Pain, 17 (1983) 179–188
Elsevier

PAI 00546

Postoperative Pain Control: Contribution of Psychological Factors and Transcutaneous Electrical Stimulation

Alan T. Lim, Geraldine Edis, Henryk Kranz, George Mendelson, Tom Selwood and David F. Scott

Pain Study Group, Prince Henry's and Alfred Hospitals, Melbourne, Victoria (Australia)

(Received 11 January 1983, accepted 16 March 1983)

Summary

The influence of transcutaneous electrical stimulation (TES) and psychological factors in determining the intensity of acute postoperative pain was examined in a prospective, double-blind controlled trial completed by 30 patients having elective surgery. Psychometric tests were administered prior to surgery. Postoperative pain was assessed by cumulative morphine requirement (M48) administered intramuscularly, and the mean score of a visual analogue scale of pain (VAS), in the first 48 h following surgery. M48 was significantly correlated with the VAS score ($r = 0.62$, $P < 0.001$), and with the psychometric test scores for trait-anxiety ($r = 0.70$, $P < 0.001$) and neuroticism ($r = 0.67$, $P < 0.001$). Though patients treated with TES required 25% less morphine than those treated with placebo, the difference was not significant using monovariate analysis and applying unpaired two-tailed Student's t-test ($P > 0.2$). When the contribution of neuroticism to the variance of M48 was adjusted using multiple regression analysis, the effect of TES became significant at the 0.05 level. Covariance analysis showed that TES contributed some 19% to the explained variance of M48 while neuroticism contributed about 80%, and there was no interaction between these two factors. These findings allow a degree of prediction of the individual patient's postoperative pain and narcotic requirement, and point to a strong correlation between postoperative pain perception and personality.

Address for correspondence: Dr. Alan Lim, Department of Surgery, Monash University, Prince Henry's Hospital, Melbourne, Victoria 3004, Australia.

Supported by grants from the National Health and Medical Research Council, the Ramaciotti Foundation and the Alfred Hospital Research Fund.

Introduction

Several therapeutic options have been explored in the management of acute postoperative pain (POP). These include regional nerve block [9], continuous opiate infusion [17] and transcutaneous electrical stimulation (TES) [13]. This study was concerned with evaluating the contribution of psychological factors to the degree of POP, and with determining the analgesic effect of TES in POP following major upper abdominal surgery. There is uncertainty about the efficacy of TES in POP control, with some studies claiming benefit [13,25] and others failing to demonstrate a significant analgesic effect [18]. The reasons for the conflicting results of TES treatment were explored. Significant variation in patients' analgesic requirement following identical surgical procedures has been noted previously, and was considered to be related to individual psychological differences [5], but this was not analysed quantitatively. In the present study the influence of psychological factors on the degree of POP and the effectiveness of TES treatment was examined. The variability between patients in the experience of POP, which may have contributed to the conflicting results of earlier trials of TES treatment [13,18], was found to be related to patients' psychological characteristics.

Since the validity of experimentally induced pain as a model for the study of acute pain in humans has been questioned [5,21], attention has been focussed on real-life events such as POP in the investigation of acute pain and analgesic therepy [20]. The influence of personality factors on the level and response to treatment of chronic pain has been documented elsewhere [23].

Methods

To establish a baseline for the present study, a retrospective examination was made of 60 patients who satisfied the criteria for the prospective trial, and who had surgery at the same hospital over the preceding 18 months. In this group, morphine had been administered at 0.15 mg/kg body weight, intramuscularly at 4 h intervals on a demand schedule. Total morphine requirement in the first 48 h postoperative period (M48) was 75 ± 26.5 mg ($\overline{X}_R \pm$ S.D.). This represented 79% of the total morphine intake (90.9 ± 45.1 mg) in the postoperative period. In view of the placebo effect previously observed in POP studies [21], it was considered that the mean M48 of a prospective TES treatment group ($\overline{X}_P$) should be less than 50% of $\overline{X}_R$ for TES to be deemed effective. Thus $\overline{X}_R - \overline{X}_P \geq 35.7$ mg morphine. The minimum number of patients needed to reject this hypothesis with 95% certainty at the 5% level of significance, using unpaired two-tailed Student's *t*-test was determined to be 14 in each of a control and test group [3].

This prospective double-blind study involved 34 patients admitted electively for upper abdominal surgery (Table I). The following criteria applied to the selection of patients: age 21–65 years, Anglo-Saxon cultural background, ability to communicate in English, absence of systemic disease requiring active medical treatment and no prior exposure to TES treatment. Patients with a history of malignant disease,

organic brain damage, major psychological disturbance and known analgesic or alcoholic abuse were excluded. The procedure and involvement of the study were explained to the patients, who were aware that routine analgesic drugs would be available on request. Informed written consent was obtained from all patients. The protocol was approved by the Hospital's Ethics Review Committee and complied with the guidelines on clinical trials of the National Health and Medical Research Council of Australia.

Patients were assessed on the day prior to surgery, and standardized psychometric tests were completed in questionnaire form. The tests were: form B of the Eysenck Personality Inventory (EPI) [16], designed to measure two major dimensions of personality, neuroticism and extraversion; State-Trait Anxiety Inventory (STAI) [29] comprising scales which measured two aspects of anxiety, state (A-state) and trait (A-trait). A-trait denotes anxiety proneness whereas A-state describes a transitory emotional state in response to situational stress; Zung's Self-Rating Depression Scale (SDS) [30], containing 20 items based upon the criteria most commonly used to characterize depressive illness.

Patients were allocated at random to TES or placebo (PL) treatment groups. The TES group received working stimulators (Neuromod 3722), and the PL group were given non-active stimulators with reversed batteries. Both groups were instructed in the use of the stimulator by the same demonstrator who explained the procedure in a neutral manner to minimize the effect of suggestion. The TES group experienced sensory stimulation from electrodes (Medtronic 3791) coated with electrode gel (Spectra 360) attached for demonstration purposes to the right subcostal margin. They were told to maintain a strong tingling sensation by adjusting the intensity and frequency of the stimulation as required. Patients in the PL group were treated similarly except they were told not to expect any particular sensation.

One hour prior to surgery diazepam 0.15 mg/kg was given orally and atropine 0.6 mg intramuscularly. Routine induction with thiopentone, suxamethonium and intubation was followed by fluothane 0.5% and nitrous oxide–oxygen anaesthesia in all cases. During the operation only a short acting opiate, fentanyl 50 μg, was given intravenously as deemed necessary by the anaesthetist. After surgery, a pair of sterile electrostrips (Epi-strip, Medtronic 3851) were placed 1 cm on either side of the incision and connected to the stimulators. In the TES group, the stimulators were turned on in the recovery room. Subsequently, patients were prescribed 0.15 mg/kg of morphine and 10 mg metoclopramide intramuscularly 4 hourly on demand. Patients were aware that the analgesic drug was available on request and the nursing staff were specifically instructed to administer the medication only when requested by the patients.

POP was assessed in the first 48 h postoperative period by a visual analogue scale of pain (VAS) and by cumulative morphine requirement [1]. The VAS consisted of a horizontal line 100 mm in length with 'no pain' and 'pain as severe as it could possibly be' at the left and right extremes respectively. Pain intensity was scored by measuring the distance of the subject's mark from the left extreme of the scale in millimeters. The VAS score was taken as the mean of that marked at 2, 4, 6, 24 and 48 h following surgery. Cumulative morphine requirement was determined 12, 24

and 48 h postoperatively. Data collection and analysis were performed by staff members unaware of the patient's treatment group.

The difference in scores between TES and PL groups was assessed using the unpaired two-tailed Student's *t*-test. Pearson correlation coefficient was used to test the relationship between the two pain rating parameters and the correlation between pain parameters and psychometric test scores. Least squares linear regression was employed to define the correspondence of M48 and neuroticism scores. The variation in patients' M48 was evaluated using covariance analysis adjusting for neuroticism score of each patient. Interaction and relative contribution of TES and neuroticism in determining the variance of M48 was evaluated using a saturated model of multiple linear regression with a dummy variable [3].

Results

The retrospective patients group provided a reference for the prospective study. It demonstrated that the mean M48 comprised 79% of the mean total postoperative morphine requirement, and that a large scatter in M48 existed (Fig. 1). Thirty patients completed the prospective study. Of the original 34 patients, one developed respiratory failure immediately after surgery, one wished to withdraw because of

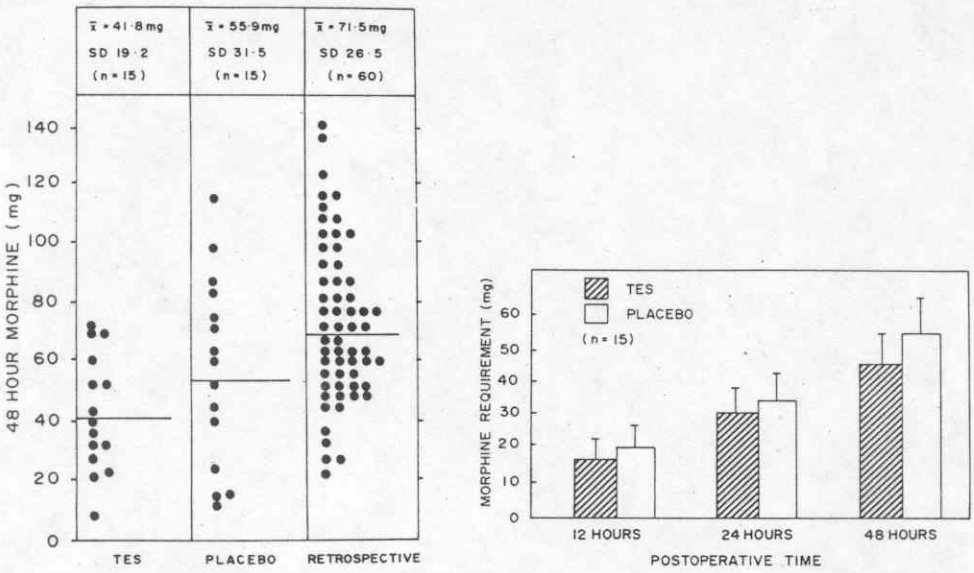

Fig. 1. Individual patients morphine requirement in the first 48 h postoperative period. From left to right, TES, placebo and retrospective treatment groups. Horizontal lines represent the group means.

Fig. 2. Cumulative morphine requirement (mean ± S.E.M.) at 12, 24 and 48 h postoperatively in TES and placebo treatment groups. None of the differences between the groups reached 0.05 level of statistical significance.

TABLE I

GENERAL CHARACTERISTICS OF THE PATIENTS

		TES (n = 15)	Placebo (n = 15)
Age	Mean	39.6	42.7
	S.D.	15.8	10.6
Weight	Mean	54.8	56.1
	S.D.	11.5	12.9
Male	(n)	6	7
Female	(n)	9	8
Cholecystectomy	(n)	11	13
Partial gastrectomy	(n)	4	2

emotional disturbance unrelated to the surgery or the trial, and in two patients data collection was incomplete. Comparison of the two treatment groups confirmed that randomization had been achieved (Table I). The mean patient age was 41.1 years, and there were 13 males and 17 females. Psychometric tests scores of the two groups before surgery were not significantly different and both were within normal limits (Table II).

The morphine requirement for both groups in the first 48 h after surgery is shown in Fig. 2. The TES group had a consistently lower mean rating, but the difference was not significant due to the large within-group variation. Individual patient's mean VAS score and M48 were significantly correlated ($r = 0.62$, $P < 0.001$) (Fig. 3). Because of this and the fact that the retrospective study showed that the major portion of total postoperative morphine intake occurred in the first 48 h, M48 was used as the single measure of individual patient's POP. The mean M48 in the prospective group of 48.8 ± 27.2 mg was significantly ($P < 0.01$) less than the

TABLE II

PATIENTS AND NORMALS PSYCHOMETRIC TESTS SCORES

		Normals	TES (n = 15)	Placebo (n = 15)
Neuroticism	Mean	10.5	11.1	10.6
(normals: n = 2000) [16]	S.D.	4.7	4.2	5.4
Extraversion	Mean	14.1	13.0	13.5
(normals: n = 2000) [16]	S.D.	3.9	4.4	3.3
Anxiety				
(normals: n = 333) [29]				
A-trait	Mean	38.1	36.2	37.4
	S.D.	8.2	8.3	8.3
A-state	Mean	40.0	39.7	40.7
	S.D.	7.8	7.4	8.0
Depression Index	Mean	0.33	0.34	0.35
(normals: n = 100) [30]	S.D.	0.05	0.08	0.05

TABLE III

CORRELATIONS OF PSYCHOMETRIC SCORES WITH 48 h MORPHINE REQUIREMENT

Parameter	Pearson correlation coefficient (n = 30)	*P* value
Neuroticism	0.67	0.001
Anxiety: A-trait	0.70	0.001
Anxiety: A-state	0.43	0.05
Depression Index	0.23	N.S.
Extraversion	0.16	N.S.

N.S., not significant.

71.5 ± 26.5 mg for the retrospective group. The mean M48 for the TES group (41.8 ± 19.2 mg) was 25% less than for the PL group (55.9 ± 31.5 mg), but this difference failed to reach statistical significance ($P > 0.20$).

Table III shows that individual patient's M48 correlated significantly with several personality factors assessed preoperatively. Some psychometric test scores correlated significantly with each other, in particular neuroticism and A-trait ($r = 0.82$, $P < 0.001$). When M48 as a dependent variable was linearly regressed against neuroticism, as an independent variable (Fig. 4), the regression coefficients of the TES ($b = 3.16$) and the PL ($b = 3.89$) groups were both significant ($P < 0.001$) but there was no significant difference between the two slopes. However, covariance analysis showed that when the bias due to neuroticism was removed, the difference between the mean M48 of two groups became significant ($t = 2.16$, df 27, $P < 0.05$).

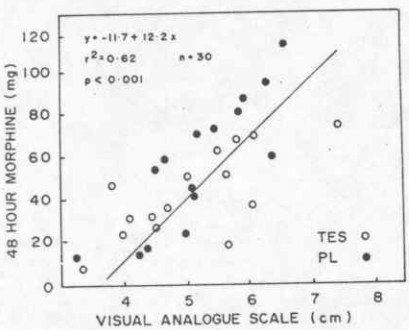

Fig. 3. Least squares linear regression for 48 h postoperative morphine requirement against the mean of visual analogue scale of pain score taken over the same period. Patients receiving TES and placebo treatment are included.

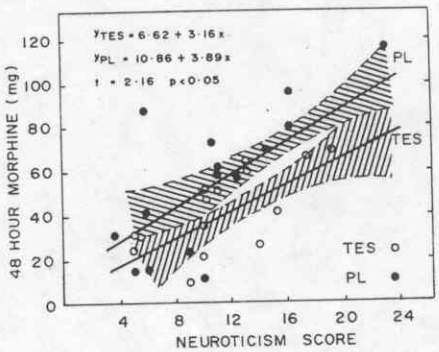

Fig. 4. Linear regressions for TES and placebo treatment groups: patient's 48 h postoperative morphine requirement against preoperative neuroticism scores. Solid lines are regressions fitted by the method of least squares. Shaded areas represent 95% confidence limits. Differences in the mean of morphine requirement between the two groups ($Y_{PL} - Y_{TES}$) is subjected to covariance analysis.

TABLE IV

ANALYSIS OF COVARIANCE

Source of variance	Sum of square (SS)	df	F	P
(1) Saturated model SS of TES, neuroticism	9446	3	7.31	0.005
(2) Additive model SS of TES and neuroticism	9373	2	10.88	0.005
SS of neuroticism adjusted for TES	7658	1	17.79	0.001
SS of TES adjusted for neuroticism	1874	1	4.35	0.05
(3) SS of interaction	72	1	0.17	N.S.
(4) SS residual	11192	26		

In order to evaluate the interactions and contribution of TES and neuroticism to the variance of M48, a saturated model of orthogonal multiple regression and covariance analysis with dummy variable for TES treatment was employed (Table IV). M48 was treated as the dependent metric variable, with neuroticism as covariate, TES as factor and their interaction term as independent variable. The model was able to explain 49% of the variance in M48 ($F = 7.31$, df = 3, 26, $P < 0.005$). It demonstrated that TES was a significant factor ($F = 4.35$, df = 1, 26, $P < 0.05$) and contributed 19% to the explained variance of M48. However, there was no interaction between TES and neuroticism ($F = 0.17$, df = 1, 26, $P > 0.05$). This finding was also confirmed by the parallel relationship between the regression slopes in Fig. 4.

Discussion

The validity of using M48 as a measure of POP appeared justified on the following grounds. Patients had analgesic medication on demand and could regulate the intake according to the need. The feasibility of patient controlled analgesic administration in the acute postoperative period has been shown in other studies [11]. As in previous reports [14], it was found that the first 48 h morphine intake accounted for some 80% of the total postoperative morphine requirement, and thus the major part of POP can be considered confined to this period. There was also a high correlation between M48 and the VAS score which assessed the patient's subjective reporting of POP. The findings support the general belief that patients who need more opiates postoperatively, experience greater pain.

The retrospective group had significantly higher mean M48 than the prospective group. There may be several responsible factors. One is the way medication orders were written and implemented. In the retrospective group the postoperative instruc-

tion was that morphine be given 4 hourly as required. Though patients had some control over analgesic intake, the precise extent of this was uncertain. The drug might have been administered at times not according to need but to minimize potential patient discomfort. A change in emphasis was introduced in the prospective group, when the patients were made directly responsible for dose schedule. An additional or alternate explanation for the difference may lie in the placebo effect. If patients thought that another form of analgesic was active, the need for narcotic medication may have been decreased. The 32% reduction in the mean M48 of the prospective group is in good agreement with the magnitude of the placebo effect reported in other studies [5,21]. Such interpretation is consistent with previous findings that placebo treatment can produce a potent analgesic effect, and that it is important to be included in clinical studies as a control. The variation of M48 in the retrospective and the prospective populations showed no tendency for clustering. The divisions of patients into placebo responders and non-responders, which is prominent in some reports [19], may be arbitrary. Patients with low A-trait and neuroticism scores in both TES and PL groups had low M48 (Fig. 4). Although a cut-off point could be designated and the patients divided into groups according to the M48 there appeared to be no justification for this in the results.

The choice of a satisfactory control for TES treatment is difficult. The patients in the PL group went through the same preoperative instruction and were physically attached to the equipment in the postoperative treatment. As none had previous exposure to TES no specific sensation was expected and no patient in the PL group inquired about the lack of this. It is common for patients exposed to a wide range of medical and physical therapeutic measures to experience no physical sensation although the treatment is exerting its effect. The lack of sensation in the PL group therefore did not appear to lead the patients to assume that no therapeutic effect was being exerted.

Monovariate analysis showed no significant difference between the mean M48 of the TES and PL groups. This is in agreement with other studies [12] and suggests that monovariate analysis is insensitive in the study of POP where multiple factors may be involved. The importance of a multivariate approach to include psychological factors becomes apparent when the contribution of the latter to M48 variance was determined. The multivariate analysis showed that some 80% of the explained variance of M48 was accounted for by the neuroticism scores alone. By controlling for this single psychological factor, a significant difference between M48 of the TES and PL groups emerged. The specific contribution of TES in reducing narcotic requirement could then be assessed. The TES group had a 25% lower narcotic requirement (Fig. 4), which was a small but significant ($P < 0.05$) analgesic effect. Since the therapeutic effect of TES did not interact with personality factors, it is probable that TES acts by modulating sensory input and not by altering the psychological state of the patients.

Electrical stimulation at various levels of the neuraxis has found therapeutic application. Stimulation of the peri-aquaductal grey area [26], posterior columns of the spinal cord [27] and peripheral nerves [10] has been used to relieve pain. TES has the advantage of being easy to apply, relatively inexpensive, non-invasive, and it can

be used for limited periods as the need arises. The potency of TES as used in this study was found to be low. If it acts by activating an endogenous pain suppression system [4] through the release of endorphins [28], it appears to be too weak and non-specific a stimulus to be of major clinical significance. It is possible that other forms and methods of TES [6] may be more effective.

To explain the variable experience of pain, models have been proposed which take account of sensory input and its modification by individual personality factors [22]. The significance of the items measured in this study, in particular A-trait and neuroticism, is not clear. These psychological parameters apparently reflect biologically determined characteristics [15]. The strong correlation between neuroticism scores and M48 suggests that certain psychological parameters may be related to the ease of activating the endogenous pain suppression system [2], and thus to the requirement of postoperative narcotics. It will be of interest to determine if personality factors exert a controlling influence on the pain suppression system, and whether this can be subjected to pharmacological or behavioural [8] modification.

The quantitative relationship established between M48 and personality factors (Fig. 4) makes it possible to predict an individual patient's analgesic requirement in the acute postoperative period. The findings point to a strong relationship between personality and postoperative pain perception. The results should find application in studies of acute pain, in particular in terms of factors which influence its apparent severity [7,24], and should help to make future studies of acute pain and analgesic therapy more productive.

Acknowledgement

We are indebted to Dr. Michael Tronson, Department of Anaesthesia, Prince Henry's Hospital, for his co-operation throughout the study.

References

1 Aitken, R.C.B., Measurement of feeling using visual analogue scales, Proc. roy. Soc. Med., 62 (1969) 989–993.
2 Almay, B.G., Johansson, F., Von Knorring, L., Terenius, L. and Wahlström, A., Endorphine in chronic pain. I. Differences in CSF endorphin levels between organic and psychogenic pain syndromes, Pain, 7 (1978) 153–162.
3 Armitage, P., Statistical Methods in Medical Research, Blackwell Scientific Publications, Oxford, 1971.
4 Basbaum, A.I. and Fields, H.L., Endogenous pain control mechanisms: review and hypothesis, Ann. Neurol., 4 (1978) 451–462.
5 Beecher, H.K., Measurement of Subjective Response, Oxford University Press, New York, 1959.
6 Birkhan, J., Carnion, A., Meretsky, P. and Zuider, H., Modifications of TENS by constant-energy stimulations delivered through multiple electrodes: method and evaluation. In: J.J. Bonica (Ed.), Advances in Pain Research and Therapy, Raven Press, New York, 1979, pp. 607–613.
7 Bond, M.R., Psychological and psychiatric aspects of pain, Anaesthesia, 33 (1978) 355–361.
8 Bonica, J.J., Neurophysiological and pathological aspects of acute and chronic pain, Arch. Surg., 112 (1977) 750–761.

9 Bridenbaugh, P.O., DuPen, D.L., Moore, D.C., Bridenbaugh, L.D. and Thompson, G.E., Postoperative intercostal nerves block analgesia versus narcotic analgesia, Anesth. Analg., 52 (1973) 81–85.
10 Campbell, J.N. and Long, D.M., Peripheral nerve stimulation in the treatment of intractable pain, J. Neurosurg., 45 (1976) 692–699.
11 Chakravarty, K., Tucker, W., Rosen, M. and Vickers, M.D., Comparison of buprenorphine and pethidine given intravenously on demand to relieve postoperative pain, Brit. med. J., 2 (1979) 895–897.
12 Chapman, C.R. and Cox, G.B., Anxiety, pain and depression surrounding elective surgery: a multivariate comparison of abdominal surgery patients with kidney donors and recipients, J. psychosom. Res., 21 (1977) 7–15.
13 Cooperman, A.M., Hall, B., Mikalacki, K., Hardy, R. and Sadar, E., Use of transcutaneous electrical stimulation in the control of postoperative pain, Amer. J. Surg., 133 (1977) 185–187.
14 Egbert, L.D., Battit, G.E., Welch, C.E. and Bartlett, M.K., Reduction of postoperative pain by encouragement and instruction of patients, New Engl. J. Med., 270 (1964) 825–827.
15 Eysenck, H.J., The Biological Basis of Personality, Thomas, Springfield, Ill., 1967.
16 Eysenck, H.J. and Eysenck, S.B.G., Manual of the Eysenck Personality Inventory, University of London Press, London, 1964.
17 Fry, E.N., Postoperative analgesic using continuous infusion of papaveretum, Ann. roy. Coll. Surg. Engl., 61 (1979) 371–372.
18 Hymes, A.C., Yonehiro, E.G., Raab, D.E., Nelson, G.D. and Printy, A.L., Electrical surface stimulation for treatment and prevention of ileus and atelectasis, Surg. Forum, 25 (1974) 222–224.
19 Levine, J.D., Gordon, N.C., Bornstein, J.C. and Fields, H.L., Role of pain in placebo analgesia, Proc. nat. Acad. Sci (Wash.), 76 (1979) 3528–3531.
20 Levine, J.D., Gordon, N.C. and Fields, H.L., Naloxone dose dependently produces analgesia and hyperalgesia in postoperative pain, Nature (Lond.) 278 (1979) 740–741.
21 Levine, J.D., Gordon, N.C., Jones, R.T. and Fields, H.L., The narcotic antagonist naloxone enhances clinical pain, Nature (Lond.), 272 (1978) 826–827.
22 Melzack, R. and Casey, K.L., Sensory, motivation, and central control determinants of pains: a new conceptual model. In: D.R. Kenshalo (Ed.), The Skin Senses, Thomas, Springfield, Ill., 1968, pp. 423–429.
23 Mendelson, G., Selwood, T.D., Kranz, H., Loh, T.S. and Scott, D.F., Acupuncture treatment of chronic back pain: a double-blind placebo-controlled trial, Amer. J. Med., 74 (1983) 49–55.
24 Parbrook, G.D., Steel, D.F. and Dalrymple, D.G., Factors predisposing to postoperative pain and pulmonary complications, Brit. J. Anaesth., 45 (1973) 21–32.
25 Pike, P.M.H., Transcutaneous electrical stimulation, Anaesthesia, 33 (1978) 165–171.
26 Richardson, D.E. and Akil, H., Pain reduction by electrical brain stimulation in man, J. Neurosurg., 47 (1977) 178–183.
27 Shealy, C.N., Mortimer, J.T. and Reswick, J.B., Electrical inhibition of pain by stimulation of the dorsal columns: preliminary clinical report, Anesth. Analg., 46 (1967) 489–491.
28 Sjölund, B., Terenius, L. and Eriksson, M., Increased cerebrospinal fluid levels of endorphins after electro-acupunture, Acta physiol. scand., 100 (1977) 382–384.
29 Spielberger, C.D., Corsuch, R.L. and Lishene, R.E., Manual for the State-Trait Anxiety Inventory, Consulting Psychologists Press, Palo Alto, Calif., 1976.
30 Zung, W.W.K., A self-rating depression scale, Arch. gen. Psychiat., 12 (1965) 63–70.