Regional Anesthesia for Knee Surgery

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Knee surgery may be performed under general anesthesia, preferably, however, under regional anesthesia because of the profound preemptive analgesic effect that is provided by regional anesthetic techniques. Both centroneuraxis (spinal, epidural) as well as peripheral nerve blocks may be used for knee surgery. Although the former may be used less frequently in the near future in knee surgery because of increasing administration of low molecular heparins with resultant epidural hematoma formation, the latter enjoy more and more popularity. Peripheral nerve blocks used mostly for knee surgery include femoral/sciatic nerve blocks and intra-articular injection of local anesthetics and/or opioids into the knee joint. They are devoid of extensive sympathectomy and provide sufficient surgical analgesia and motor block.

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Successful anesthesia for orthopedic procedures on the knee can be achieved by a variety of regional techniques. These not only offer an alternative or supplement to general anesthesia (GA), they add the following distinct advantages:

1. Preemptive analgesic effects, ie, reduction of pain beyond the pharmacologic action of the local anesthetic agent,1,3 reduction of the stress response.6
2. Catheters inserted during these blocks can be used for postoperative pain relief.
3. Allowance of earlier mobilization,3 reduction of deep venous thrombosis formation, and pulmonary embolism.8
4. Reduced PACU time and cost.7

The three most common interventions on the knee are arthroscopy, arthroplasty, and repair of the anterior cruciate ligament (ACL). In general, surgical time for these procedures only rarely exceeds the pharmacologic duration of longer lasting local anesthetic agents.

However, open knee procedures are extremely painful; therefore, continuous catheters for continuous analgesia are frequently inserted. These catheters enable patients to tolerate mobilization immediately after surgery. This provides faster, less painful rehabilitation as well as superior functional results.9

This report describes our rationale for selecting one regional anesthetic technique over the other and what we believe are key points in order to achieve successful regional anesthesia [or surgical procedures on the knee.

Spinal Anesthesia

Spinal anesthesia provides a temporary interruption of nerve transmission achieved by the injection of a relatively small amount of a local anesthetic solution into the subarachnoid space. This space is separated from the epidural space by the dura and contains cerebrospinal fluid and nerve fibers. In most adults, the spinal cord ends at L1-L2, therefore spinal anesthesia can be safely administered between L2 and L5. Generally, spinal anesthesia is achieved via single injection of a local anesthetic agent. Continuous spinal anesthesia can be achieved with the use of extremely thin intrathecal catheters (28 and 32 gauge [G]) that were briefly commercially available in the United States. This technique has been widely abandoned in the United States because of fear of cauda equina syndrome (paresthesia, motor weakness, and paralysis of the lower extremities, bladder and bowel dysfunction) that were associated with the microcatheter technique.9 However, large cumulative doses of local anesthetic agents, not the microcatheter technique, may have been responsible for the development of neurotoxicity.9 Microcatheters continue to be used in Europe with great success. The most common agent used is 0.5% bupivacaine administered in doses of 5 to 7.5 mg.10 Continuous spinal anesthesia is still performed here with microcatheters (18 to 20 G) placed through an epidural needle. This technique is particularly attractive if an epidural needle is inserted accidentally into the subarachnoid space. Rather than remove the needle and reinsert it at a different interspace, the authors recommend intrathecal injection of the local anesthetic through the epidural needle and/or insertion of an intrathecal catheter. Surgical anesthesia may then be managed with repeat injections of 0.5% bupivacaine in 0.5 mL increments.

Spinal anesthesia compared with epidural anesthesia offers the advantage of a dense sensory and motor block with a short onset time. Administration of a hypobaric local anesthetic such as plain bupivacaine 0.5% enables the patient to perceive a temperature increase in the lower extremities about 30 to 60 seconds after injection, hindering towards correct subarachnoid needle placement. If a unilateral block is preferred, a hypobaric local anesthetic solution should be used.

Complex procedures on the knee frequently require the use of an upper thigh tourniquet. Tourniquet pain develops despite adequate sensory or motor block at various times, depending on the local anesthetic used. Concepcion reported a statistically significant difference in the incidence of tourniquet pain when bupivacaine (15 mg) was compared to tetracaine (15 mg) in patients undergoing lower extremity procedures using thigh tourniquets.11 Patients given bupivacaine reported tourniquet pain 25% of the time compared to 60% for patients given tetracaine despite longer tourniquet times in the bupivacaine group. An explanation for the prolonged tourniquet

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tolerance with bupivacaine is that tetracaine offers less pro-
longed blockade of C fibers. Other maneuvers shown to
improve tourniquet tolerance time are the addition of an
opioid, the addition of epinephrine, larger volumes of local
anesthetic, and avoidance of glucose in the local anesthetic
solution. When glucose was added to bupivacaine, the
incidence of tourniquet pain at similar sensory levels was 37% 
versus 13% when the same volume of plain isobaric bupiva-
caine was used. The addition of an intrathecal opioid extends 
and outlasts the effect of even long-acting local anesthetics. 
The addition of morphine 0.25 to 0.3 mg to the local anesthetic 
extends the duration of the anesthesia and analgesia in a dose
dependent fashion.

Epidural Anesthesia

Epidural anesthesia provides both surgical anesthesia and 
effective postoperative pain relief and is the most extensively 
used regional anesthesia technique for procedures on the lower 
extremities. When employed for knee replacements, this 
technique has been shown to reduce perioperative mortality 
due to pulmonary embolism. This reduction in postoperative 
mortality from pulmonary embolism is consistent with reports 
of decreased incidence of deep venous thrombosis in patients 
receiving epidural anesthesia. Sonographically detected lower 
extremity deep venous thrombosis (DVT) is more frequent in 
patients who had received general rather than epidural aneste-
sia. Both spinal and epidural techniques improve blood flow 
to the lower limbs by inducing arterial and venodilation. 
Venous stasis is thereby reduced. Epidural anesthesia may 
**have the added benefit of generating high local anesthetic** 
plasma concentrations which have been shown to decrease 
platelet aggregation.

Earlier ambulation and discharge times may also play an 
important role in preventing deep venous thrombosis forma-
tion. Effective continuous epidural analgesia with local anes-
thesics with or without opioids allows early postoperative 
ambulation, use of continuous passive motion (CPM) ma-
chines, and active physical rehabilitation immediately follow-
ing surgery. In contrast, even high dose epidural fentanyl (5 
pg/kg) was unable to sufficiently relieve pain for passive 
mobilization following knee surgery. Of note is that effective 
epidural analgesia with low concentrated local anesthetic 
solutions such as lidocaine 0.25% does not interfere with 
normal muscle function; muscle strength improved most likely 
due to the reduction in pain, and thereby prevented some of 
the postoperative muscle atrophy.

To access the epidural space the patient is positioned in the 
sitting or lateral decubitus position. Although the effect of 
gravity is controversial, reliability of blockade of S1, which 
is necessary for knee procedures, is probably increased with 
the patient in the sitting position. Alternatively, patients who have 
a history of fainting or who are heavily premedicated should 
have their catheter inserted while in the lateral position. To 
increase involvement of the S1 segment, patients should then 
be placed in a modified reverse Trendelenburg position (Ham-
mock position) prior to injection of the local anesthetic. When 
patients were randomly allocated to one of two groups with 
supine horizontal position versus supine 30° trunk elevation 
with 30° leg elevation (hammock position), the latter position 
markedly improved the percentage of patients (60% v 13%) 
having adequate anesthesia for knee surgery.

Higher volumes of local anesthetic solutions compared to 
spinal anesthesia are necessary to ensure sensory and motor 
blockade of the knee. A combination of lidocaine 2% with 
epinephrine (5 μg/mL) and ropivacaine 0.75% or 1%, or 
 ropivacaine 2% with epinephrine (5 μg/mL) and bupivacaine 
0.5% or 0.75% in a 1:1 ratio provide both rapid onset and long 
duration of blockade.

Postoperative pain following major knee surgery can be 
effectively managed with patient controlled epidural analgesia 
(PCEA). The patient receives a basic continuous infusion and 
may additionally self-administer bolus doses. Dilute solutions 
of local anesthetic with the addition of an opioid such as 
morphine, fentanyl, or hydromorphone have been shown to 
provide effective pain relief in the absence of motor blockade. 
Very dilute bupivacaine (1132%) combined with hydromor-
phone (10 μg/mL) at a rate of 10 to 12 mL/h is used for pain 
relief in the authors' institution and enables the patients to 
undergo early postoperative rehabilitation.

**Combined Spinal/Epidural Anesthesia**

Combined spinal-epidural anesthesia (CSE) offers distinct 
advantages for surgery on the knee. First, it provides the rapid 
onset and reliable sensory and motor blockade of spinal 
anesthesia. Second, there is the option to improve an inade-
quate spinal blockade or extend the dermatomal level. Third, 
it permits repeat injections through an indwelling epidural 
catheter, and fourth the needle-through-needle technique con-
vens proper positioning of the Tuohy needle and therefore 
may improve the rate of successful catheter placement.

The technique usually involves placing an epidural needle 
into the epidural space first and then advancing a long 27-G 
spinal needle through the Tuohy needle into the subarachnoid 
space. Placing the Tuohy needle in the midline rather than 
paraspinally is preferred by the investigators because it seems

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to lead to a higher success rate of spinal needle placement. Provided the spinal needle is correctly positioned, a local anesthetic with or without the addition of an opioid is injected intrathecally. Following removal of the spinal needle the epidural catheter is inserted. In the investigators' institution, patients frequently receive intrathecal hypobaric bupivacaine 0.5% 1 to 3 mL with epinephrine (5 μg/mL) and epidural hydromorphone 0.5 to 1 mg. This combination provides long lasting intraoperative surgical anesthesia that extends into the postoperative period. Further postoperative pain relief is then achieved by the previously mentioned combination of dilute bupivacaine and hydromorphone.

Theoretically, there is the concern of accidental passage of the epidural catheter through the hole of the dural puncture site. This possibility is very small as demonstrated in cadavers by epiduroscopy where even after multiple dural punctures with 25 to 26 G spinal needles no migration of epidural catheters was seen (Table 1).

**Femoral/Sciatic Nerve Block**

Many anesthesiologists prefer spinal and/or epidural techniques over peripheral nerve blocks for lower extremity surgery. Because of the risk of permanent neurologic damage from epidural hematoma formation, neuraxial techniques are contraindicated in anticoagulated patients. Low molecular weight heparin, in particular, has elicited discussions on safety of centroneuraxis blockade following publication of a series of neuraxial hematomas, which resulted in long-term or permanent paralysis. Several incidences occurred when the first dose of low molecular weight heparin was administered within 12 hours after surgery Epidural hematomas were also described following epidural catheter removal within 10 to 12 hours after dosing low molecular weight heparin, or when subsequent dosing was not delayed at least 2 hours after epidural catheter removal (See Horlocker, “Regional Anesthesia and Analgesia in the Orthopedic Patient Receiving Thromboprophylaxis”). Because of these concerns anesthesiologists may shift away from neuraxial towards peripheral nerve blocks. Further advantages of peripheral nerve blocks are that hemodynamic changes as seen with spinal and epidural anesthesia are less likely to occur, and normal bladder and bowel function are preserved. A theoretical disadvantage of lower extremity peripheral nerve blockade is larger volumes of local anesthetic that are required. However, the risk of systemic toxicity is not proportionately increased because of the decreased uptake of local anesthetics from peripheral sites.

Four nerves innervate the knee, ie, the femoral, the lateral femoral cutaneous, the obturator, and the sciatic nerves. The first three arise from L1-L4, the sciatic nerve originates from L5-S2. The femoral nerve is blocked inferior to the inguinal ligament and immediately lateral to the femoral artery. The lateral femoral cutaneous nerve is anesthetized as it emerges from the fascia lata inferomedial to the anterior superior iliac spine. The obturator nerve is blocked as it emerges from the obturator canal (Fig 1). An alternative to these individual

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**Fig 1. Obturator nerve block technique. Reprinted with permission from Brown: Atlas of Regional Anesthesia, Philadelphia, PA, Saunders, 1992.**

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Fig 2. Laying across the forceps, the femoral (middle) and lateral femoral cutaneous (right) nerves are dyed blue following femoral intraneural injection of 40 mL of methylene blue dye. The obturator nerve (left) is not dyed. Reprinted from J Clin Anesth, 7, Ritter JW, Femoral nerve “sheath” for inguinal paravascular lumbar plexus block is not found in human cadavers, 470-473, 1995, with permission of Elsevier Science.

blocks is the 3-in-1 block which theoretically blocks the three nerves by a single injection, provided sufficient volume of local anesthetic is injected. For knee arthroscopy the 3-in-1 block provides a greater degree of muscle relaxation and a longer postoperative analgesia than the femoral nerve block alone. Electromyographic and anatomical studies, however, have shown that the obturator nerve may not be blocked even when using up to 50 mL of local anesthetic solution (Fig 2). This may not be an important factor in ACL repair or knee arthroscopy, but as the obturator nerve provides sensory innervation to the medial aspect of the thigh and knee, separate blockade of this nerve may be warranted for knee arthroplasty.

To provide complete anesthesia for the knee, a sciatic nerve block must accompany the 3-in-1 block. The sciatic nerve can be located by a variety of approaches. The classic posterior approach described by Labat (Fig 3), the anterior approach (Fig 4), or the lithotomy approach. Combined 3-in-1 sciatic nerve blocks for knee arthroscopy provides excellent intraoperative and postoperative analgesia and reduces postoperative complication rates.

For postoperative pain management following open-knee procedures, the 3-in-1 block is an excellent adjunct to general anesthesia. Two studies have documented lower pain scores with less narcotic usage in patients who received continuous 3-in-1 blocks added to a general anesthetic compared to those who received general anesthesia only.

### Intrarticular Anesthesia

Knee arthroscopy and ACL repair are frequently performed on an outpatient basis. Knee arthroscopy is performed in many centers using intraarticular local anesthetics with monitored anesthesia care. Volumes of 50 to 60 mL of a local anesthetic solution (ie, bupivacaine 0.25%) are required to ensure sufficient surgical anesthesia. Even with those high volumes, plasma levels remain 10 to 15 times below a nontoxic plasma level. This is presumably due to slow absorption through the synovia and considerable washout of the local anesthetic after the arthroscopy. Furthermore, peak serum bupivacaine concentrations can be reduced by adding epinephrine and injecting the local anesthetic solution after tourniquet inflation. A questionnaire sent to patients who had undergone arthroscopy as an outpatient procedure showed that the degree of satisfaction after local or spinal anesthesia was the same. A retrospective review examined a series of knee arthroscopic procedures that were completed using local, general, or regional anesthesia to evaluate the efficacy of these anesthetic techniques. Surgical time, complications or failures, procedures successfully performed, recovery room time, postoperative stay, and patient satisfaction were recorded. Local anesthesia with intravenous sedation compared favorably with the other techniques: surgical time was not increased, a large variety of operative procedures were successfully completed, recovery time was significantly shortened, and patient satisfaction remained high. It was concluded that this technique may offer several advantages over other types of anesthesia for knee arthroscopy, including improved cost effectiveness.

In the presence of inflammation, peripheral opioid receptors may become accessible. Systemically ineffective doses administered into the knee joint after surgery have been shown to elicit potent and long lasting postoperative analgesia. The low lipid solubility of morphine and therefore its slow uptake into the circulation were postulated to account for the high degree of analgesia. In contrast, two other studies could not confirm the existence of peripheral opioid receptors in the knee joint after arthroscopy, described, however, the analgesic advantages of intraarticular local anesthetics.

In conclusion there are several viable options of regional anesthetic techniques for knee surgery They all have in common substantial preemptive analgesic effects and may contribute to an overall reduction of patient morbidity.

#### References


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