the child's health problem varied considerably. Some parents were able to provide a precise diagnostic label whereas others were uncertain about the nature of the child's illness. From parental reports, many children seemed to be undergoing preliminary investigations of a yet undiagnosed illness. Many others were having laboratory work completed as part of ongoing care related to a wide variety of specific health problems. In short, children who participated in this study had both acute and chronic health problems; they were typical of the pediatric outpatient laboratory population. Socioeconomic status and cultural backgrounds of the subjects were diverse and typical of the local population.

Descriptive statistics for the three treatment groups are summarized in Table II. There were no significant treatment group differences related to subjects' age, expected pain and state anxiety (with analysis of variance) and gender (with chi-square analysis). Overall mean VAS pain was 28.7 (S.D. 30.6) and affective pain was 49.1 (S.D. 26.8). The distribution of pain scores is presented in Fig. 1.

Effect of TENS on venipuncture pain

As data collection was suspended before all cases were obtained for the two lowest age groups, cell sizes were unequal and the design became non-orthogonal. A regression approach was therefore taken for the analysis of covariance, as recommended (Tabachnick and Fidell 1983). Separate omnibus 3×6 between groups analysis of covariance were computed for the dependent variables of VAS pain and affective faces pain. State anxiety and expected pain served as the covariates.

The treatment group main effect was significant for VAS pain (F (2, 494) = 2.9, $P = 0.05$) and affective faces pain (F (2, 494) = 4.2, $P = 0.02$). Post-hoc comparisons (least significant differences, $P = 0.05$) indicated that the three groups were significantly different. Inspection of the group means, as presented in Table III, indicated that lowest pain and pain affect were reported by those who had TENS followed by those with placebo–TENS and then those with no treatment.

TABLE II

CHARACTERISTICS OF SUBJECTS BY TREATMENT GROUPS

Traits	Treatment group			
	TENS	Placebo TENS	Control	Total
Age				
mean	11.2	11.3	11.4	11.3
S.D.	3.4	3.4	3.3	3.3
Gender				
males	97	85	82	264
females	77	87	86	250
Expected pain				
mean	28.8	30.2	31.6	30.2
S.D.	29.2	28.2	30.3	29.2
Anxiety				
mean	49.0	50.5	50.5	50.0
S.D.	9.9	9.5	10.5	10.0
Total subjects	174	172	168	514

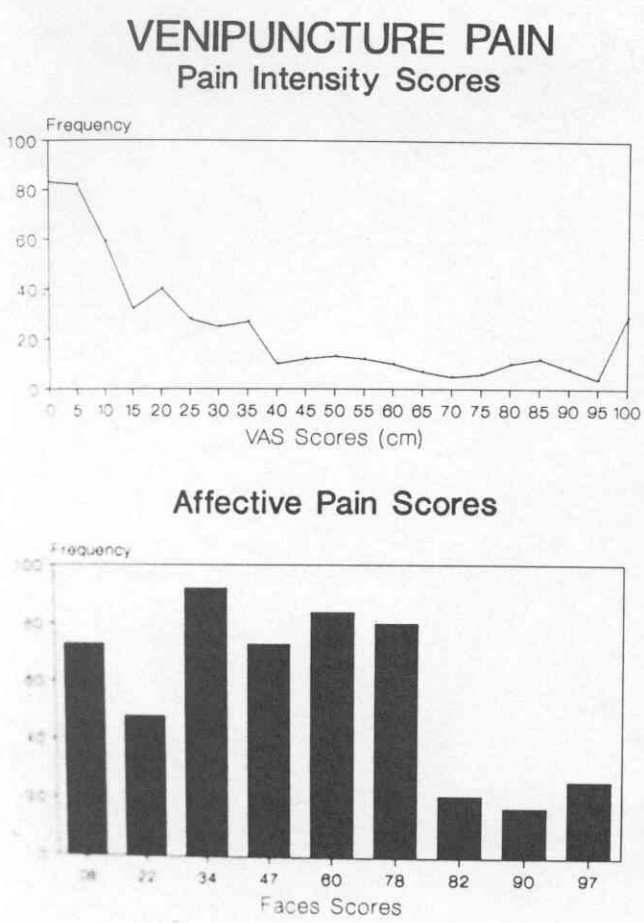

Fig. 1. Distribution of VAS and Faces Pain Scores.

The interaction effects were also assessed in the same analyses. The interactions between age and treatment were not significant for either VAS or affective pain, after adjustment for the covariates.

The duration of time that subjects remained in the room waiting for a technician, following the conclusion of the 12 min treatment interval, varied and was the result of a technician not being immediately available. The duration of time that TENS was administered ranged from 12 to 22.8 min (mean = 14.2, S.D. = 1.5). Pearson correlations were computed for duration of TENS treatment and affective pain ($r = -0.05$) and VAS pain ($r = -0.11$). Both Pearson correlations were near zero and non-significant.

TABLE IV

INTERCORRELATIONS FOR COVARIATES AND DEPENDENT VARIABLES [a]

	State anxiety	Expected pain	VAS pain
Expected pain	0.48		
VAS pain	0.29	0.42	
Affective pain	0.35	0.40	0.74

[a] All significant at $P < 0.001$.

Effect of age on venipuncture pain

Both VAS pain (F (5, 494) = 11.3, $P < 0.001$) and affective faces pain (F (5, 494) = 5.3, $P < 0.001$) varied significantly by age group, as determined by the omnibus analysis of covariance. From the post-hoc comparisons it was determined that the lowest age group was significantly different from all others (least significant differences, $P = 0.05$). Greatest pain and pain affect were observed in the lowest age group (Table III). Mean pain scores became lower with increasing age of the age groups. The inter-correlations among the covariates and the dependent variables are displayed in Table IV.

Discussion

The TENS treatment group had lower VAS and faces pain scores compared to the control group. The scores of the placebo–TENS group fell midway. Thus, from a comparison of the TENS and placebo groups, there was an effect on pain which could not be attributed merely to suggestion or expectancy, but which was also due to the TENS. The results of this study, therefore, support the theoretical underpinnings of TENS. While these data do support the TENS theory, it should be noted that the effect was rather small and a very large sample size was required to detect it. Although significantly less pain was reported by those who had brief intense TENS for procedural pain, the effect could not be regarded as clinically significant. It may be that TENS is not a particularly potent analgesic for children undergoing venipuncture or it may be that a more substantial clinical effect could be obtained with a different TENS protocol than was employed in this study.

As much of the day-to-day practice of TENS is driven by clinical wisdom rather than sound research, our choice of stimulation parameters was made on the basis of clinical experience rather than data derived from thorough and systematic investigations. With regard to the placement of electrodes, we chose to stimulate over the brachial plexus and the peripheral nerves which innervate the antecubital fossa because of suggestions that electrodes be placed near the site (Ottoson and Lundeberg 1988). It may well be that another electrode placement would produce different results.

Other stimulation parameters, such as duration and intensity, may also produce different results. We were guided in our choice of duration of stimulation by previous research about TENS for adults' procedural pain (Hargreaves and Lander 1989) and our pilot work with the equipment. The delay in arrival of the laboratory technician in this study extended the opportunity for us to assess the effect of different durations of stimulation on pain. At least within the range which occurred in this study, there was no indication that the effect would be enhanced with longer stimulation. Future research could include a more systematic assessment of duration of stimulation.

It was not possible to record intensity with the equipment employed in this study and, therefore, we do not know the characteristics of children who chose low or high intensities and any consequences for venipuncture pain. Increasing the intensity of stimulation may be a useful improvement to this protocol. However, children may not tolerate high intensity stimulation since the higher the intensity, the more uncomfortable the treatment. Hence, the treatment may cause more pain than the venipuncture and therefore negate the value of using TENS. Children seemed to tolerate the intensity utilized in this study. The children's reactions to the TENS were interesting. They reported tickling and tingling sensations. Some giggled and others seemed wary. Some tracked the random pattern of stimulation.

TENS was well accepted by this diverse group of children and parents. The diversity of the sample aids in generalization of the results. This was one of several strengths related to the design and conduct of this study. At the same time, it should be noted that we do not know whether TENS is more or less effective for certain children (for example, those with various illnesses or backgrounds).

In this study, we suspected that children would be naive about TENS and therefore, that the application of electrodes would be sufficient to produce a placebo effect. We have reason to believe that the placebo was credible. Many children in the placebo group asked for their 'stimulation intensity' to be altered during the treatment. A 7-year-old subject from the placebo group returned to the laboratory with her mother to ask when sensation would return to her arm. A zero intensity stimulation thus seems effective as a placebo. An alternative approach for a placebo could be a very brief stimulation to induce minimal, that is, threshold sensation. As soon as threshold is reached (taking 5–10 sec), the TENS equipment could be turned off. This brief stimulation should not affect pain but would be sufficient to produce a placebo effect.

A second major finding from this study is that age is related to venipuncture pain. This outcome corroborates previous research (Fradet et al. 1990; Lander and Fowler-Kerry 1991). The mean pain scores obtained in this study declined progressively across the six age groups. Venipuncture pain was most severe and distressing for children who were 5–7 years old. Clearly, distress of this magnitude deserves attention so that young children do not develop avoidance behaviours. Pain management strategies may be of value in reducing venipuncture pain but may not reduce distress or anxiety associated with needles. Longitudinal investigations about the effect of repeated treatment for needle stick distress and discomfort is required.

Almost all parents were willing to have their children participate in the study. Only 6% ($n = 54$) of children refused to participate. This participation rate is indicative of support for children's pain research and of concern about children's pain. Little is known about those children who refused to participate. It may be that these children are exceptionally fearful of needles or are less well and therefore unable to cope with additional demands. There may be simple reasons for not participating, like that mentioned by one 5 year old who said, "I don't like experiments". Whereas characteristics of adults who do or do not participate in research have been investigated, little is known about children who participate.

There were too few drop-outs from this study for analysis of their traits. One was a child who was unable to continue because of her illness. Another was a child who refused to report his pain, perhaps because he was distressed and angry about the venipuncture. We also observed that the adolescent who participated in the study but ran away to escape the venipuncture had a state anxiety score which was in the upper 15% of scores. This latter case points to the need to intervene when children are distressed and suffering from pain related to medical procedures. The substantial number of children who experienced greater than average needle pain in this study further supports the need for improved assessment and intervention.

In summary, we recommend continued investigation of the use of TENS for children's pain. We also support the need for further research about children's experiences with procedural pain, including long-term effects of repeated unpleasant experiences and strategies to circumvent or treat avoidance behaviours.

Acknowledgements

We thank Gwen Spracklin, Terry Hartley and the staff of the Outpatient Laboratory. This study was supported in part by a grant from the National Health Research Development Program, Health and Welfare Canada (Grant 6608-1249).

References

Abu-Saad, H., Assessing children's responses to pain, Pain, 19 (1984) 163–171.

Beyer, J., The Oucher: a pain intensity scale for children. In: S. Funk, E. Tornquist, M. Champagne, L. Copp and R. Wiese (Eds.), Key Aspects of Comfort: Management of Pain, Fatigue and Nausea. Springer, New York, 1989, pp. 341.

Brown, J., Imagery coping strategies in the treatment of migraine, Pain, 18 (1984) 157–167.

Bussey, J.G. and Jackson, A., Post surgical analgesia with T.E.N.S. In: R.A. Ersek (Ed.), Pain Control with T.E.N.S., Warren H. Green, St. Louis, MO, 1981, pp. 151–159.

Carmen, D. and Roach, J., Transcutaneous electrical nerve stimulation for the relief of postoperative pain in children, Spine, 13 (1988) 109–110.

Chan, C.W.Y. and Tsang, H., Inhibition of the human flexion reflex by low intensity, high frequency transcutaneous electrical nerve stimulations (TENS) has a gradual onset and offset, Pain, 28 (1987) 239–253.

Cheng, R.S.S. and Pomeranz, B., Electrotherapy of chronic musculoskeletal pain: comparison of electroacupuncture and acupuncture-like transcutaneous electrical nerve stimulation, Clin. J. Pain, 2 (1987) 143–149.

Cooperman, A., Hall, B., Mikalacki, K., Hardy, R. and Sadar, E., Use of transcutaneous electrical nerve stimulation in the control of postoperative pain, Am. J. Surg., 133 (1977) 185–187.

Cohen, J., Statistical Power Analysis for the Behavioral Sciences, Academic Press, New York, 1977, 474 pp.

Cronbach, L.J., Essentials of Psychological Testing. Harper and Row, New York, 1970, pp. 752.

Domjan, M. and Burkhard, B., Principals of Learning and Behavior. Brooks-Cole, Monterey, CA, 1986, pp. 365.

Eland, J.M., Minimizing pain associated with prekindergarten intramuscular injections, Issues Compr. Pediatr. Nurs., 71 (1981) 36–40.

Facchinetti, F., Sandrini, G., Petraglia, F., Alfonsi, E., Nappi, G. and Genassani, A.R., Concomitant increase in nociceptive flexion reflex threshold and plasma opioids following transcutaneous nerve stimulation Pain, 19 (1984) 295–303.

Finley, G. and Steward, D., Transcutaneous electric nerve stimulation for control of postoperative pain following spinal fusion in adolescents, Can. Anesthetists Soc. J., 30 (1983) 67.

Fowler-Kerry, S., Adolescent oncology survivors' recollection of pain. In: D.C. Tyler and E.J. Krane (Eds.), Advances in Pain Research and Therapy, Vol. 15, Raven Press, New York, 1990, pp. 365–371.

Fowler-Kerry, S.E. and Lander, J., Management of injection pain in children, Pain, 30 (1987) 169–175.

Fradet, C., McGrath, P.J., Kay, J., Adams, S. and Luke, B., A prospective survey of reactions to blood tests by children and adolescents, Pain, 40 (1990) 53–60.

Hallen, B., Olsson, G.L. and Uppfeldt, A., Pain-free venepuncture: effect of timing of application of local anesthetic cream, Anaesthesia, 39 (1984) 969–972.

Hargreaves, A. and Lander, J., Tens for postoperative pain, Nurs. Res., 38 (1989) 159–161.

Harrison A., Preparing children for venous blood sampling, Pain, 45 (1991) 299–306.

Issenman, J., Nolan, M., Rowley, J. and Hobby, R. Transcutaneous electrical nerve stimulation for pain control after spinal fusion with Harrington rods, Phys. Ther., 65 (1985) 1517–1520.

Katz, E.R., Kellerman, J. and Seigel, S.E., Distress behaviour in children with cancer undergoing medical procedures: developmental considerations, J. Consult. Clin. Psychol., 48 (1980) 356–365.

Katz, E.R., Kellerman, J. and Ellenberg, L., Hypnosis in the reduction of acute pain and distress in children with cancer, J. Pediat. Psychol., 12 (1987) 379–394.

Kuttner, L. and Lepage, T., Face scales for the assessment of pediatric pain: a critical review, Can. J. Behav. Sci., 21 (1989) 198–209.

Lander, J. and Fowler-Kerry S., Age differences in children's pain, Percept. Mot. Skills, 73 (1991) 415–418.

Lehmann, T., Russell, D., Spratt, K., Colby, H., Liu, Y., Fairchild, M. and Christensen, S., Efficacy of electroacupuncture and TENS in the rehabilitation of chronic low back pain patients, Pain, 26 (1986) 277–290.

Loeser, J., Black, R. and Christman, R., Relief of pain by transcutaneous stimulation, J. Neurosurg., 42 (1975) 308–314.

Macora, F., Aladjemoff, L., Tannenbaum, J. and Magora, A., Treatment of pain by transcutaneous electrical nerve stimulation, Acta Anaesth. Scand., 22 (1978) 589–592.

Mannheimer, C. and Lampe, G., Clinical Transcutaneous Electrical Nerve Stimulation, Davis, Philadelphia, PA, 1984.

Mannheimer, C., Carlsson, C., Vedin, A. and Wilhelmsson, C., Transcutaneous electrical nerve stimulation (TENS) in angina pectoris, Pain, 26 (1986) 291–300.

Mather, L. and Mackie, J., The incidence of postoperative pain in children, Pain, 15 (1983) 271–282.

Maunuksela E.L., Korpela R., Double-blind evaluation of a lignocaine-prilocaine cream (EMLA) in children: effect on the pain associated with venous cannulation, Br. J. Anaesth., 58 (1986) 1242–1245.

McGrath, P.A., Pain in Children: Nature, Assessment and Treatment, Guilford Press, New York, pp. 466.

McGrath, P.A., DeVeber, L. and Hearn, M., Multidimensional pain assessment in children. In: Fields, Dubner and Cervero (Eds.), Advances in Pain Research and Therapy, Vol. 9, Raven Press, New York, 1985, pp. 387–393.

McGrath, P.J. and Unruh, A., Pain Research and Clinical Management, Elsevier, Amsterdam, 1987, pp. 351.

Ottoson, D. and Lundeberg, T., Pain Treatment by TENS, Springer, Berlin, 1988, pp. 130.

Papay, J. and Spielberger, C., Assessment of anxiety and achievement in kindergarten and first- and second-grade children, J. Abnorm. Child Psychol., 14 (1986) 279–286.

Richardson, R., Meyer, P. and Cerullo, L., Neurostimulation in the modulation of intractable paraplegic and traumatic neuroma pains, Pain, 8 (1980) 75–84.

Richter, I.L., McGrath, P.J., Humphreys, P.J., Goodman, J.T., Firestone, P. and Keene, D., Cognitive and relaxation treatment of paediatric migraine, Pain, 25 (1986) 195–203.

Roche, P.A., Gijsbers, K., Belch, J.J.F. and Forbes, C.D., Modification of haemophiliac haemorrhage pain by transcutaneous electrical nerve stimulation, Pain, 21 (1985) 43–48.

Rosenberg, M., Curtis, L. and Bourke, D.L., Transcutaneous electrical nerve stimulation for the relief of postoperative pain, Pain, 5 (1978) 129–133.

Schuster, G.D. and Infante, M.C., Pain relief after low back surgery: the efficacy of transcutaneous electrical nerve stimulation, Pain, 8 (1980) 299–302.

Smith, C., Guralnick, M., Gelfand, M. and Jeans, M., The use of transcutaneous electrical nerve stimulation on post-cesarean pain, Pain, 27 (1986) 181–193.

Spielberger, C.D., Gorsuch, R.L., Lushene, R.E., Vagg, P. and Jacobs, G., Manual for the State-Trait Anxiety Inventory, Consulting Psychologists Press, Palo Alto, CA, 1983, p. 35.

Tabachnick, B.G. and Fidell, L.S., Using Multivariate Statistics, Harper and Row, New York, 1983, p. 509.

Willer, J.C., Relieving effect of TENS on painful muscle contraction produced by an impairment of reciprocal innervation: an electrophysiological analysis, Pain, 32 (1988) 271–174.

Wolfner, J.A. and Visintainer, M.A., Pediatric surgical patient's stress responses and adjustment, Nurs. Res., 24 (1975) 244–255.

Woolfson, A.D., McCafferty, D.F. and Boston, V., Clinical experiences with a novel percutaneous amethocaine preparation: prevention of pain due to venepuncture in children, Br. J. Clin. Pharmacol., 30 (1990) 273–279.