Comparison between patient-controlled analgesia and intramuscular meperidine after thoracotomy

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A prospective randomized controlled study was performed to assess the efficacy and safety of patient-controlled analgesia (PCA) in patients undergoing thoracotomy. This method was compared with a conventional pain management technique consisting of regularly scheduled im injections of analgesics. Forty adult patients were randomly assigned to receive intravenous PCA or im meperidine treatment over a 48-hr period after surgery. Care was taken to optimize analgesia in patients of both groups. The McGill Pain Questionnaire, visual analogue and verbal-numeric scales were administered at regular intervals to measure various components of the patients' pain experience, degree of pain relief, adverse side effects and overall treatment efficacy. Functional recovery after surgery was also examined. The results showed good and comparable analgesia with both pain-control methods. However, a greater number of patients receiving im injections required dosage adjustments than in the PCA group. Patients' and nurses' evaluations of overall treatment efficacy also favoured PCA treatment. There were no major group differences in the side effect profile. Recovery pattern was also comparable in the two groups except for the length of hospitalisation. There were fewer long-stay patients in the PCA than in the im group. Meperidine intake was similar in both groups but considerable interpatient variation was seen. In conclusion, PCA is a safe, effective and individualized treatment method for controlling pain after thoracotomy. There appears to be some clinical advantages of PCA over im dosing regimens for analgesia after thoracotomy.

Une étude prospective dûment contrôlée fut effectuée afin d'évaluer l'efficacité et la sécurité de l'auto-analgésie intraveineuse (patient-controlled analgesia: PCA) chez des patients ayant subi une thoractomie. Cette méthode était comparée à un mode conventionnel d'analgésie où des injections intramusculaires (im) d'analgésiques étaient administrées de façon régulière. Quarante patients adultes furent assignés au hasard à l'un ou l'autre groupe de traitement où de la mépéridine était administrée soit en mode PCA, soit en mode im. L'étude s'est échelonnée sur une période de 48 hr après la chirurgie. L'obtention d'une analgésie optimale a fait l'objet d'une attention particulière et ce, chez les patients des deux groupes. Le questionnaire McGill sur la douleur de même que des échelles de type visuel analogique et verbal-numérique furent administrés à intervalles fréquents afin de mesurer différentes composantes de la douleur des patients, le degré de soulagement, les effets secondaires et l'efficacité globale du traitement. Certains paramètres de récupération fonctionnelle ont également été mesurés. Les résultats ont démontré une analgésie adéquate et comparable avec les deux types de traitement. Toutefois, un nombre plus élevé de patients du groupe im a nécessité des changements de dosage par rapport au groupe PCA. Les mesures d'efficacité globale obtenues en fin de traitement auprès des patients et des infirmières militaient également en faveur du mode PCA. Le profil des effets secondaires ne montrait pas de différence majeure entre les deux groupes. Les paramètres de récupération étaient également comparables sauf pour le séjour hospitalier qui était moindre chez les patients du groupe PCA. La consommation de mépéridine était similaire chez les deux groupes mais les quantités variaient considérablement d'un patient à l'autre. En conclusion, le PCA apparaît être une méthode efficace et sécuritaire pour soulager la douleur post-thoracotomie; elle fournit un traitement individualisé et avantageux par rapport au mode traditionnel d'injections im.

Key words
ANALGESIA: PCA postoperative;
ANALGESICS: meperidine;
PAIN: postoperative;
SURGERY: thoracic.

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Pain after thoracotomy is recognized as one of the most severe type of post-surgical pain.[1] The pain usually lasts longer than after abdominal or orthopaedic surgery, and its intensity can reach excruciating levels.[2,3] Pain in the thorax prevents the patients from breathing and coughing, thereby increasing the probability of pulmonary complications.[4] Adequate analgesia is often difficult to achieve and several analgesic techniques including conventional *im* dosing regimens have been tried with varying degrees of success.[1,5] However, little attention has been paid to the potential usefulness of patient-controlled analgesia (PCA). This technique allows the patient to self-administer narcotic medication intravenously within limits prescribed by the physician.[6] As the patient can titrate his medication according to his own needs, the marked differences in the pharmacokinetic and pharmacodynamic behaviour of opioids in individual patients can be overcome.[7] Patients' acceptance of PCA is usually very high, and numerous clinical reports have demonstrated its efficacy and safety for postsurgical pain.[6-8] However, many of these studies have been criticized for their methodological shortcomings.[6,7] Furthermore, the suitability of PCA has not been clearly established for situations such as after thoracotomy where the patient's condition is more critical and the pain very severe. Very few studies on the use of PCA after thoracotomy have been reported[9-12] and further research is clearly needed to assess the therapeutic merit of PCA against more conventional treatment methods for this type of postsurgical pain.

The present study was undertaken to assess the efficacy and safety of *iv* PCA in patients undergoing a thoracotomy. Patient-controlled analgesia was compared with *im* meperidine injections in order to examine whether PCA offered clinical advantages over traditional pain therapy.

Methods

The study protocol was approved by the Hospital Ethics Committee. A prospective, randomized design was used to compare the PCA and *im* treatments. The trial was not carried out in a double-blind manner based on technical difficulties experienced in previous trials.[13,14]

Forty patients aged 18 to 70 yr, ASA physical status I–III, who were scheduled for elective thoracotomy, participated in this prospective study. Upon enrollment in the study, patients provided informed written consent and were randomly assigned to PCA ($n = 20$) or *im* treatment groups ($n = 20$). According to tables,[15] a sample size of 26 was indicated to assure a power of 0.80 for detecting a large effect size at the 0.05 level of confidence. Such an effect size ensures that group differences are not negligible but sufficiently large to be clinically important.[16] In the present study, sample size was further reduced to 20 due to time limitation and financial contingencies.

All patients received standardized anaesthesia. Premedication was with meperidine *im* and anaesthesia was maintained with fentanyl *iv*, isoflurane and nitrous oxide. After surgery, both groups were given boluses of meperidine in the recovery room until they were pain-free. In the PCA group, the boluses consisted of 0.2 $mg \cdot kg^{-1}$ *iv* every ten minutes; in the *im* group, they consisted of 0.1 $mg \cdot kg^{-1}$ *iv* + 0.6 $mg \cdot kg^{-1}$ *im*, followed by 0.5 $mg \cdot kg^{-1}$ *im* every 30 min. Once the patient's base level of analgesia had been established, the trial was started and lasted for 48 hr. Patients allocated to the PCA group were provided with a Lifecare® PCA infuser (Abbott Laboratories) which was connected to an *iv* line and programmed to administer initial bolus of 0.2 $mg \cdot kg^{-1}$ of meperidine with a lockout interval of six minutes. In the *im* group, the initial meperidine doses were 1 $mg \cdot kg^{-1}$ *im* every four hours. Care was taken to optimize analgesia while minimizing sedation in control subjects as well as in PCA subjects. If the patient did not obtain acceptable analgesia (pain intensity score ≥ 4 on the visual analogue scale), the dosages of the PCA bolus or *im* injections were first increased by 50% and then adjusted in increments of 25% of the initial dose. If the patient's respiratory rate was less than eight breaths per minute or the patient was over-sedated, the dosage was decreased by 25%. Orders for dimenhydrinate PRN for nausea were written for each patient. No sedatives, central nervous system-acting agents or analgesics other than meperidine were allowed during the study.

Patients' pain was assessed using two measures. The first series was collected at one hour after the beginning of the study, every two hours for four hours and every four hours thereafter (*im* group: one hour after each injection). On each occasion, the nurses asked the patients to rate the intensity of their present pain using a 10 cm visual analogue scale (VAS). At 24 and 48 hr after the start of the study, a second set of pain assessments was collected by a research assistant. These measures included the McGill Pain Questionnaire[17] which was used to assess the overall pain during the previous 24 hr; VAS scales were administered to measure pain intensity at its worst, its least and overall during the previous 24 hr; pain relief and nausea ratings were also obtained from each patient with VAS scales. Upon completion of the study, the same type of scale was used by the patient to rate the overall efficacy of the analgesic treatment. When used to assess pain intensity, the anchor words of the VAS scale were "no pain – unbearable pain"; for the nausea scale, they were "not at all – extremely"; and they were replaced by the expressions "not at all – completely" when used to measure pain relief and overall treatment efficacy.[18,19]

Patients' vital signs (respiratory rate, blood pressure and pulse rate) were monitored one hour after the start

of the study, every two hours for four hours and every four hours thereafter. At the same time, the nurse recorded analgesic intake and evaluated patient's somnolence using a five-point scale where 1 represented wide awake, 2 drowsy, 3 dozing intermittently, 4 sleeping frequently, 5 wakens only when aroused. Any other adverse side effects of the analgesic medication were also noted. At the end of the work shift, each treating nurse was asked to provide a VAS rating of the overall efficacy of the analgesic treatment.

Pulmonary function tests were performed in each patient using a portable pneumotachograph spirometer (Vitalograph Co, London, England) which measured forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). The tests were performed on the day before the surgery, and at 24 and 48 hr postoperatively, while the patients were in an upright sitting position. Arterial blood gas analysis, ($PaCO_2$: partial pressure of carbon dioxide) were done preoperatively, in the recovery room (upon arrival, after extubation, one hour after the first meperidine dose) and in the intensive care unit (20 min, six hours and 12 hr after arrival).

Additional outcome measures included the number of hours in the intensive care unit (ICU), time to first ambulation and duration of hospitalisation after surgery. Other relevant medical or demographic information was obtained by chart review.

Following the 48-hr study period, PCA treatment was discontinued and the patients were given *im* meperidine for pain relief. The dosage was assigned according to the customary schedule of the treating physician. The same procedure was used with the patients of the *im* group.

Group comparability on demographic and medical variables was analyzed using t tests (continuous data) and chi-square analyses (categorical data). Pain and sedation scores, collected every four hours, were averaged over 24 hr periods and were analysed using repeated measures ANOVAs. Comparable ANOVAs were performed on the outcome variables which were measured once a day and on the medication data cumulated over 24 hr periods. For other measures, parametric (t test) and non-parametric tests (chi-square test and Fisher exact test) were performed where applicable. For all analyses, $P < 0.05$ was considered statistically significant.

Results

The two study groups were comparable in weight, sex, ASA status, type of surgery, and dose of fentanyl during surgery (Table I). The PCA patients were slightly younger than patients of the *im* group ($P < 0.05$).

The pain profile was comparable for the PCA and *im* groups during the 48 hr of the study (Figure 1). When the VAS scores were averaged over 24 hr periods, no difference was found between the two groups. However, the pain scores in the *im* group were higher on the first than on the second day (4.1 ± 1.9 vs 3.0 ± 1.4) ($P < 0.05$). No difference was found in the PCA group (3.3 ± 1.4 vs 3.6 ± 1.9).

No group difference was found in any of the measures except for the pain relief scale. During the first day after the surgery, patients of the PCA group reported more pain relief than the *im* group ($P < 0.05$). On the second day, the two groups did not differ (Table II).

Upon completion of the study, the overall efficacy of the analgesic treatment was rated higher by the patients in the PCA group. Their mean VAS score was 8.6 ± 1.3 compared with 7.5 ± 1.7 in *im* group ($P < 0.05$). A similar pattern of results was observed for the nurses' overall evaluations of the pain therapy. Their VAS efficacy ratings averaged over the study period was superior

TABLE I Patient group characteristics

	PCA group	*IM group*
Age (yr)	50.4 ± 13.5	57.4 ± 7.2*
Sex: Female/male	9/11	4/16
Weight (kg)	68.9 ± 12.1	70.9 ± 8.1
ASA: I/II/III	8/11/1	9/9/2
Surgery		
- Pneumonectomy	6	4
- Lobectomy	9	12
- Diagnostic thoracotomy	5	4
Intraoperative fentanyl dose ($\mu g \cdot kg^{-1}$)	7.8 ± 2.3	8.2 ± 2.0

Values are number of patients or units shown, mean ± SD.
* $P < 0.05$.

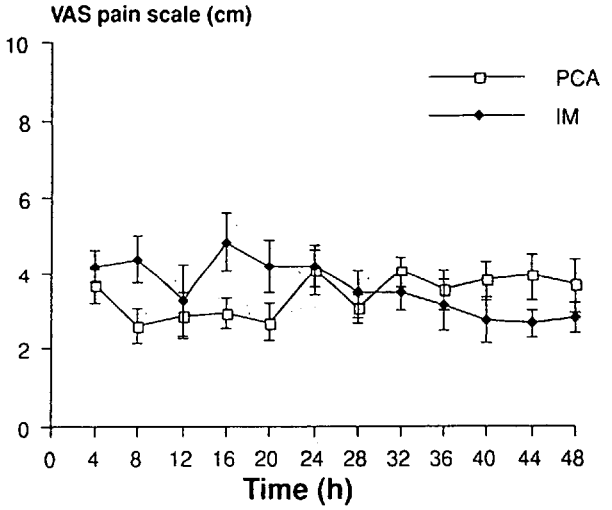

FIGURE 1 Visual analogue pain scores (mean ± SEM) of PCA and *im* groups recorded at four-hour intervals for the duration of the study.

TABLE II Comparison of scores (mean ± SD) obtained using the McGill Pain Questionnaire and the visual analogue scales for the PCA and *im* groups

	Day	*PCA group*	*IM group*
McGill Pain Questionnaire	1	36.9 ± 13.4	35.2 ± 15.2
	2	31.3 ± 15.3	30.6 ± 18.5
Visual analogue scales			
- Pain at its worst	1	7.1 ± 2.2	7.6 ± 2.0
	2	6.6 ± 2.5	7.3 ± 1.3
- Pain at its least	1	0.8 ± 1.1	1.0 ± 1.3
	2	0.5 ± 1.0	0.6 ± 1.3
- Overall pain	1	3.9 ± 1.5	4.0 ± 2.1
	2	3.9 ± 1.7	4.5 ± 1.8
- Pain relief	1	7.5 ± 2.1	6.0 ± 2.4
	2	7.7 ± 2.0	7.7 ± 1.9

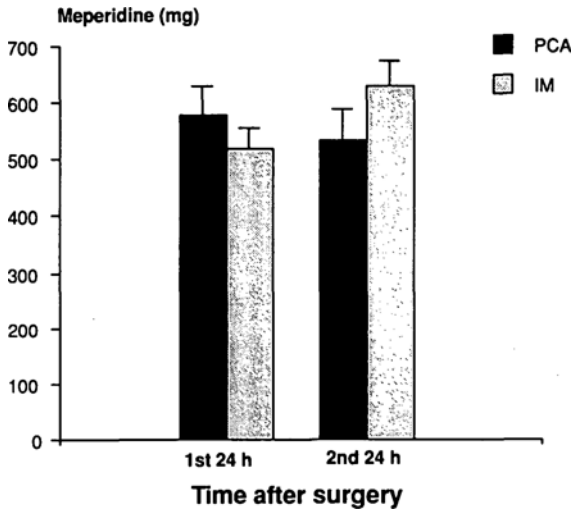

FIGURE 2 Meperidine intake (mean ± SEM mg) in PCA and *im* groups during the 48 hr of the study.

for the PCA treatment (6.7 ± 1.3) than for the *im* dosing regimens (5.5 ± 1.5) ($P < 0.01$).

For the patients assigned to the PCA group, the mean dose of meperidine administered in the recovery room before initiating the study was 72 ± 66 mg (range: 10–251 mg) compared with 163 ± 63 mg (range: 60–290 mg) in the control group (*im*) ($P < 0.001$). However, there was no difference between the two groups with respect to the total amount of meperidine they received over the whole study period (PCA: 1185 ± 444 mg vs *im*: 1316 ± 344 mg).

There was no difference in the meperidine consumption in the PCA and *im* groups during the first or second 24 hr of the study (Figure 2). No time effect was found in the PCA group but in the *im* group patients required more meperidine on the second day than on the first ($P < 0.05$).

Seventy percent of the *im* group patients (14/20) required one or more dosage changes over the study period. In the PCA group, only 35% (7/20) of the patients required an increase or decrease in medication ($P < 0.05$).

Analgesic consumption was highly variable. In both groups, considerable interpatient variation was found in the total meperidine intake: 156 mg to 1860 mg in the PCA group, and 600 mg to 1720 mg in the *im* group.

Sedation scores were similar for the PCA and *im* groups (2.1 ± 0.7 vs 2.1 ± 0.6) over the study period. Both groups tended to be more sedated on the first day (2.3 ± 0.8) than on the second (1.9 ± 0.8) ($P < 0.05$).

Little or no nausea was reported by the majority of the patients. The mean VAS score of the PCA patients was 1.5 ± 2.0 for the two days of the study, compared with 0.4 ± 0.8 in the other group ($P < 0.05$). There was no difference in the number of patients who were given antiemetic medication in each group (PCA: 5 vs *im*: 3).

No hypotension or respiratory depression was observed with either treatment. Pulmonary function tests revealed no difference between the groups. The mean $PaCO_2$ values were comparable for the two groups (Figure 3A) and the reduction in forced expiratory volume (FEV_1) and vital capacity (FVC) was also similar (Figure 3B and 3C).

There was no difference between the groups in the time they spent in the ICU (PCA: 23.4 ± 13.5 hr; *im*: 21.8 ± 12.7 hr) or in the time to first ambulation (PCA: 32.5 ± 11.1 hr; *im*: 30.4 ± 8.7 hr). On average, the length of hospitalisation in the PCA treated patients was 7.2 ± 2.7 days compared with 9.3 ± 5.2 in the *im* group. The reduction observed in the PCA group failed to reach statistical significance. However, when the percentage of patients who left the hospital within one week of thoracotomy was compared for the two groups (PCA: 80% (16/20); *im* group: 45% (9/20)), the difference was statistically significant ($P < 0.05$) (Figure 4). There was no correlation between patient's age and length of hospitalisation after surgery.

Discussion

Post-thoracotomy pain can be very severe and difficult to manage with conventional analgesic techniques. The present study compared the efficacy and safety of PCA with a traditional *im* dosing regimen using a prospective randomized controlled design. Contrary to previous PCA studies,[6] comparison was made by providing equianalgesia with both methods of treatment and then assessing the potential benefits and clinical advantages of PCA.

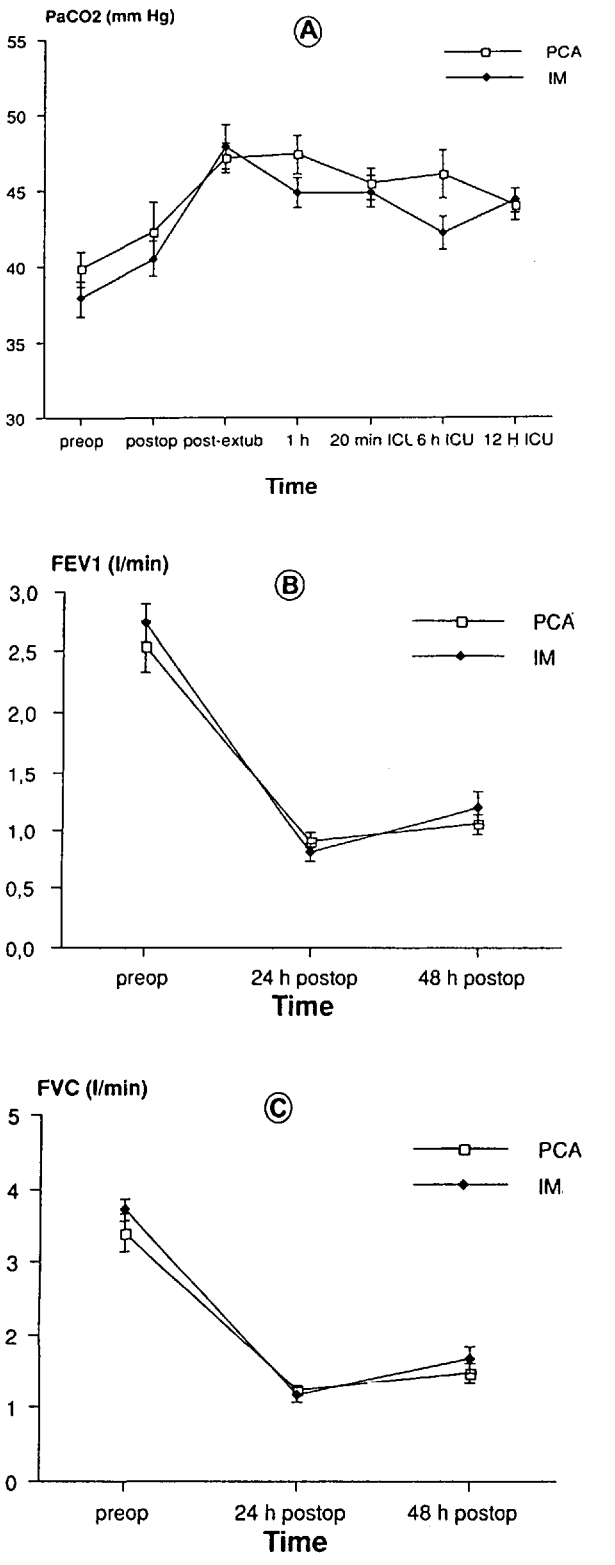

FIGURE 3 Results (mean ± SEM) of pulmonary function tests (A: $PaCO_2$; B: FEV_1; C: FVC) for the PCA and *im* groups before and after surgery.

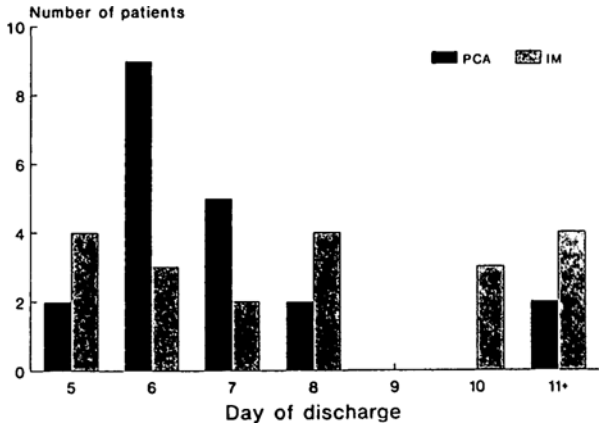

FIGURE 4 Distribution of the length of hospitalisation for the patients of the PCA and *im* groups.

Results obtained on the various pain scales confirmed that it was possible to achieve good and comparable analgesia with both pain-controlling methods. Pain intensity scores were similar in the two groups but higher levels of pain relief were reported by the PCA patients. Furthermore, when PCA and *im* therapy were compared with respect to their overall efficacy, both the patients and the nurses favoured the PCA technique. These results suggest that other factors, such as the patients' satisfaction, may contribute to PCA success.[20-22] In other words, the efficacy of PCA may not lie only in the superiority of the technique in reducing pain but may involve other factors such as patient's feeling of "being in control" and faster narcotic onset. As pointed out by Ready,[7] PCA also provides comfort which is prompt, independent of the availability of a nurse, regulated according to the individual patient's needs, and painless.

Early observations[6,23-25] suggested that PCA-treated patients required less medication than patients receiving conventional *im* injections. The results of the present study did not confirm these observations. Comparable levels of meperidine intake were found in the two treatment groups, a finding consistent with more recent studies.[21,26,27]

Considerable variability was observed in the amount of medication that patients required after thoracotomy. Interpatient variation was especially striking in the PCA group where meperidine consumption varied ten-fold. These results stressed the marked variations among thoracotomized patients with regard to analgesic requirements, and the need for highly individualized treatment strategies. The observed difficulty in titrating *im* doses for optimal treatment in the control group also illustrates the problem for the prescribing physician to find the right dose for each patient. Frequent dosage adjustments were

required in the *im* group. Prescription changes were also required in the PCA group but in fewer patients. As pointed out by many authors,[6,13,20,28] PCA has the advantage of accommodating a wider range of analgesic requirements.

Results of the present study confirm that PCA is a safe method for controlling pain in thoracotomized patients. Respiratory depression was not observed in any patient. Postoperative pulmonary function in patients receiving PCA was not different from that in *im*-treated patients. The PCA patients also maintained normal levels of $PaCO_2$ in the postsurgical period, confirming previous observations made with other types of surgery.[28,29]

Some clinical reports suggest that PCA reduces morbidity, complications and length of hospitalisation while others have failed to confirm better outcome in PCA-treated patients.[9,25,31,32] In a more recent report, Wasylak *et al.*[33] provided additional evidence supporting the clinical benefits of PCA over conventional *im* regimens. In patients after hysterectomy, PCA was associated with earlier ambulation, fewer complications and reduced duration of hospitalisation. The results of the present study extend some of these findings to patients undergoing more extensive surgery. Among the patients who took part in the present study, there were fewer long-stay patients in the PCA group than in the *im* group. On average, the duration of hospitalisation was reduced by 2.1 days for the PCA-treated patients, a difference which is perhaps more important from a clinical point of view than the reduction of 0.29 days observed by Wasylak *et al.*[33] In the present study, the difference may have failed to reach level of statistical significance due to small sample size.

Wasylak *et al.*[33] and Ready[7] have proposed several explanations to account for improved recovery in PCA-treated patients. Early self-titrated pain control may (1) alter the course of the metabolic response to surgery, (2) reduce the deleterious side effects of narcotics by avoiding high peaks in serum drug concentration that are associated by *im* injections, and (3) provide a more consistent matching of narcotic availability to changing needs after surgery. Ready[7] further suggests that PCA may affect the process of recovery from surgery by providing the patient with a greater sense of control. With conventional therapy, less control over pain may increase anxiety and this may, in turn, facilitate the establishment of a pattern of increased pain perception and illness conviction. Further research is needed to understand the beneficial effects of PCA on functional recovery after surgery. In addition to improved patient well-being, the potential clinical benefits of PCA such as earlier discharge from hospital must also be investigated considering the profound impact they may have on health care costs.

It is concluded that, compared with *im* dosing regimens, PCA is a better method for controlling post-thoracotomy pain. It is a safe and effective method which provides excellent pain relief and individualised treatment to patients after thoracotomy. Finally, PCA may reduce hospitalisation.

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