Patient controlled epidural analgesia for bilateral versus unilateral total knee arthroplasty: A retrospective study of pain control

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Abstract

Background: Patient controlled epidural analgesia (PCEA) has been used commonly for postoperative pain management following total knee arthroplasty (TKA). The purpose of this study was to compare a single standardized PCEA protocol in patients who received unilateral TKA with patients who received simultaneous bilateral TKA.

Methods: From October 2003 to October 2008, 912 patients were enrolled. Patient-machine interaction data were retrieved from PCA machines and stratified into 12 hour intervals. The data were analyzed according to the side of surgery, gender and methods of anesthesia. Patient demographic data, pain scores and side effect scores were compared to evaluate clinical efficacy.

Results: There was no significant difference between the unilateral and bilateral TKA groups for pain scores, severity of side effects, and total drug use. However, there was a paradoxical increase in demand, delivery, and demand/delivery ratio of analgesics for unilateral rather than bilateral TKA. This was only noted in the first 12 hours. Both genders demanded more bolus doses than set by the standard protocol. Women with unilateral TKA received more delivery doses. All of the patients who received general anesthesia had a higher demand/delivery ratio while spinal anesthesia patients had no significant ratio difference.

Conclusion: PCEA provided equal analgesia for patients with unilateral or bilateral TKA. However, the paradoxical increase in demand suggested that psychological factors may play a role in pain perception. A comprehensive pain management program that addresses gender and anesthesia methods in the first 12 hours will improve clinical efficacy and patient satisfaction of PCEA.

Keywords: clinical efficacy; demand/delivery ratio; epidural analgesia; patient controlled analgesia; patient-machine interaction; total knee arthroplasty

1. Introduction

Total knee arthroplasty (TKA) is a successful procedure to improve the quality of life in patients with degenerative joint disease. Severe postoperative pain is a significant concern for patients who are considering surgery, and can impact the physiological and psychological status of patients and affect clinical outcomes. Most of the candidates for TKA are elderly and have medical comorbidities that can worsen when subjected to stress. As a result, postoperative pain management has become an essential part of the perioperative care program for TKA. The clinical benefits and safety of bilateral simultaneous TKA remains controversial. There is an increased risk of cardiovascular events, pulmonary complications and mortality. Improvements in surgical techniques, prostheses, and medications make bilateral TKA safer. The authors believe that an optimized, effective pain management could also raise the efficacy of simultaneous TKA by helping functional recovery.
and decreasing complications from surgical stress. Therefore, we question if there are differences between patients receiving unilateral and bilateral simultaneous TKA on the requirement and response to pain management.

Patient controlled epidural analgesia (PCEA) is frequently used to relief acute postoperative pain. Evidence suggests it is more effective and has fewer side effects than intravenous patient controlled anesthesia (IVPCA) with morphine in TKA. In patients receiving IVPCA, the pain scores, total opioid use and side effects were similar for unilateral and bilateral TKA. However, there is no study to our knowledge that compared the efficacy, dosage and side effects of epidural analgesia for patients with unilateral and bilateral TKA.

The purpose of this study was to determine whether patients who underwent bilateral TKA respond differently to a standardized PCEA protocol from those who underwent unilateral TKA. The PCEA efficacy was evaluated by dosing records and validated pain scoring tools. Side effects such as sedation, sensory and motor blockade, nausea and vomiting were also compared. The patient-machine interaction was analyzed with demand/delivery patterns, which had been automatically recorded by the PCA machines. Confounding factors, which might influence pain perception, such as gender differences and anesthesia methods were also examined.

2. Methods

Data from patients who received PCEA for unilateral or bilateral TKA in the authors’ institute were routinely registered and collected into a PCA database. Ethical approval was obtained from our Institutional Review Board (VGH IRB No.: 2011-03-037IC). A total of 1068 patients were entered into the database from October 2003 to October 2008 and had been classified as American Society of Anesthesiologists Class I or II. Those who had the following conditions were excluded: early termination of PCEA program prior to schedule due to technical problems such as catheter disconnection or catheter misplacement; receiving premedication; and otherwise received additional intravenous or oral analgesics during PCEA program or associated with severe postoperative complications such as infections, bleedings, and cardiovascular or pulmonary events. A total of 912 (85.3%) patients were selected for the final analysis.

The database contained all the detail dosing data retrieved from the PCA machine. The clinical information was collected by a special PCA team who monitored patients throughout their PCA use. Data on age, height, weight, anesthesia method (general anesthesia, spinal anesthesia), and epidural catheter puncture site were also collected. In patients receiving spinal anesthesia, the anesthesia was provided at levels L2/3, L3/4, or L4/5 with a 25-gauge Quincke needle and 13 mg of Bupivacaine with dextrose.

Epidural catheterization was performed in the operating room with a Perifix catheter set (B/Braun Medical Inc., Bethlehem, PA, USA) at the same lumbar spinal space as that used for spinal anesthesia. For patients receiving general anesthesia, the epidural catheter was placed in the operating room at lumbar spaces L2/3, L3/4, and L4/5. Immediately after epidural catheter insertion, general anesthesia was induced using Propofol 2 mg/kg, and Fentanyl 3 μg/kg administered intravenously. Rocuronium 50 mg was used to facilitate intubation. General anesthesia was maintained with Desflurane with no additional analgesics throughout the operation.

A PCEA regimen consisted of 0.1% Marcaine and 1 μg/ml Fentanyl in 0.9% normal saline was administered through an Abbott Aim Plus PCA machine (Abbott Laboratories, Abbott Park, IL, USA). The pain pump was programmed to deliver a continuous dose of medications and was connected to the patients immediately after arrival in the postoperative recovery room. Initially, a continuous dosage with a range of 3 ~ 5 ml/hour was set and then adjusted by PCA nurses to maintain patient satisfaction and pain level.

The dose of medication was lowered if patients experienced nausea, vomiting or over-sedation. It was increased if patients experienced intolerable pain. A rescue PCA bolus dosage of 2~3 ml/bolus was delivered as requested (when patient pushed the bottom) with a lock-out time of 10 minutes. There was also a 4-hour upper limit of 30 ml for total dosage. Therefore, the maximum infusion volume permitted in 12 hours was 90 ml. Data of demand and delivery (expressed as numbers of PCA button being pressed) were retrieved from PCA machines for each patient after the PCA course was completed. Total use (infusion rate x time + number of boluses x bolus dosage) was calculated automatically by the PCA machine. The dosing data were also automatically converted to volume delivered in milliliters and stratified into a 12-hour period for each category.

Postoperative pain scores during rest, movement, and cough were assessed using a visual analog scale (0 = no pain, 1 = a little pain, 10 = extreme pain). Sensory block effects (0 = normal sensation, 1 = mild block, 2 = moderate block, 3 = total block) and motor block effects (0 = normal motor, 1 = mild block, 2 = moderate block, 3 = total block) were evaluated using a four-point scale. In addition, sedation effects (0 = good awareness, 1 = arousable sedation, 2 = arousable to pain, 3 = comatose) were also evaluated using a four-point scale. Finally, the severity of postoperative side effects such as nausea, vomiting and dizziness was evaluated by a four-point scale (0 = no side effect, 1 = mild, 2 = moderate, 3 = severe). Questionnaires were conducted by individual PCA nurses at 12 hour intervals within 48 hours postoperatively.

Parametrical data were presented as mean ± standard deviation and categorical data were expressed as a count with percentage calculation. Independent t tests were used to compare continuous variables including patients’ characteristics and variables related to PCA usage of the two groups. Chi-square tests were used to compare ordinal variables such as postoperative pain, sedation, sensory and motor blockade, and side effects between the two groups. Any p value <0.05 was considered statistically significant. All statistical analyses were carried out with the SPSS version 17.0 for Windows.
(SPSS Inc., Chicago, IL, USA). Comparisons between spinal
anesthesia and general anesthesia, and between female and
male patients were also analyzed.

3. Results

A total of 912 eligible patients were enrolled. The demo-
graphic data are shown in Table 1. The unilateral group was
slightly older than the bilateral group (71.9 vs. 70.43, 
\( p = 0.02 \)). Otherwise, there was no difference in body weight,
body height, sex, puncture sites, and methods of anesthesia
between the two groups.

The severity of side effects such as sedation, sensory and
motor blockade, nausea and vomiting were comparable
between the two groups and are shown in Table 2.

The visual analog scores (VAS) at rest and during move-
ment are shown in Table 3. The majority of patients reported
low V AS. There was no significant difference in pain scores
between the two groups.

Dosing data at 12 hour intervals were compared (Fig. 1).
There was no significant difference in the total use of PCA
drugs between unilateral and bilateral knee groups throughout
the entire period. There was a slight decrease in the total
analgesic use on the second day, but this was not statistically
significant. Interestingly, there was significantly more demand
for patients in the unilateral group during the first 12 hours.
However, in female patients, drug demand (18.46 \( \pm \) 2.08 \( /C6 \),
\( p = 0.04 \)) and demand/delivery ratio (2.63 \( \pm \) 0.16 vs.
1.99 \( \pm \) 0.19, \( p = 0.01 \)), but not the delivery, showed a signif-
ificant increase in the first 12-hour period for those who received unilateral surgery. In male patients, the demand (18.46 \( \pm \) 2.08 \( /C6 \),
\( p = 0.04 \)) and demand/delivery ratio (2.63 \( \pm \) 0.16 vs.
1.99 \( \pm \) 0.19, \( p = 0.01 \)), but not the delivery, showed a signif-
ificant increase in the unilateral group during the first 12 hours.

There was no difference in total drug use between unilateral
and bilateral knee groups when analyzed by gender (Fig. 2).

However, in female patients, drug demand (23.60 \( \pm \) 1.63 vs.
16.62 \( \pm \) 2.04, \( p = 0.03 \)), delivery (6.63 \( \pm \) 0.21 vs.
5.74 \( \pm \) 0.33, \( p < 0.01 \)) and demand/delivery ratio (3.17 \( \pm \) 0.20
vs. 2.40 \( \pm \) 0.17, \( p < 0.01 \)) showed a significant increase in the
first 12-hour period for those who received unilateral surgery. In male patients, the demand (18.46 \( \pm \) 2.08 vs. 12.90 \( \pm \) 2.16,
\( p = 0.04 \)) and demand/delivery ratio (2.63 \( \pm \) 0.16 vs.
1.99 \( \pm \) 0.19, \( p = 0.01 \)), but not the delivery, showed a signif-
ificant increase in the unilateral group during the first 12 hours.

When all patients were re-grouped according to their
anesthesia mode (Fig. 3), no significant differences in total
drug use were found between the unilateral and bilateral
groups. However, both anesthesia modes revealed significantly
higher demand for the unilateral patients during the first 12
postoperative hours (spinal: 21.35 \( \pm \) 1.61 vs. 15.79 \( \pm \) 1.94,
\( p = 0.03 \), general: 21.51 \( \pm \) 2.82 vs. 11.95 \( \pm \) 2.08, \( p < 0.01 \)). A
higher demand/delivery ratio in the unilateral group was also
noted for those who received general anesthesia in the first 12
hours (3.31 \( \pm \) 0.56 vs. 2.23 \( \pm \) 0.40, \( p = 0.01 \)), but not for those who received spinal anesthesia did not (2.84 \( \pm \) 0.15 vs.
2.27 \( \pm \) 0.16, \( p = 0.11 \)).
4. Discussion

Pain following surgery remains as the major factor that limits patients seeking TKA. Adequate pain control is important to reduce the postoperative stress response, facilitate rehabilitation, shorten hospital stay, and decrease the cost of care. PCA remains the most popular pain management in the authors’ country due to its accessibility. It provided better pain relief, anxiety relief, and patient satisfaction than nurse-controlled analgesia, and therefore facilitated recovery.

Evaluation of pain control efficacy and efficiency is important in determining patient satisfaction. The VAS and pain relief scoring are widely used to objectify the severity of pain. However, over-reporting and under-reporting occur in situations when patients are influenced by family members, social cultural pressure, or concerns about the consequences of reporting pain. For example, if some patients are concerned about potential side effects from a higher dose of analgesics, they may report lower VAS. This is done in order to receive a lower continuous dose, which is controlled by the medical staff. The results of our study demonstrated satisfactory VAS and pain relief scoring in both TKA groups (Table 3). However, VAS is affected by the timing of drug administration to data collection and the patient’s perception of their state of health. Therefore, we analyzed the interaction between the patient and the PCA machine so that more objective information could be collected.

Interaction between the patients and PCA machine is determined by the number of demands and bolus drug delivery. The number of PCA demands is the number of times a patient presses the button. This is usually used as an indicator of pain perception and to a certain degree reflects the

Table 3
Visual analog score (scale of 0–10, 0 = no pain, 10 = worst pain).

<table>
<thead>
<tr>
<th>POH</th>
<th>Visual analog score during rest</th>
<th></th>
<th>Visual analog score during movement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unilateral knee (n = 711)</td>
<td></td>
<td>Bilateral knee (n = 201)</td>
<td>p</td>
</tr>
<tr>
<td>0–12</td>
<td>0.76 ± 1.19</td>
<td>1.11 ± 1.57</td>
<td>0.06</td>
<td>2.03 ± 1.86</td>
</tr>
<tr>
<td>12–24</td>
<td>1.13 ± 1.53</td>
<td>1.12 ± 1.42</td>
<td>0.95</td>
<td>1.85 ± 1.84</td>
</tr>
<tr>
<td>24–36</td>
<td>1.01 ± 1.16</td>
<td>1.25 ± 1.54</td>
<td>0.29</td>
<td>2.50 ± 1.76</td>
</tr>
<tr>
<td>36–48</td>
<td>0.88 ± 1.27</td>
<td>1.33 ± 1.32</td>
<td>0.17</td>
<td>2.34 ± 1.90</td>
</tr>
</tbody>
</table>

POH = postoperative hours.
Data expressed as mean ± standard deviation.

Fig. 1. Comparison of dosing data on total drug consumption, demand, delivery, and demand/delivery ratio between unilateral and bilateral TKA group. (★ p < 0.05, ★★ p < 0.01).
The number of bolus drug deliveries represents the amount of rescue analgesics actually given to the patient. It closely correlates with the degree of pain. However, the total potential delivery of drug is influenced by the lock-out time and the maximum allowed dose in a set period of time. The demand/delivery ratio reflects the average number of times the button is pressed in order to deliver an actual bolus dosage. It reflects the anxiety of pain and also the skill of the patient to request analgesic bolus doses.

A retrospective, patient-based, matched-pair study conducted by Powell et al compared patients receiving unilateral and bilateral TKA. They found that the pain scores and use of intravenous narcotics differed only in the first postoperative day, but were higher for the bilateral TKA. In theory, the pain level of bilateral surgery should exceed that of unilateral surgery. However, the results from our study suggest that similar amounts of epidural pain medication are sufficient to achieve an adequate level of pain control for unilateral and
bilateral TKA. Epidural analgesia produced a bilateral effect, therefore it produced equally effective pain control in unilateral and bilateral TKA. The total use of epidural medications decreased over time, indicating a gradual decrease in nociceptive input. In this study, however, the demand, delivery and demand/delivery ratio were higher in the unilateral group than the bilateral group in the first 12 hours but then equalized. This paradoxical phenomenon denotes that pain response differs in the very early postoperative stage.

The paradoxical phenomenon may be due to the learning curve effect of PCA in pain perception. First impressions of the pain aggravated the anticipation and anxiety of pain. Patients in the bilateral group might be psychologically more prepared for the pain before surgery, and thus expressed a lower level of anxiety of pain. Anticipation of pain and anxiety have been reported to be important predictors of postoperative pain. Anticipation of pain before surgery and perception of pain after surgery might contribute to the increased demand in the first 12 hours. However, in a systematic review performed by Ip et al, coping strategies, such as emotional support, religious-based, or intrusive thought/avoidant behavior, help diminish postoperative pain level and analgesic consumption. The paradoxical phenomenon found in our study could be attributed to the learning curve effect of PCA in pain perception. After allowing time for epidural analgesia to reach a balanced dose, the demand and delivery reached a steady state in the second 12 hours, thus the demand data have a better association with the physiological need for pain medication.

Gender differences in pain response were observed in this study and might add to the paradoxical increase in analgesics demand in the unilateral group. Pain perception and processing differed in men and women. Several studies had demonstrated that anticipation of pain was more common in women and thus had more effect on pain responses. However, studies concerning postoperative pain perception in female and male patients are still controversial.

In a study conducted by Kindler et al concerning psychological and demographic predictors of pain perception, women reported greater clinical pain and had a lower pain threshold then men in experimental pain. Therefore treatment responses to pain were different between women and men. Some evidence suggests that women reported more pain after surgery. In our study, there was an increase in demand and delivery in the first 12 hours in the female group. In the male group, only demand was increased. This indicated that female patients not only had a higher anxiety level but also a lower threshold for pain.

The ideal method of anesthesia for TKA or total hip arthroplasty is still debated by surgeons and anesthetists in terms of a painless recovery, side effects, rehabilitation and length of hospital stay. In this study, total drug use for PCEA did not differ among patients receiving spinal or general anesthesia. The paradoxical increase in demand occurred in patients who received either type of anesthesia, but the paradoxical demand/delivery ratio increase was only observed in patients who received general anesthesia. This suggests that these patients experienced a higher level of anxiety in the early stage. This may be due to residual effect of spinal anesthesia that provided a buffer period for the first sensation of pain and eased the anxiety.

In conclusion, psychological factors play an important role in pain perception and response in the immediate postoperative stage. This had been shown by the paradoxical phenomenon discovered in our study. The results also suggest that female patients experience a higher anxiety level and lower pain threshold in the first 12-hour period. The patients receiving spinal anesthesia might benefit from the residual effect of anesthetics and therefore experience a lower anxiety level. A comprehensive pain management protocol for patients undergoing TKA should include preoperative education, coping skills, psychological support, and a sophisticated analgesic regimen, which can adapt to special needs immediately following surgery and account for gender difference in pain response. This may increase patient satisfaction and decrease bolus dosing requirements.

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