Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain (Review)

Hudcova J, McNicol E, Quah C, Lau J, Carr DB

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ABSTRACT

Background
Patients may control postoperative pain by self-administration of intravenous opioids using devices designed for this purpose (patient controlled analgesia or PCA). A 1992 meta-analysis by Ballantyne found a strong patient preference for PCA over conventional analgesia but disclosed no differences in analgesic consumption or length of postoperative hospital stay. Although Ballantyne's meta-analysis found that PCA did have a small but statistically significant benefit upon pain intensity, Walder's review in 2001 did not find a significant differences in pain intensity and pain relief between PCA and conventionally treated groups.

Objectives
To evaluate the efficacy of PCA versus conventional analgesia (such as a nurse administering an analgesic upon a patient's request) for postoperative pain control.

Search strategy
Randomized controlled trials (RCTs) were identified from the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2004, Issue 3), MEDLINE (1966 to 2004), and EMBASE (1994 to 2004). Additional reports were identified from the reference lists of retrieved papers.

Selection criteria
RCTs of PCA versus conventional analgesia that employed pain intensity as a primary or secondary outcome were selected. These trials included RCTs that compared PCA without a continuous background infusion versus conventional parenteral analgesic regimens. Studies that explicitly stated they involved patients with chronic pain were excluded.

Data collection and analysis
Trials were scored using the Oxford Quality Scale. Meta-analyses were performed of outcomes that included analgesic efficacy assessed by a Visual Analog Scale (VAS), analgesic consumption, patient satisfaction, length of stay and adverse effects. A sufficient number of the retrieved trials reported these parameters to permit meta-analyses.

Main results
Fifty-five studies with 2023 patients receiving PCA and 1838 patients assigned to a control group met inclusion criteria. PCA provided better pain control and greater patient satisfaction than conventional parenteral 'as-needed' analgesia. Patients using PCA consumed higher amounts of opioids than the controls and had a higher incidence of pruritus (itching) but had a similar incidence of other adverse effects. There was no difference in the length of hospital stay.

Authors' conclusions
This review provides evidence that PCA is an efficacious alternative to conventional systemic analgesia for postoperative pain control.

PLAIN LANGUAGE SUMMARY

Patient controlled opioid analgesia versus conventional opioid analgesia for controlling postoperative pain

Patients may control postoperative pain by self-administration of intravenous opioids using devices designed for this purpose (patient controlled analgesia or PCA). Postoperative PCA involves self-administration of small doses of opioids (such as morphine) intravenously by means of a programmable pump designed for this purpose. Previous studies have shown that often patients prefer PCA to traditional methods of pain management, such as a nurse administering an analgesic upon a patient's request. This review demonstrated that PCA provided slightly better pain control and increased patient satisfaction when compared with conventional methods. Patients tended to use higher doses of medication with PCA and suffered a higher occurrence of itching, but otherwise adverse effects were similar between groups.

BACKGROUND

Many postoperative analgesic regimens rely upon a patient to self administer analgesics. For example, a patient may be given a prescription for tablets and told to take one every few hours as needed. The development in the late 1960s of devices (Evans 1976; Keeri-Szanto 1971; Harmer 1985; Schezer 1968; Schug 2000) for the precise intravenous (or, on occasion, subcutaneous) delivery of bolus (single) doses of opioids upon the demand of the patient, with provision of regulation by their healthcare provider, led to coinage of the term 'patient controlled analgesia' (PCA).

PCA is now routinely used in postoperative care throughout much of the developed world (Carr 1998; Warfield 1995). PCA devices are programmable by the healthcare provider to deliver a specific amount of medication upon each request by the patient. A continuous 'background' infusion may be co-administered in addition to patient controlled bolus doses. Bolus doses are limited by a programmed 'lockout interval' within which subsequent requests are ignored or a cumulative limit to drug dose permitted in a fixed interval, such as one or more hours (Ferrante 1990). PCA may be applied via intravenous, subcutaneous, epidural or intrathecal routes (Crews 2000). Recently, a clinical trial evaluated an iontophoretic device for patient controlled transdermal opioid delivery (Viscusi 2004) and other routes (for example, pulmonary or nasal) are known to be under investigation.

Commonly, PCA devices are applied to deliver intravenous opioids after operations although PCA has also been used following trauma or to treat cancer pain (Lehmann 1999) and to deliver non-opioids such as non-steroidal anti-inflammatory drugs (Cepeda 1995) or local anesthetics (Cepeda 1996; DeKock 1994). PCA is a widely applied modality although its costs (particularly in comparison to those of conventional intramuscular analgesics) are not fully determined (Jacox 1997).

A previous systematic review (Ballantyne 1993) found pain control during PCA to be superior to conventional postoperative analgesia. However, the magnitude of the difference (5.6 mm on a zero to 100 mm visual analog scale (VAS) was small. A later systematic review (Walder 2001) did not find differences in pain intensity or pain relief between PCA and conventional treatment, although patients expressed a strong preference for PCA. Those findings suggest that the strong patient preference for PCA over conventional analgesia described in both reviews reflect factors other than analgesia per se, such as increased autonomy (Ferrante 1989; Kiecolt-Glaser 1998). The present review examines randomized controlled trials (RCTs) of patient controlled intravenous analgesia versus conventional postoperative opioid analgesia to treat postoperative pain.

OBJECTIVES

To evaluate the efficacy of patient controlled intravenous opioid analgesia (termed PCA in this review) versus conventional regimens of as-needed opioid analgesia for postoperative pain relief.

CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

Types of studies

RCTs were included in this review if they compared the efficacy of opioid PCA versus conventional opioid injections. Studies with pain intensity as the primary or secondary outcome were included. Non-randomized studies and case reports were excluded as were retrieved trials that presented insufficient data to allow assessment of outcomes of interest or study quality.

Types of participants

We set no age limits for patient inclusion except to require that the patient (and not a surrogate such as a parent or nurse) operated the PCA and reported pain intensity. Thus, patients in the enrolled studies had to have the cognitive ability to understand the concept of PCA and to report pain intensity on a standardized scale. Trials in which patients received an initial period of analgesia other than PCA postoperatively (for example, those sedated and ventilated for one to two days after surgery) were excluded. However, studies in which nurses administered analgesia immediately after surgery in order to stabilize the patient were included in the review. We

also excluded trials that explicitly stated they enrolled patients with chronic pain or who were receiving chronic opioid therapy if data from such patients were not separable from those of patients without preoperative chronic pain or opioid therapy.

Types of intervention

Intermittent intravenous doses of opioids self administered to patients via PCA pumps were compared to conventionally administered opioids. The route of the latter was not restricted and might be intramuscular, intravenous, subcutaneous or even oral.

The opioids included in this review were limited to morphine and other mu opioid agonists (a drug that binds to and activates an opioid receptor) such as meperidine (synonymous with pethidine), codeine, fentanyl, piritramide, and ketobemidone. Trials in which PCA was used to administer opioids whose actions are pharmacologically distinct from those of morphine or that display a plateau dose response (for example, partial mu opioid agonists such as buprenorphine, or mixed kappa opioid agonist and mu opioid antagonist compounds such as butorphanol) were excluded. Studies in which non-steroidal anti-inflammatory drugs (NSAIDs) were co-administered during opioid PCA were excluded because the opioid-sparing effect of NSAIDs might decrease the generalizability of study results by decreasing opioid requirements or pain intensity, or both, in all participants in the trial (Souter 1995). Studies in which continuous (background) intravenous opioid infusion was provided were excluded from this review. Trials frequently rely on nurses to administer the conventional analgesics but the lack of information on this aspect of a trial was not an exclusion criterion.

Types of outcome measures

Data on the following outcomes were extracted from each trial included in the review: pain intensity using a visual analog scale (VAS), type and amount of opioid used, patient satisfaction, and length of stay in hospital. In addition, we tabulated the incidence of adverse effects during postoperative pain treatment with PCA versus conventional regimens.

Pain intensity data assessed by means other than a zero to 100 VAS were normalized to such a scale. To do so, we either multiplied the original scale employed by an appropriate factor (for example, by ten if the original scale was a zero to ten scale) or by assigning values on a zero to 100 scale that corresponded to choices on the original assessment scale. For example if a patient was offered a five-point scale, selection of the second point was scored as 50 on a zero to 100 scale (0 = no pain, 1 = 25, 2 = 50, 3 = 75, 4 = 100).

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

See: Cochrane Pain, Palliative and Supportive Care Group methods used in reviews.

Trials for inclusion in the review were identified by searching MEDLINE from 1966 to November 2004 using the MeSH terms: "analgesia, patient-controlled" and "patient controlled analgesia"(more elaborate strategies did not appear to increase the sensitivity of a preliminary search). A search using similar terminology was also performed in the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2004, Issue 3) and EMBASE (January 1994 to February 2004). Additional reports were identified from the reference lists of retrieved papers. No language restrictions were applied.

METHODS OF THE REVIEW

Study selection

Eligibility was initially determined by reading the titles retrieved from each search. Titles that exclusively described patient controlled epidural or intrathecal analgesia; local anesthetic administration for pain control; routine postoperative admission for ventilation and concurrent sedation in the intensive care unit; administration of NSAIDs, partial opioid agonists or mixed opioid agonists-antagonists; or that studied nonpharmacological interventions such as music were excluded.

All remaining reports were screened by reading each abstract; those that described the above factors were dropped. The remaining references were then retrieved, as were any where abstracts, MeSH headings, or titles suggested that the full article might have contained an RCT. Eligibility, during both the title scan and the abstract evaluation, was determined by the lead review author and one other review author. These evaluators were not blinded nor were the retrieved trials masked in any way prior to assessment. Disagreement was resolved by discussion or, if persistent, by a third review author.

Data extraction

A data extraction form was used to tabulate the extracted data. This form included:

- numbers, ages and genders of the patients;
- type of operation;
- pain intensity at all time points when it was measured;
- PCA settings (bolus dose, lockout, limit dose);
- total analgesic consumption expressed as mg of morphine sulfate or equivalent where equivalents were calculated using equianalgesic conversions for commonly used opioids (APS 2003): for ketobemidone a 1:1 conversion was used (Micromedex 2005); papaveretum was considered 0.85 times as strong as morphine (an approximation based on inconsistency of proportion of constituents) (Micromedex 2005); and for piritramide 15 mg was considered equivalent to 10 mg of morphine (Micromedex 2005);

- patient satisfaction (preference for PCA versus conventional analgesic regimen);
- length of hospital stay;
- degree or incidence of adverse events.

Two review authors accomplished data extraction and the results were compared. In the event of a disagreement a third review author was asked to comment.

We applied a random-effects model to combine outcomes data related to pain intensity or pain relief and opioid consumption across trials at comparable time points (for example, one average pain score per 24-hour interval). To the extent that pooling of data across studies was possible, our goal was to derive a measure of total pain relief or summed pain intensity difference across the longest possible observation interval for PCA versus conventional analgesic regimens, so as to permit meta-analysis. Discrete events such as preference for PCA versus conventional analgesic regimens or the number of patients with adverse effects were combined using odds ratios (OR) and relative risks (RR). Where significant, numbers needed to treat (NNT) or numbers needed to harm (NNH) were calculated. Continuous outcomes (for example, pain intensity, analgesic consumption in mg of morphine equivalent, intensity of a specific adverse event) were combined using weighted mean differences (WMD).

Quality assessment

Each report was scored for quality by the lead author and the second member of the review team. The three-item Oxford Quality Scale devised by the Oxford Group (Jadad 1996) was used to assess study quality. This scoring system employs the following five questions, yielding a maximum possible score of five points.

1a) Is the study randomized? If yes, add one point.

1b) Is there a description of an adequate generation of the random sequence? If yes, add one point. If not, deduct one point.

2a) Is the study double blind? If yes, add one point.

2b) Is there an explicit statement that the patients and evaluators were blinded and the treatment was indistinguishable? If yes, add one point. If not, deduct one point.

3) Are withdrawals and dropouts described? If yes, add one point.

Where there was disagreement between review authors about the score allocated to each trial, consensus was achieved by the involvement of the third review author. Quality scores were not used to weight the studies in any way. Studies with a score of three or more were termed 'high quality'; those with two or less were described as 'low quality'.

DESCRIPTION OF STUDIES

We screened 3462 papers: 2043 from MEDLINE; 845 from CENTRAL; and 574 from EMBASE. Eighty papers were identified as potentially eligible for meta-analysis.

We excluded 28 papers because they did not meet inclusion criteria. The numbers below add up to more than 28 due to some studies failing to meet multiple criteria; see 'Characteristics of excluded studies' table). A continuous background infusion was used in the PCA group in twelve studies (D'haese 1998; Duggleby 1992; Gust 1999; Kilbride 1992; Knudsen 1993; Nitschke 1996; Peters 1999; Rundshagen 1999; Searle 1994; Tsang 1999; Weldon 1993; Zacharias 1990). Opioids other than pure mu agonists were used in four studies. In two of these four studies (Gaitini 1996; Lange 1988) buprenorphine (a partial agonist) was used in either control or both groups and in another two studies (Shin 2001; Woods 1991) nalbuphine (a mixed agonist-antagonist) was evaluated. NSAIDs (ketorolac or indomethacin) and acetaminophen were added to opioids or used as the sole analgesic in four studies (Gust 1999; Moreno 2000; Searle 1994; Shin 2001). Tramadol, which is not considered a conventional mu opioid, was used in two trials (Forst 1999; Jellinek 1990). Comparison of two different PCA regimens instead of PCA and conventional analgesia was done in four studies (Robinson 1991; Viscusi 2004; Weldon 1993; Woodhouse 1997). Two trials evaluated outcomes other than those considered in the present review: plasma catecholamines, blood cortisol and glucose levels (Moller 1988), and cost (Rittenhouse 1999). One study evaluated patients with both acute and chronic pain but did not separately report results from each group (White 1998). In one paper the control group was from a retrospective chart review (Spetzler 1987), in another (Atwell 1984) the data were incompletely presented, making extraction impossible, and lastly one study was not randomized (Knapp-Spooner 1995).

Fifty-two papers met inclusion criteria. Two papers (Chan 1995a; Chan 1995b; Ellis 1982a; Ellis 1982b) reported demographics and outcomes for different operations separately. A third paper (Hecker 1988a; Hecker 1988b) compared two PCA pumps with different delivery characteristics to a control group and reported results separately. These three papers were analyzed as comprising two different studies in each paper. As a result we had 55 studies eligible for analysis. Of these 55 studies, 16 trials (14 papers) had been included in Ballantyne's 1992 meta-analysis. Walder's meta-analysis (Walder 2001) involved 32 papers, comprising 33 studies; we excluded six of these latter studies (Gust 1999; Jellinek 1990; Robinson 1991; Rundshagen 1999; Woods 1991; Zacharias 1990) as detailed above (see 'Characteristics of excluded studies' table).

We were not able to include all 55 studies in all of our meta-analyses. Some trials did not examine or report all outcomes of interest (for example, Bedder 1991 assessed morphine consumption, VAS and some adverse effects but did not examine patient satisfaction and length of stay). In some of the papers the data were incomplete (for example, missing standard deviations (SD)) and so could not be used for statistical analysis. We could not use data from other trials because they were not clearly defined or were presented in an idiosyncratic manner (for example, in Harrison 1988 analgesia was assessed according to the percentages of patients reporting mild, moderate, or severe pain). Therefore, we reported numbers

of analyzed studies separately according to the different outcomes studied.

In the 55 included studies, 2023 patients were randomly allocated to PCA groups and 1838 patients to control groups. In aggregate, the trials spanned all ages (children, adolescents, elderly) with the youngest patient being seven years old. Nine of the 55 studies enrolled more than 100 patients. The largest study involved 510 patients (PCA: n = 266; control: n = 246) (Taylor 1994). The majority of studies (34 of 55) enrolled less than 50 patients. The smallest study enrolled five patients in a crossover trial (Walson 1992).

Patients underwent various operations, including cesarean section; the most common were abdominal procedures. In the control groups analgesia was administered intramuscularly (37 trials), subcutaneously (two trials), as intravenous boluses (four trials), intravenous infusions plus intravenous boluses (six trials), combined intravenous and intramuscular injections (five trials), and combined oral and intramuscular administration (one trial).
Forty-nine studies compared the same analgesic in both groups (40 morphine, six meperidine, one piritramide, ketobemidone, and papaveretum). Six trials compared two different medications (meperidine PCA versus morphine analgesia (two trials) and morphine PCA versus meperidine or hydromorphone or codeine analgesia (four trials)).

The most often used PCA opioid was morphine (44 studies). In these 44 studies the most frequent bolus was 1 mg (22 trials) (range: 0.25 mg to 2.5 mg). The most frequent lockout intervals were 10 min (13 trials) and 6 min (12 trials) (range: 5 min to 30 min). In the majority of trials there was no dose limit.

METHODOLOGICAL QUALITY

Each report was scored independently for quality by two of the review authors using a three-item scale (Jadad 1996). The review authors then met to agree a 'consensus' score for each report. The quality scores for individual trials are reported in the notes section of 'Characteristics of included studies' table. These scores were not used to weight the results in any way.

The maximum possible score (indicating a trial of high methodological quality) was five. Because none of the studies comparing PCA with conventional analgesia was double blinded, we could not assign any points based upon blinding. Therefore, the highest possible score for included studies was three.

The median quality score of the included studies was two.

RESULTS

Quality of analgesia

Quality of analgesia was assessed by asking patients to report their pain intensity using a VAS. Different authors recorded this outcome on different scales and at different intervals. All VAS scales were normalized to a zero to 100 range. The majority of authors reported average results over the following intervals: zero to 24 h, 25 to 48 h, 48 to 72 h, and zero to 48 h. One trial reported the average VAS over 36 hours (Bedder 1991) and was included in the zero to 48 h analysis. Data were generally reported as the average pain intensity of multiple observations over any given time period; however, in studies in which the only data available were single measurements at the end of a time period (for example, 24 h) we used this measurement. Pain intensity over the first 24 hours was reported in 27 studies, which involved 2065 patients with 1068 in the PCA group and 997 in the control group. Patients in the PCA group reported a weighted mean difference in pain intensity 8 points lower than in the control group (95 % CI: -12 to - 4) (Comparison 01 01). Average pain intensity in the postoperative 25 to 48 hours was described in 17 trials (756 patients, 396 with PCA and 360 controls). Meta-analysis favored the PCA group: patients in the PCA group had lower pain scores than their counterparts (WMD - 9, 95% CI - 14 to - 5) (Comparison 01 02). Five studies (783 patients, 403 patients with PCA and 380 controls) analyzed pain intensity in the interval from 49 to 72 hours. Our analysis again favored the PCA group. Patients in the PCA group had VAS scores 13 points lower than their controls (95% CI - 20 to - 6) (Comparison 01 03). Six trials examined pain scores over the zero to 48 hours interval (292 patients, 166 with PCA and 126 controls). Patients in the PCA group scored their pain nine points less than those given conventional therapy (95% CI - 14 to - 5) (Comparison 01 04). Only two studies reported results of pain intensity in the zero to 72 hour interval and there was no significant difference between PCA and control groups (Comparison 01 05).

To evaluate heterogeneity we subanalyzed pain intensity according to the type of surgery. We were able to create only two subgroups: abdominal surgery (15 trials) and cardiac surgery (three trials). The number of trials for the rest of the operative sites and types were insufficient to create other subgroups (thoracic surgery: two studies, orthopedic surgery: two studies, craniotomy: one study, orthognathic surgery: one study, and miscellaneous (thoracic and abdominal, thoracic and abdominal and orthopedic, nonthoracic): three studies in total). In the subcategory of abdominal surgery (920 patients, 482 with PCA and 438 controls) meta-analysis favored PCA (WMD -8, 95% CI -13 to - 3) in the zero to 24 hour post-operative interval. However, there was no difference in the pain scores for patients undergoing cardiac surgery (WMD - 0.2, 95% CI -3 to 3) over the first 24 hours postoperatively (Comparison 01 06).

We performed further subanalyses based on removing trials which were considered to be inadequately randomized (Jadad 1996). Five trials (Bollish 1985; Perez-woods 1991; Rayburn 1988; Snell 1997; Thomas 1995) were inadequately randomized and were re-

moved from any meta-analysis in which they had previously been included (zero to 24 hours, 25 to 48 hours, and zero to 48 hours) (Comparisons 01 07, 01 08, 01 09). In each meta-analysis the results for pain intensity remained significantly lower for the PCA group and the degree of reduction remained similar.

One of the studies included in the analyses employed a crossover design (Walson 1992). The Cochrane Handbook (Deeks 2006) suggests three approaches towards incorporating crossover trials into a meta-analysis. One approach involves calculating a correlation coefficient to describe how similar the measurements on interventions A and B were within a participant. The study by Walson did not provide sufficient information to calculate this coefficient. A second approach involves including data from only the first period. We did this for the outcome analgesic consumption since means and SDs were not reported for both periods combined (see Opioid consumption below). A third approach is to simply treat results as if they were from a parallel trial. We used this approach for calculating differences between the two groups in pain scores at zero to 24 hours.

All three approaches carry the potential for bias. For this reason, and again as suggested by the Cochrane Handbook, we performed a sensitivity analysis with this study removed from relevant comparisons (Comparisons 01 01, 01 07). Neither the direction of the comparisons nor their magnitude was affected by removing the study.

Opioid consumption

We analyzed opioid consumption in 35 trials. The total number of patients in those trials was 2514, with 1294 patients in a PCA group and 1220 patients in a control group. Different authors reported opioid consumption across different intervals. The most frequently reported results were over the first 24 hours (23 studies); eight studies continued to report results over the next 24 hours; and 11 studies reported opioid consumption over 48 hours. Five trials described opioid consumption over the first 72 hours. Some studies reported opioid consumption during more than one interval.

The first analysis, for opioid consumption in the zero to 24 hour post-operative interval, showed a significantly lower value in the control group (WMD 7 mg, 95% CI 0.50 to 13) (Comparison 02 01).

In the intervals from 25 to 48 hours and zero to 48 hours there were no significant differences in cumulative opioid consumption between the PCA and control groups (WMD 3, 95% CI -1 to 7; WMD 7, 95% CI -12 to 27, respectively) (Comparisons 02 02, 02 03 respectively). In a subcategory of cumulative opioid consumption over 72 hours (zero to 72 hours) there was significantly lower consumption of opioids in the control groups (WMD 24, 95% CI 13 to 35) (Comparison 02 04).

In a similar manner to the subanalyses based upon the quality of analgesia results, we explored subcategories based on type of surgery and eliminating inadequately randomized trials.

Surgery subgroup meta-analysis was performed if at least three trials of the same type of surgery were available over any given postoperative interval. Based on this requirement we were able to create only two subcategories: abdominal surgery (756 patients, 384 with PCA and 372 controls) and cardiac surgery (235 patients, 120 with PCA and 115 controls) and to analyze opioid consumption over the first 24 hours. In both subcategories the opioid consumption was slightly higher in the PCA group but the difference was not significant; abdominal surgery: WMD 7, (95% CI -3 to 18) and cardiac surgery: WMD 5 (95% CI - 3 to 13) (Comparison 02 05).

Exclusion of four inadequately randomized trials (Bollish 1985; Perez-woods 1991; Rayburn 1988; Thomas 1995) from opioid consumption meta-analyses at the postoperative time intervals zero to 24 hours and zero to 48 hours did not alter the significance, and only slightly altered the magnitude of the lower opioid consumption in the control group (Comparisons 02 06, 02 07 respectively).

In a similar manner to the analyses of pain scores, we performed sensitivity analyses by removing the crossover study by Walson (Walson 1992) from relevant comparisons (Comparisons 02 01, 02 06). Again, neither the direction of the comparisons nor their magnitude was affected by removing the study.

Patient satisfaction

Patient satisfaction results were presented as either continuous or dichotomous data, that is, on a scale (usually zero to ten, where ten is the most satisfied) or as the number of patients in a study arm satisfied with therapy.

For continuous data, all scales were normalized to a zero to 100 range. The nine studies available for analysis (585 patients, 311 with PCA and 274 controls) reported increased satisfaction with PCA versus control (WMD 6, 95% CI 1 to 11) (Comparison 03 01).

The incidence of patient satisfaction was determined in twelve trials with a total of 675 patients (334 with PCA and 341 in control groups). More patients in the PCA groups were satisfied with their mode of analgesia (84% versus 65%; OR 3.0, 95% CI 1.6 to 5.4; RR 1.26, 95% CI 1.1 to 1.5) (Comparison 03 02). The NNT was calculated as 5.3 (95% CI 3.4 to 12.5).

We were not able to perform subanalyses according to type of surgery due to an insufficient number of trials reporting data.

Subanalysis with removal of inadequately randomized trials (Perez-woods 1991; Snell 1997) from the continuous data meta-analysis did not change the magnitude of the difference in satisfaction, but overall results were no longer significant (WMD 5.1, 95% CI -0.9 to 11.1) (Comparison 03 03).

Length of stay

Twenty-six studies reported differences in length of stay between patients using PCA and those in the control groups. Twelve of

these studies did not report SDs. Four other trials stated that there were no significant differences between groups while another trial stated that patients using PCA were discharged earlier than the control group. However, none of these five trials supplied data. The nine remaining trials that were suitable for meta-analysis (501 patients, 274 with PCA and 227 controls) demonstrated a slight but nonsignificant reduction in length of stay in those patients using PCA (WMD - 0.3, 95% CI - 0.9 to 0.3) (Comparison 04 01). Again, there were insufficient trials to perform subanalyses based on type of surgery.

Subanalysis with removal of inadequately randomized trials (Snell 1997; Thomas 1995) changed neither the direction of effect estimate nor the significance of the original analysis (Comparison 04 02).

Adverse Events

The most frequently reported adverse events were sedation, nausea and vomiting, pruritus, and urinary retention. Many studies did not specify the setting or timing of adverse events. In a similar fashion to the subanalyses performed with efficacy data and where enough studies were available, meta-analyses based on type of surgery and with removal of inadequately randomized trials were also performed. NNHs were not statistically significant for any outcome and, therefore, are not reported.

Sedation

Twenty-three studies evaluated sedation. Three studies commented on sedation and stated that there were no significant differences between groups; however, they did not report data. According to another study, patients in the PCA group "felt less groggy" but again the authors did not support this statement with data. Analyzable data on sedation were reported in nineteen studies (1186 patients). Twelve trials (554 patients, 293 with PCA and 261 in controls) evaluated sedation by means of a scale. Different scales were used (zero to 100, zero to ten, one to five, and a four-point scale). We normalized all scales to the zero to 100 range. Meta-analysis demonstrated that patients in the PCA group reported a nonsignificant degree of sedation (WMD - 6, 95% CI - 13 to 1) (Comparison 05 01). Removal of three inadequately randomized trials (Bollish 1985; Perez-woods 1991; Rayburn 1988) did not change the magnitude nor the insignificance of this difference (Comparison 05 03). Five out of 12 trials evaluated severity of sedation during the first and second postoperative day. Overall, patients were more sedated during the first postoperative day in both groups.

Seven studies (632 patients, 319 with PCA and 313 in control groups) expressed sedation as the number of patients reporting sedation. Nineteen per cent of patients in the PCA group versus 21% of those in the control group reported sedation. We calculated the OR for sedation between patients using PCA and those receiving control as 0.8 (95% CI 0.5 to 1.3) and the RR as 0.8 (95% CI 0.7 to 1.1), that is, there was no difference in the incidence of sedation between groups (Comparison 05 02).

Nausea or vomiting, or both

Nausea and vomiting were evaluated in 28 trials (1789 patients).

Five trials (197 patients, 102 with PCA and 95 in control groups) assessed nausea and vomiting using a scale. Two different scales were used (zero to ten and a four-point scale). We normalized both scales to a zero to 100 range. Meta-analysis yielded a WMD of 4 (95% CI - 3 to 11), showing a nonsignificant tendency favoring the control group (Comparison 06 01). Four of the five trials evaluated nausea or vomiting, or both, during the first and second postoperative days and they were more pronounced during the first postoperative day in both groups.

Twenty-three trials (1592 patients, 802 with PCA, 790 in control groups) expressed numbers of patients in each group reporting nausea or vomiting, or both. Dichotomous data again demonstrated no significant difference between groups (29% versus 27%; OR 1.0, 95% CI 0.7 to 1.4; RR 1.0, 95% CI 0.9 - 1.3) (Comparison 06 02). Both subanalysis by surgery type and sensitivity analysis by removal of inadequately randomized trials failed to show significant differences between PCA and control groups (Comparisons 06 03, 06 04, respectively).

Pruritus

The incidence of pruritus was evaluated in nine studies (456 patients, 228 with PCA, 228 in control groups). All studies used the same opioid in each arm. Meta-analysis yielded an OR of 1.7 (95% CI 1.1 to 2.8) and an RR of 1.4 (95% CI 1.0 to 2.0), demonstrating that significantly more patients complained of pruritus in the PCA groups (26%) than in the control groups (18%) (Comparison 07 01).

We were able to subanalyze the incidence of pruritus by those patients undergoing either abdominal (five studies) or orthopedic surgery (three studies). While both subgroup analyses still demonstrated an increased incidence of pruritus in patients receiving PCA, only in the abdominal surgery group was this difference statistically significant (38% versus 25%; OR 2.0, 95% CI 1.1 to 3.6; RR 1.5, 95% CI 1.0 to 2.1) (Comparison 07 02).

Urinary retention

The incidence of urinary retention was reported in ten trials (667 patients, 341 with PCA, 326 in control groups). There was no significant difference in the incidence of urinary retention between the groups (22% versus 25%; OR 0.8, 95% CI 0.6 to 1.2; RR 0.9, 95% CI 0.7 to 1.2) (Comparison 08 01).

We were able to subanalyze the incidence of urinary retention for patients undergoing either abdominal (five studies) or orthopedic surgery (three studies). As with the larger analysis, both subgroups demonstrated a nonsignificant tendency towards a reduction in urinary retention in patients using PCA (Comparison 08 02).

DISCUSSION

Quality of analgesia

The results of our meta-analyses demonstrate that PCA provided better pain control than conventional analgesia. Pain intensity on a VAS scale was lower in patients using PCA versus those receiving conventional analgesia, at all time intervals. Statistical significance was achieved at all times with the exception of the small meta-analysis of results reported over 72 hours.

Walder's meta-analysis (Walder 2001) did not reach the same conclusions as ours. In that analysis, neither continuous data on pain intensity nor dichotomous data on combined pain intensity and pain relief produced statistically significant differences. The different results between the present analysis and that of Walder 2001 may result from the different inclusion criteria employed. Walder's meta-analysis included studies in which patients received continuous background infusions or that used non-opioid analgesics and partial mu agonists. The addition of non-opioid analgesics (either acetaminophen or NSAIDs) to an opioid regimen has been shown to improve quality of analgesia and thus may have minimized differences in efficacy and adverse effects between analgesic regimens (Cepeda 2005; Marret 2005). The discordance between the two reviews may simply be due to our having a greater number of studies available for analysis and, therefore, a greater possibility of achieving statistical significance.

Our findings are consistent with Ballantyne's 1993 meta-analysis (Ballantyne 1993). Ballantyne's review showed that patients treated with PCA were more comfortable than patients given conventional analgesia even though the authors questioned the clinical significance of these findings (six points lower pain score in PCA patients on a zero to 100 VAS). Although the difference is greater in the present review, it is still questionable whether an eight-point lowering of pain intensity is clinically significant.

PCA may have varying effectiveness depending on the extent and degree of invasiveness of the surgery after which it is administered. Walder 2001 did not stratify patients according to the type of operation. We were able to create only two subgroups. Patients with abdominal surgery had better pain relief with PCA than with conventional analgesia. However, post-cardiac surgical patients reported similar VAS scores regardless of mode of postoperative pain control. The anesthetic technique in cardiac surgery, which often involves administration of large doses of opioids that may have potentially lingering effects postoperatively, might have been responsible for the lack of a difference between PCA and control groups.

Lastly, heterogeneity of PCA regimens in various trials might have affected the magnitude of difference in VAS score. In a few trials boluses were small (Ceriati 2003; McGrath 1989) or infrequent, or both (McGrath 1989; Murphy 1994; Passchier 1993). We can only speculate as to whether more liberal PCA regimens would have improved analgesia.

Opioid consumption

In contrast to Ballantyne's and Walder's reviews we found that opioid consumption was higher in patients using PCA than those administered conventional analgesia. This difference was statistically significant over the postoperative intervals of zero to 24 hours and zero to 72 hours; 6.72 and 23.78 morphine equivalents respectively. The clinical significance of this small difference is questionable. Morphine is a strong opioid analgesic. A single intravenous or intramuscular dose for moderate-to-severe pain in a healthy adult may be 5 to 10 mg (often given incrementally). Taking into consideration the elimination half time (1.7 h to 3.3 h (Stoelting 1999)) and duration of effect (three to four hours after either intravenous or intramuscular dosing (Fee 1996)), the daily dose may reach up to 80 to 120 mg. Thus, an increased consumption of morphine by less than 8 mg/24 hours does not seem important clinically. On the other hand, in the included PCA trials the average morphine equivalent consumption during the first 24 h was about 45 mg in the PCA group, so 8 mg/24 h would represent about 20% of this dose. The difference in opioid consumption was greater in studies that performed analysis over the first 72 hours. Patients in the PCA group consumed about 33% more morphine equivalents than patients in the control group (77 mg versus 52.5 mg).

The conversion of doses of opioid agonists other than morphine to morphine equivalents may have affected our results. Some studies reported amounts of both the particular opioid used and the conversion to morphine equivalents. Most stated the conversion factor used (Eisenach 1988; Kyzer 1995; Precious 1997; Stoneham 1996). In those trials that did not convert to morphine equivalents (Boldt 1998; Boulanger 1993; Ellis 1982a; Ellis 1982b; Murphy 1994; Pettersson 2000; Rayburn 1988; Thomas 1995; Wang 1991) we used standard conversion factors (APS 2003; Micromedex 2005). Only one study reported results in morphine equivalents without stating the corresponding amount of the original opioid (Walson 1992).

Our exclusion criteria may have played a role in our finding higher opioid consumption in the PCA arm. Walder's review included studies in which patients using PCA also had 'background infusions' of opioids. The continuous infusion of opioid in these studies may have contributed to more constant plasma levels and decreased demand for bolus doses. However, the use of a background infusion is generally discouraged (APS 2003) as it may lead to opioid overdosage.

We did not find a statistically significant difference in opioid consumption between the PCA group and control group in patients undergoing abdominal or cardiac surgery. In cardiac surgical patients this negative finding might be explained by the prolonged effect of large intraoperative opioid doses into the postoperative period. Studies in which patients underwent more painful operations (orthopedic, thoracic) but that could not be analyzed as a

subgroup due to the small number of participants may have contributed to higher consumption of opioids in the PCA group.

As mentioned in the section 'Types of participants', in some studies nurses controlled immediate postoperative pain prior to initiation of the trial. In most studies the immediate postoperative consumption was either not commented upon or was simply stated to be similar in both groups.

Our results could also have been affected by the fact that the opioid administration regimen in the respective arms varied considerably between studies. Of the 35 trials that evaluated opioid consumption, seven had a study design that included a flexible dosing regimen (adjustment of doses in either direction). Five studies enabled dose titration in both the treatment and control groups (one was a crossover study), one study allowed titration in the PCA group only, and one in the control group only. Therefore, flexibility in dosing regimen was equally distributed among groups and we do not think that it contributed to bias in our results. The study where opioid dose adjustment was permitted only in the PCA group reported lower opioid consumption in the treatment group at both time points, zero to 24 hours and 25 to 48 hours.

Lastly, it is possible that the difference in opioid consumption may not reflect a true difference between modes but may simply be due to factors like nurse availability or a result of the nurse's assessment of pain and subsequent judgment of the need for opioid administration.

Patient satisfaction

Although many studies investigated patient satisfaction, several did not supply extractable data. Twenty-one trials (1260 patients) were analyzed. None of the studies demonstrated that patients were more satisfied with conventional treatment. Meta-analysis of both the degree of satisfaction and the number of patients satisfied with therapy significantly favored patients in the PCA group. Our analysis is consistent with the results of Ballantyne, even though the meta-analysis involved only 160 patients in that review. Walder's analysis did not find a difference in patient satisfaction between groups but reported that more patients expressed a preference for PCA over conventional therapy. Most of the studies did not indicate why patients reported satisfaction with a given therapy. It is not surprising to find greater satisfaction with PCA. Patients are given a greater degree of autonomy which, in turn, may reduce fears of insufficient analgesia. Instant availability of the medication may also contribute to greater satisfaction with the mode of treatment. We had insufficient data to perform subanalyses based upon type of surgery. It would be interesting to investigate whether patients undergoing more invasive surgeries would be less inclined to be in charge of their own pain management.

The measurement of satisfaction in trials where patients are not blinded to study arm assignment creates a potential for bias. All studies in our analysis were unblinded. Patients who received a 'new breakthrough' treatment may have expressed a preference compared to those who 'missed out'. The small difference demonstrated on a zero to 100 mm VAS might reflect this bias. Alternatively, some people, especially the elderly, may prefer conservative and established treatments to new and unproven technologies. However, this would not appear to be the explanation in our meta-analysis since the mean age of patients was only 52 years after excluding pediatric patients and women who underwent cesarean section.

Length of stay

Nine trials provided data that could be meta-analyzed for length of stay. Two trials reported that length of stay was significantly shorter in the PCA group, one trial favored conventional analgesia, and five did not find a significant difference between groups. Our meta-analysis showed that length of stay was 0.4 days shorter in the PCA group but the difference was not clinically significant. Our results are consistent with Ballantyne's and Walder's results. There are multiple factors that contribute to length of stay. These factors, in combination with the relatively small number of trials available for analysis, may contribute to our not finding a difference for the different modes of analgesia.

Adverse events

Both previous meta-analyses (Ballantyne 1993; Walder 2001) were unable to find significant differences in the incidence or severity of adverse events between groups. Our analyses also failed to show any differences, either clinical or statistical, for all but one of the most commonly reported events. Patients using PCA had a higher incidence of pruritus, especially in studies in which patients underwent abdominal surgery. This increase in pruritus (and the lack of reduction in other adverse events) may simply be attributable to higher opioid consumption in the PCA group. Importantly, none of the six trials that administered a different opioid to each arm were included in the pruritus analysis. Differing adverse effect profiles of different opioids can, therefore, be excluded as possible confounding factor in our results.

Exclusion of inadequately randomized trials

It has been suggested that trials of low methodological quality (Moher 1998) may overestimate differences between therapies. From the information provided in the included studies we were able to ascertain that six studies were inadequately randomized. Exclusion of these trials (removal of non-blinded trials was unnecessary since by nature of the intervention none of the trials were non-blinded) made little difference either statistically or clinically to any of our analyses.

While intravenous administration remains the most commonly used mode of PCA, several alternative modes have been applied in the clinical setting or in controlled clinical trials. Alternative routes of administration include oral, transdermal, inhaled, intranasal, and epidural, each with their own potential benefits and disadvantages. Oral, transdermal, inhaled, and intranasal administration modalities offer the potential advantage of reductions in cost, labor, and required expertise of staff, and increased patient mobil-

ity when compared to intravenous PCA. Oral immediate-release opioids theoretically present the lowest cost and simplest mode of administration (Pasero 2000; Striebel 1996a). Results of trials in which patients have been administered controlled-release opioids have, however, demonstrated that patients with postoperative ileus may have insufficient systemic levels of drug due to decreased absorption (Lew 1989; Pinnock 1986). Oral administration may be appropriate after operations in which postoperative ileus or nausea, or both, are less prevalent, such as minimally invasive procedures, those of short duration, or when regional anesthetic techniques such as epidural injections are employed. Further studies of the bioavailability of oral medications in the early postoperative period may need to be undertaken before any recommendations are made regarding their routine use for pain relief during that time. If intravenous administration is required for breakthrough pain in patients on an oral regimen, cost and labor savings may be negated.

An RCT of the use of patient controlled transdermal fentanyl, delivered via iontophoresis, suggests that patients have similar analgesic outcomes to those using traditional intravenous PCA (Viscusi 2004). The transdermal system currently under development, however, lacks programming flexibility in that it does not allow for adjustments in bolus doses, nor in lockout times.

Additional advantages of administering opioids via inhalation include rapid onset of effect and bypass of hepatic first-pass metabolism (Thipphawong 2003). Improvements in delivery devices may increase the low bioavailability of opioids administered via this route (Chrubasik 1998; Thipphawong 2003). Results from trials of intranasal administration of opioids have been mixed (Paech 2003; Striebel 1996b; Ward 2001), possibly due to different devices used for administration, technical difficulty of use, and patients' perception of the intravenous route as offering 'stronger' drugs than via the intranasal route (Ward 2001).

Finally, epidural administration of opioids theoretically offers an advantage over intravenous administration in that opioid is applied near to opioid receptors in the spinal column, and in turn reducing systemic adverse effects (McQuay 1999). Indeed, a large meta-analysis of the use of epidural versus intravenous analgesia (including studies in which administration was patient controlled) concluded that epidural administration provided superior postoperative analgesia than intravenous administration (Block 2003). Insertion and maintenance of an epidural catheter requires a greater degree of expertise than intravenous cannulation, however.

There are currently insufficient RCTs available to determine whether any of the above modes of PCA will prove more safe or efficacious than intravenous PCA.

We excluded studies that explicitly mentioned they enrolled patients with chronic pain. A potential weakness of our analysis is that while not specified, some participants, particularly orthopedic patients, might have experienced some degree of chronic pain preoperatively.

AUTHORS' CONCLUSIONS

Implications for practice

PCA for postoperative pain control has been slowly supplanting conventional analgesia in most hospitals in both the USA and the rest of the western world. PCA has gained acceptance among both patients and healthcare providers despite the lack of convincing advantages from previous reviews. The fact that PCA is now standard practice may account for the scarcity of new RCTs about PCA in the 21st century. Our meta-analysis provides evidence that PCA provides marginally superior analgesia in comparison to conventional analgesia. Patients report greater satisfaction with, and in general prefer, PCA. Despite slightly higher opioid consumption in patients using PCA there is generally no increase in adverse effects, with the exception of pruritus. Finally, length of stay was similar in both groups.

In clinical practice NSAIDs are frequently administered with opioids in order to potentiate analgesia while reducing the incidence of adverse effects. We excluded studies where NSAIDs were also administered as they could confound the interpretation of results. Therefore, we are unable to confirm the widely acknowledged theory that this combination improves analgesia while reducing adverse effects.

Implications for research

While further trials investigating subpopulations and different surgeries may be helpful, the number of trials currently available is already extensive. It may now be timely to compare less invasive approaches to postoperative analgesia with either conventional injections or intravenous PCA in order to characterize clinical differences in efficacy or adverse events, if any.

POTENTIAL CONFLICT OF INTEREST

None known.

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* *Indicates the major publication for the study*

TABLES

Characteristics of included studies

Study	**Albert 1988**
Methods	Parallel, 16 h Control: IM/IV morphine
Participants	PCA 32, IM 30 partial or total colon resection
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg (increases by 0.5 mg on physician order)/10 min/NR
Outcomes	PCA group: 72 h morphine requirement lower Analgesic costs higher NS difference in level of postoperative pain, level of activity after receiving medication, duration of hospital stay or total hospital cost.
Notes	Adverse events: nature - PCA vs control (n/N or continuous data); withdrawals: sedation: 21/32 vs 23/30; nausea: 10/32 vs 9/30 duration of ileus: 4.9 days PCA vs 4.4 days QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Characteristics of included studies (*Continued*)

Study	**Bedder 1991**
Methods	Parallel, 24 h Control: IV morphine
Participants	PCA 20, IV 18 non thoracic elective or emergency surgery - ICU environment
Interventions	Morphine. Bolus/lockout/ 4 h limit: 2 mg/10 min/NR
Outcomes	PCA group: 12 and 16 h morphine requirements higher, 20 h requirements similar. Pain scores similar at all time points
Notes	Sedation scores similar at all times Oxygen saturation < 90%: 2/20 PCA vs 1/18 No respiratory rate < 10 QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Bennett 1982**
Methods	Parallel, 60 h Control: IM morphine
Participants	PCA 12, IM 12 gastric bypass
Interventions	Morphine. Bolus/lockout/4 h limit: 0.6 mg/M2BSA (increases by 0.2 mg/M2BSA)/6 min/NR
Outcomes	PCA group: Less frequent inadequate analgesia (NS), less interference with physical activity.
Notes	Adverse events: nature - PCA vs control (n/N): sedation 6/12 vs 10/12 QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Berde 1991**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 32, IM 23 children and adolescents, major orthopedic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 0.025 mg/kg/10 min/0.24 mg/kg
Outcomes	PCA group: similar morphine requirements, lower pain scores, greater satisfaction scores
Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (0-10): 5.6+/-2.53 vs 6.64+ /-2.19; nausea and vomiting: 1.1+/-2.1 vs 1.0+/-1.2; urinary retention: 6/32 vs 6/23 No respiratory depression in either group Withdrawals: Anesthetic or surgical factors that altered the patient's eligibility (n = 10), lack of beds on participating units (n = 5), unspecified (n = 2) QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Bhise 1997**
Methods	Parallel, time frame unclear

Characteristics of included studies (*Continued*)

	Control: IV morphine
Participants	PCA 10, IV 10 coronary artery bypass graft
Interventions	Morphine. Bolus/lockout/4 h limit: 2 mg/15 min/15 mg
Outcomes	PCA group: similar morphine requirements, pain scores, greater number of patients satisfied with pain relief
Notes	Adverse events: nature - PCA vs. control: sedation: (1 = fully awake, 4 = asleep): 1.56+/-0.61 vs. 1.71+/-1.15 No vomiting in either group QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Boldt 1998**
Methods	Parallel, 72 h Control: IV piritramide
Participants	PCA 30, IV 30 elective cardiac surgery
Interventions	Piritramide. Bolus/lockout/1 h limit: 2 mg/10 min/6 doses
Outcomes	PCA group: piritramide requirements higher, pain scores lower at all times, degree of satisfaction higher
Notes	Adverse events: nature - PCA vs control (n/N): severe sedation: 8/30 vs. 9/30; nausea: 7/30 vs 9/30; vomiting: 3/30 vs 4/30; gut atony: 3/30 vs 2/30 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Bollish 1985**
Methods	Crossover, 48 h Control: IM morphine
Participants	PCA 20, IM 20 abdominal surgery
Interventions	Morphine Bolus/lockout/4 h limit: 1 mg/10 min/NR
Outcomes	PCA group: morphine requirements similar, less discomfort, similar levels of activity
Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (0-10): 2.4+/-0.9 vs 2.5+/-0.8; nausea and vomiting: 3/20 vs. 7/20; euphoria: 2/20 vs 4/20 No respiratory depression in either group QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Boulanger 1993**
Methods	Parallel, 48 h Control: IM meperidine
Participants	PCA 20, IM 20 thoracotomy
Interventions	Meperidine.

Characteristics of included studies (*Continued*)

	Bolus/lockout/4 h limit: 0.2 mg/kg (could be increased or decreased)/6 min/NR
Outcomes	PCA group: similar meperidine requirements, no difference in any pain measure (except more pain relief on first day), overall efficacy rated higher, greater percentage of patients discharged within one week.
Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (1 = wide awake, 5 = awakens only when aroused): 2.1+/-0.7 vs 2.1+/-0.6; nausea and vomiting (0-10) 1.5+/-2 vs 0.4+/-0.8; antiemetic required: 5/20 vs 3/20 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Brewington 1989**
Methods	Parallel, 72 h Control: IM morphine
Participants	PCA 95, IM 97 gynecologic oncology surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/12 minutes/NR
Outcomes	PCA group: total morphine requirements lower, no significant difference in pain scores
Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (1 = alert, 5 = unarousable): 2.1 vs 3.6 (day 1), 1.5 vs 3.0 (day 2), 1.1 vs 1.9 (day 3); nausea and vomiting: 6/95 vs 8/97 Withdrawals: PCA vs control (n): Admitted to ICU: 7 vs 9; unspecified side effects: 6 vs 8; inadequate relief: 2 vs 0 QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Ceriati 2003**
Methods	Parallel, 72 h Control: IV morphine
Participants	PCA 20, IV 20 major abdominal surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 0.5 mg/5 min/NR
Outcomes	PCA group: no information on total morphine requirements, although no patients required supplemental analgesia (vs. 55%), lower VAS and simple descriptive pain scores
Notes	No respiratory depression or prolonged ileus in either group QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Chan 1995a**
Methods	Parallel, 48 h Control: IM morphine
Participants	Cholecystectomy: PCA 12, IM 11
Interventions	Morphine. Bolus/lockout/4 h limit: 1.5-2 mg/5-10 min/NR
Outcomes	PCA group: morphine requirements, VAS pain scores and overall satisfaction all similar, nursing time less, NS reduction in LOS

Characteristics of included studies (*Continued*)

Notes	Adverse events (cholecystectomy and laminectomy groups combined): nature - PCA vs control (n/N): nausea and vomiting: 1/36 vs 3/31; pruritus: 1/36 vs 1/31 No excessive somnolence or respiratory depression in either group QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Chan 1995b**
Methods	Parallel, 48 h Control: IM morphine
Participants	Laminectomy: PCA 24, IM 20
Interventions	Morphine. Bolus/lockout/4 h limit: 1.5-2 mg/5-10 min/NR
Outcomes	PCA group: morphine requirements, VAS pain scores and overall satisfaction all similar, nursing time less
Notes	Adverse events (cholecystectomy and laminectomy groups combined): nature - PCA vs control (n/N): nausea and vomiting: 1/36 vs 3/31; pruritus: 1/36 vs 1/31 No excessive somnolence or respiratory depression in either group QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Chang 2004**
Methods	Parallel, 24 h Control: IM morphine
Participants	PCA 62, IM 63 Abdominal gynecologic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: NR/8-10 min/NR
Outcomes	PCA group: morphine requirements higher, VAS pain scores lower, satisfaction higher, equipment costs higher.
Notes	Adverse events: nature - PCA vs control (n/N): nausea: 24/62 vs 13/63; vomiting: 20/62 vs 12/63; dizziness: 20/62 vs 13/63 (only differences in nausea significant). No respiratory depression or pruritus in either group QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Choiniere 1998**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 60, IM 63 Abdominal hysterectomy
Interventions	Morphine. Bolus/lockout/4 h limit: 1-1.5 mg/6 min/NR
Outcomes	PCA group: morphine requirements lower, lower frequency of required dose adjustments, similar (low) VAS pain scores, higher percentage of satisfied patients.

Characteristics of included studies (*Continued*)

Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (0 = no sedation, 3 = difficult to arouse): median 0.8 vs 0.7; nausea and vomiting: 45/60 vs. 40/63; pruritus: 25/60 vs 21/63; respiratory depression: 4/60 vs 1/63; urinary retention: 8/60 vs 14/63 Withdrawals: PCA group, n = 3: allergic reaction to morphine, pneumothorax, defective pump QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	A – Adequate

Study	**Colwell 1995**
Methods	Parallel, 72 h Control: IM morphine or meperidine (doses converted to morphine equivalents)
Participants	PCA 91, IM 93 Elective joint replacement or spinal procedure
Interventions	Morphine or meperidine (converted to morphine equivalents). Bolus/lockout/4 h limit: 0.25-0.5 mg/6 min/10-20 mg
Outcomes	PCA group: morphine requirements lower on first day, but no difference overall, higher overall pain score, joint replacement group walked farther on first day if using PCA, more patients would recommend PCA, cost per patient higher
Notes	Adverse events: nature - PCA vs control (n/N): oversedation: 4/91 vs 7/93; nausea and vomiting: 16/91 vs 12/93; urinary retention: 32/91 vs 30/93 Withdrawals: n = 11 Unplanned admission to ICU, lack of preoperative instruction, allergy to a medication used, operation cancelled (numbers not specified) QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Coyle 1990**
Methods	Parallel, 72 h Control: IM/IV morphine
Participants	PCA 27, IM/IV 25 Coronary artery bypass graft
Interventions	Morphine. Bolus/lockout/4 h limit: 0.01-0.02 mg/kg/15-20 min/NR
Outcomes	PCA group: no information on morphine requirements, mean daily VAS scores similar, but incidence of severe pain (> 5/10) lower
Notes	Oxygen saturation < 90%: PCA 3/27 vs 3/25 No difference in sedation scores, hemodynamic parameters, or incidence of post-operative complications. Withdrawals: intraoperative death (n = 1), postoperative neurologic deficits (n = 3), lack of understanding of PCA by caregivers (n =2), inadequate data collection (n = 2) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Dahl 1987**
Methods	Parallel, 16 h Control: IM/IV morphine
Participants	PCA 18, IM/IV 18

Characteristics of included studies (*Continued*)

	Lower abdominal surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 2.5 mg/10 min/NR
Outcomes	PCA group: no difference in morphine requirements, linear analog pain scores or verbal pain relief scores.
Notes	Adverse events: nature - PCA vs control (n/N): severe nausea: 8/18 vs 4/18; vomiting: 6/18 vs 2/18 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Egbert 1993**
Methods	Parallel, 48 h Control: IV ketobemidone nurse controlled infusion
Participants	PCA 43; IM 40 Major elective surgery in frail elderly men
Interventions	Morphine. Bolus/lockout/4 h limit: 0.01 mg/kg (titration allowed)/10 min/NR
Outcomes	PCA group: similar morphine requirements, pain scores lower on day 2,3 and overall, more would choose this method again. 86% of PCA patients preferred PCA. Improved analgesia independent of psychological factors
Notes	Adverse events: nature - PCA vs control (n/N): asymptomatic desaturation: 6/43 vs 6/40; significant confusion and hypoventilation: 0/43 vs 4/40; urinary retention: 10/43 vs 11/40. Ileus duration: PCA 1.6 days vs 1.5 days Similar sedation scores QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Eisenach 1988**
Methods	Parallel, 24 h Control: IM morphine or meperidine (doses converted to morphine equivalents)
Participants	PCA 20, IM 20 Repeat Cesarean section
Interventions	Morphine. Bolus/lockout/4 h limit: 2 mg/15 min/NR
Outcomes	PCA group: total morphine requirements higher, fewer patients reported being very uncomfortable or in pain, more patients satisfied with therapy compared to previous surgery
Notes	Adverse events: nature - PCA vs control (n/N): nausea: 6/20 vs 5/20; nausea requiring treatment: 1/20 vs 2/20; pruritus: 12/20 vs 14/20; pruritus requiring treatment: 1/20 vs 1/20 Patients asleep: PCA 45% of 120 observations, IM 20% of 120 observations QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Ellis 1982a**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 15, IM 17 cholecystectomy

Characteristics of included studies (*Continued*)

Interventions	Meperidine. Bolus/lockout/4 h limit: NR
Outcomes	PCA group: higher morphine requirements (NS), similar linear analog pain scores, number of satisfied patients.
Notes	Adverse events: nature - PCA vs control: sedation (0-10, 10 = max sedation): 4.8+/-0.8 (SEM) vs 6.1+/-0.7 (day 1), 3.7+/-1.0 vs 3.4+/-0.7 (day 2), 0.4+/-0.2 vs 1.4+/-0.6 (day 5); nausea and vomiting: 0.4+/-0.1 vs 1.8+/- 0.6 (day 1), 2.3+/-0.8 vs 1.2+/-0.5 (day 2), 0.4+/-0.2 vs 0.3+/-0.1 (day 5) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Ellis 1982b**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 20, IM 20 hysterectomy
Interventions	Meperidine. Bolus/lockout/4 h limit: NR
Outcomes	PCA group: higher morphine requirements during first 24 h, similar analog pain scores, number of satisfied patients
Notes	Adverse events: nature - PCA vs control: sedation (0-10, 10 = max sedation): 5.8+/-0.7 (SEM) vs 6.0+/-0.7 (day 1), 2.4+/-0.7 vs 3.2+/-0.6 (day 2); nausea and vomiting: 2.3+/-0.7 vs 3.4+/- 0.7 (day 1), 2.0+/-0.7 vs 1.1+/-0.4 (day 2) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	C – Inadequate

Study	**Ferrante 1988**
Methods	Parallel, 40 h Control: IM morphine or meperidine
Participants	PCA 20, IM 20 Total knee replacement
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/10 min/10 mg
Outcomes	PCA group: no difference in morphine requirements, more hours of moderate pain, higher satisfaction scores
Notes	Adverse events: nature - PCA vs control: sleepiness (1-4, 1 = awake): 1.9 vs 2.4 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Gillman 1995**
Methods	Parallel, 42 h Control: IM morphine
Participants	PCA 11, IM 11 Total abdominal hysterectomy
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/6 min/NR

Characteristics of included studies (*Continued*)

Outcomes	PCA group: higher morphine requirements at all times (NS), higher VAS pain scores at all times (NS, except at 2 h), no difference in number of patients satisfied with therapy, higher cost of therapy
Notes	Adverse events: nature - PCA vs control (n/N): nausea 6/11 vs 7/11; vomiting 2/11 vs 1/11; pruritus 5/11 vs 1/11 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Harrison 1988**
Methods	Parallel, 24 h Control: IM morphine
Participants	PCA 18, IM 20 Cesarean section
Interventions	Morphine. Bolus/lockout/4 h limit: 2 mg/6 min/NR
Outcomes	PCA group: NS difference in morphine requirements, VAS pain scores, LOS. All patients receiving PCA stated that they would choose it again
Notes	Adverse events: nature - PCA vs control (n/N): pruritus: 7/18 vs 3/20; nausea and vomiting: same incidence (numbers not stated) No respiratory rate < 10/min in either group QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Hecker 1988a**
Methods	Parallel/crossover, 48 h Control: IM/IV morphine
Participants	PCA 11, IM/IV 7 cholecystectomy
Interventions	Morphine. Patients in PCA group first used PCA apparatus that emitted a beep only if drug was delivered, then crossed over on day 2 to apparatus which beeped whenever patient depressed button, regardless of whether drug was delivered ("placebo effect"). Bolus/lockout/4 h limit: 1 mg (titration allowed)/6 min/NR
Outcomes	No difference in morphine requirements between Hecker (a) group and Hecker (b). Combined PCA groups used less morphine overall (48 h) than control group (also significant at several time points) Pain intensity and relief superior to control group, but only significant when patients used non- "placebo effect" PCA Also, statistically less anxiety and increased nursing satisfaction reported only with non-"placebo effect" PCA "Placebo-effect" pump cost (equipment plus labor) similar to control treatment. Non-"placebo effect" pump more expensive
Notes	Adverse events: nature - PCA vs. control (n/N or continuous data): sedation (0-100): 60.3+/-24.7 vs 65.1+/-19 (day 1), 56.2+/-28.2 vs 56.4+/-23.5 (day 2); nausea and vomiting: 6/11 vs 4/11; urinary retention: 5/11 vs 4/11 Withdrawals (from both parts of study): Incorrect data collection or disruption of protocol (n =6), additional surgery (n = 1) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Characteristics of included studies (*Continued*)

Study	**Hecker 1988b**
Methods	Parallel/crossover, 48 h Control: IM/IV morphine
Participants	PCA 10, IM/IV 7 cholecystectomy
Interventions	Morphine. Patients in PCA group first used PCA apparatus that beeped whenever patient depressed button ("placebo effect"), regardless of whether drug was delivered, then crossed over on day 2 to apparatus which emitted a beep only if drug was delivered, i.e., opposite order to Hecker (a). Bolus/lockout/4 h limit: 1 mg (titration allowed)/6 min/NR
Outcomes	No difference in morphine requirements between Hecker (a) group and Hecker (b) Combined PCA groups used less morphine overall (48 h) than control group (also significant at several time points) Pain intensity and relief superior to control group, but only significant when patients used non-"placebo effect" PCA Also, statistically less anxiety and increased nursing satisfaction reported only with non-"placebo effect" PCA "Placebo-effect" pump cost (equipment plus labor) similar to control treatment. Non-"placebo effect" pump more expensive.
Notes	Adverse events: nature - PCA vs control (n/N or continuous data): sedation (0-100): 65.1+/-29.5 vs 65.1+/-19 (day 1), 48.8+/-28.3 vs 56.4+/-23.5 (day 2); nausea and vomiting: 6/11 vs 4/11; urinary retention: 6/11 vs 4/11 Withdrawals: See "Hecker (a)" QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Jackson 1989**
Methods	Parallel, 48 h Control: IM meperidine (with hydroxyzine or promethazine).
Participants	Cholecystectomy group: PCA 71, IM 34 Hysterectomy group: PCA 72, IM 151
Interventions	Meperidine. Bolus/lockout/4 h limit: 10 mg/8 min/NR
Outcomes	PCA group: both cholecystectomy and hysterectomy patients lower meperidine requirements, quicker switch to oral therapy (2 vs. 3 days) 96% of patients in PCA groups preferred PCA to IM therapy 100% of nurses thought patients pain controlled better with PCA
Notes	Not reported QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Keita 2003**
Methods	Parallel, 48 h Control: SC morphine
Participants	PCA 20, SC 20 Total hip replacement in elderly patients
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/8 min/NR

Characteristics of included studies (*Continued*)

Outcomes	PCA group: no differences in morphine requirements at any time, VAS pain scores lower at all times, LOS and mental status scores similar
Notes	Adverse events: nature - PCA vs control (n/N): nausea and vomiting: 8/20 vs 6/20; pruritus: 4/20 vs 2/20; urinary retention: 5/20 vs 4/20. No severe sedation in either group. QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Kenady 1992**
Methods	Parallel, 72 h Control: IM morphine
Participants	PCA 35, IM 18 cholecystectomy
Interventions	Morphine. Bolus/lockout/4 h limit: NR
Outcomes	PCA group: higher morphine requirements at all times (NS), less patients reported pain more than 50% of the time, less patients had limited mobility
Notes	PCA group less groggy (no details) Withdrawals: Admitted to ICU (n = 1), PCA malfunction (n = 1) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Kleiman 1988**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 15, IM 15 Colectomy, orthopedic spinal
Interventions	Morphine. Bolus/lockout/4 h limit: 2 mg (titration allowed)/15 min/NR
Outcomes	PCA group: NS differences in morphine requirements, or verbal rating of pain.
Notes	Wakefulness Scale (1 = wide awake, 5 = awakens only when aroused): PCA 2.62 vs 2.375 Nausea scale (0 = no nausea, 4 = frequent vomiting): PCA 1.27+/-0.26 vs 1.42+/-0.37 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Kyzer 1995**
Methods	Parallel, 24 h Control: IM meperidine (converted to morphine equivalents)
Participants	PCA 12, IM 11 Gastroplasty
Interventions	Morphine. Bolus/lockout/4 h limit: 2 mg/15 min/NR
Outcomes	PCA group: greater cumulative morphine requirements, lower percentage of patients with severe pain, longer LOS
Notes	No difference between groups in nausea, pruritus or urinary retention. Numbers NR

	QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Martinez-Ubieto 1992**
Methods	Parallel, 24 h Control: IV morphine continuous infusion
Participants	PCA 15, IV 15 Abdominal surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 0.5 mg/30 min/NR
Outcomes	PCA group: lower morphine requirements (significance not described), higher VAS pain scores at all times.
Notes	Adverse events NR QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**McGrath 1989**
Methods	Parallel, 72 h Control: IM meperidine
Participants	PCA 44, IM 44 cholecystectomy
Interventions	Meperidine. Bolus/lockout/4 h limit: 0.25 mg/kg (titration allowed)/20 min/NR
Outcomes	PCA group: lower morphine requirements at 4 and 24 h, increased VAS pain scores at 2 and 4 h, no difference in patients' perceived locus of control, more patients satisfied with therapy
Notes	Adverse events NR QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Munro 1998**
Methods	Parallel, 4 days Control: SC morphine
Participants	PCA 39, SC 41 Elective cardiac surgery
Interventions	Morphine. Bolus/lockout/1 h limit: 1 mg/6 min/10 mg
Outcomes	PCA group: NS difference in total morphine requirements, pain relief scores, VAS pain scores at rest and on movement, or patient satisfaction.
Notes	Adverse events: nature - PCA vs control: nausea (0 = no nausea, 3 = vomiting not relieved by medication): 0.92 vs 0.97 (day 1), 1.02 vs 0.92 (day 2); pruritus (0 = no pruritus, 3 = severe not relieved by medication): 0.35 vs 036 (day 1), 0.37 vs 0.26 (day 2) Withdrawals: n = 12: delayed extubation (numbers from each group not given) QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Characteristics of included studies (*Continued*)

Study	**Murphy 1994**
Methods	Parallel, 24 h Control: IV meperidine nurse controlled infusion
Participants	PCA 100, IV 100 Laparotomy, thoracotomy
Interventions	Meperidine. Bolus/lockout/4 h limit: 20 mg/5 min/NR
Outcomes	PCA group: similar meperidine requirements and similar VAS pain scores at all times. Similar numbers in both groups had inadequate analgesia.
Notes	Adverse events: nature - PCA vs control (n/N): sedation: 18/100 vs 14/100; severe nausea: 28/100 vs 18/100; respiratory depression requiring treatment with naloxone: 1/100 vs 1/100 Withdrawals: previous neurological deficit preventing use of PCA (n = 1) QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Myles 1994**
Methods	Parallel, 72 h Control: IV morphine nurse controlled infusion
Participants	PCA 36, IV 33 Elective cardiac surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/5 min/no limit
Outcomes	PCA group: NS higher morphine requirements from 0-24 and 25-48 h, similar verbal pain ratings, cortisol concentrations at all times
Notes	Adverse events: nature - PCA vs control: nausea: (0-4): 0+/-0 vs 0.33+/-0.67 Withdrawals: Control, n = 3: 2 deaths, 1 cerebrovascular accident QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**O'Halloran 1997**
Methods	Parallel, 24 h Control: IV morphine nurse controlled infusion
Participants	PCA 35, IM 31 Elective cardiac surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/5 min/no limit
Outcomes	PCA group: higher total morphine requirements, similar VAS pain scores, although peak pain at rest, mean pain on movement and peak pain on movement all lower during second 6 h period
Notes	Adverse events: nature - PCA vs control (n/N): sedation: 1/35 vs 2/35; nausea requiring treatment: 0 vs 6/31 Withdrawals: PCA vs control (n): consent withdrawn: 2 vs 4; protocol violation: 2 vs 5; late extubation: 1 vs 3; postoperative complications: 4 vs 2; postoperative confusion: 0 vs 1 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Characteristics of included studies (*Continued*)

Study	**Paoletti 1993a**
Methods	Parallel, 12 h Control: IV morphine continuous infusion
Participants	PCA 20, IM 20 Orthopedic surgery in elderly patients
Interventions	Morphine. Bolus/lockout/4 h limit: 0.007 mg/kg/15 min/NR
Outcomes	PCA group: lower morphine requirements, lower pain scores at 2 and 12 h (NS)
Notes	Adverse events: nature - PCA vs control (n/N): nausea: 3/20 vs 6/20; pruritus: 2/20 vs 4/20. Withdrawal: see "Paoletti gyn" QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Paoletti 1993b**
Methods	Parallel, 42 h Control: IM morphine
Participants	PCA 22, IM 22 Gynecologic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/6-15 min/NR
Outcomes	PCA group: lower morphine requirements, lower pain scores at 36 and 42 h, more satisfied patients
Notes	Adverse events: nature - PCA vs control (n/N): nausea: 11/22 vs 13/22; vomiting: 5/22 vs 6/22; pruritus: 1/22 vs 2/22. Withdrawal (total from both studies): PCA, n = 1: hypotension/apnea QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Passchier 1993**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 17, IM 14 Elective upper abdominal surgery (cholecystectomy, intestinal resection)
Interventions	Morphine. Bolus/lockout/1 h limit: 1 mg/5 min/10 mg
Outcomes	PCA group: higher morphine requirements, higher VAS pain scores (NS), but greater pain relief, trend towards greater satisfaction
Notes	PCA group: Increased fatigue, lower vigor (Profile of Mood State) Withdrawals: PCA vs control (n): refused to continue postoperatively: 4 vs 5 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Perez-woods 1991**
Methods	Parallel, 48 h Control: IM morphine

Characteristics of included studies (*Continued*)

Participants	PCA 25, IM 17 Cesarean section
Interventions	Morphine. Bolus/lockout/1 h limit: 1-1.5 mg/6 min/10 doses
Outcomes	PCA group: higher total morphine requirements, lower VAS pain scores (NS), increased satisfaction and ambulation score, no difference in LOS.
Notes	Adverse events: nature - PCA vs control: sedation (1-5): 1.4+/-0.3 vs. 1.6+/-0.4 Degree of reduction in vital capacity and expiratory volume similar between groups QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Pettersson 2000**
Methods	Parallel, 48 h Control: IV ketobemidone nurse controlled infusion
Participants	PCA 24, IV 24 Coronary artery bypass graft
Interventions	Ketobemidone. Bolus/lockout/4 h limit: 1mg/6 min/30 mg
Outcomes	PCA group: higher total ketobemidone requirements, lower VAS pain scores after first day postoperatively
Notes	Adverse events: nature - PCA vs. control (n/N): nausea and vomiting: 15/24 vs 9/24; respiratory rate < 10/min: 5/24 vs 3/24 No somnolence or arterial desaturation Withdrawals (group not specified): incomplete protocol (n = 1), minor neurological deficit (n = 1) QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	C – Inadequate

Study	**Precious 1997**
Methods	Parallel, 48 h Control: IM/PO codeine or IM morphine
Participants	PCA 25, IM 25 Orthognathic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/10 min/NR
Outcomes	PCA group: less than half the total morphine equivalent requirements, lower VAS pain scores on both days, higher overall patient rating
Notes	Adverse events: nature - PCA vs control (n/N): nausea: 4/25 vs 15/25; vomiting: 2/25 vs 6/25 No respiratory depression in either group QS = 3 (R = 2, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Rayburn 1988**
Methods	Parallel, 24 h Control: IM meperidine
Participants	PCA 67, IM 62 Cesarean section

Characteristics of included studies (*Continued*)

Interventions	Meperidine. Bolus/lockout/1 h limit: 10 mg/10 min/60 mg
Outcomes	PCA group: higher total meperidine requirements, similar verbal rated pain scores, higher total cost to hospital. Nurses preferred PCA.
Notes	Adverse events: nature - PCA vs control (continuous data); sedation (0 = no sedation, 3 requires arousal): 1.37+/-0.03 (SEM) vs. 1.98+/-0.02 QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Rogers 1990**
Methods	Parallel, 24 h Control: IM/IV morphine
Participants	PCA 34, IM 35 cholecystectomy
Interventions	Morphine. Bolus/lockout/4 h limit: 0.6 mg/m2/6 min/NR
Outcomes	PCA group: higher total morphine requirements, pain scores NR, similar LOS.
Notes	Adverse events: nature - PCA vs control (n/N): urinary retention: 2/34 vs 6/35 Clinical indicators of bowel function similar Atelectasis occurred in one patient in PCA group QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Rosen 1998**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 36, IM 36 Gynecologic laparoscopy
Interventions	Morphine. Bolus/lockout/4 h limit: 1.5 mg/5 min/NR
Outcomes	PCA group: no significant difference in morphine requirements, VAS pain scores during any time period, LOS or patient satisfaction scores.
Notes	Adverse events: nature - PCA vs control: sedation (0 = asleep, 4 = fully awake): 0.9 vs. 0.65 QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Sanansilp 1995**
Methods	Parallel, 48 h Control: IM morphine, around the clock.
Participants	PCA 21, IM 21 Elective major orthopedic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/6-8 min/20 mg

Characteristics of included studies (*Continued*)

Outcomes	PCA group: lower total morphine requirements, VAS pain scores at rest and with movement similar. Satisfaction scores similar, but all patients in PCA group said they would use it again vs. 15/21 in the IM group.
Notes	Adverse events: nature - PCA vs control (n/N): nausea/vomiting: 7/21 vs 12/21 (day1), 2/21 vs 5/21 (day 2); itching: 2/21 vs 2/21 (day 1), 3/21 vs 1/21 (day 2); bladder dysfunction: 5/21 vs 6/21 (day 1), 1/21 vs 0/21 (day 2); pain at injection site: 2/21 vs 14/21 (day 1), 3/21 vs 8/21 (day 2); sleeplessness: 11/21 vs 8/21 (day 1), 3/21 vs 5/21 (day 2) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Smythe 1994**
Methods	Parallel, 24 h Control: IM meperidine
Participants	PCA 19, IM 17 hysterectomy
Interventions	Morphine. Bolus/lockout/4 h limit:1 mg/6 min/NR or Meperidine. Bolus/lockout/4 h limit: 10 mg/6 min/NR
Outcomes	Morphine. PCA group: meperidine requirements NR, lower percentage of patients with moderate to severe pain, mean nursing and pharmacy time greater, similar LOS, higher direct costs.
Notes	Adverse events: nature - PCA vs control (n/N): drowsiness: 2/19 vs 0; nausea: 10/19 vs. 9/17; vomiting: 1/19 vs 2/17; urinary retention: 0 vs 1/17 Withdrawals: PCA - severe nausea: 1 patient discontinued after 2 h QS = 1 (R = 1, DB = 0, W = 0)
Allocation concealment	B – Unclear

Study	**Snell 1997**
Methods	Parallel, 48 h Control: IM meperidine
Participants	PCA 44, IM 23 Major abdominal surgery
Interventions	Morphine or meperidine. Bolus/lockout/4 h limit: NR
Outcomes	PCA group: no significant differences in opioid requirements, VAS pain scores, degree of patient satisfaction or LOS, later ambulation
Notes	Adverse events: nature - PCA vs. control: sedation (0-10): 6.85 vs 6.12; nausea and vomiting (0-10): 3.24 vs 2.57 Patients in IM group received almost 3x as much antiemetic as PCA group Withdrawals: PCA vs control (n): 6 vs 12: physician changing analgesic route (n = 8), change in operation (n = 7) QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Stoneham 1996**
Methods	Parallel, 24 h

Characteristics of included studies (*Continued*)

	Control: IM codeine
Participants	PCA 15, IM 15 Craniotomy
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/10 min/NR
Outcomes	PCA group: no significant differences in morphine equivalent requirements, VAS pain scores
Notes	Median nausea score = 0 (0 = none) and Glasgow coma score = 15 in both groups at 24 h No respiratory rate < 10/min in either group QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	A – Adequate

Study	**Taylor 1994**
Methods	Parallel, 72 h Control: IM morphine
Participants	PCA 266, IM 246 Various
Interventions	Morphine. Bolus/lockout/4 h limit: NR
Outcomes	PCA group: higher total morphine requirements, lower VAS and VRS pain scores, less nursing time required
Notes	"no difference in reported side effects" (NR) QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Thomas 1995**
Methods	Parallel, 24 h Control: IM papaveretum
Participants	PCA 61, IM 49 Total abdominal hysterectomy
Interventions	Papaveretum. Bolus/lockout/4 h limit: 2-4 mg/10-15 min/NR
Outcomes	PCA group: lower total papaveretum requirements, lower McGill Pain Questionnaire Short Form total pain scores, reduced LOS Patients with high level state anxiety experienced the greatest reduction in total pain scores with PCA
Notes	Adverse events NR QS = 1 (R = 0, DB = 0, W = 1)
Allocation concealment	D – Not used

Study	**Walson 1992**
Methods	Crossover, 48 h Control: IM hydromorphone or meperidine
Participants	10 (crossover study; 5 vs 5) spinal fusion in adolescents
Interventions	Morphine. Bolus/lockout/1 h limit: 0.6 mg/m2/6 min/10 doses

Characteristics of included studies (*Continued*)

Outcomes	PCA group: higher morphine equivalent requirements (NS), lower VAS pain scores
Notes	Equal sedation (no data) between groups, no systematic recording of nausea, pruritus or ileus QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Wang 1991**
Methods	Parallel, 48 h Control: IM meperidine
Participants	PCA 13, IM 13 Thoracotomy
Interventions	Meperidine. Bolus/lockout/4 h limit: 8-15 mg/6-12 min/100-150 mg
Outcomes	PCA group: higher meperidine requirements on both days, lower VAS pain scores on both days
Notes	IM group had more disturbance of nocturnal sleep, slower recovery of lung function QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Wasylak 1990**
Methods	Parallel, 48 h Control: IM morphine
Participants	PCA 20, IM 18 Gynecologic surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/10 min/NR
Outcomes	PCA group: similar total morphine requirements, although initially higher, lower VAS and McGill Pain Questionnaire Short Form total pain scores, earlier ambulation, decreased LOS
Notes	Respiratory rate reduced to greater extent in PCA group, but never < 10/min. Reduction in vital capacity and recovery rate similar QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

Study	**Wheatley 1992**
Methods	Parallel, 24 h Control: IM morphine
Participants	PCA 19, IM 20 Upper abdominal surgery
Interventions	Morphine. Bolus/lockout/4 h limit: 1 mg/5 min/NR
Outcomes	PCA group: similar morphine consumption, lower VAS pain scores at 12, 16 and 24 h, greater proportion of patients rating analgesia as excellent
Notes	Oxygen saturation < 85% for > 6 min: PCA 1/19 vs 3/20 Withdrawals: PCA, n = 1: insufficient data collected for technical reasons QS = 2 (R = 1, DB = 0, W = 1)
Allocation concealment	B – Unclear

ICU = intensive care unit; IM = intramuscular; IV = intravenous; LOS = length of stay; NR = not reported; PO = by mouth; SC = subcutaneous; VAS = visual analog score; VRS = verbal rating scores.

Characteristics of excluded studies

Study	Reason for exclusion
Atwell 1984	Data poorly presented, extraction not possible
D'haese 1998	Used continuous background infusion with PCA
Duggleby 1992	Used continuous background infusion with PCA
Forst 1999	Control group administered tramadol (non-conventional opioid)
Gaitini 1996	Control group administered buprenorphine (partial agonist)
Gust 1999	Control group also received NSAID Used continuous background infusion with PCA
Jellinek 1990	Both groups administered tramadol (non-conventional opioid)
Kilbride 1992	Used continuous background infusion with PCA
Knapp-Spooner 1995	Non RCT
Knudsen 1993	Used continuous background infusion with PCA
Lange 1988	Administered buprenorphine, a partial agonist
Moller 1988	Outcomes presented (plasma catecholamines, cortisol and glucose levels) were not those listed in inclusion criteria
Moreno 2000	NSAID included in both groups
Nitschke 1996	Used continuous background infusion with PCA in unspecifed number of patients
Peters 1999	Used continuous background infusion with PCA
Rittenhouse 1999	Outcomes presented (costs) were not those listed in inclusion criteria
Robinson 1991	Both groups received PCA
Rundshagen 1999	Used continuous background infusion with PCA
Searle 1994	Used continuous background infusion with PCA Control group could receive opioid/acetaminophen combination
Shin 2001	PCA group administered nalbuphine (agonist/antagonist) combined with NSAID
Spetzler 1987	Control group from retrospective chart review, one time questionnaire assessment, no VAS, poor quality paper.
Tsang 1999	Used continuous background infusion with PCA
Viscusi 2004	Both groups received PCA
Weldon 1993	Both groups received PCA Used continuous background infusion with PCA in one group
White 1998	Proportion of patients had chronic pain Results not provided separately
Woodhouse 1997	Both groups received PCA - study compared outcomes based on age of patients
Woods 1991	Administered nalbuphine (agonist/antagonist)
Zacharias 1990	Used continuous background infusion with PCA

Characteristics of excluded studies (*Continued*)

ANALYSES

Comparison 01. VAS pain scores (0-100): PCA versus control

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Pain scores 0 - 24 h	27	2065	Weighted Mean Difference (Random) 95% CI	-7.97 [-11.72, -4.21]
02 Pain scores 25 - 48 h	17	756	Weighted Mean Difference (Random) 95% CI	-9.48 [-14.27, -4.69]
03 Pain scores 49 - 72 h	5	783	Weighted Mean Difference (Random) 95% CI	-12.70 [-19.63, -5.76]
04 Pain scores 0 - 48 h	6	292	Weighted Mean Difference (Random) 95% CI	-9.33 [-13.71, -4.95]
05 Pain scores 0 - 72 h	2	113	Weighted Mean Difference (Random) 95% CI	-3.13 [-12.34, 6.07]
06 Pain scores 0 - 24 h: by surgery type			Weighted Mean Difference (Random) 95% CI	Subtotals only
07 Pain scores 0 - 24 h minus inadequately randomized trials	24	1759	Weighted Mean Difference (Random) 95% CI	-7.15 [-10.93, -3.37]
08 Pain scores 25 - 48 h minus inadequately randomized trials	16	689	Weighted Mean Difference (Random) 95% CI	-9.31 [-14.36, -4.27]
09 Pain scores 0 - 48 h minus inadequately randomized trials	3	143	Weighted Mean Difference (Random) 95% CI	-11.98 [-18.82, -5.14]

Comparison 02. Opioid consumption: PCA versus control

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Consumption of morphine equivalents 0 - 24 h	23	1418	Weighted Mean Difference (Random) 95% CI	6.72 [0.50, 12.94]
02 Consumption of morphine equivalents 25 - 48 h	8	400	Weighted Mean Difference (Random) 95% CI	2.99 [-1.40, 7.37]
03 Consumption of morphine equivalents 0 - 48 h	11	529	Weighted Mean Difference (Random) 95% CI	7.43 [-11.91, 26.77]
04 Consumption of morphine equivalents 0 - 72 h	5	756	Weighted Mean Difference (Random) 95% CI	23.78 [12.87, 34.70]
05 Consumption of morphine equivalents 0 - 24 h by surgery type			Weighted Mean Difference (Random) 95% CI	Subtotals only
06 Consumption of morphine equivalents 0 - 24 h minus inadequately randomized trials	20	1139	Weighted Mean Difference (Random) 95% CI	7.43 [2.96, 11.90]
07 Consumption of morphine equivalents 0 - 48 h minus inadequately randomized trials	10	487	Weighted Mean Difference (Random) 95% CI	2.85 [-16.12, 21.82]

Comparison 03. Patient satisfaction: PCA versus control

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Satisfaction on a 0 - 100 scale (100 = most satisfied)	9	585	Weighted Mean Difference (Random) 95% CI	6.21 [1.19, 11.23]
02 Number of patients in arm satisfied with therapy	12	675	Relative Risk (Random) 95% CI	1.26 [1.08, 1.48]

03 Satisfaction on a 0 - 100 scale (100 = most satisfied) minus inadequately randomized trials	7	476	Weighted Mean Difference (Random) 95% CI	5.12 [-0.86, 11.11]

Comparison 04. Length of stay

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Number of days: PCA versus control	9	501	Weighted Mean Difference (Random) 95% CI	-0.29 [-0.89, 0.32]
02 Number of days: PCA versus control minus inadequately randomized trials	7	324	Weighted Mean Difference (Random) 95% CI	-0.23 [-0.89, 0.42]

Comparison 05. Sedation

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Sedation on a 0-100 scale (100 = most sedated)	12	554	Weighted Mean Difference (Random) 95% CI	-5.96 [-13.07, 1.16]
02 Number of patients in arm reporting sedation	7	632	Relative Risk (Random) 95% CI	0.85 [0.67, 1.08]
03 Sedation on a 0-100 scale (100 = most sedated) minus inadequately randomized trials	9	343	Weighted Mean Difference (Random) 95% CI	-3.86 [-8.66, 0.93]

Comparison 06. Nausea and vomiting

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Nausea and vomiting on a 0 - 100 scale (100 = most severe)	5	197	Weighted Mean Difference (Random) 95% CI	3.79 [-3.09, 10.67]
02 Number of patients reporting nausea or vomiting, or both	23	1592	Relative Risk (Random) 95% CI	1.05 [0.86, 1.27]
03 Number of patients reporting nausea or vomiting, or both, by surgery type			Relative Risk (Random) 95% CI	Subtotals only
04 Number of patients reporting nausea or vomiting, or both, minus inadequately randomized trials	21	1360	Relative Risk (Random) 95% CI	1.08 [0.89, 1.32]

Comparison 07. Pruritus

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Number of patients reporting pruritus	9	456	Relative Risk (Random) 95% CI	1.44 [1.04, 2.01]
02 Number of patients reporting pruritus by surgery type			Relative Risk (Random) 95% CI	Subtotals only

Comparison 08. Urinary retention

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Number of patients reporting urinary retention	10	667	Relative Risk (Random) 95% CI	0.91 [0.70, 1.18]
02 Number of patients reporting urinary retention by surgery type			Relative Risk (Random) 95% CI	Subtotals only

INDEX TERMS

Medical Subject Headings (MeSH)

*Analgesia, Patient-Controlled; Analgesics, Opioid [*administration & dosage]; Pain, Postoperative [*drug therapy]; Patient Satisfaction; Randomized Controlled Trials

MeSH check words

Humans

COVER SHEET

Title	Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain
Authors	Hudcova J, McNicol E, Quah C, Lau J, Carr DB
Contribution of author(s)	Jana Hudcova: organizing retrieval of papers, screening retrieved papers against inclusion criteria, appraising quality of papers, extracting data from papers, writing the review. Ewan McNicol: appraising quality of papers, extracting data from papers, entering data into RevMan, analysis of data, compiling of "table of included studies" and "table of excluded studies", writing the review. Cheng Quah: design, coordination, data collection, screening search results, organizing retrieval of papers, screening retrieved papers against inclusion criteria, appraising quality of papers, extracting data from papers. Daniel Carr: conceiving the review, design, coordination, developing search strategy. Providing a methodological, clinical, policy and consumer perspective. Providing general advice on the review. Securing funding for the review. Joseph Lau: analysis of data. Providing a methodological and clinical perspective. Providing general advice on the review.
Issue protocol first published	2001/4
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What's New	Information not supplied by author
Date new studies sought but none found	Information not supplied by author
Date new studies found but not yet included/excluded	Information not supplied by author

Date new studies found and included/excluded	Information not supplied by author
Date authors' conclusions section amended	Information not supplied by author
Contact address	Dr Jana Hudcova Anaesthesiologist Department of Anaesthesiology Tufts - New England Medical Center 750 Washington Street Box 298 Boston Massachusetts 02111 USA E-mail: jhudcova@tufts-nemc.org Tel: +1 617 636 6044 Fax: +1 617 636 8384
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GRAPHS AND OTHER TABLES

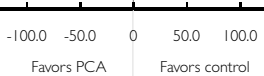
Analysis 01.01. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 01 Pain scores 0 - 24 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 01 Pain scores 0 - 24 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Rayburn 1988	67	40.92 (16.35)	62	45.00 (18.37)		4.3	-4.08 [-10.10, 1.94]
Sanansilp 1995	21	41.00 (22.00)	21	52.00 (25.00)		2.9	-11.00 [-25.24, 3.24]
Egbert 1993	43	45.90 (19.00)	40	47.70 (18.00)		4.0	-1.80 [-9.76, 6.16]
McGrath 1989	44	45.00 (17.00)	44	48.00 (18.00)		4.1	-3.00 [-10.32, 4.32]
Wasylak 1990	20	37.50 (2.50)	18	48.00 (5.00)		4.8	-10.50 [-13.06, -7.94]
Hecker 1988a	11	40.31 (19.78)	7	50.10 (24.24)		1.9	-9.79 [-31.22, 11.64]
Passchier 1993	17	45.80 (12.50)	14	37.20 (12.30)		3.9	8.60 [-0.16, 17.36]
Choiniere 1998	60	18.00 (10.00)	63	17.00 (11.00)		4.7	1.00 [-2.71, 4.71]



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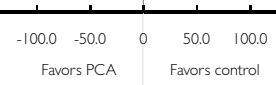
Study	PCA		Control		Weighted Mean Difference (Random)	Weight	Weighted Mean Difference (Random)
	N	Mean(SD)	N	Mean(SD)	95% CI	(%)	95% CI
Boulanger 1993	20	33.00 (14.00)	20	41.00 (19.00)		3.6	-8.00 [-18.34, 2.34]
Thomas 1995	61	36.10 (16.40)	49	68.00 (21.70)		4.1	-31.90 [-39.24, -24.56]
Taylor 1994	266	33.30 (16.67)	246	39.00 (20.00)		4.7	-5.70 [-8.90, -2.50]
Boldt 1998	30	47.00 (14.00)	30	49.00 (16.00)		4.1	-2.00 [-9.61, 5.61]
Chang 2004	62	15.84 (9.27)	63	27.67 (16.44)		4.5	-11.83 [-16.50, -7.16]
Pettersson 2000	24	19.00 (12.00)	24	22.00 (18.00)		3.9	-3.00 [-11.65, 5.65]
Ellis 1982a	15	43.00 (31.00)	17	39.00 (24.70)		2.1	4.00 [-15.60, 23.60]
Snell 1997	44	31.70 (18.10)	23	36.00 (18.60)		3.8	-4.30 [-13.59, 4.99]
Ceriati 2003	20	7.70 (11.20)	20	32.80 (27.10)		3.1	-25.10 [-37.95, -12.25]
Murphy 1994	100	21.00 (15.00)	100	17.00 (15.00)		4.6	4.00 [-0.16, 8.16]
Bhise 1997	10	19.50 (3.60)	10	18.80 (4.40)		4.7	0.70 [-2.82, 4.22]
Wang 1991	13	37.00 (11.00)	13	61.00 (9.00)		4.0	-24.00 [-31.73, -16.27]
Walson 1992	10	29.00 (13.00)	10	44.00 (23.00)		2.5	-15.00 [-31.37, 1.37]
Chan 1995b	24	41.10 (5.50)	20	65.40 (9.10)		4.6	-24.30 [-28.85, -19.75]
Wheatley 1992	19	19.00 (21.80)	20	38.00 (26.80)		2.7	-19.00 [-34.30, -3.70]
Ellis 1982b	20	27.00 (22.40)	20	35.00 (31.30)		2.5	-8.00 [-24.87, 8.87]
Hecker 1988b	10	41.68 (22.14)	7	50.10 (24.24)		1.8	-8.42 [-31.02, 14.18]
Chan 1995a	12	26.00 (7.40)	11	24.70 (6.80)		4.4	1.30 [-4.50, 7.10]
Precious 1997	25	23.00 (15.00)	25	35.00 (16.00)		3.9	-12.00 [-20.60, -3.40]
Total (95% CI)	1068		997			100.0	-7.97 [-11.72, -4.21]

Test for heterogeneity chi-square=233.40 df=26 p=<0.0001 I^2 =88.9%

Test for overall effect z=4.16 p=0.00003



Analysis 01.02. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 02 Pain scores 25 - 48 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

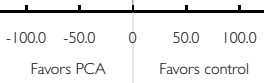
Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 02 Pain scores 25 - 48 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Sanansilp 1995	21	25.00 (19.00)	21	45.00 (22.00)		5.2	-20.00 [-32.43, -7.57]
Egbert 1993	43	26.40 (18.60)	40	36.00 (23.00)		6.3	-9.60 [-18.64, -0.56]
McGrath 1989	44	37.00 (13.00)	44	43.00 (17.00)		7.1	-6.00 [-12.32, 0.32]
Hecker 1988a	11	33.83 (19.50)	7	40.21 (20.94)		3.5	-6.38 [-25.70, 12.94]
Wasylak 1990	20	30.00 (2.50)	18	47.00 (5.00)		7.9	-17.00 [-19.56, -14.44]
Boulanger 1993	20	36.00 (19.00)	20	30.00 (14.00)		5.9	6.00 [-4.34, 16.34]
Boldt 1998	30	31.00 (15.00)	30	49.00 (16.00)		6.6	-18.00 [-25.85, -10.15]
Pettersson 2000	24	16.00 (10.00)	24	30.00 (17.00)		6.6	-14.00 [-21.89, -6.11]
Ellis 1982a	15	26.00 (19.40)	17	22.00 (23.20)		4.6	4.00 [-10.77, 18.77]
Snell 1997	44	26.00 (17.60)	23	37.90 (21.00)		6.0	-11.90 [-21.93, -1.87]
Ceriati 2003	20	6.90 (13.00)	20	29.80 (25.00)		5.3	-22.90 [-35.25, -10.55]
Wang 1991	13	28.00 (8.00)	13	53.00 (11.00)		6.8	-25.00 [-32.39, -17.61]
Chan 1995b	24	37.30 (11.50)	20	40.10 (5.90)		7.4	-2.80 [-8.08, 2.48]
Ellis 1982b	20	29.00 (26.80)	20	23.00 (17.90)		4.7	6.00 [-8.12, 20.12]
Hecker 1988b	10	30.78 (21.29)	7	40.21 (20.94)		3.3	-9.43 [-29.80, 10.94]
Chan 1995a	12	20.80 (12.50)	11	13.70 (5.90)		6.6	7.10 [-0.79, 14.99]
Precious 1997	25	19.00 (13.00)	25	33.00 (18.00)		6.4	-14.00 [-22.70, -5.30]
Total (95% CI)	396		360			100.0	-9.48 [-14.27, -4.69]

Test for heterogeneity chi-square=94.43 df=16 p=<0.0001 I^2 =83.1%

Test for overall effect z=3.88 p=0.0001



Analysis 01.03. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 03 Pain scores 49 - 72 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 03 Pain scores 49 - 72 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Egbert 1993	43	20.00 (15.70)	40	31.80 (23.70)		17.4	-11.80 [-20.52, -3.08]
McGrath 1989	44	38.00 (16.00)	44	39.00 (17.00)		19.5	-1.00 [-7.90, 5.90]
Boldt 1998	30	20.00 (12.00)	30	43.00 (10.00)		20.8	-23.00 [-28.59, -17.41]
Taylor 1994	266	37.00 (23.10)	246	53.10 (26.40)		22.0	-16.10 [-20.41, -11.79]
Ceriati 2003	20	6.10 (5.40)	20	16.50 (13.00)		20.2	-10.40 [-16.57, -4.23]
Total (95% CI)	403		380			100.0	-12.70 [-19.63, -5.76]

Test for heterogeneity chi-square=26.07 df=4 p=<0.0001 I^2 =84.7%

Test for overall effect z=3.59 p=0.0003

Analysis 01.04. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 04 Pain scores 0 - 48 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 04 Pain scores 0 - 48 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Perez-woods 1991	25	41.00 (51.00)	17	64.00 (96.00)		0.8	-23.00 [-72.82, 26.82]
Berde 1991	32	45.80 (24.50)	23	55.50 (24.60)		11.1	-9.70 [-22.86, 3.46]
Bollish 1985	20	32.00 (11.00)	20	42.00 (16.00)		26.5	-10.00 [-18.51, -1.49]
Snell 1997	44	35.70 (14.10)	23	40.70 (16.10)		31.7	-5.00 [-12.79, 2.79]
Bedder 1991	20	38.00 (102.90)	18	42.00 (76.40)		0.6	-4.00 [-61.27, 53.27]
Precious 1997	25	21.00 (13.00)	25	34.00 (16.00)		29.4	-13.00 [-21.08, -4.92]
Total (95% CI)	166		126			100.0	-9.33 [-13.71, -4.95]

Test for heterogeneity chi-square=2.33 df=5 p=0.80 I^2 =0.0%

Test for overall effect z=4.17 p=0.00003

Analysis 01.05. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 05 Pain scores 0 - 72 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

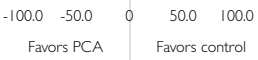
Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 05 Pain scores 0 - 72 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Kleiman 1988	15	30.00 (8.40)	15	28.60 (9.80)		51.8	1.40 [-5.13, 7.93]
Egbert 1993	43	32.50 (15.30)	40	40.50 (18.80)		48.2	-8.00 [-15.41, -0.59]
Total (95% CI)	58		55			100.0	-3.13 [-12.34, 6.07]

Test for heterogeneity chi-square=3.48 df=1 p=0.06 I^2 =71.3%

Test for overall effect z=0.67 p=0.5



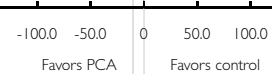
Analysis 01.06. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 06 Pain scores 0 - 24 h: by surgery type

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 06 Pain scores 0 - 24 h: by surgery type

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
01 Abdominal							
Ceriati 2003	20	7.70 (11.20)	20	32.80 (27.10)		5.9	-25.10 [-37.95, -12.25]
Chan 1995a	12	26.00 (7.40)	11	24.70 (6.80)		8.3	1.30 [-4.50, 7.10]
Chang 2004	62	15.84 (9.27)	63	27.67 (16.44)		8.7	-11.83 [-16.50, -7.16]
Choiniere 1998	60	18.00 (10.00)	63	17.00 (11.00)		8.9	1.00 [-2.71, 4.71]
Ellis 1982a	15	43.00 (31.00)	17	39.00 (24.70)		4.0	4.00 [-15.60, 23.60]
Ellis 1982b	20	27.00 (22.40)	20	35.00 (31.30)		4.6	-8.00 [-24.87, 8.87]
Hecker 1988a	11	40.31 (19.78)	7	50.10 (24.24)		3.6	-9.79 [-31.22, 11.64]
Hecker 1988b	10	41.68 (22.14)	7	50.10 (24.24)		3.3	-8.42 [-31.02, 14.18]
McGrath 1989	44	45.00 (17.00)	44	48.00 (18.00)		7.9	-3.00 [-10.32, 4.32]
Passchier 1993	17	45.80 (12.50)	14	37.20 (12.30)		7.3	8.60 [-0.16, 17.36]
Rayburn 1988	67	40.92 (16.35)	62	45.00 (18.37)		8.3	-4.08 [-10.10, 1.94]
Snell 1997	44	31.70 (18.10)	23	36.00 (18.60)		7.2	-4.30 [-13.59, 4.99]
Thomas 1995	61	36.10 (16.40)	49	68.00 (21.70)		7.8	-31.90 [-39.24, -24.56]



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Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Wasylak 1990	20	37.50 (2.50)	18	48.00 (5.00)		9.1	-10.50 [-13.06, -7.94]
Wheatley 1992	19	19.00 (21.80)	20	38.00 (26.80)		5.1	-19.00 [-34.30, -3.70]
Subtotal (95% CI)	482		438			100.0	-7.83 [-12.96, -2.70]
Test for heterogeneity chi-square=106.87 df=14 p=<0.0001 I^2 =86.9%							
Test for overall effect z=2.99 p=0.003							
02 Cardiac							
Bhise 1997	10	19.50 (3.60)	10	18.80 (4.40)		72.5	0.70 [-2.82, 4.22]
Boldt 1998	30	47.00 (14.00)	30	49.00 (16.00)		15.5	-2.00 [-9.61, 5.61]
Pettersson 2000	24	19.00 (12.00)	24	22.00 (18.00)		12.0	-3.00 [-11.65, 5.65]
Subtotal (95% CI)	64		64			100.0	-0.16 [-3.16, 2.84]
Test for heterogeneity chi-square=0.87 df=2 p=0.65 I^2 =0.0%							
Test for overall effect z=0.11 p=0.9							

-100.0 -50.0 0 50.0 100.0
Favors PCA Favors control

Analysis 01.07. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 07 Pain scores 0 - 24 h minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 07 Pain scores 0 - 24 h minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bhise 1997	10	19.50 (3.60)	10	18.80 (4.40)		5.5	0.70 [-2.82, 4.22]
Boldt 1998	30	47.00 (14.00)	30	49.00 (16.00)		4.7	-2.00 [-9.61, 5.61]
Boulanger 1993	20	33.00 (14.00)	20	41.00 (19.00)		4.0	-8.00 [-18.34, 2.34]
Ceriati 2003	20	7.70 (11.20)	20	32.80 (27.10)		3.5	-25.10 [-37.95, -12.25]
Chan 1995a	12	26.00 (7.40)	11	24.70 (6.80)		5.1	1.30 [-4.50, 7.10]
Chan 1995b	24	41.10 (5.50)	20	65.40 (9.10)		5.3	-24.30 [-28.85, -19.75]
Chang 2004	62	15.84 (9.27)	63	27.67 (16.44)		5.3	-11.83 [-16.50, -7.16]
Choiniere 1998	60	18.00 (10.00)	63	17.00 (11.00)		5.4	1.00 [-2.71, 4.71]
Egbert 1993	43	45.90 (19.00)	40	47.70 (18.00)		4.6	-1.80 [-9.76, 6.16]
Ellis 1982a	15	43.00 (31.00)	17	39.00 (24.70)		2.3	4.00 [-15.60, 23.60]

-100.0 -50.0 0 50.0 100.0
Favors PCA Favors control

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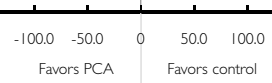
Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Ellis 1982b	20	27.00 (22.40)	20	35.00 (31.30)		2.7	-8.00 [-24.87, 8.87]
Hecker 1988a	11	40.31 (19.78)	7	50.10 (24.24)		2.0	-9.79 [-31.22, 11.64]
Hecker 1988b	10	41.68 (22.14)	7	50.10 (24.24)		1.9	-8.42 [-31.02, 14.18]
McGrath 1989	44	45.00 (17.00)	44	48.00 (18.00)		4.7	-3.00 [-10.32, 4.32]
Murphy 1994	100	21.00 (15.00)	100	17.00 (15.00)		5.4	4.00 [-0.16, 8.16]
Passchier 1993	17	45.80 (12.50)	14	37.20 (12.30)		4.4	8.60 [-0.16, 17.36]
Pettersson 2000	24	19.00 (12.00)	24	22.00 (18.00)		4.4	-3.00 [-11.65, 5.65]
Precious 1997	25	23.00 (15.00)	25	35.00 (16.00)		4.4	-12.00 [-20.60, -3.40]
Sanansilp 1995	21	41.00 (22.00)	21	52.00 (25.00)		3.2	-11.00 [-25.24, 3.24]
Taylor 1994	266	33.30 (16.67)	246	39.00 (20.00)		5.5	-5.70 [-8.90, -2.50]
Walson 1992	10	29.00 (13.00)	10	44.00 (23.00)		2.8	-15.00 [-31.37, 1.37]
Wang 1991	13	37.00 (11.00)	13	61.00 (9.00)		4.6	-24.00 [-31.73, -16.27]
Wasylak 1990	20	37.50 (2.50)	18	48.00 (5.00)		5.6	-10.50 [-13.06, -7.94]
Wheatley 1992	19	19.00 (21.80)	20	38.00 (26.80)		3.0	-19.00 [-34.30, -3.70]
Total (95% CI)	896		863			100.0	-7.15 [-10.93, -3.37]

Test for heterogeneity chi-square=186.51 df=23 p=<0.0001 I^2 =87.7%

Test for overall effect z=3.71 p=0.0002



Analysis 01.08. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 08 Pain scores 25 - 48 h minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

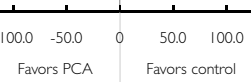
Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 08 Pain scores 25 - 48 h minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Boldt 1998	30	31.00 (15.00)	30	49.00 (16.00)		7.0	-18.00 [-25.85, -10.15]
Boulanger 1993	20	36.00 (19.00)	20	30.00 (14.00)		6.2	6.00 [-4.34, 16.34]
Ceriati 2003	20	6.90 (13.00)	20	29.80 (25.00)		5.6	-22.90 [-35.25, -10.55]
Chan 1995a	12	20.80 (12.50)	11	13.70 (5.90)		7.0	7.10 [-0.79, 14.99]
Chan 1995b	24	37.30 (11.50)	20	40.10 (5.90)		7.8	-2.80 [-8.08, 2.48]
Egbert 1993	43	26.40 (18.60)	40	36.00 (23.00)		6.7	-9.60 [-18.64, -0.56]
Ellis 1982a	15	26.00 (19.40)	17	22.00 (23.20)		4.9	4.00 [-10.77, 18.77]
Ellis 1982b	20	29.00 (26.80)	20	23.00 (17.90)		5.1	6.00 [-8.12, 20.12]
Hecker 1988a	11	33.83 (19.50)	7	40.21 (20.94)		3.8	-6.38 [-25.70, 12.94]
Hecker 1988b	10	30.78 (21.29)	7	40.21 (20.94)		3.6	-9.43 [-29.80, 10.94]
McGrath 1989	44	37.00 (13.00)	44	43.00 (17.00)		7.5	-6.00 [-12.32, 0.32]
Pettersson 2000	24	16.00 (10.00)	24	30.00 (17.00)		7.0	-14.00 [-21.89, -6.11]
Precious 1997	25	19.00 (13.00)	25	33.00 (18.00)		6.8	-14.00 [-22.70, -5.30]
Sanansilp 1995	21	25.00 (19.00)	21	45.00 (22.00)		5.6	-20.00 [-32.43, -7.57]
Wang 1991	13	28.00 (8.00)	13	53.00 (11.00)		7.2	-25.00 [-32.39, -17.61]
Wasylak 1990	20	30.00 (2.50)	18	47.00 (5.00)		8.3	-17.00 [-19.56, -14.44]
Total (95% CI)	352		337			100.0	-9.31 [-14.36, -4.27]

Test for heterogeneity chi-square=94.42 df=15 p=<0.0001 I^2 =84.1%

Test for overall effect z=3.62 p=0.0003



Analysis 01.09. Comparison 01 VAS pain scores (0-100): PCA versus control, Outcome 09 Pain scores 0 - 48 h minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 01 VAS pain scores (0-100): PCA versus control

Outcome: 09 Pain scores 0 - 48 h minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bedder 1991	20	38.00 (102.90)	18	42.00 (76.40)		1.4	-4.00 [-61.27, 53.27]
Berde 1991	32	45.80 (24.50)	23	55.50 (24.60)		27.0	-9.70 [-22.86, 3.46]
Precious 1997	25	21.00 (13.00)	25	34.00 (16.00)		71.6	-13.00 [-21.08, -4.92]
Total (95% CI)	77		66			100.0	-11.98 [-18.82, -5.14]

Test for heterogeneity chi-square=0.25 df=2 p=0.88 I^2 =0.0%

Test for overall effect z=3.43 p=0.0006

Analysis 02.01. Comparison 02 Opioid consumption: PCA versus control, Outcome 01 Consumption of morphine equivalents 0 - 24 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 02 Opioid consumption: PCA versus control

Outcome: 01 Consumption of morphine equivalents 0 - 24 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bedder 1991	20	39.60 (74.70)	18	27.70 (50.50)		1.6	11.90 [-28.30, 52.10]
Bhise 1997	10	15.00 (2.30)	10	13.80 (1.09)		5.2	1.20 [-0.38, 2.78]
Bollish 1985	20	34.10 (22.40)	20	37.30 (21.40)		4.2	-3.20 [-16.78, 10.38]
Boulanger 1993	20	77.33 (35.80)	20	68.00 (23.90)		3.5	9.33 [-9.53, 28.19]
Chang 2004	62	45.65 (27.96)	63	22.35 (11.56)		4.8	23.30 [15.78, 30.82]
Egbert 1993	43	28.80 (19.20)	40	31.20 (19.20)		4.8	-2.40 [-10.67, 5.87]
Eisenach 1988	20	62.00 (29.60)	20	48.00 (24.30)		3.8	14.00 [-2.78, 30.78]
Ellis 1982a	15	50.10 (24.10)	17	38.40 (10.30)		4.2	11.70 [-1.44, 24.84]
Ellis 1982b	20	56.60 (26.20)	20	39.80 (10.30)		4.3	16.80 [4.46, 29.14]
Gillman 1995	11	28.00 (16.00)	11	16.00 (12.00)		4.4	12.00 [0.18, 23.82]
Harrison 1988	18	74.20 (21.00)	20	76.20 (17.00)		4.3	-2.00 [-14.23, 10.23]
Kyzer 1995	12	52.71 (6.34)	11	32.73 (15.12)		4.6	19.98 [10.35, 29.61]
McGrath 1989	44	55.10 (22.50)	44	69.40 (23.60)		4.6	-14.30 [-23.93, -4.67]

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Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Munro 1998	39	33.00 (22.00)	41	37.00 (20.00)		4.7	-4.00 [-13.23, 5.23]
Murphy 1994	100	70.80 (44.30)	100	78.24 (31.60)		4.5	-7.44 [-18.11, 3.23]
Myles 1994	36	25.40 (14.00)	33	20.10 (10.00)		5.0	5.30 [-0.41, 11.01]
O'Halloran 1997	35	33.10 (17.45)	31	15.50 (5.39)		5.0	17.60 [11.52, 23.68]
Rayburn 1988	67	63.30 (1.10)	62	42.90 (1.00)		5.2	20.40 [20.04, 20.76]
Rogers 1990	34	29.50 (15.00)	35	22.80 (17.10)		4.8	6.70 [-0.88, 14.28]
Stoneham 1996	15	34.32 (26.64)	15	24.24 (16.32)		3.9	10.08 [-5.73, 25.89]
Thomas 1995	61	34.50 (12.90)	49	51.40 (12.90)		5.0	-16.90 [-21.75, -12.05]
Walson 1992	5	49.90 (24.20)	5	25.00 (14.10)		2.9	24.90 [0.35, 49.45]
Wang 1991	13	33.30 (13.00)	13	21.50 (8.10)		4.8	11.80 [3.47, 20.13]
Total (95% CI)	720		698			100.0	6.72 [0.50, 12.94]
Test for heterogeneity chi-square=939.71 df=22 p=<0.0001 I^2 =97.7%							
Test for overall effect z=2.12 p=0.03							

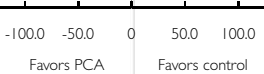
Analysis 02.02. Comparison 02 Opioid consumption: PCA versus control, Outcome 02 Consumption of morphine equivalents 25 - 48 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 02 Opioid consumption: PCA versus control

Outcome: 02 Consumption of morphine equivalents 25 - 48 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Boulanger 1993	20	69.30 (35.80)	20	86.70 (29.80)		4.1	-17.40 [-37.81, 3.01]
Egbert 1993	43	21.60 (14.40)	40	21.60 (28.80)		13.2	0.00 [-9.91, 9.91]
Ellis 1982a	15	36.40 (28.60)	17	29.40 (7.80)		7.1	7.00 [-7.94, 21.94]
McGrath 1989	44	53.00 (22.40)	44	56.40 (24.90)		13.2	-3.40 [-13.30, 6.50]
Wang 1991	13	24.70 (18.40)	13	12.90 (10.40)		10.7	11.80 [0.31, 23.29]
Ellis 1982b	20	22.30 (12.20)	20	17.90 (11.60)		18.9	4.40 [-2.98, 11.78]
Myles 1994	36	34.80 (19.00)	33	26.60 (15.00)		17.2	8.20 [0.16, 16.24]
Gillman 1995	11	13.00 (10.00)	11	12.00 (11.00)		15.5	1.00 [-7.79, 9.79]
Total (95% CI)	202		198			100.0	2.99 [-1.40, 7.37]
Test for heterogeneity chi-square=10.25 df=7 p=0.17 I^2 =31.7%							
Test for overall effect z=1.34 p=0.2							



Analysis 02.03. Comparison 02 Opioid consumption: PCA versus control, Outcome 03 Consumption of morphine equivalents 0 - 48 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

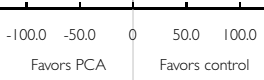
Comparison: 02 Opioid consumption: PCA versus control

Outcome: 03 Consumption of morphine equivalents 0 - 48 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Choiniere 1998	60	93.00 (50.00)	63	132.00 (37.00)		10.2	-39.00 [-54.61, -23.39]
Munro 1998	39	42.70 (32.40)	41	53.30 (29.30)		10.3	-10.60 [-24.16, 2.96]
Perez-woods 1991	25	96.60 (43.30)	17	49.10 (17.60)		9.9	47.50 [28.58, 66.42]
Precious 1997	25	15.70 (11.90)	25	34.00 (23.40)		10.6	-18.30 [-28.59, -8.01]
Sanansilp 1995	21	33.00 (22.40)	21	49.50 (27.10)		10.2	-16.50 [-31.54, -1.46]
Wang 1991	13	57.70 (29.60)	13	34.40 (17.30)		9.9	23.30 [4.66, 41.94]
Wasylak 1990	20	109.80 (50.80)	18	117.00 (52.50)		8.3	-7.20 [-40.12, 25.72]
Kleiman 1988	15	216.30 (108.80)	15	209.60 (77.10)		4.7	6.70 [-60.78, 74.18]
Chan 1995a	12	70.60 (28.10)	11	53.00 (25.50)		9.5	17.60 [-4.31, 39.51]
Chan 1995b	24	184.60 (101.90)	20	142.40 (64.80)		6.3	42.20 [-7.48, 91.88]
Passchier 1993	17	84.10 (25.30)	14	34.50 (18.20)		10.2	49.60 [34.25, 64.95]
Total (95% CI)	271		258			100.0	7.43 [-11.91, 26.77]

Test for heterogeneity chi-square=118.92 df=10 p=<0.0001 I^2 =91.6%

Test for overall effect z=0.75 p=0.5



Analysis 02.04. Comparison 02 Opioid consumption: PCA versus control, Outcome 04 Consumption of morphine equivalents 0 - 72 h

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 02 Opioid consumption: PCA versus control

Outcome: 04 Consumption of morphine equivalents 0 - 72 h

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Boldt 1998	30	51.10 (22.30)	30	13.40 (21.30)		23.5	37.70 [26.66, 48.74]
Kenady 1992	35	63.00 (42.10)	18	46.00 (25.00)		16.7	17.00 [-1.11, 35.11]
Pettersson 2000	24	61.90 (24.00)	24	36.30 (20.20)		21.9	25.60 [13.05, 38.15]
Taylor 1994	266	84.94 (59.50)	246	55.94 (44.60)		25.5	29.00 [19.93, 38.07]
Egbert 1993	43	64.80 (43.20)	40	72.00 (64.80)		12.5	-7.20 [-31.07, 16.67]
Total (95% CI)	398		358			100.0	23.78 [12.87, 34.70]

Test for heterogeneity chi-square=12.88 df=4 p=0.01 I^2 =68.9%

Test for overall effect z=4.27 p=0.00002

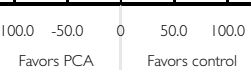
Analysis 02.05. Comparison 02 Opioid consumption: PCA versus control, Outcome 05 Consumption of morphine equivalents 0 - 24 h by surgery type

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 02 Opioid consumption: PCA versus control

Outcome: 05 Consumption of morphine equivalents 0 - 24 h by surgery type

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
01 Abdominal							
Thomas 1995	61	34.50 (12.90)	49	51.40 (12.90)		9.0	-16.90 [-21.75, -12.05]
Bollish 1985	20	34.10 (22.40)	20	37.30 (21.40)		7.9	-3.20 [-16.78, 10.38]
Chang 2004	62	45.65 (27.96)	63	22.35 (11.56)		8.7	23.30 [15.78, 30.82]
Eisenach 1988	20	62.00 (29.60)	20	48.00 (24.30)		7.3	14.00 [-2.78, 30.78]
Ellis 1982a	15	50.10 (24.10)	17	38.40 (10.30)		8.0	11.70 [-1.44, 24.84]
Ellis 1982b	20	56.60 (26.20)	20	39.80 (10.30)		8.1	16.80 [4.46, 29.14]
Gillman 1995	11	28.00 (16.00)	11	16.00 (12.00)		8.2	12.00 [0.18, 23.82]
Harrison 1988	18	74.20 (21.00)	20	76.20 (17.00)		8.1	-2.00 [-14.23, 10.23]
Kyzer 1995	12	52.71 (6.34)	11	32.73 (15.12)		8.5	19.98 [10.35, 29.61]
McGrath 1989	44	55.10 (22.50)	44	69.40 (23.60)		8.5	-14.30 [-23.93, -4.67]



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Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Rayburn 1988	67	63.30 (1.10)	62	42.90 (1.00)		9.2	20.40 [20.04, 20.76]
Rogers 1990	34	29.50 (15.00)	35	22.80 (17.10)		8.7	6.70 [-0.88, 14.28]
Subtotal (95% CI)	384		372			100.0	7.33 [-2.91, 17.57]
Test for heterogeneity chi-square=315.81 df=11 p=<0.0001 I² =96.5%							
Test for overall effect z=1.40 p=0.2							
02 Cardiac							
Bhise 1997	10	15.00 (2.30)	10	13.80 (1.09)		29.0	1.20 [-0.38, 2.78]
Munro 1998	39	33.00 (22.00)	41	37.00 (20.00)		20.8	-4.00 [-13.23, 5.23]
Myles 1994	36	25.40 (14.00)	33	20.10 (10.00)		25.3	5.30 [-0.41, 11.01]
O'Halloran 1997	35	33.10 (17.45)	31	15.50 (5.39)		24.9	17.60 [11.52, 23.68]
Subtotal (95% CI)	120		115			100.0	5.24 [-2.57, 13.05]
Test for heterogeneity chi-square=29.01 df=3 p=<0.0001 I² =89.7%							
Test for overall effect z=1.31 p=0.2							

Analysis 02.06. Comparison 02 Opioid consumption: PCA versus control, Outcome 06 Consumption of morphine equivalents 0 - 24 h minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 02 Opioid consumption: PCA versus control

Outcome: 06 Consumption of morphine equivalents 0 - 24 h minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bedder 1991	20	39.60 (74.70)	18	27.70 (50.50)		1.1	11.90 [-28.30, 52.10]
Bhise 1997	10	15.00 (2.30)	10	13.80 (1.09)		7.4	1.20 [-0.38, 2.78]
Boulanger 1993	20	77.33 (35.80)	20	68.00 (23.90)		3.2	9.33 [-9.53, 28.19]
Chang 2004	62	45.65 (27.96)	63	22.35 (11.56)		6.2	23.30 [15.78, 30.82]
Egbert 1993	43	28.80 (19.20)	40	31.20 (19.20)		6.0	-2.40 [-10.67, 5.87]
Eisenach 1988	20	62.00 (29.60)	20	48.00 (24.30)		3.6	14.00 [-2.78, 30.78]
Ellis 1982a	15	50.10 (24.10)	17	38.40 (10.30)		4.5	11.70 [-1.44, 24.84]
Ellis 1982b	20	56.60 (26.20)	20	39.80 (10.30)		4.8	16.80 [4.46, 29.14]
Gillman 1995	11	28.00 (16.00)	11	16.00 (12.00)		4.9	12.00 [0.18, 23.82]

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Study	PCA		Control		Weighted Mean Difference (Random)	Weight	Weighted Mean Difference (Random)
	N	Mean(SD)	N	Mean(SD)	95% CI	(%)	95% CI
Harrison 1988	18	74.20 (21.00)	20	76.20 (17.00)		4.8	-2.00 [-14.23, 10.23]
Kyzer 1995	12	52.71 (6.34)	11	32.73 (15.12)		5.6	19.98 [10.35, 29.61]
McGrath 1989	44	55.10 (22.50)	44	69.40 (23.60)		5.6	-14.30 [-23.93, -4.67]
Munro 1998	39	33.00 (22.00)	41	37.00 (20.00)		5.7	-4.00 [-13.23, 5.23]
Murphy 1994	100	70.80 (44.30)	100	78.24 (31.60)		5.2	-7.44 [-18.11, 3.23]
Myles 1994	36	25.40 (14.00)	33	20.10 (10.00)		6.7	5.30 [-0.41, 11.01]
O'Halloran 1997	35	33.10 (17.45)	31	15.50 (5.39)		6.6	17.60 [11.52, 23.68]
Rogers 1990	34	29.50 (15.00)	35	22.80 (17.10)		6.2	6.70 [-0.88, 14.28]
Stoneham 1996	15	34.32 (26.64)	15	24.24 (16.32)		3.9	10.08 [-5.73, 25.89]
Walson 1992	5	49.90 (24.20)	5	25.00 (14.10)		2.3	24.90 [0.35, 49.45]
Wang 1991	13	33.30 (13.00)	13	21.50 (8.10)		5.9	11.80 [3.47, 20.13]
Total (95% CI)	572		567			100.0	7.43 [2.96, 11.90]
Test for heterogeneity chi-square=107.53 df=19 p=<0.0001 I^2 =82.3%							
Test for overall effect z=3.26 p=0.001							

Analysis 02.07. Comparison 02 Opioid consumption: PCA versus control, Outcome 07 Consumption of morphine equivalents 0 - 48 h minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

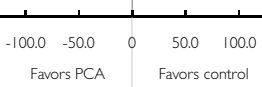
Comparison: 02 Opioid consumption: PCA versus control

Outcome: 07 Consumption of morphine equivalents 0 - 48 h minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Chan 1995a	12	70.60 (28.10)	11	53.00 (25.50)		10.6	17.60 [-4.31, 39.51]
Chan 1995b	24	184.60 (101.90)	20	142.40 (64.80)		6.7	42.20 [-7.48, 91.88]
Choiniere 1998	60	93.00 (50.00)	63	132.00 (37.00)		11.4	-39.00 [-54.61, -23.39]
Kleiman 1988	15	216.30 (108.80)	15	209.60 (77.10)		4.8	6.70 [-60.78, 74.18]
Munro 1998	39	42.70 (32.40)	41	53.30 (29.30)		11.6	-10.60 [-24.16, 2.96]
Passchier 1993	17	84.10 (25.30)	14	34.50 (18.20)		11.4	49.60 [34.25, 64.95]
Precious 1997	25	15.70 (11.90)	25	34.00 (23.40)		11.9	-18.30 [-28.59, -8.01]
Sanansilp 1995	21	33.00 (22.40)	21	49.50 (27.10)		11.5	-16.50 [-31.54, -1.46]
Wang 1991	13	57.70 (29.60)	13	34.40 (17.30)		11.0	23.30 [4.66, 41.94]
Wasylak 1990	20	109.80 (50.80)	18	117.00 (52.50)		9.0	-7.20 [-40.12, 25.72]
Total (95% CI)	246		241			100.0	2.85 [-16.12, 21.82]

Test for heterogeneity chi-square=92.60 df=9 p=<0.0001 I^2 =90.3%

Test for overall effect z=0.29 p=0.8



Analysis 03.01. Comparison 03 Patient satisfaction: PCA versus control, Outcome 01 Satisfaction on a 0 - 100 scale (100 = most satisfied)

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

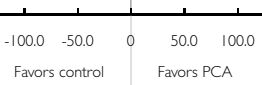
Comparison: 03 Patient satisfaction: PCA versus control

Outcome: 01 Satisfaction on a 0 - 100 scale (100 = most satisfied)

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Perez-woods 1991	25	63.75 (13.75)	17	53.75 (13.75)		11.4	10.00 [1.53, 18.47]
Sanansilp 1995	21	78.00 (20.00)	21	78.00 (20.00)		8.5	0.00 [-12.10, 12.10]
Berde 1991	32	77.00 (24.00)	23	78.00 (23.00)		8.2	-1.00 [-13.55, 11.55]
Passchier 1993	17	77.50 (25.00)	14	80.00 (7.50)		8.2	-2.50 [-15.02, 10.02]
Choiniere 1998	60	87.00 (15.00)	63	88.00 (15.00)		14.2	-1.00 [-6.30, 4.30]
Boulanger 1993	20	86.00 (13.00)	20	75.00 (17.00)		10.6	11.00 [1.62, 20.38]
Boldt 1998	30	56.70 (16.70)	30	33.30 (13.30)		12.1	23.40 [15.76, 31.04]
Chang 2004	62	28.84 (2.70)	63	26.03 (2.54)		16.8	2.81 [1.89, 3.73]
Snell 1997	44	84.20 (18.00)	23	73.90 (21.40)		9.9	10.30 [0.06, 20.54]
Total (95% CI)	311		274			100.0	6.21 [1.19, 11.23]

Test for heterogeneity chi-square=38.41 df=8 p=<0.0001 I^2 =79.2%

Test for overall effect z=2.42 p=0.02



Analysis 03.02. Comparison 03 Patient satisfaction: PCA versus control, Outcome 02 Number of patients in arm satisfied with therapy

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 03 Patient satisfaction: PCA versus control

Outcome: 02 Number of patients in arm satisfied with therapy

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Egbert 1993	29/40	18/39		7.6	1.57 [1.06, 2.32]
Gillman 1995	10/11	10/11		10.1	1.00 [0.77, 1.30]
Rosen 1998	28/36	25/36		9.8	1.12 [0.85, 1.48]
Wheatley 1992	9/19	2/20		1.2	4.74 [1.17, 19.16]
Choiniere 1998	56/60	52/63		12.9	1.13 [0.99, 1.29]
Ellis 1982a	12/15	13/17		8.0	1.05 [0.73, 1.51]
Bhise 1997	10/10	6/10		5.7	1.67 [1.00, 2.76]
McGrath 1989	42/44	22/44		9.3	1.91 [1.41, 2.58]
Munro 1998	35/39	37/41		12.6	0.99 [0.86, 1.15]
Ellis 1982b	10/20	9/20		4.1	1.11 [0.58, 2.14]
Paoletti 1993a	19/20	17/20		11.3	1.12 [0.91, 1.38]
Eisenach 1988	20/20	11/20		7.4	1.82 [1.22, 2.70]
Total (95% CI)	334	341		100.0	1.26 [1.08, 1.48]

Total events: 280 (PCA), 222 (Control)

Test for heterogeneity chi-square=38.49 df=11 p=<0.0001 I^2 =71.4%

Test for overall effect z=2.90 p=0.004

Analysis 03.03. Comparison 03 Patient satisfaction: PCA versus control, Outcome 03 Satisfaction on a 0 - 100 scale (100 = most satisfied) minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 03 Patient satisfaction: PCA versus control

Outcome: 03 Satisfaction on a 0 - 100 scale (100 = most satisfied) minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Berde 1991	32	77.00 (24.00)	23	78.00 (23.00)		10.8	-1.00 [-13.55, 11.55]
Boldt 1998	30	56.70 (16.70)	30	33.30 (13.30)		15.4	23.40 [15.76, 31.04]
Boulanger 1993	20	86.00 (13.00)	20	75.00 (17.00)		13.7	11.00 [1.62, 20.38]
Chang 2004	62	28.84 (2.70)	63	26.03 (2.54)		20.5	2.81 [1.89, 3.73]
Choiniere 1998	60	87.00 (15.00)	63	88.00 (15.00)		17.7	-1.00 [-6.30, 4.30]
Passchier 1993	17	77.50 (25.00)	14	80.00 (7.50)		10.8	-2.50 [-15.02, 10.02]
Sanansilp 1995	21	78.00 (20.00)	21	78.00 (20.00)		11.2	0.00 [-12.10, 12.10]
Total (95% CI)	242		234			100.0	5.12 [-0.86, 11.11]

Test for heterogeneity chi-square=33.90 df=6 p=<0.0001 I^2 =82.3%

Test for overall effect z=1.68 p=0.09

Analysis 04.01. Comparison 04 Length of stay, Outcome 01 Number of days: PCA versus control

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

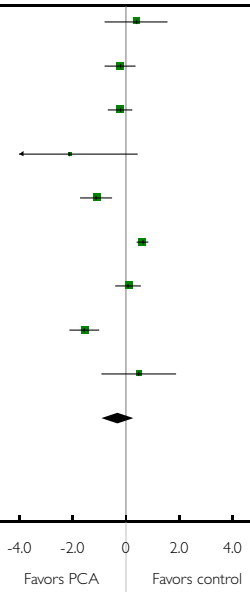
Comparison: 04 Length of stay

Outcome: 01 Number of days: PCA versus control

Study	PCA		Control		Weighted Mean Difference (Random)	Weight	Weighted Mean Difference (Random)
	N	Mean(SD)	N	Mean(SD)	95% CI	(%)	95% CI
Berde 1991	32	5.40 (2.60)	23	5.00 (1.80)		9.4	0.40 [-0.76, 1.56]
McGrath 1989	44	5.30 (1.30)	44	5.50 (1.40)		12.8	-0.20 [-0.76, 0.36]
Harrison 1988	18	5.40 (0.90)	20	5.60 (0.50)		13.2	-0.20 [-0.67, 0.27]
Boulanger 1993	20	7.20 (2.70)	20	9.30 (5.20)		4.0	-2.10 [-4.67, 0.47]
Thomas 1995	61	6.80 (1.00)	49	7.90 (2.00)		12.5	-1.10 [-1.71, -0.49]
Chan 1995b	24	6.24 (0.35)	20	5.59 (0.38)		14.1	0.65 [0.43, 0.87]
Smythe 1994	19	4.10 (0.80)	17	4.00 (0.70)		13.2	0.10 [-0.39, 0.59]
Chan 1995a	12	3.83 (0.25)	11	5.36 (0.93)		12.8	-1.53 [-2.10, -0.96]
Snell 1997	44	6.10 (4.03)	23	5.60 (1.88)		8.0	0.50 [-0.92, 1.92]
Total (95% CI)	274		227			100.0	-0.29 [-0.89, 0.32]

Test for heterogeneity chi-square=76.83 df=8 p=<0.0001 I^2 =89.6%

Test for overall effect z=0.93 p=0.4



Analysis 04.02. Comparison 04 Length of stay, Outcome 02 Number of days: PCA versus control minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 04 Length of stay

Outcome: 02 Number of days: PCA versus control minus inadequately randomized trials

Study	PCA		Control		Weighted Mean Difference (Random)	Weight	Weighted Mean Difference (Random)
	N	Mean(SD)	N	Mean(SD)	95% CI	(%)	95% CI
Berde 1991	32	5.40 (2.60)	23	5.00 (1.80)		11.6	0.40 [-0.76, 1.56]
Boulanger 1993	20	7.20 (2.70)	20	9.30 (5.20)		4.8	-2.10 [-4.67, 0.47]
Chan 1995a	12	3.83 (0.25)	11	5.36 (0.93)		16.1	-1.53 [-2.10, -0.96]
Chan 1995b	24	6.24 (0.35)	20	5.59 (0.38)		18.0	0.65 [0.43, 0.87]
Harrison 1988	18	5.40 (0.90)	20	5.60 (0.50)		16.8	-0.20 [-0.67, 0.27]
Smythe 1994	19	4.10 (0.80)	17	4.00 (0.70)		16.6	0.10 [-0.39, 0.59]
McGrath 1989	44	5.30 (1.30)	44	5.50 (1.40)		16.1	-0.20 [-0.76, 0.36]
Total (95% CI)	169		155			100.0	-0.23 [-0.89, 0.42]

Test for heterogeneity chi-square=60.18 df=6 p=<0.0001 I^2 =90.0%

Test for overall effect z=0.70 p=0.5

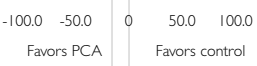
Analysis 05.01. Comparison 05 Sedation, Outcome 01 Sedation on a 0-100 scale (100 = most sedated)

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 05 Sedation

Outcome: 01 Sedation on a 0-100 scale (100 = most sedated)

Study	PCA		Control		Weighted Mean Difference (Random)	Weight	Weighted Mean Difference (Random)
	N	Mean(SD)	N	Mean(SD)	95% CI	(%)	95% CI
Rayburn 1988	67	45.70 (8.20)	62	66.00 (5.30)		12.3	-20.30 [-22.67, -17.93]
Perez-woods 1991	25	10.00 (7.50)	17	15.00 (10.00)		11.6	-5.00 [-10.59, 0.59]
Egbert 1993	43	17.50 (22.50)	40	20.00 (17.50)		10.6	-2.50 [-11.14, 6.14]
Bedder 1991	20	50.00 (20.00)	18	56.70 (26.70)		8.0	-6.70 [-21.83, 8.43]
Berde 1991	32	56.00 (25.30)	23	66.40 (21.90)		9.0	-10.40 [-22.93, 2.13]
Bollish 1985	20	24.00 (9.00)	20	25.00 (8.00)		11.7	-1.00 [-6.28, 4.28]
Hecker 1988a	11	56.20 (28.20)	7	56.40 (23.50)		5.1	-0.20 [-24.30, 23.90]
Boulanger 1993	20	27.50 (17.50)	20	27.50 (15.00)		10.0	0.00 [-10.10, 10.10]
Ellis 1982a	15	37.00 (38.70)	17	34.00 (28.90)		5.2	3.00 [-20.92, 26.92]



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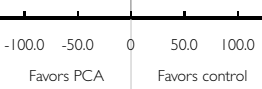
Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bhise 1997	10	18.67 (20.33)	10	23.67 (38.33)		4.5	-5.00 [-31.89, 21.89]
Hecker 1988b	10	48.80 (28.30)	7	56.40 (23.50)		5.0	-7.60 [-32.31, 17.11]
Ellis 1982b	20	24.00 (31.30)	20	32.00 (26.83)		6.9	-8.00 [-26.07, 10.07]
Total (95% CI)	293		261			100.0	-5.96 [-13.07, 1.16]
Test for heterogeneity chi-square=80.16 df=11 p=<0.0001 I^2 =86.3%							
Test for overall effect z=1.64 p=0.1							



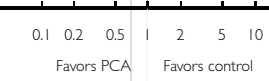
Analysis 05.02. Comparison 05 Sedation, Outcome 02 Number of patients in arm reporting sedation

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 05 Sedation

Outcome: 02 Number of patients in arm reporting sedation

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Bennett 1982	6/12	10/12		15.0	0.60 [0.32, 1.12]
Albert 1988	21/32	23/30		56.5	0.86 [0.62, 1.18]
Colwell 1995	4/91	7/93		4.0	0.58 [0.18, 1.93]
Smythe 1994	2/19	0/17		0.7	4.50 [0.23, 87.61]
Boldt 1998	8/30	9/30		8.8	0.89 [0.40, 1.99]
O'Halloran 1997	1/35	2/31		1.0	0.44 [0.04, 4.65]
Murphy 1994	18/100	14/100		14.0	1.29 [0.68, 2.44]
Total (95% CI)	319	313		100.0	0.85 [0.67, 1.08]
Total events: 60 (PCA), 65 (Control)					
Test for heterogeneity chi-square=4.91 df=6 p=0.56 I^2 =0.0%					
Test for overall effect z=1.31 p=0.2					



Analysis 05.03. Comparison 05 Sedation, Outcome 03 Sedation on a 0-100 scale (100 = most sedated) minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 05 Sedation

Outcome: 03 Sedation on a 0-100 scale (100 = most sedated) minus inadequately randomized trials

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bedder 1991	20	50.00 (20.00)	18	56.70 (26.70)		10.0	-6.70 [-21.83, 8.43]
Berde 1991	32	56.00 (25.30)	23	66.40 (21.90)		14.7	-10.40 [-22.93, 2.13]
Bhise 1997	10	18.67 (20.33)	10	23.67 (38.33)		3.2	-5.00 [-31.89, 21.89]
Boulanger 1993	20	27.50 (17.50)	20	27.50 (15.00)		22.5	0.00 [-10.10, 10.10]
Egbert 1993	43	17.50 (22.50)	40	20.00 (17.50)		30.8	-2.50 [-11.14, 6.14]
Ellis 1982a	15	37.00 (38.70)	17	34.00 (28.90)		4.0	3.00 [-20.92, 26.92]
Ellis 1982b	20	24.00 (31.30)	20	32.00 (26.83)		7.0	-8.00 [-26.07, 10.07]
Hecker 1988a	11	56.20 (28.20)	7	56.40 (23.50)		4.0	-0.20 [-24.30, 23.90]
Hecker 1988b	10	48.80 (28.30)	7	56.40 (23.50)		3.8	-7.60 [-32.31, 17.11]
Total (95% CI)	181		162			100.0	-3.86 [-8.66, 0.93]

Test for heterogeneity chi-square=2.54 df=8 p=0.96 I^2 =0.0%

Test for overall effect z=1.58 p=0.1

Analysis 06.01. Comparison 06 Nausea and vomiting, Outcome 01 Nausea and vomiting on a 0 - 100 scale (100 = most severe)

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 06 Nausea and vomiting

Outcome: 01 Nausea and vomiting on a 0 - 100 scale (100 = most severe)

Study	PCA N	PCA Mean(SD)	Control N	Control Mean(SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Kleiman 1988	15	31.75 (6.50)	15	35.50 (9.25)		30.9	-3.75 [-9.47, 1.97]
Berde 1991	32	11.00 (21.00)	23	10.00 (12.00)		24.0	1.00 [-7.77, 9.77]
Ellis 1982a	15	23.00 (33.00)	17	12.00 (19.40)		9.8	11.00 [-8.08, 30.08]
Ellis 1982b	20	20.00 (31.30)	20	11.00 (17.90)		12.8	9.00 [-6.80, 24.80]
Boulanger 1993	20	15.00 (20.00)	20	4.00 (8.00)		22.6	11.00 [1.56, 20.44]
Total (95% CI)	102		95			100.0	3.79 [-3.09, 10.67]

Test for heterogeneity chi-square=8.95 df=4 p=0.06 I^2 =55.3%

Test for overall effect z=1.08 p=0.3

Analysis 06.02. Comparison 06 Nausea and vomiting, Outcome 02 Number of patients reporting nausea or vomiting, or both

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 06 Nausea and vomiting

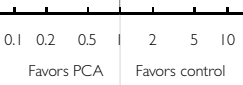
Outcome: 02 Number of patients reporting nausea or vomiting, or both

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Gillman 1995	6/11	7/11		5.2	0.86 [0.43, 1.73]
Sanansilp 1995	2/21	5/21		1.5	0.40 [0.09, 1.84]
Bollish 1985	3/20	7/20		2.2	0.43 [0.13, 1.43]
Dahl 1987	8/18	4/18		3.0	2.00 [0.73, 5.47]
Hecker 1988a	6/11	4/7		4.0	0.95 [0.41, 2.21]
Hecker 1988b	6/10	4/7		4.2	1.05 [0.46, 2.38]
Albert 1988	10/32	9/30		4.8	1.04 [0.49, 2.21]
Choiniere 1998	45/60	40/63		13.3	1.18 [0.93, 1.50]
Chan 1995b	1/36	3/31		0.7	0.29 [0.03, 2.62]
Brewington 1989	6/95	8/97		3.0	0.77 [0.28, 2.12]
Keita 2003	8/20	6/20		3.9	1.33 [0.57, 3.14]
Smythe 1994	10/19	9/17		6.2	0.99 [0.54, 1.85]
Paoletti 1993b	11/22	13/22		7.2	0.85 [0.49, 1.46]
Paoletti 1993a	3/20	6/20		2.1	0.50 [0.14, 1.73]
Boldt 1998	7/30	9/30		4.0	0.78 [0.33, 1.82]
Chang 2004	24/62	13/63		6.7	1.88 [1.05, 3.34]
Pettersson 2000	15/24	9/24		6.4	1.67 [0.91, 3.04]
Precious 1997	4/25	15/25		3.3	0.27 [0.10, 0.69]
Eisenach 1988	6/20	5/20		3.0	1.20 [0.44, 3.30]
O'Halloran 1997	0/35	6/31		0.5	0.07 [0.00, 1.17]
Murphy 1994	28/100	18/100		7.5	1.56 [0.92, 2.62]
Colwell 1995	16/91	12/93		5.3	1.36 [0.68, 2.72]
Boulanger 1993	5/20	3/20		2.0	1.67 [0.46, 6.06]
Total (95% CI)	802	790		100.0	1.05 [0.86, 1.27]

Total events: 230 (PCA), 215 (Control)

Test for heterogeneity chi-square=31.92 df=22 p=0.08 I^2 =31.1%

Test for overall effect z=0.47 p=0.6



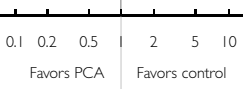
Analysis 06.03. Comparison 06 Nausea and vomiting, Outcome 03 Number of patients reporting nausea or vomiting, or both, by surgery type

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 06 Nausea and vomiting

Outcome: 03 Number of patients reporting nausea or vomiting, or both, by surgery type

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
01 Abdominal					
Albert 1988	10/32	9/30		4.8	1.04 [0.49, 2.21]
Bollish 1985	3/20	7/20		1.9	0.43 [0.13, 1.43]
Brewington 1989	6/95	8/97		2.6	0.77 [0.28, 2.12]
Chang 2004	24/62	13/63		8.1	1.88 [1.05, 3.34]
Choiniere 1998	45/60	40/63		47.8	1.18 [0.93, 1.50]
Dahl 1987	8/18	4/18		2.7	2.00 [0.73, 5.47]
Eisenach 1988	6/20	5/20		2.6	1.20 [0.44, 3.30]
Gillman 1995	6/11	7/11		5.5	0.86 [0.43, 1.73]
Hecker 1988a	6/11	4/7		3.8	0.95 [0.41, 2.21]
Hecker 1988b	6/10	4/7		4.0	1.05 [0.46, 2.38]
Paoletti 1993b	11/22	13/22		9.1	0.85 [0.49, 1.46]
Smythe 1994	10/19	9/17		7.0	0.99 [0.54, 1.85]
Subtotal (95% CI)	380	375		100.0	1.12 [0.95, 1.31]
Total events: 141 (PCA), 123 (Control)					
Test for heterogeneity chi-square=9.47 df=11 p=0.58 I^2 =0.0%					
Test for overall effect z=1.30 p=0.2					
02 Cardiac					
Boldt 1998	7/30	9/30		41.1	0.78 [0.33, 1.82]
O'Halloran 1997	0/35	6/31		12.8	0.07 [0.00, 1.17]
Pettersson 2000	15/24	9/24		46.1	1.67 [0.91, 3.04]
Subtotal (95% CI)	89	85		100.0	0.81 [0.25, 2.60]
Total events: 22 (PCA), 24 (Control)					
Test for heterogeneity chi-square=7.27 df=2 p=0.03 I^2 =72.5%					
Test for overall effect z=0.35 p=0.7					
03 Orthopedic					
Keita 2003	8/20	6/20		48.6	1.33 [0.57, 3.14]
Paoletti 1993a	3/20	6/20		29.8	0.50 [0.14, 1.73]
Sanansilp 1995	2/21	5/21		21.6	0.40 [0.09, 1.84]



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Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Subtotal (95% CI)	61	61		100.0	0.77 [0.35, 1.68]
Total events: 13 (PCA), 17 (Control)					
Test for heterogeneity chi-square=2.76 df=2 p=0.25 I^2 =27.5%					
Test for overall effect z=0.66 p=0.5					

Analysis 06.04. Comparison 06 Nausea and vomiting, Outcome 04 Number of patients reporting nausea or vomiting, or both, minus inadequately randomized trials

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 06 Nausea and vomiting

Outcome: 04 Number of patients reporting nausea or vomiting, or both, minus inadequately randomized trials

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Albert 1988	10/32	9/30		5.0	1.04 [0.49, 2.21]
Boldt 1998	7/30	9/30		4.1	0.78 [0.33, 1.82]
Boulanger 1993	5/20	3/20		2.1	1.67 [0.46, 6.06]
Chan 1995b	1/36	3/31		0.8	0.29 [0.03, 2.62]
Chang 2004	24/62	13/63		7.1	1.88 [1.05, 3.34]
Choiniere 1998	45/60	40/63		14.5	1.18 [0.93, 1.50]
Colwell 1995	16/91	12/93		5.6	1.36 [0.68, 2.72]
Dahl 1987	8/18	4/18		3.1	2.00 [0.73, 5.47]
Eisenach 1988	6/20	5/20		3.1	1.20 [0.44, 3.30]
Gillman 1995	6/11	7/11		5.5	0.86 [0.43, 1.73]
Hecker 1988a	6/11	4/7		4.2	0.95 [0.41, 2.21]
Hecker 1988b	6/10	4/7		4.4	1.05 [0.46, 2.38]
Keita 2003	8/20	6/20		4.1	1.33 [0.57, 3.14]
Murphy 1994	28/100	18/100		8.0	1.56 [0.92, 2.62]
O'Halloran 1997	0/35	6/31		0.5	0.07 [0.00, 1.17]
Paoletti 1993b	11/22	13/22		7.6	0.85 [0.49, 1.46]
Paoletti 1993a	3/20	6/20		2.2	0.50 [0.14, 1.73]
Pettersson 2000	15/24	9/24		6.7	1.67 [0.91, 3.04]

(*Continued* . . .)

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Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Precious 1997	4/25	15/25		3.4	0.27 [0.10, 0.69]
Sanansilp 1995	2/21	5/21		1.5	0.40 [0.09, 1.84]
Smythe 1994	10/19	9/17		6.5	0.99 [0.54, 1.85]
Total (95% CI)	687	673		100.0	1.08 [0.89, 1.32]
Total events: 221 (PCA), 200 (Control)					
Test for heterogeneity chi-square=28.76 df=20 p=0.09 I^2 =30.5%					
Test for overall effect z=0.79 p=0.4					

Analysis 07.01. Comparison 07 Pruritus, Outcome 01 Number of patients reporting pruritus

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 07 Pruritus

Outcome: 01 Number of patients reporting pruritus

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Gillman 1995	5/11	1/11		2.8	5.00 [0.69, 36.13]
Sanansilp 1995	3/21	1/21		2.3	3.00 [0.34, 26.56]
Harrison 1988	7/18	3/20		7.7	2.59 [0.79, 8.55]
Choiniere 1998	25/60	21/63		52.1	1.25 [0.79, 1.98]
Chan 1995b	1/36	1/31		1.5	0.86 [0.06, 13.20]
Keita 2003	4/20	2/20		4.4	2.00 [0.41, 9.71]
Paoletti 1993b	1/22	2/22		2.0	0.50 [0.05, 5.12]
Paoletti 1993a	2/20	4/20		4.4	0.50 [0.10, 2.43]
Eisenach 1988	12/20	7/20		22.7	1.71 [0.85, 3.44]
Total (95% CI)	228	228		100.0	1.44 [1.04, 2.01]
Total events: 60 (PCA), 42 (Control)					
Test for heterogeneity chi-square=6.32 df=8 p=0.61 I^2 =0.0%					
Test for overall effect z=2.17 p=0.03					

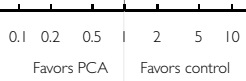
Analysis 07.02. Comparison 07 Pruritus, Outcome 02 Number of patients reporting pruritus by surgery type

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 07 Pruritus

Outcome: 02 Number of patients reporting pruritus by surgery type

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
01 Abdominal					
Choiniere 1998	25/60	21/63		59.6	1.25 [0.79, 1.98]
Eisenach 1988	12/20	7/20		26.0	1.71 [0.85, 3.44]
Gillman 1995	5/11	1/11		3.2	5.00 [0.69, 36.13]
Harrison 1988	7/18	3/20		8.9	2.59 [0.79, 8.55]
Paoletti 1993b	1/22	2/22		2.3	0.50 [0.05, 5.12]
Subtotal (95% CI)	131	136		100.0	1.48 [1.04, 2.11]
Total events: 50 (PCA), 34 (Control)					
Test for heterogeneity chi-square=3.86 df=4 p=0.43 I^2 =0.0%					
Test for overall effect z=2.17 p=0.03					
02 Orthopedic					
Keita 2003	4/20	2/20		39.0	2.00 [0.41, 9.71]
Paoletti 1993a	2/20	4/20		39.0	0.50 [0.10, 2.43]
Sanansilp 1995	3/21	1/21		21.9	3.00 [0.34, 26.56]
Subtotal (95% CI)	61	61		100.0	1.27 [0.44, 3.68]
Total events: 9 (PCA), 7 (Control)					
Test for heterogeneity chi-square=2.25 df=2 p=0.32 I^2 =11.2%					
Test for overall effect z=0.44 p=0.7					



Analysis 08.01. Comparison 08 Urinary retention, Outcome 01 Number of patients reporting urinary retention

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 08 Urinary retention

Outcome: 01 Number of patients reporting urinary retention

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
Sanansilp 1995	1/21	0/21		0.7	3.00 [0.13, 69.70]
Egbert 1993	10/43	11/40		12.5	0.85 [0.40, 1.77]
Berde 1991	6/32	6/23		6.9	0.72 [0.27, 1.95]
Hecker 1988a	5/11	4/7		8.3	0.80 [0.32, 1.98]
Hecker 1988b	6/10	4/7		10.3	1.05 [0.46, 2.38]
Rogers 1990	2/34	6/35		2.9	0.34 [0.07, 1.58]
Colwell 1995	32/91	30/93		41.7	1.09 [0.73, 1.64]
Choiniere 1998	8/60	14/63		10.9	0.60 [0.27, 1.33]
Keita 2003	5/20	4/20		5.1	1.25 [0.39, 3.99]
Smythe 1994	0/19	1/17		0.7	0.30 [0.01, 6.91]
Total (95% CI)	341	326		100.0	0.91 [0.70, 1.18]

Total events: 75 (PCA), 80 (Control)

Test for heterogeneity chi-square=5.22 df=9 p=0.81 I^2 =0.0%

Test for overall effect z=0.73 p=0.5

Analysis 08.02. Comparison 08 Urinary retention, Outcome 02 Number of patients reporting urinary retention by surgery type

Review: Patient controlled opioid analgesia versus conventional opioid analgesia for postoperative pain

Comparison: 08 Urinary retention

Outcome: 02 Number of patients reporting urinary retention by surgery type

Study	PCA n/N	Control n/N	Relative Risk (Random) 95% CI	Weight (%)	Relative Risk (Random) 95% CI
01 Abdominal					
Choiniere 1998	8/60	14/63		33.0	0.60 [0.27, 1.33]
Hecker 1988a	5/11	4/7		25.0	0.80 [0.32, 1.98]
Hecker 1988b	6/10	4/7		31.1	1.05 [0.46, 2.38]
Rogers 1990	2/34	6/35		8.9	0.34 [0.07, 1.58]
Smythe 1994	0/19	1/17		2.1	0.30 [0.01, 6.91]
Subtotal (95% CI)	134	129		100.0	0.72 [0.46, 1.13]
Total events: 21 (PCA), 29 (Control)					
Test for heterogeneity chi-square=2.55 df=4 p=0.64 I^2 =0.0%					
Test for overall effect z=1.42 p=0.2					
02 Orthopedic					
Berde 1991	6/32	6/23		54.4	0.72 [0.27, 1.95]
Keita 2003	5/20	4/20		40.2	1.25 [0.39, 3.99]
Sanansilp 1995	1/21	0/21		5.5	3.00 [0.13, 69.70]
Subtotal (95% CI)	73	64		100.0	0.97 [0.47, 2.02]
Total events: 12 (PCA), 10 (Control)					
Test for heterogeneity chi-square=1.03 df=2 p=0.60 I^2 =0.0%					
Test for overall effect z=0.08 p=0.9