

# Motor-Sparing Regional Anesthesia for Knee Surgery: Current Evidence on Adductor Canal, IPACK, and 4-in-1 Blocks

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## Abstract:

**Background:** Regional anesthesia techniques play an important role in perioperative pain management for knee surgery by providing effective analgesia while preserving motor function and facilitating early mobilization. The adductor canal block targets mainly the saphenous nerve and the nerve to vastus medialis, providing sensory analgesia to the anterior and medial aspects of the knee with relative preservation of quadriceps strength. However, its analgesic coverage of the posterior knee capsule may be inadequate. The infiltration between the popliteal artery and the capsule of the knee block was therefore developed to selectively anesthetize the terminal articular branches supplying the posterior capsule without significantly affecting the major motor branches of the tibial and common peroneal nerves. Combining the adductor canal block with the IPACK block can provide more comprehensive anterior and posterior knee analgesia, reduce opioid requirements, and support early ambulation. The modified 4-in-1 block is a more recent ultrasound-guided, single-injection technique designed to target the saphenous nerve, nerve to vastus medialis, posterior branch of the obturator nerve, and articular branches of the sciatic nerve. It aims to provide broad sensory blockade while preserving quadriceps motor function. This mini-review describes the relevant anatomy, indications, techniques, advantages, limitations, contraindications, and potential complications of the adductor canal, IPACK, and modified 4-in-1 blocks. These motor-sparing techniques represent valuable components of multimodal analgesia and Enhanced Recovery After Surgery protocols for total knee arthroplasty and other major knee procedures. Postoperative pain following knee surgery may delay mobilization, increase opioid consumption, impair rehabilitation, and reduce patient satisfaction. Motor-sparing ultrasound-guided regional anesthesia techniques have therefore been developed to provide effective pain relief without causing significant quadriceps weakness. Adductor canal block provides mainly anterior and medial knee analgesia, whereas the IPACK block targets posterior capsular pain. The modified 4-in-1 block was introduced as a single-injection alternative capable of covering several major sensory contributors to the knee joint while preserving motor function.

**Keywords:** Adductor canal block; IPACK block; Modified 4-in-1 block; Knee surgery; Regional anesthesia; Postoperative analgesia; Motor-sparing block; ERAS.

## Introduction:

Postoperative pain following knee surgery remains a major challenge because of the complex sensory innervation of the knee joint and the involvement of both its anterior and posterior capsules. Inadequate analgesia may delay ambulation and rehabilitation, prolong hospital stay, increase opioid requirements, and contribute to persistent postoperative pain. Although multimodal analgesia is widely used, peripheral nerve blocks have become

particularly important because they can provide targeted pain relief while limiting opioid-related adverse effects (1).

The adductor canal block (ACB) is commonly used as a motor-sparing technique that provides analgesia mainly to the medial and anteromedial aspects of the knee through blockade of the saphenous nerve and related articular branches. However, its limited coverage of the posterior capsule may result in residual posterior knee pain. The infiltration between the popliteal artery and capsule of the knee (IPACK) block was developed to target the terminal articular branches supplying the posterior capsule while preserving the major motor components of the tibial and common peroneal nerves. Therefore, combining ACB with IPACK may provide more comprehensive analgesia without producing marked motor weakness (2).

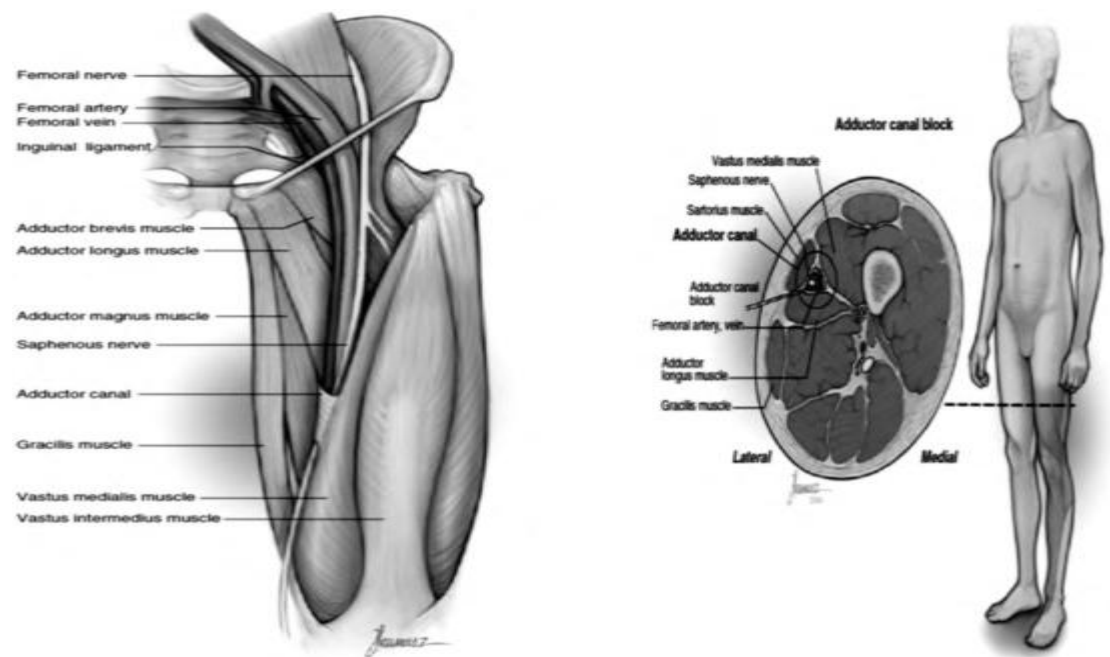
The modified 4-in-1 block has recently been introduced as a single-injection ultrasound-guided technique intended to cover multiple sensory contributors to the knee joint, including the saphenous nerve, nerve to vastus medialis, posterior obturator branches, and articular branches related to the sciatic nerve. This mini-review discusses the anatomical basis, techniques, indications, advantages, limitations, and possible complications of ACB, IPACK, and the modified 4-in-1 block in perioperative analgesia for knee surgery.

### **Adductor canal block:**

#### **Anatomy:**

The saphenous nerve, a terminal branch of the posterior division of the femoral nerve, provides sensory innervation to the medial, anteromedial, and posteromedial aspects of the lower extremity from the distal thigh to the medial malleolus. It travels along the lateral aspect of the superficial femoral artery in the proximal artery within the adductor canal (Hunter's canal). It then crosses over the superficial femoral artery anteriorly just proximal of the lower end of the Adductor Magnus muscle and runs medially alongside the superficial femoral artery until emerging from the canal with the saphenous branch of the descending genicular artery. After leaving the adductor canal, the saphenous nerve divides into the infrapatellar branch, which provides a sensory branch to the peripatellar plexus of the knee, and the sartorial branch, which perforates the superficial fascia between the gracilis and sartorius muscles and emerges to lie in the subcutaneous tissue below the knee fold. It then descends along the medial tibial border with the saphenous vein giving cutaneous branches to the medial aspect of the leg, ankle, and the forefoot (3).

The nerve of the vastus medialis is also a branch of the posterior division of the femoral nerve. It travels laterally to the superficial femoral artery within the adductor canal and sends multiple branches to the vastus medialis and supplies the anteromedial portion of the knee capsule, the adductor canal is an aponeurotic tunnel in the middle third of the thigh. It courses between the anterior-medial compartment of the thigh and is covered by strong aponeurosis, the Vasto-adductor membrane. The canal contains the superficial femoral artery, vein, saphenous nerve, nerve to the vastus medialis, and the terminal nerve endings of the posterior branch of the obturator nerve (3).



**Figure (1):** Anatomy of adductor canal (3).

#### **Procedure:**

The patient will receive unilateral spinal anesthesia.

#### **Then**

The Patient will be placed in supine position with knee slightly flexed and leg externally rotated (frog-leg position).



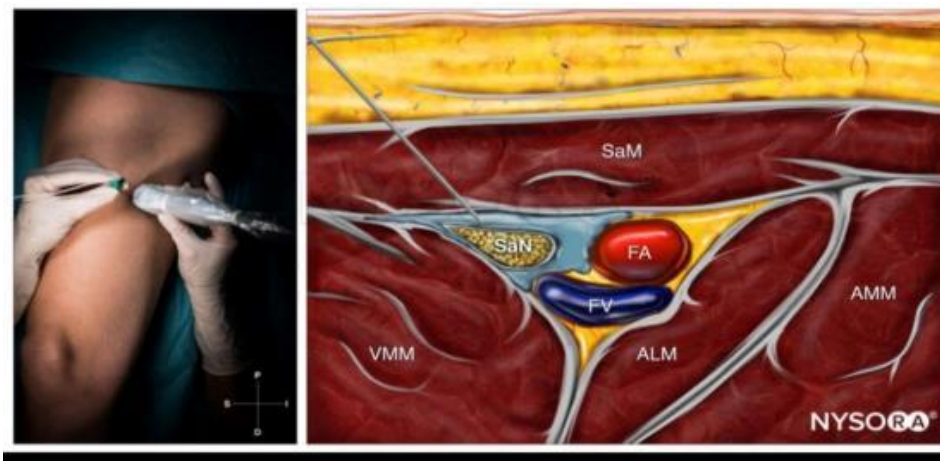
**Figure (2):** Patient positioning (3).

Cleaning the area with Povidone-iodine 10% (Betadine), stand to the side of the patient to will be blocked with the ultrasound machine on the opposite side and the screen facing, placing a high frequency ultrasound probe is done then standing on the anterior aspect of the patient's thigh, approximately mid-point between the inguinal crease and medial condyle, Identifying the femur (usually at a depth of 3-5cm although variable) and move probe medially until the trapezoid/boat shaped Sartorius' muscle is visualized.

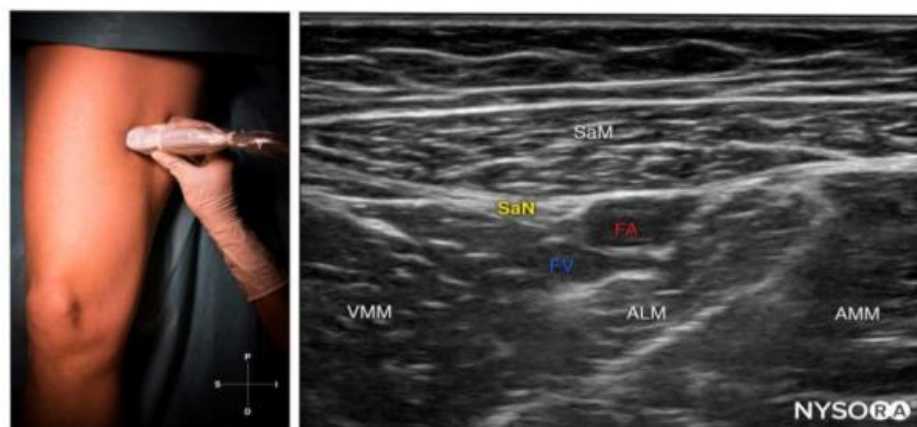
The femoral artery lies just under this muscle within the adductor canal. Considering the saphenous nerve is almost always too small to be reliably imaged and the aim of the technique is, therefore, to deposit local anesthetic under Sartorius and around the femoral artery.

Optimizing image, adjusting depth, gain and frequency settings as required, the appropriate probe position is just proximal to where the femoral artery "dives" posteriorly and the probe should be positioned perpendicular to the artery. At this point the femoral artery should start to pass deeper to form the popliteal artery, the vastus medialis muscle lies anterolateral, the adductor magnus muscle posteromedial and the sartorius muscle medial. Use an in-plane approach from lateral to medial ensuring that your needle tip can be seen at all times, advance your needle into the adductor canal. This can be achieved by traversing Sartorius or Vastus Medialis, Aspirate and inject a test dose of 1 ml of the local anesthetic solution, observe the spread of the local anesthetic to ensure your needle tip is definitely within the adductor canal.

Injection of 20 ml mixture of bupivacaine 0.5% combined with epinephrine (1:200,000) plus 8 mg dexamethasone and 500 mg magnesium sulfate (5 ml of 10% solution) and dextrose 5% will be added to the mixture (4).



**Figure (3):** Adductor canal block; reverse ultrasound anatomy with needle insertion in-plane and local anesthetic spread. FA: femoral artery; FV: femoral vein; AMM: adductor magnus muscle; ALM: adductor longus muscle; VMM: vastus medialis muscle; SaM, Sartorius muscle; SaN: saphenous nerve.



**Figure (4):** Adductor canal block; transducer position and sonoanatomy. The saphenous nerve (SaN) at the adductor canal is visualized between the sartorius muscle (SaM), vastus medialis muscle (VMM), and adductor longus muscle (ALM). FA, femoral artery; FV, femoral vein; AMM, adductor magnus muscle.

#### Indications:

- Knee arthroscopy.
- Anterior Cruciate Ligament (ACL) reconstruction.
- Lower leg, foot and ankle surgery involving areas of skin supplied by the saphenous nerve.

- Total and uni-compartmental knee replacement.

**Contraindications:**

**Absolute:**

- Patient refusal.
- Inflammation or infection at the injection site.
- Allergy to local anesthetics.

**Relative:**

- Anticoagulation or bleeding disorders.
- Pre-existing peripheral neuropathies.

**Complications:**

**These are the same as for any regional anesthetic technique:**

- Block failure.
- Bleeding/Bruising.
- Infection.
- Local anesthetic toxicity.
- Nerve injury (5).

**Limitations:**

The sensory innervations of the knee joint is not only from nerves passing through the adductor canal but also from articular filaments arising from the nerves to the vastus lateralis and intermedius, which both arise from the posterior division of the femoral nerve proximal to the adductor canal, and in fact only just distal to the inguinal ligament. Therefore, ACB may not provide post knee surgery analgesia as effective as that produced by a combined femoral and obturator block, being a compartment block, it is likely that intermittent boluses are required to block all nerves within the canal. This will necessitate either nurse administered boluses or a pump enabling relatively high bolus volumes. As the site of catheter placement is close to the knee, there is increased the risk of catheter displacement (6).

**The IPACK block** (Infiltration between the Popliteal Artery and the Capsule of the Knee) is an ultrasound-guided motor-sparing regional anesthesia technique introduced to provide analgesia for the posterior aspect of the knee after knee surgery, especially Total Knee Arthroplasty (TKA).

Its principle is to inject local anesthetic into the tissue plane between the popliteal artery and the posterior capsule of the knee, where the terminal articular branches supplying the posterior capsule travel. This selectively blocks sensory innervation while preserving the major motor branches of the tibial and common peroneal nerves.

**Why is IPACK needed?**

The Adductor Canal Block (ACB) provides excellent analgesia for the anterior and medial knee, but it inadequately covers the posterior capsule, which is a major source of pain after TKA.

Combining ACB + IPACK provides nearly complete perioperative analgesia while maintaining quadriceps strength and allowing early mobilization.

**Sensory innervation of the posterior knee:**

**The posterior capsule receives articular branches from:**

- Tibial nerve
- Common peroneal nerve
- Obturator nerve (posterior branch)
- Genicular nerves

The IPACK block targets these terminal articular branches without anesthetizing the main sciatic nerve trunk.

**Ultrasound Anatomy:**

**Important structures to identify:**

- Femoral condyles
- Popliteal artery
- Popliteal vein
- Posterior capsule of the knee
- Femur

The local anesthetic is deposited between the popliteal artery and the posterior capsule, avoiding spread around the tibial nerve.

**Technique**

- Patient position
- Supine with knee slightly flexed or
- Lateral position
- Ultrasound probe
- Curvilinear or high-frequency linear probe
- Transverse orientation at distal femur
- Needle
- 80–100 mm echogenic needle
- In-plane approach (usually lateral → medial)
- Target

**Advance the needle until its tip lies:**

Between the popliteal artery and the posterior femoral cortex/capsule.

**After careful aspiration:**

Inject local anesthetic while observing hydrodissection.

**Indications:**

- Total Knee Arthroplasty (most common)
- Revision knee replacement

- Knee ligament reconstruction
- Major knee surgery with significant posterior pain

**Advantages:**

- Excellent posterior knee analgesia
- Preserves quadriceps strength
- Minimal motor blockade
- Earlier ambulation
- Reduced opioid consumption
- Improved patient satisfaction
- Facilitates Enhanced Recovery After Surgery (ERAS) protocols

**Disadvantages:**

- Requires ultrasound expertise
- Risk of vascular puncture
- Inadequate analgesia if injection is misplaced
- Possible spread to tibial/common peroneal nerve causing transient foot weakness (uncommon)

**Complications:**

**Although uncommon:**

- Vascular puncture
- Local anesthetic systemic toxicity (LAST)
- Infection
- Hematoma
- Transient foot drop if the sciatic nerve is inadvertently affected

**4-in-1 Block:**

The 4-in-1 block is a relatively recent ultrasound-guided regional anesthesia technique developed to provide comprehensive perioperative analgesia for knee surgery by targeting the major sensory innervation of the knee joint while preserving quadriceps muscle strength. This technique was introduced as a motor-sparing alternative to more proximal nerve blocks, aiming to achieve effective postoperative pain control with early mobilization and improved functional recovery.

The rationale behind the 4-in-1 block is based on the complex sensory innervation of the knee joint. The anterior aspect of the knee receives its sensory supply primarily from branches of the femoral nerve, particularly the saphenous nerve and the nerve to vastus medialis. The medial aspect is innervated by branches of the obturator nerve, whereas the posterior capsule receives articular branches from the tibial nerve and, to a lesser extent, the common peroneal nerve.

Conventional regional anesthesia techniques often fail to anesthetize all these articular branches simultaneously, resulting in incomplete analgesia. The 4-in-1 block was therefore designed to target these nerves using a single ultrasound-guided injection.

The technique The patient will be in a supine frog-leg position (external rotation, slight abduction, and knees slightly flexed). Using a linear high-frequency probe, the medial femoral condyle was identified, sliding

proximally from the condyle, and the intersection of vastus medialis and sartorius muscles was identified. Then, proximal to the adductor hiatus, the superficial femoral artery was identified. The injection will be by moving the probe proximal to visualise the descending genicular artery, just 1 cm proximal to this branching. The needle will be inserted to reach the perivascular space in the in-plane from lateral to medial. With a repeated negative aspiration for blood, local anesthetic mixture will be injected to push the femoral artery posteriorly with every 2 mL aliquot of injection.

The principal advantage of the 4-in-1 block is its ability to provide broad sensory blockade while largely preserving quadriceps motor function. Preservation of muscle strength facilitates early ambulation, reduces the risk of falls, improves participation in physiotherapy, and enhances recovery following total knee arthroplasty and other major knee procedures. Consequently, the technique has gained increasing popularity within Enhanced Recovery After Surgery (ERAS) pathways.

Clinical studies have demonstrated that the 4-in-1 block is associated with lower postoperative pain scores, reduced opioid consumption, delayed time to first rescue analgesia, and improved patient satisfaction compared with conventional analgesic strategies.

Some comparative studies have also suggested analgesic efficacy comparable to combinations of adductor canal block and posterior knee blocks while requiring only a single injection.

Despite these advantages, the 4-in-1 block has several limitations. It is technically more demanding than a conventional adductor canal block and requires considerable expertise in ultrasound-guided regional anesthesia. Accurate identification of the adductor hiatus and surrounding vascular structures is essential to ensure appropriate spread of local anesthetic. Inadequate injectate distribution may result in incomplete blockade of the posterior articular branches and reduced analgesic efficacy. Furthermore, because this technique relies on fascial plane spread rather than direct nerve visualization, individual anatomical variation may influence block success.

Potential complications are similar to those encountered with other ultrasound-guided peripheral nerve blocks. These include vascular puncture, hematoma formation, infection, local anesthetic systemic toxicity, transient nerve injury, and block failure. Strict adherence to ultrasound guidance, frequent aspiration, incremental injection, and appropriate dose calculations substantially reduce these risks.

Overall, the 4-in-1 block represents an effective motor-sparing regional anesthesia technique that provides comprehensive perioperative analgesia for knee surgery. By simultaneously targeting the major sensory contributors to the knee joint, it combines effective pain control with preservation of quadriceps strength, making it an attractive component of multimodal analgesia and ERAS protocols.

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