Continuous Femoral Blocks Improve Recovery and Outcome of Patients Undergoing Total Knee Arthroplasty

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Abstract: This study was designed to determine the effects of continuous femoral infusion (CFI) on total knee arthroplasty recovery. A total of 92 patients were distributed in 3 groups: Patients in group 1 received general anesthesia followed by patient-controlled analgesia (PCA) with morphine (n = 33), patients in group 2 received 3-in-1 and sciatic blocks followed by CFI (n = 29), and patients in group 3 received epidural analgesia (n = 30). Blocks reduced postoperative morphine requirement by 74% (vs group 1; $P<.05$) and 35% (vs group 3; $P<.05$). Blocks provided better recovery than PCA with morphine or an epidural. The use of CFI was associated with a reduction of postoperative bleeding by 72% (vs group 1; $P<.05$) and allowed better performance on continuous passive motion. CFI was associated with a 90% decrease in serious complications and a 20% decrease in the length of hospitalization. CFI represents a better alternative than PCA or epidural analgesia for postoperative pain management and immediate rehabilitation after total knee arthroplasty. **Key words:** continuous femoral infusion, ropivacaine, total knee arthroplasty, acute pain management, blood loss.

Postoperative pain control has been shown to be an important factor in immediate recovery and length of hospital stay [1]. Accepted postoperative analgesia techniques include patient-controlled analgesia (PCA) with morphine [2], epidural analgesia (EPA) [3,4], and nonsteroidal anti-inflammatory drugs (NSAIDs) such as ketorolac [5]. Significant side effects have been described with each of these techniques, however. Respiratory depression, constipation, nausea and vomiting, pruritus, sedation, and urinary retention are associated with the use of morphine (PCA) or fentanyl (EPA). Renal and hepatic failure as well as bleeding are associated with the use of NSAIDs [6]. The frequency and severity of these complications suggest that current postoperative pain control techniques need improvement. Since the 1980s, EPA has been considered the technique of choice for postoperative analgesia in patients undergoing lower extremity joint arthroplasty. The preference for EPA is based on the associated improved postoperative analgesia, reduction in surgical blood loss, and incidence of deep vein thrombosis. The introduction of low-molecular-weight heparin for the prevention of postoperative deep vein thrombosis and pulmonary emboli [7–9] has been shown, however, to increase the estimated risk for epidural hematoma and associated irrevers-

ible nerve damage by 50 times [10]. Continuous femoral infusion (CFI) of local anesthetics was shown to compare favorably with EPA in providing postoperative analgesia in patients undergoing total knee arthroplasty (TKA) [11,12]. Capdevila et al [13] showed that CFI enhanced rehabilitation and shortened the length of stay in a rehabilitation facility. The effects of CFI on anesthesia requirement and immediate postoperative outcome have not been established. This study compared 3 techniques of anesthesia and postoperative analgesia and their effects on anesthesia requirement and postoperative outcome in patients undergoing TKA.

Methods

Following institutional review board approval, 92 consecutive patients aged 37 to 78 years with American Society of Anesthesiologists' ratings of I to III scheduled to undergo 92 TKAs were enrolled in this cohort study. After obtaining informed consent, patients were assigned to 1 of 3 groups: Group 1 patients received general anesthesia followed by PCA morphine (n = 33), group 2 patients received general anesthesia combined with 3-in-1 paravascular and anterior sciatic blocks followed by CFI (n = 29), and group 3 patients received general anesthesia combined with EPA followed by a continuous EPA infusion. Patients in groups 2 and 3 had free access to PCA morphine during the postoperative period. Excluded from the study were patients with severe systemic arthritis, rheumatoid arthritis, severe chronic pain syndrome, or diabetes with significant peripheral neuropathies as well as patients allergic to morphine, fentanyl, or local anesthetics. Before surgery, each patient was educated about the use of PCA.

Protocol

The patients in groups 2 and 3 were taken to a preoperative block room. In *group 2*, under sterile conditions, a 3-in-1 paravascular block was performed followed by the placement of a femoral catheter. A single anterior sciatic block also was performed. The blocks were performed at least 30 minutes before surgery. Midazolam, 2 to 4 mg intravenously, and fentanyl, 50 to 100 μg intravenously, were given for sedation, and vital signs were monitored.

The femoral and sciatic nerves were located using a nerve stimulator. After proper positioning of the needle, 15 mL of 0.75% ropivacaine plus 15 mL of 1.5% mepivacaine were injected slowly 5 mL at a time. After surgery, the femoral catheter was infused with 0.2% ropivacaine at a rate of 12 mL/h.

For the *3-in-1 paravascular block* [14], patients were placed in the supine position. The pulse of the femoral artery was identified. The needle entry site was at the level of the femoral crease 2 cm lateral to the femoral pulse. An 18G, 89-mm insulated Tuohy needle (B Braun Medical, Bethlehem, PA) connected to a nerve stimulator (Stimuplex-Dig, B-Braun Medical, Bethlehem, PA) set up to deliver 1.5 mA was introduced cephalad at a 45° angle to the skin. In almost every case, 2 distinct pops were noted as the needle passed through thick fascia planes. Then the needle was positioned correctly to produce patellar movement. The local anesthetic mixture was injected when the motor response was maintained with a current <0.6 mA and after negative blood aspiration. At the end of the local anesthetic injection, a 20G catheter was introduced 10 cm and secured in place with 12 mm × 100 mm Steri-strips (3M Health Care, St Paul, MN) and covered with a transparent Tegaderm (3M Health Care, St Paul, MN).

For the *anterior sciatic nerve block technique* [15], patients were placed in the supine position with the lower extremity in the neutral position. A sacropubis line was drawn between the anterior iliac spine and the superior angle of the pubic tubercle. At the midpoint, a perpendicular line was marked on the thigh. The site of introduction of the needle was 8 cm from the top of this perpendicular line. A 20G 150-mm b-beveled Stimuplex insulated needle (B-Braun Medical, Bethlehem, PA) connected to a nerve stimulator (Stimuplex-Dig, B-Braun Medical, Bethlehem, PA) was introduced vertically. If the femur was contacted, the needle was withdrawn and introduced 1.5 to 2 cm medially.

In *group 3*, the epidural was placed with patients in a sitting position at least 30 minutes before surgery. After appropriate positioning and preparation of the patient, an 18G Tuohy needle was placed in the epidural space between L2 and L4. After placement of the epidural catheter, the patients received 20 mL of a mixture containing 2% lidocaine and 0.5% bupivacaine (V/V).

Before the induction of anesthesia, all patients received 1 to 2 mg of midazolam intravenously. After proper positioning on the operating table and placement of monitors, including oxygen saturation, blood pressure cuff, and electrocardiogram, the patients were preoxygenated and vital signs were recorded. General anesthesia was induced with propofol, 2 to 4 mg/kg intravenously, or thiopental, 4 to 5 mg/kg intravenously. Patients were intubated after administration of rocuronium, 0.6

mg/kg, and mechanically ventilated with a mixture of nitrous oxide and oxygen (60%/40%). General anesthesia was maintained with isoflurane and fentanyl to preserve blood pressure and heart rate within 20% of baseline. Surgery was performed with a tourniquet inflated at 350 mmHg. Most prostheses were cemented in place (Table 1). At the end of surgery, a Hemovac drain was placed. The drain was removed on the morning of the 3rd postoperative day. All patients were extubated in the operating room and transferred to the postanesthesia care unit (PACU) to recover.

Postoperative Analgesic Management and Discharge Criteria

On arrival in the PACU and after placement of standard monitors, pain and other symptoms were evaluated by an independent observer, and morphine was titrated to maintain the pain at a level of ≤1 using a 4-level scale (0 = no pain, 1 = mild pain, 2 = moderate pain, and 3 = severe pain). After being provided with initial pain control, the patients were connected to a PCA morphine pump (Lifecare PCA Plus III Infuser, Abbott Laboratories, Chicago, IL) that delivered 1-mg doses with a 5-minute lockout period and a maximum dose of 10 mg/h. If the pain was not controlled, the dose was increased by 50% at a time up to a maximum of 2 mg and a maximum dose of 15 mg/h. The patients were encouraged to use the PCA as often as needed. The femoral catheter of patients in group 2 was connected to a pump (Baxter AP II, Baxter Healthcare, Deerfield, IL) that delivered 0.2% ropivacaine at 12 mL/h, and the epidural catheter of patients in group 3 was connected to a pump (Baxter AP II, Baxter Healthcare, Deerfield, IL) that delivered 0.125% bupivacaine plus 3 μg/mL of fentanyl at a rate of 10 mL/h. CFI and EPA were maintained for 72 hours.

After discharge from the PACU, patients were transferred to the orthopaedic floor until discharge from the hospital. On the morning before the expected day of discharge or on the 4th postoperative day, the femoral and epidural catheters were removed. According to our clinical protocol, the Foley catheter was removed on the 3rd postoperative day. During the first 3 postoperative days, fever, wound infection, blood loss and blood transfusions, level of pain using the 4-level scale (no pain, mild, moderate, and severe), and morphine consumption and associated side effects were recorded at least twice a day by an independent observer. Indications for blood transfusion included hemoglobin <9 mg/dL without clinical symptoms or <10 mg/dL associated with tachycardia, hypotension, or tachypnea.

Continuous passive motion (CPM) of the knee was initiated on postoperative day 1 and continued until discharge, using a Danniplex 500 (Danniger Medical, Columbus, OH) and maintained to the limit of patient tolerance. The goals for postoperative days 1, 2, and 3 were a passive flexion of 40°, 50°, and 60°. Respectively, after being evaluated independently, patients were discharged in the absence of medical and surgical complications when they were able to flex the knee passively at an angle of 60° with the CPM for 3 hours twice a day.

Statistical Analysis

A one-way analysis of variance was used to analyze the differences in demographics between groups. A Kruskal–Wallis test was used to analyze between-group differences for morphine consumption, CPM, blood loss, time to walk, and length of hospital stay. For significant differences, a Mann–Whitney test was performed for paired comparisons. Percentage differences between groups were analyzed using a Fisher exact test. α was set at .05. Demographics are presented as mean (range). Morphine consumption, CPM, blood loss, time to walk, and length of hospital stay are expressed as median (25th–75th percentiles). Complications during and after surgery as well as blood transfusions are presented as percentages [16].

Results

No significant differences with respect to age, weight, preoperative medical history, or duration of tourniquet time were observed (Table 1). As indicated in Fig. 1, the use of 3-in-1 paravascular and

Table 1. Patient Demographics

	PCA (n = 33)	CFI (n = 29)	EPA (n = 30)
Age (y)*	65 (57–73)	66 (60–74)	70 (65–74)
Weight (kg)*	82 (71–96)	91 (69–103)	84 (74–93)
HTN (%)	45	65	56
DM (%)	12	17	10
CAD (%)	9	0	10
Tourniquet time (min)*	96 (80–112)	91 (70–118)	86 (70–124)
Cemented prostheses (%)	70	83	80

PCA, patient-controlled analgesia with morphine; CFI, contiuous femoral infusion; EPA, epidural anesthesia and analgesia; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease.
  * Mean (range).

Fig. 1. Morphine, isoflurane (ISO), and fentanyl requirements during surgery. ☐ General anesthesia (group 1); ■3-in-1 paravascular and sciatic blocks (group 2); ☐Epidural anesthesia (group 3).
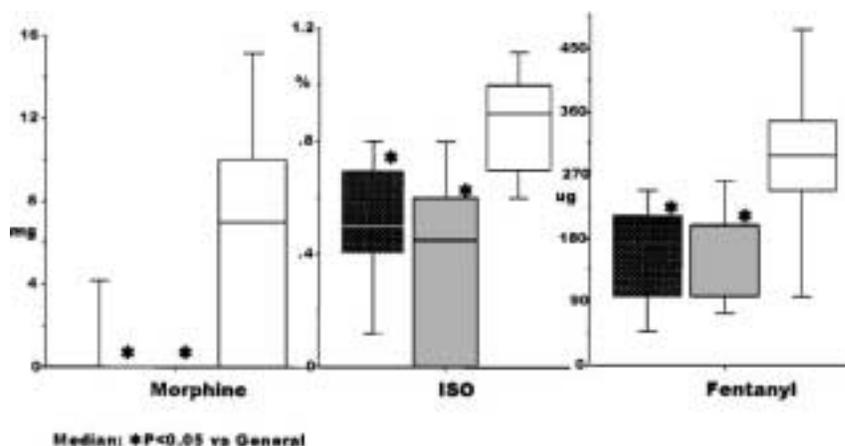
sciatic blocks (group 2) or EPA (group 3) was associated with a significant reduction in anesthetic requirement during surgery compared with general anesthesia alone. In groups 2 and 3, the need for isoflurane was decreased by 44% and 50%, and the need for fentanyl was decreased by 63% and 66%. Simultaneously the overall cardiovascular stability was increased with the use of blocks, as indicated by a 56% reduction in cardiovascular complications compared with either EPA or general anesthesia alone (Fig. 2). The use of blocks was associated with a reduction of hypotension by 66% and bradycardia by 77% compared with general anesthesia and by 69% and 81% compared with EPA.

During recovery in the PACU, the use of peripheral nerve blocks decreased postoperative nausea and vomiting episodes by 62% versus PCA morphine and EPA (Fig. 3). Blocks and EPA similarly reduced the immediate morphine requirement by 100% (Fig. 4).

During the postoperative period, morphine requirements were at a maximum on the 2nd day in the PCA morphine group (Fig. 4). Associated morphine side effects included pruritus (33%), constipation (24%), and nausea and vomiting (48%) (Fig. 5). Despite the use of PCA morphine, mild, moderate, and severe pain was recorded in 22%, 48%, and 30% of patients in group 1 (Fig. 6). Postoperative bleeding was 580 mL and 100 mL during the first 2 postoperative days (Fig. 7), and almost 50% of the patients received transfusions (Fig. 8). Patients were able to exercise passively at a level of 30°, 40°, and 50° on the postoperative days 1, 2, and 3 (Fig. 9). Patients in the PCA group walked on the 3rd postoperative day and were discharged on the 5th postoperative day (Fig. 10).

Compared with PCA morphine alone (group 1), the use of either CFI or EPA resulted in a decrease in morphine requirement by 74% (group 2) and 59% (group 3) (Fig. 4). CFI provided better pain

Fig. 2. Cardiovascular complications during surgery. ☐ General anesthesia; ■ 3-in-1 paravascular and sciatic blocks; ☐ Epidural anesthesia; Tachy, tachycardia; Brady, bradycardia; Hypo, hypotension; Hyper, hypertension.
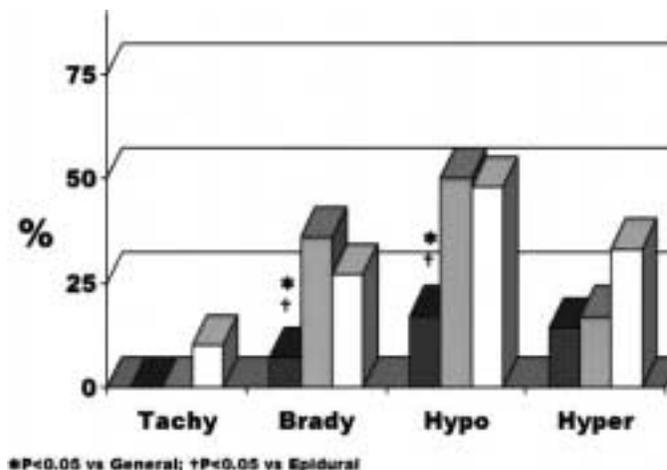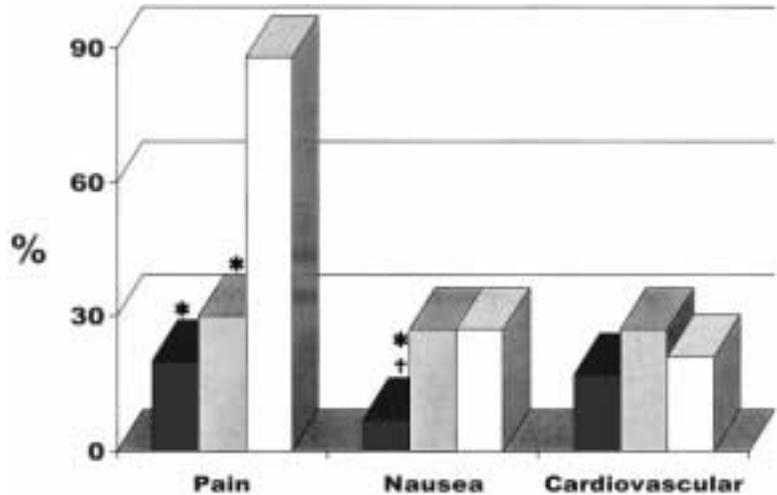
Fig. 3. Postoperative complications during recovery in the postanesthesia care unit. ■ Continuous femoral infusion blocks; ▨ Epidural anesthesia; □ General anesthesia.

control than EPA, however, as indicated by decreased morphine requirement (20% lower than with EPA) and fewer severe and moderate pain episodes. CFI resulted in fewer mild pain episodes compared with EPA (38% vs 66%) (Fig. 6). The frequency of constipation and nausea and vomiting was reduced in patients receiving CFI compared with patients receiving PCA morphine alone (88% and 63%), and frequency of constipation was reduced compared with patients receiving EPA (66%). The use of regional anesthesia (CFI and EPA) reduced the frequency of pruritus episodes compared with PCA morphine (73%). Although

the postoperative analgesia technique did not affect the frequency of wound infection significantly (3%, 6%, and 0%), CFI, but not EPA, was associated with a decrease in the number of patients who developed fever postoperatively compared with PCA morphine alone (Fig. 8): Fever was recorded in 60% of patients who used PCA morphine and in 27% of patients infused postoperatively with 0.2% ropivacaine.

The use of CFI was associated with a 72% reduction in postoperative bleeding and a 68% reduction in transfusions compared with PCA morphine. Postoperative bleeding and transfusions were re-

Fig. 4. Postoperative morphine consumption during recovery in the postanesthesia care unit (PACU) and the first 3 postoperative days. ■Continuous femoral infusions; ▨Epidural analgesia; □ Patient-controlled analgesia; D1, postoperative day 1; D2, postoperative day 2; D3, postoperative day 3.
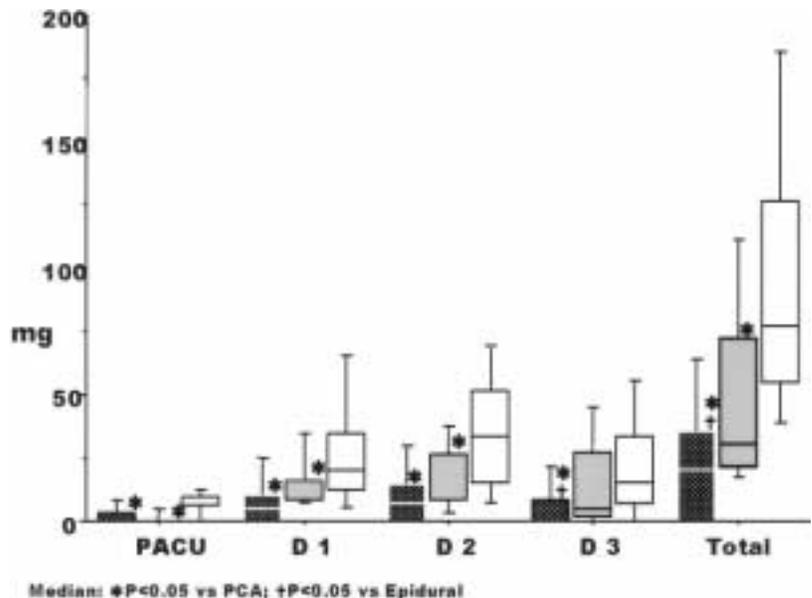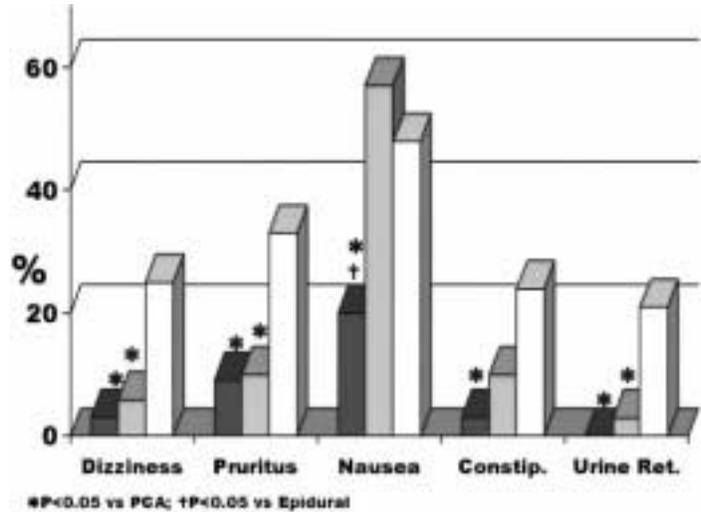
Fig. 5. Morphine-related postoperative complications during the first 3 postoperative days. ■ 3-in-1 paravascular and sciatic blocks; ▨ Epidural analgesia; □ Patient-controlled analgesia; Constip, constipation; Urine ret, urine retention.

duced by 64% and 50% in patients with EPA compared with PCA morphine (Figs. 7 and 8). Although the use of CFI and EPA increased passive knee flexion during the first 3 postoperative days (Fig. 9), only the use of CFI allowed earlier mobilization of patients and resulted in a 20% reduction of length of hospital stay (vs PCA morphine alone; Fig. 10). The distribution of serious complications occurring during the postoperative period is presented in Table 2.

Discussion

Our data show that a 3-in-1 paravascular block combined with a single sciatic block decreases anesthetic requirements in patients undergoing TKA.

The data show that postoperative CFI of 0.2% ropivacaine provides better postoperative pain control with fewer side effects than either PCA morphine or EPA. CFI was associated with an increased ability to tolerate CPM, which is considered to be a determinant of functional recovery [13]. In this regard, our data are in agreement with the results previously obtained in Europe by Singelyn et al [12] and Capdevila et al [13].

Singelyn et al [12] reported a 19% reduction in length of hospital stay with the use of CFI. In Belgium, however, the length of stay included postoperative recovery and initial rehabilitation. More recently, Capdevila et al [13] showed that CFI was associated with an 8% reduction of duration of rehabilitation but no reduction in the length of hospital stay. In
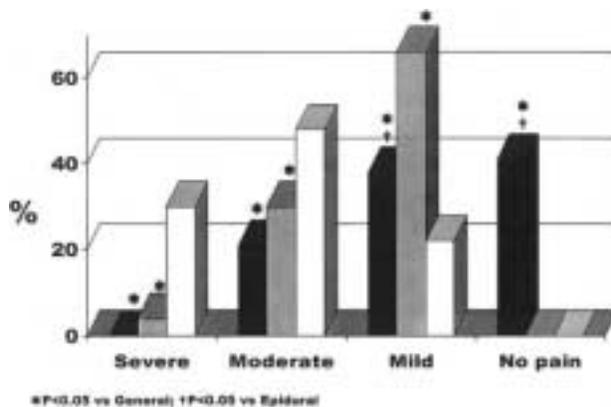

Fig. 6. Pain level distribution during the first 3 postoperative days. ■ Continuous femoral infusion; ▨ Epidural analgesia; □ General anesthesia.
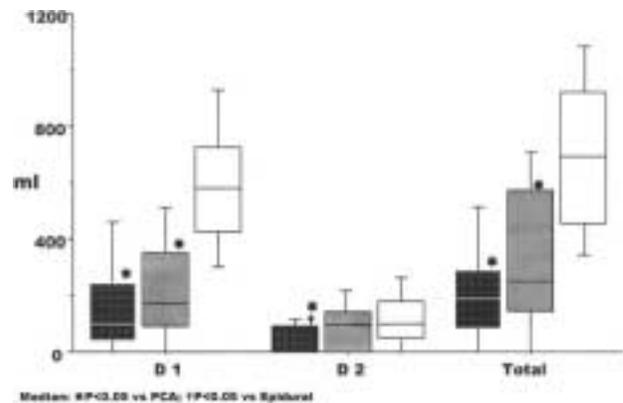

Fig. 7. Blood loss during the first 2 postoperative days. ■ Continuous femoral infusion; ▨ Epidural analgesia; □ Patient-controlled analgesia; D1, postoperative day 1; D2, postoperative day 2.
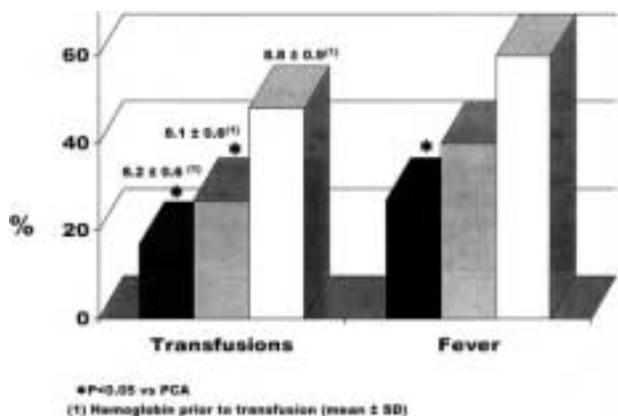
Fig. 8. Requirement for blood transfusion and fever episodes during the first 3 postoperative days. ■ Continuous femoral infusion; ▨ Epidural analgesia; ☐ Patient-controlled analgesia.

Fig. 10. Time to walk and length of hospital stay. ■ Continuous femoral infusion; ▨ Epidural analgesia; ☐ Patient-controlled analgesia.

the United States, many patients undergo rehabilitation as outpatients. In this regard, our data demonstrate that the use of CFI facilitates patient recovery and consequently reduces the length of stay. This beneficial effect most likely is related to an increased ability to perform CPM and a reduction in associated postoperative side effects and complications.

Ganapathy et al [17] reported that continuous fascia iliac block with 0.2% bupivacaine performed immediately after surgery produced similar postoperative results as ours. Our technique appears to produce better immediate postoperative pain control, however. The morphine requirement reported by Ganapathy et al [17] was higher on the day of
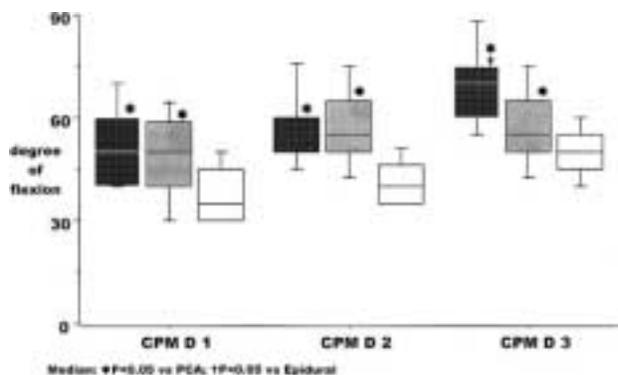
surgery than with our protocol, which included a 3-in-1 paravascular and sciatic block performed preoperatively rather than postoperatively. This higher morphine requirement may explain why these authors failed to show any associated decrease in morphine-related side effects in contrast to our findings. Our peripheral nerve block protocol allowed a reduction in opioid-related side effects produced by either intravenous (PCA morphine) or intrathecal (EPA) administration, such as postoperative constipation, pruritus, and nausea and vomiting.

In the patients who underwent TKA under general anesthesia followed by PCA morphine (group 1), intraoperative and postoperative blood loss were similar to losses reported by Cushner and Friedman [18]. Our data show that the use of regional

Fig. 9. Continuous passive movement (CPM) during the first 3 postoperative days. ■ Continuous femoral infusion; ▨ Epidural analgesia; ☐ Patient-controlled analgesia; D1, postoperative day 1; D2, postoperative day 2; D3, postoperative day 3.
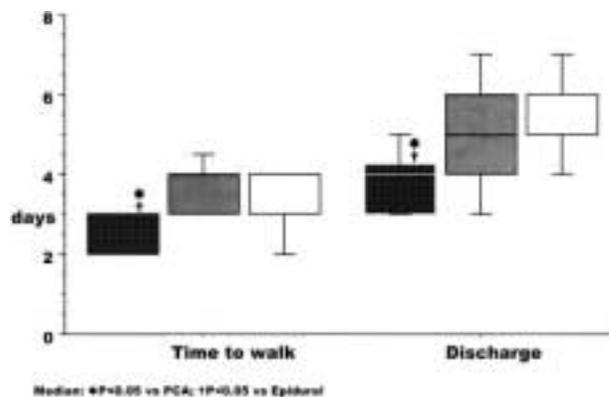
Table 2. Postoperative Serious Complications

	PCA (n = 33)	CFI (n = 29)	EPA (n = 30)
Hypoxia and change in mental status	3	0	2
Hypotension	1	1	2
DVT	2	0	1
MI	1	0	0
CVA	1	0	0
Ateleactasis	2	0	1
Upper gastrointestinal bleeding	1	0	0
Total	11 (33%)	1 (3%)*	6 (20%)

PCA, patient-controlled analgesia with morphine; CFI, continuous femoral infusion; EPA, epidural analgesia; DVT, deep vein thrombosis; MI, myocardial infarction; CVA, cerebrovascular accident.

* $P < .05$ vs PCA.

anesthesia techniques—either CFI or EPA—was associated with decreased blood loss. It is established that EPA [19] and lumbar plexus block [20] reduce surgical bleeding in patients undergoing hip arthroplasty. Our data show that the use of CFI was associated with a significant reduction in postoperative blood loss and requirement for postoperative blood transfusions.

Several local anesthetic solutions have been advocated for CFI, including bupivacaine at a concentration of 0.25% or 0.125% bupivacaine [21] with sufentanil and clonidine [12] at a rate of 10 mL/h. Capdevila et al [13] reported on an infusion of 1% lidocaine with morphine and clonidine. Our protocol included the use of 1.5% mepivacaine and 0.75% ropivacaine initially, followed by an infusion of 0.2% ropivacaine at 12 mL/h. The choice of 0.2% ropivacaine was based on the preferential sensory block that ropivacaine produces at this concentration and its decreased toxicity compared with bupivacaine [22,23]. The absence of a motor block is important to facilitate immediate active rehabilitation. Patients with CFI were able to walk earlier than patients receiving PCA morphine. The absence of opioids in the local anesthetic solutions that were infused through the femoral catheter minimized the related side effects and allowed an easier renewal of the local anesthetic solution. In our institution, any solution containing opioids requires a physician order, whereas in the absence of opioids, the solution can be obtained by the pharmacy until the order is discontinued. In the United States, the use of clonidine is approved only for the treatment of cancer-associated pain, and its route of administration is intrathecal [24]. Our data do not justify the inclusion of clonidine in our solution of local anesthetics. We have included a specific cyclooxygenase-2 inhibitor, rofecoxib, in our postoperative pain management protocol to reduce further postoperative requirement for opioids. Rofecoxib, in a dose of 50 mg, has been shown to be safer than NSAIDs, which are nonselective inhibitors [25]. Our new postoperative pain management protocol includes 50 mg of rofecoxib before surgery as well as once a day after surgery until discharge. Our preliminary results indicate that the addition of rofecoxib to CFI decreases further the patient's morphine requirement. In this respect, Ruben and Connelly [26] showed that rofecoxib, not celecoxib, decreases by 39% postoperative morphine requirement after spinal fusion surgery.

Akca et al [27] showed that control of postoperative pain is a major determinant of surgical wound infection. Our data showed that fewer episodes of fever were recorded in patients receiving CFI compared with PCA morphine alone or EPA. Because CFI also produced better postoperative pain control, the beneficial antipyretic properties of CFI were related to the quality of postoperative pain control or the infusion of local anesthetics through the femoral catheter. Morphine has been shown to depress oxidative killing function by neutrophils [28], and reduction of morphine consumption may lead to a lesser risk of immediate postoperative infection.

Our data show that CFI provides better postoperative analgesia than EPA or PCA morphine. EPA is still considered the gold standard for analgesia in patients undergoing TKA. Although EPA provides adequate analgesia and decreased blood loss, this technique was associated with more postoperative side effects than blocks and did not reduce the length of stay. EPA-mediated hypotension is not always well tolerated, especially in patients with poor cardiac function, which is often the case in patients undergoing TKA. EPA carries the risk for serious complications, such as epidural hematoma and abscess. The risk for epidural hematoma is a major concern in patients undergoing total hip arthroplasty and TKA who receive low-molecular-weight heparin treatment for the prevention of postoperative deep venous thrombosis and pulmonary emboli. Such treatment has been shown to be more effective than the postoperative use of warfarin now employed in our institution. Although guidelines have been developed to minimize the risk for epidural hematoma in patients receiving low-molecular-weight heparin therapy and EPA, of the 43 reported cases of epidural hematoma that occurred, almost 37% resulted in irreversible neurologic damage, including paraplegia [29]. The present guidelines do not guarantee against the occurrence of postoperative epidural hematoma [8,30]. In hospitals where low-molecular-weight heparin therapy is used, caution should be exercised in the use of EPA. Although we and others [12,13,17,21] did not report any serious complications associated with the use of CFI technique, theoretically it exposes patients to the same risks as EPA, including hematoma, abscess, and nerve damage. The frequency and consequences of these complications are estimated to be less with peripheral than with neuraxial blocks, however [31]. One important factor contributing to the lesser risk of continuous perineural block is that with this technique the catheter is placed peripherally and not centrally.

Hirst et al [21] reported that a 3-in-1 paravascular single block with 0.5% bupivacaine with epinephrine was as effective as a combination of the same initial injection of 0.5% bupivacaine followed by an infusion of 0.125% bupivacaine at 6 mL/h. These

authors concluded that CFI did not provide better postoperative analgesia than single femoral blocks. Ganapathy et al [17] showed that 0.125% bupivacaine at 10 mL/h was ineffective but that 0.2% bupivacaine at 10 mL/h reduced postoperative morphine requirement and improved range of motion. It appears that postoperative CFI provides better analgesia as long as the concentration of local anesthetics in the absence of opioids and clonidine is at least 0.2% bupivacaine. Additional studies are required to determine the minimum effective concentration of ropivacaine for this indication. Based on the previous experience with ropivacaine, however, it is unlikely that in the absence of opioids and clonidine a concentration lower than 0.2% would be effective.

Our data support the concept that CFI represents a better alternative than PCA or EPA for postoperative pain management and improves immediate mobilization. CFI reduces postoperative blood loss, transfusion requirements, frequency of serious complications, and hospital length of stay in patients undergoing TKA.

Acknowledgment

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