Review Article

Supralinguinal fascia iliaca compartment block in pediatric-aged patients: An educational focused review

ABSTRACT

Regional anesthesia has become an integral component of postoperative analgesia and multimodal analgesia during surgery, providing opioid sparing effects and maintaining a beneficial adverse effect profile. Although neuraxial techniques were initially the primary techniques used for intraoperative and postoperative anesthesia and analgesia, many of these techniques have been replaced by selective nerve blockade. This has been facilitated by the widespread use of ultrasound-guided over conventional landmark techniques. Fascia iliaca compartment blockade (FICB) is performed by depositing a local anesthetic agent underneath the FI fascial sheath which lies on top of the iliopsoas muscle. With the landmark technique, the FICB is more commonly applied using an approach below the inguinal ligament. Advancements in the use of ultrasound have led to development of a potentially superior suprainguinal fascia iliaca (SIFI) block for hip and thigh surgery. An improved cephalad distribution of the local anesthetic solution within the fascia iliaca compartment and comparable analgesic efficacy compared to the more invasive lumbar plexus block has resulted in increased use of the SIFI block in both adults and pediatric-aged patients. The SIFI block aims to target the femoral nerve (FN), lateral femoral cutaneous nerve (LFCN), and obturator nerve (ON), thus providing analgesic coverage for hip, femur, and thigh surgery. Although the FN and LFCN are reported to be consistently blocked by the suprainguinal approach, blockade of the ON may be less reliable and requires a higher volume of the local anesthetic agent, proving this technique to be a volume-dependent block. A lower volume of local anesthetic solution may be associated with block failure, especially in the area supplied by the ON and less frequently in the distribution of the LFCN. Thus, local anesthetic concentration must be adjusted in smaller children and infants to maintain effective volume while not exceeding local anesthetic dosing limitations. The current manuscript reviews the innervation of the lower extremity including the anatomy of the fascia iliaca compartment, outlines different approaches for the fascia iliaca block, and reviews the current practice of SIFI blockade in adults and children.

Key words: Infrainguinal fascia iliaca block, lumbar plexus, regional anesthesia, suprainguinal fascia iliaca block

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Introduction

Regional anesthetic techniques provide effective intraoperative and postoperative analgesia, reduce opioid requirements, decrease the time to discharge, and minimize the exposure to general anesthetic agents in children undergoing major orthopedic procedures.[1-3] With advances in pediatric regional anesthetic techniques including the use of ultrasound to identify peripheral nerves and fascial planes, neuraxial blockade is being replaced with peripheral nerve blockade to achieve selective unilateral anesthesia and analgesia for procedures involving the lower extremity including the hip and thigh.[4,5] Advantages of the peripheral versus neuraxial approach include a less invasive trajectory, fewer contraindications, avoidance of sympathetic blockade, unilateral lower extremity motor blockade, and a decreased incidence of urinary retention.

The most frequently used peripheral nerve blockade techniques to provide analgesia following major orthopedic and other surgical procedures of the hip and thigh include femoral nerve (FN), fascia iliaca (FI), sciatic nerve, lumbar plexus, and pericapsular nerve blockade.[6] Among these techniques, the fascia iliaca compartment block (FICB) has the longest history of use, being introduced 30–40 years ago for analgesia of the lower limb.[7] Initial reports in adults and children described an approach to the FIB from below the inguinal ligament, potentially limiting its applicability for hip surgery. In recent years, a novel above the ligament approach to the FIB has been introduced.[8] Following its initial description, this suprainguinal fascia iliaca (SIFI) block has been reported to have utility for procedures involving the hip and pelvis. The SIFI block aims to provide anesthesia in the distribution of the FN, superficial lateral femoral cutaneous nerve (LFCN), and obturator nerve (ON) with a single injection in a superficial fascial plane.[9-11] Clinical studies using the SIFI block have demonstrated effective analgesia and decreased postoperative opioid consumption for hip arthroplasty and other above-the-knee orthopedic surgical procedures in adults.[11-14] The beneficial effects of SIFI block among adults have led to its use among adolescents and children. During the past decade, several studies in adults and children have demonstrated effective use of the SIFI block for hip and thigh surgery with demonstration of potentially superior analgesia when compared to the infrainguinal approach.[10,15-18] Procedure types listed in these investigations have included fixation of femoral neck and proximal femur fracture, proximal femoral osteotomy and osteoplasty, hip joint arthroscopy, and total hip arthroplasty, all of which involve sensory territory innervated by the FN, LFCN, and ON. These three nerves, while in proximity to each other in the FI compartment, are not contained within a single nerve sheath, mandating the use of a higher volume of the local anesthetic solution to ensure effective spread and coverage. Use of smaller volumes may be associated with failure of local anesthetic spread to the ON and less commonly to the LFCN. As the SIFI block requires a higher volume of local anesthetic to block all the three nerves, its utility among smaller children and infants may be limited if local anesthetic concentration is not adjusted to maintain adequate block volume while respecting maximum dose recommendations. The following educational review outlines the history of the SIFI block, describes the sensory innervation of the lower extremity pertinent to surgery of the hip and thigh, reviews the technique of fascia iliaca compartment block (FICB), and examines previous reports of the use of the SIFI block in pediatric-aged patients.

History of the suprainguinal fascia iliaca compartment block

The FICB was first described for use in the pediatric population by Dr. Bernard Dalens *et al.* in 1989.[7] It was initially a landmark-based technique, which was considered an alternative to 3-in-1 femoral block, as described by Winnie *et al.* in 1973,[19] to provide analgesia in the distribution of the lumbar plexus. The FICB using the landmark technique was proposed as a simple, low-risk procedure to provide coverage of the three main nerves of the lumbar plexus (FN, LFCN, and ON). As described by Dalens *et al.*,[7] a line is drawn from the pubic tubercle to the anterior superior iliac spine (ASIS) and the line is divided into three equal sections. Palpation of the femoral artery in the inguinal crease can be used to identify a point where the medial and middle thirds of this line meet. A needle (22 gauge, 1-2" needle) is introduced at a 60° angle directing the tip cephalad, 0.5 to 1 cm caudad (distal) to a point between the middle and lateral sections of the line drawn between the ASIS and the pubic tubercle. To avoid injury to the FN, the femoral pulse should be 1.5–2 cm medial to the intended injection point. This differentiates the FICB from the FN block as the needle is inserted immediately lateral to the pulse of the femoral artery for FN block. During the FICB, the needle is kept in the sagittal plane to avoid injury to the major vessels medially and the peritoneum posteriorly. Two pops or losses of resistance are felt when penetrating the fascia lata and then the FI. After the double loss of resistance, the local anesthetic agent is injected deep to the FI. Manual pressure is held distal to the injection site to facilitate cephalad spread.

The infrainguinal FICB reliably provides anesthesia to the areas of the lower extremity that are supplied by the FN and

LFCN. After Dalen's description of this novel landmark-based technique in 1989, Capdevila studied a cohort of 100 adult patients comparing the 3-in-1 femoral block with the FICB (landmark technique) and defining the sensory pattern of the two approaches.[20] Lumbar plexus coverage (FN, ON, and LFCN) was achieved in 38% of patients with the 3-in-1 block and 34% of patients with the FICB. The study suggested that onset of sensory blockade of the LFCN was more rapid with FICB compared to 3-in-1 block and that the FICB may be more effective in simultaneous blockade of the FN and LFCN as compared to the 3-in-1 block. In the same study, radiological examination was performed in 92 patients to evaluate the spread of the local anesthetic agent. A greater number of patients had spread of the local anesthetic agent under the iliacus muscle (IM) fascia with the FICB; however, the number of patients who had spread of the local anesthetic under both the psoas muscle (PM) fascia and IM fascia was comparable between two approaches. Eighteen of 27 patients who received an FICB and had spread of the local anesthetic under the fascia of PM and IM developed obturator nerve sensory blockade. Similarly, 19 of 35 patients who received a 3-in-1 block and had spread of the local anesthetic under the IM fascia and PM fascia developed obturator sensory blockade. Only one patient in the FICB group showed spread of the local anesthetic to the lumbar plexus compared to four in 3-in-1 block group. Given the pattern of spread of the local anesthetic agent, the authors suggested that neither technique (FICB or 3-in-1 block) would reliably block the ON.

The landmark technique of the infrainguinal FICB was subsequently reported for preoperative, intraoperative, and postoperative analgesia in patients with femoral neck fracture as well as hip and knee surgery in both adults and children.[21-24] Before the widespread use of ultrasound, the landmark technique of the infrainguinal FICB saw significant clinical use despite the potential adverse effect profile, which included block failure, hematoma formation, neuropraxia, local anesthetic toxicity, quadriceps weakness, perforation of the peritoneal cavity, and bladder puncture.[21] Despite these theoretical risks, clinical practice generally demonstrated the safety of the infrainguinal FICB. However, the spread of the local anesthetic agent tended to be unreliable and inconsistent with limited potential to achieve sensory anesthesia in all three nerves (FN, LFCN, and ON) with the infrainguinal approach. The potential for a higher incidence of adverse effects, the unreliable cephalad spread of the local anesthetic agent, and the efficacy of pain control decreased the popularity of the landmark technique, and with the advent of ultrasound in clinical practice, ultrasound-guided approaches became popular.[25,26]

As landmark-based regional anesthesia techniques transitioned to ultrasound- guided methods in the mid-2000s, new precision was established in the performance of the infrainguinal FICB. Studies comparing the landmark technique with ultrasound-guided infrainguinal FICB demonstrated that sensory anesthesia in all parts of the thigh was significantly improved using the US-guided infrainguinal approach compared to a landmark technique.[27] US-guided infrainguinal FICB was shown to be more effective in blocking the ON and FN compared to the landmark techniques.[11] Dolan *et al.*[27] compared the ultrasound-guided technique of infrainguinal FICB with the landmark technique. They reported an increase in the incidence of sensory loss in the medial aspect of the thigh from 60% to 95% and in the incidence of complete loss of sensation in the anterior, medial, and lateral aspects of the thigh from 47% to 82%, with the use of an ultrasound-guided technique. The incidence of motor blockade of the ON increased from 22% to 44% with the use of ultrasound.

Using MRI to evaluate the spread of the local anesthetic agent injected with ultrasound guidance, Swenson and colleagues noted spread of the injectate over the surface of the iliacus and psoas muscles to the level of retroperitoneum but no medial extension to the ON with either the 3-in-1 block or the FICB.[28] Although there was a reliable clinical effect (sensory and motor blockade) on the FN and the LFCN, none of the injections produced evidence of ON block at either the level of the retroperitoneum or the inguinal ligament. All patients had weakness with extension of the knee and sensory loss over the anterior, lateral, and medial thigh; however, no patient demonstrated decreased hip adductor strength (ON motor component). Given the anatomic arrangement and course of the three primary nerves of the lumbar plexus (FN, LFCN, and ON), the success of FICB for hip and thigh surgery requires proximal spread of the local anesthetic agent in the fascial plane. Given these anatomical constraints, the studies evaluating sensory/motor block and local anesthetic spread have suggested that there is limited coverage of all three nerves with either the 3-in-1 block or the infrainguinal FICB.

With that being said, a newer approach referred to as the suprainguinal approach for the FICB has been suggested as an alternative technique which may provide more reliable blockade of the three nerves, especially the LFCN and ON, due to improved cephalad spread of the LA agent. The suprainguinal approach began with a landmark-based technique first described by Stevens and colleagues.[29] The described needle insertion point for the novel block was 1 cm above the inguinal ligament instead of 0.5 cm caudal to the inguinal ligament (as described by Dalen and colleagues) at a junction of middle and outer third of the line joining the pubic tubercle and ASIS. This approach was associated with increased risk of injury to the bladder, deep circumflex iliac artery, inferior epigastric artery, external iliac artery, spermatic cord, and hernia contents. Given these concerns, Hebbard and colleagues developed a novel approach to the SIFI block using ultrasound guidance in 2011.[30] Hebbard's description involved needle insertion caudad to the inguinal ligament and needle advancement to beneath the suprainguinal ligament to the SIFI with real-time ultrasound guidance. Using this technique in six cadavers, injection of dye (total volume 20 mL) was used to identify the distribution of the injectate within the iliaca fossa. The FN was stained by the dye in all 12 injections. The LFCN was stained bilaterally in five cadavers, but the nerve was absent on both sides in the sixth cadaver. The ilioinguinal nerve passed into the iliac fossa over the iliacus muscle in eight of the hemipelvi and was stained in seven. There was no evaluation of spread to the ON.

More recently, a modification to the ultrasound-guided SIFI block was introduced by Desmet and colleagues, wherein the needle insertion point is cephalad to the inguinal ligament.[11] Utilizing this technique in a cadaveric study, Kantakam and colleagues demonstrated that the minimum effective volume of dye required to stain the FN, LFCN, and ON in adults with an ultrasound-guided SIFI block in 90% of cases (MEV90) was 62.55 mL.[31] Most recently, another cadaveric study compared the consistency of the suprainguinal versus infrainguinal approach in reaching the FN, LFCN, and ON using 40 mL of injectate.[32] The authors determined that while the FN and LFCN were more consistently covered by the suprainguinal approach, neither technique reliably reached the ON. These findings were noted despite more cephalad spread of the injectate within the FI compartment with the suprainguinal approach.

Anatomy of the fascia iliaca compartment and sensory innervation of the hip and thigh region

The FI is a fascial layer covering the IM and the PM in the thigh. The PM is composed of a deep and superficial component with the deep component originating from the transverse process of the L1-L5 vertebrae, while the superficial component originates from the lateral surfaces of the bodies of T12 and L1-4 and the adjacent intervertebral discs. The IM originates from the iliac fossa and the iliac crest and joins the PM with both inserting into the lesser trochanter of the femur. The IM, PM, and FI form the boarders of the FI compartment that extends from the lumbar vertebrae to the lesser trochanter. The FI compartment is a potential space lying between the FI superiorly/anteriorly and the iliacus and psoas muscles posteriorly. Superiorly and laterally, the FI is attached to the inner margin of the iliac crest. Inferiorly and laterally, it extends to the thigh and unites with the femoral sheath. Medially, it attaches to the periosteum of the ileum and the iliopubic eminence. The FI compartment lies posterior (deep) to the iliac/femoral vessels.[8,21]

The three primary nerves of the lumbar plexus (FN, LFCN, and ON), which provide innervation to the upper half of the lower extremity and the hip, course through this space.[7] These three nerves are the terminal branches of the lumbar plexus, which is formed by the ventral rami of the L1-L4 spinal nerves with a small contribution from T12.[21] The FN and LFCN are formed from the dorsal divisions of the L2-L4 and L2-L3 nerve roots, respectively. The FN forms within the PM and exits from the medial to lateral direction deep to the FI. The FN courses in a caudad direction, behind the inguinal ligament, anterior to the iliopsoas muscle, and lateral to the femoral artery and femoral vein. The LFCN of the thigh also forms within the PM and exits it laterally, deep to the FI. It then dives under the inguinal ligament at the level of the anterior superior iliac spine (ASIS), continuing anterior to the sartorius muscle. The obturator nerve (ON) is formed from the ventral divisions of the L2-L4 nerve roots. It exits the PM medially and continues outside the FI compartment toward the obturator canal leaving the pelvis.

The FN, LFCN, and ON briefly travel together, sharing a compartment beneath the fascia iliaca. However, their paths diverge as they approach the inguinal ligament. The FN continues in the fascial plane and gives off branches to the iliacus and acetabulum before reaching the inguinal ligament. The LFCN consistently exists in the same fascial plane as the FN just proximal to the inguinal ligament. At or below the level of the inguinal ligament, the LFCN has a variable course. Its branches may travel superficially to, through, or deep to the inguinal ligament. The ON divides into anterior and posterior divisions in this plane. The anterior branch descends to innervate the superficial adductors, sensory innervation of hip joint, and medial aspect of the distal thigh. The posterior branch provides motor innervation to deep adductors and sensory innervation to posterior knee joint. The accessory ON, when present, innervates the adductor longus muscle.[33]

Dermatomal innervation of the hip region is mainly through the branches of the LFCN, FN, and sciatic nerves [Figure 1]. The FN, LFCN, and sciatic nerve provide cutaneous sensation to the anterior, lateral, and posterior aspects of the hip and thigh, respectively. The ON is classically described as providing sensation coverage to the medial compartment

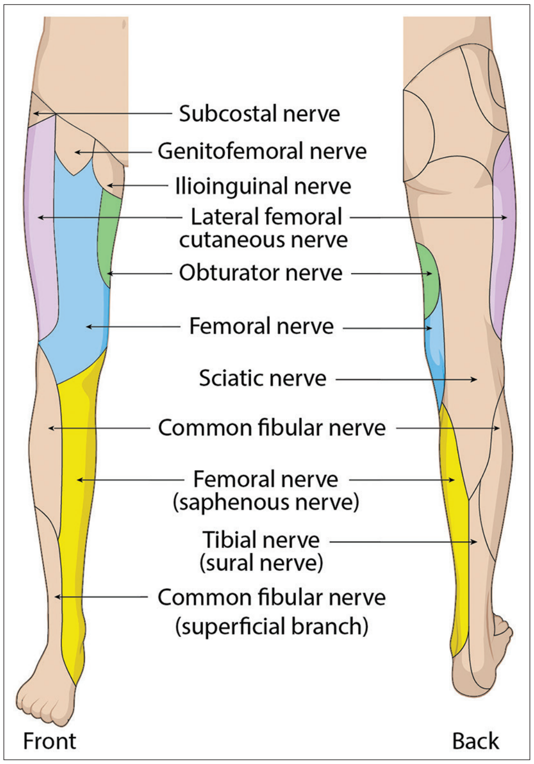

Figure 1: Diagram showing the cutaneous innervation of the hip and thigh and cutaneous coverage of the femoral and saphenous (blue and yellow), obturator (green), and lateral femoral cutaneous nerves (purple)

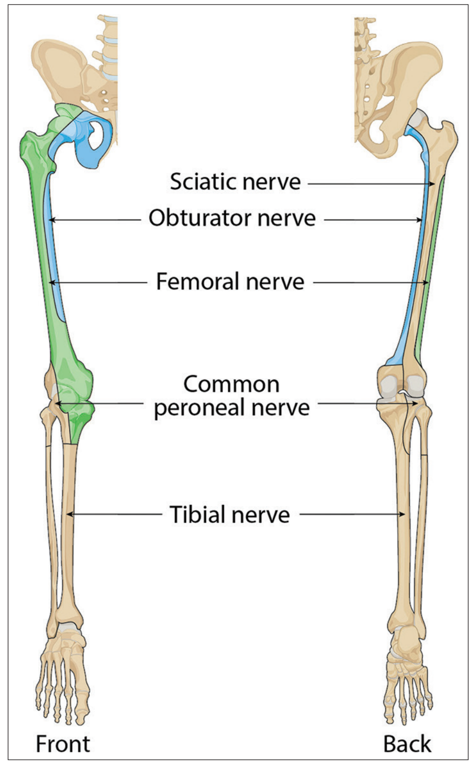

Figure 2: Diagram showing the innervation of the osseous structures of the hip and thigh by the obturator (blue) and femoral (green) nerves. The distribution of other nerves including the sciatic nerve and its branches (posterior tibial and common fibular nerve or common peroneal nerve) are shown but not highlighted in color as these distributions are not covered by the SIFI block

of the thigh; however, this has been questioned by Bouaziz and colleagues in a study that evaluated the cutaneous distribution of the ON using selective blockade.[34] When the ON is not involved in cutaneous sensation, the FN appears to be the source of innervation to the skin of the medial thigh.

The sensory innervation of the hip joint is multifaceted, with articular branches originating from two different sources, the lumbar plexus and sacral plexus. The lumbar plexus provides sensory function to the anterolateral and anteromedial aspects of the hip capsule, whereas the posterior capsule has afferent branches stemming from the sacral plexus. The articular branches of the lumbar plexus consist of the FN, ON, and accessory ON. The sacral plexus supplies the posterior capsule with sensory branches of the sciatic nerve coursing to the quadratus femoris/inferior gemellus, the superior gluteal nerve, and/or directly from the sciatic nerve. However, the nociceptors of the hip capsule are primarily located in the distribution of the lumbar plexus.[35]

More specifically, the ligamentum teres is supplied by posterior branches of the obturator nerve. Acetabular labrum innervation comes from a branch of the sacral plexus and ON. The femur also receives its nerve supply from different group of nerves. Proximally, the nerve supply for the periosteum of femur is derived from the nerves that supply the hip joint (FN and ON), whereas the distal periosteum is supplied by the nerves that innervate the knee, which includes femoral, obturator, tibial, and common fibular nerves [Figure 2].[36]

Given the anatomic arrangement of the FN, LFCN, and ON, a single injection of a local anesthetic agent between the PM and FI near the inguinal ligament (the FI compartment) can theoretically block all the three nerves concomitantly. The FICB (both infra- and suprainguinal approaches) was developed as a promising regional anesthesia technique to provide analgesia to the hip and thigh.

Technique for the suprainguinal fascia iliaca compartment block

Both the infrainguinal and suprainguinal approaches to the FICB are performed with the patient in the supine position. A high-frequency linear ultrasound probe (6–14 MHz) is used for scanning. The ultrasound-guided infrainguinal FICB block is performed by obtaining an ultrasound image just inferior to the inguinal ligament in the transverse orientation focusing on the femoral artery, femoral nerve, and iliac and sartorius muscles. After proper skin preparation, using a sterile technique, the needle is introduced in-plane with the ultrasound beam, advancing from the lateral to the medial direction. The needle tip pierces the fascia lata and fascia iliaca at the junction of the iliac and sartorius muscles. Correct needle positioning is demonstrated by free lateral and medial spread of the local anesthetic solution immediately above the iliacus and sartorius muscles.

For the SIFI block, as initially described by Hebbard and colleagues, the patient lies flat on bed with the hip extended. The ASIS is palpated and probe is placed over the inguinal ligament, close to ASIS in the parasagittal plane (craniocaudal orientation), so that the AIIS may be visualized. The periosteum of the ileum is identified as a thick hyperechoic line deep to the darker appearing IM and overlying FI. The DCIA should be identified superficial to the fascia iliaca 1–2 cm superior to the inguinal ligament. This forms the landmark for needle placement. The needle is inserted parallel to the probe with the in-plane technique 2–3 cm inferior to the inguinal ligament and advanced through the FI at the level of inguinal ligament. Injection of a local anesthetic resulting in hydrodissection beneath the FI and DCIA and above the IM confirms correct needle location.[30]

A modification of this method was described by Desmet and colleagues in 2017. The transducer is placed medial and inferior to ASIS in a sagittal oblique orientation, perpendicular to the inguinal ligament at the intersection of the lateral and middle thirds of the line connecting the ASIS and the pubic tubercle [Figure 3]. The transducer is then slid slightly caudally and medially along the inguinal ligament until the anterior inferior iliac spine (AIIS) is visualized as a hyperechoic outline deep to the iliacus muscle [Figure 4]. The sartorius muscle is seen laterally and the internal oblique muscle medially, superficial to the FI forming a bowtie or hourglass image. The knot of the bow tie is formed by the confluence of fascia covering the sartorius and internal oblique muscles. The deep circumflex iliac artery can be identified between the abdominal muscle and the FI. The block needle is then introduced 1–2 cm superior to the inguinal ligament in-plane with the ultrasound probe and advanced to just beneath the FI. Injection of a local anesthetic results in hydrodissection of the IM from the FI via hydrodissection. The needle is further advanced in the cranial and slightly dorsal direction within the hydrodissected plane to complete the injection of the local anesthetic. Superficial movement of DCIA upon injection serves as a marker of successful block.[11]

Both the techniques of SIFI block have been studied in the pediatric population. Eastburn and colleagues used the technique comparable to Desmet *et al.*, and Quan and colleagues performed the technique described by Hebbard *et al*.[10,11,18,30] These described techniques can be used for both adults and children because of the predominant anatomical resemblance of the fascia iliaca compartment in both groups. The anatomical differences between the fascia iliaca compartments in children compared to adults include a more superficial location, smaller surrounding structures, and closer proximity to critical structures. In particular, the DCIA may be difficult to visualize in young children. Special caution must be made to avoid intraperitoneal puncture.

The SIFI block requires the LA agent to spread in a large potential space, thus necessitating a high volume for coverage of the intended nerves. Although one recent

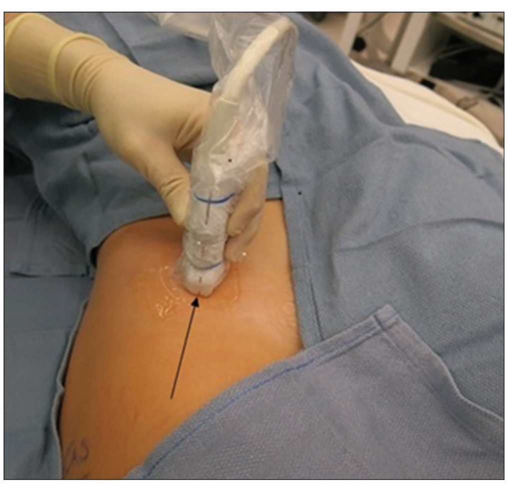

Figure 3: Photograph showing placement of the ultrasound probe for suprainguinal fascia iliaca block. The arrow indicates the insertion site and direction of needle

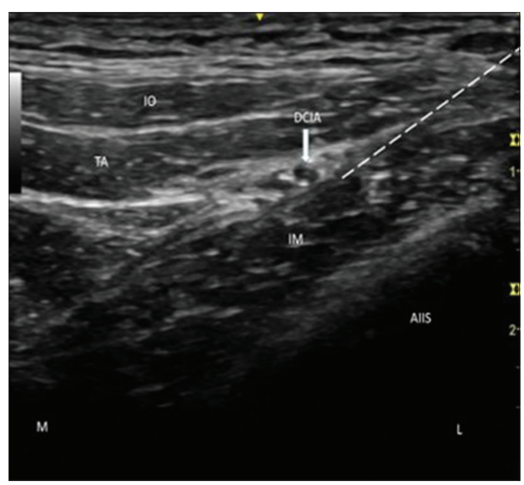

Figure 4: Ultrasound image of a suprainguinal fascia iliaca block. The dotted white line shows the trajectory of the needle and the site of local anesthetic deposition. AIIS: Anterior inferior iliac spine; DCIA: Deep circumflex iliac artery; IM: Iliacus muscle; IO: Internal oblique muscle; TA: Transversus abdominis muscle. L: Lateral side, M: Medial side

cadaveric study in adults demonstrated that a volume of 40 mL of LA is required for the SIFI block to cover all three nerves, and another indicated MEV90 of over 60 mL, similar data are not available for pediatric patients.[31,32] Currently, well-defined local anesthetic dosing guidelines do not exist for SIFI block in the pediatric population. The majority of studies in the pediatric population report use of local anesthetic volumes between 0.4 and 0.6 mL/kg.[10,15-17] Dosing strategies to maximize the volume of the LA with an effective concentration must always remain within safe dosing recommendations. The practice in our institution is to use 0.2–0.5% ropivacaine with 1:200,000 epinephrine and dexamethasone (0.2 mg/mL), not to exceed the maximum dose of ropivacaine (3 mg/kg) for the single-shot SIFI block.

A few reports exist on the use of continuous infusions of local anesthetics for SIFI block in either the adult or pediatric population.[37,38] A matched historical cohort study in adults suggested that ultrasound-guided suprainguinal fascia iliaca catheterization is safe in patients with hip fracture as the authors detected no serious complications and no difference in 30-day mortality and pressure ulcer rate when compared to patients receiving single-shot fascia iliaca block. Patients received 40 ml of 0.25% levobupivacaine as a bolus dose before starting an infusion of levobupivacaine 0.125% at 8 ml/hr. The bolus and infusion rate was reduced for patients weighing less than 50 kg. The infusion was continued for 24 hours postoperatively.

Our group previously described the use of continuous SIFI local anesthetic infusions for postoperative analgesia in 26 patients with a median age of 15 years (IQR 12, 17) undergoing femoral limb lengthening surgery.[39] A bolus dose of 0.2% ropivacaine was administered after the surgeon performed a postoperative neurologic exam in the postanesthesia care unit, followed by an infusion of 0.1% ropivacaine at 0.1 ml/kg/h. The lower local anesthetic concentration was used to minimize motor block and facilitate early postoperative physical therapy. The infusions were typically continued after hospital discharge with catheter removal on postoperative day 5.

Suprainguinal fascia iliaca compartment block in adults

To date, the adult literature regarding the FICB (both suprainguinal and infrainguinal) significantly outweighs the pediatric literature. The nerve blockade has been cited being applied to various procedures for postoperative analgesia following surgery of the hip, femur, and knee, generally as an alternative to neuraxial anesthesia or lumbar plexus blockade [Table 1].

Given the decreased invasiveness of the procedure compared to neuraxial and lumbar plexus block, the FICB has been suggested to have an improved safety profile.[40]

Additionally, the SIFI block is performed in the supine position, which may be technically easier and take less time, especially when lateral positioning is problematic or challenging due to patient habitus. A systematic review of the FICB for lower limb surgery in adults reported a more favorable adverse effect profile with improved ease of performance compared to neuraxial techniques (epidural

Table 1: Suggested nerve blockade based on the types of lower limb surgery involving the hip and thigh

	Pediatric procedures	Adult procedures
Femoral nerve	Patellar injuries Knee arthroscopic procedures Anterior thigh procedures Quadriceps muscle tear and tendon rupture repairs Quadriceps muscle biopsy	Patellar injuries Knee arthroscopy Knee arthroplasty Anterior thigh procedures Quadriceps muscle tear and tendon repairs Quadriceps muscle biopsy Long saphenous vein stripping
Femoral nerve and Lateral femoral cutaneous nerve	Hip arthroscopy Split skin graft from lateral aspect of thigh Quadriceps muscle biopsy from vastus lateralis Hip fractures	Split skin graft from lateral aspect of thigh Quadriceps muscle biopsy for vastus lateralis Skin incision for total hip arthroplasty Provide comfort for thigh tourniquet usage in awake distal femur, knee surgery and leg surgery Hip fractures
Femoral nerve, Obturator nerve	Knee surgery Adductor tendon release Gracilis tendon harvesting for ACL reconstruction.	Knee surgery and total knee replacement Gracilis tendon harvesting for ACL reconstruction Chronic hip pain after hip trauma and surgery
Femoral nerve, Lateral femoral cutaneous nerve and obturator nerve	Fracture neck of femur and proximal femoral fracture Proximal femoral osteotomy and osteoplasty Hip joint osteoplasty Hip arthroscopy Acetabular reconstruction	Fracture neck of femur and proximal femoral fracture Proximal femoral osteotomy and osteoplasty Acetabular reconstruction

or subarachnoid blockade).[40] One of the purported primary benefits of the FICB is improved analgesia with better pain scores and decreased requirements for systemic opioids following surgery in the hip region.[41] In a prospective, double-blinded randomized controlled trial in 88 adults undergoing hip arthroplasty, there was reduced morphine use in patients who received an SIFI block compared to no block (mean morphine consumption of 10.25 mg vs 19.0 mg in the first 24-hour postoperative period).[11] Similarly, in a retrospective evaluation of 67 adults, Azizoğlu *et al*.[14] noted that 56% of the patients who received an SIFI block did not require morphine administration in the first 24-hour postoperative period. Additionally, the VAS (Visual Analog Scale) score for pain was significantly lower in the block group compared to the PCA group.

The potential superiority of the suprainguinal versus the infrainguinal approach to the fascia iliaca compartment has been demonstrated by several differently designed studies. In a double-blinded, randomized trial in 10 healthy adult volunteers, suprainguinal and infrainguinal FICBs were performed on the right and left sides, respectively, in the same volunteer.[42] The suprainguinal FICB produced a more complete sensory block of the medial, anterior, and lateral regions of the thigh compared to the infrainguinal approach. MR imaging also demonstrated the spread of the LA agent to the vicinity of the ON in 8 of 10 in the suprainguinal group compared to 1 of 10 in the infrainguinal group.

When evaluating postoperative opioid requirements and pain scores, clinical trials have also demonstrated the potential superiority of the suprainguinal approach. In a prospective, randomized trial in 32 adults undergoing above the knee lower limb surgery, the suprainguinal approach resulted in lower tramadol requirements, lower pain scores, and increased patient satisfaction.[13] Similarly, when evaluating postoperative morphine requirements in a prospective, randomized trial of 40 adult patients undergoing total hip arthroplasty, patients who received an SIFI block required significantly less morphine in first 24 hours after surgery when compared to the infrainguinal approach.[12]

Zheng and colleagues found that while using the SIFI block provided effective analgesia for hip surgery, MR imaging demonstrated spread of the local anesthetic agent (30 mL of 0.3% ropivacaine) to the ON in only 12 of 28 patients.[43] Given the variable cutaneous coverage of the ON, an EMG-based study was conducted evaluating the effect of the SIFI block compared to the infrainguinal approach on hip adductor strength. The authors of this randomized controlled trial reported significant decreases in mean amplitude of compound muscle action potentials with the suprainguinal versus infrainguinal group.[44] While the SIFI block remained imperfect at covering the ON, the technique appeared to be an improvement over its predecessor, the infrainguinal approach. Data to support the hypothesis that the volume of the injectate may be the primary factor in determining SIFI block coverage of the FN, LFCN, and ON are provided by a recent cadaveric study.[45]

Not all the clinical trials have demonstrated the efficacy of the SIFI block in providing analgesia after lower extremity orthopedic surgery. Two prospective randomized controlled trials by Huang *et al*.[46] and Behrends *et al*.[47] concluded that the SIFI block did not improve postoperative pain control and more often resulted in quadriceps weakness in adults following arthroscopic hip surgery. The inadequate pain control and motor weakness due to SIFI block in these studies could potentially be explained by the complex nerve supply of the hip with successful blockade of the FN and failure to capture either the LFCN or ON. Alternatively, arthroscopic hip surgery may not provide sufficient postsurgical stimulus to elucidate differences in analgesia between the SIFI block and local infiltration/pericapsular infiltration. Further supporting this latter possibility is a prospective randomized study demonstrating equivalent postoperative analgesia after hip arthroscopy using lumbar plexus block or pericapsular injection.[48] The mixed results in adults combined with the potential anatomical differences in children highlight the need for specific investigations of the efficacy and safety of the SIFI block in the pediatric population.

Suprainguinal fascia iliaca compartment block in pediatric-aged patients

A systematic search of PubMed®, Scopus, and Google Scholar was conducted using the terms: suprainguinal fascia iliaca block, ultrasound-guided suprainguinal fascia iliaca block, suprainguinal fascia iliaca compartment block, fascia iliaca block, and pediatric patients. The abstracts from the publications were reviewed, and those pertaining to the technique's use in pediatric-aged patients were identified. Additionally, the reference lists of these publications were reviewed to ensure that all the applicable manuscripts had been identified.

Studies of the SIFI block in the pediatric population are limited in number. Our systematic search of published literature revealed only six publications related to the SIFI block in children [Table 2].[10,15-18,39] Of these six reports, one was a case series, three were retrospective investigations, and two were prospective randomized studies. These six reports

Table 2: Studies related to suprainguinal fascia iliaca blockade in the pediatric population

Authors and reference	Study type and cohort	Inclusion criteria	Intervention	Results and main conclusions
Miller BR.[16]	Case series of 3 patients (8,13, 14 years of age).	Orthopedic procedures of the hip, femur, and thigh.	Supra-inguinal FICB with 0.2% ropivacaine (20-40 mL).	Analgesia in lateral, anterior, and medial aspects of thigh. Acceptable pain scores and minimal postoperative opioid requirements.
Eastburn E *et al*.[10]	Retrospective study of 17 patients, 13-17 years of age.	Hip arthroscopy.	Supra-inguinal FICB with 0.2% ropivacaine (0.33-0.6 mL/kg).	Sensory changes in anterior and lateral thigh in 16/17 patients. Average ME consumption in OR, PACU, postoperative 1-12 h and 12-24 hours were 0.18 mg/kg, 0.06 mg/kg, 0.04 mg/kg, and 0.11 mg/kg. Pain score in PACU: mild: 9/17, moderate: 7/17, severe 1/17. Post-operative pain scores in 12 admitted patients: mild 9/12, moderate 3/12, severe 0/12.
Alrayashi W *et al*.[17]	Retrospective study of 716 patients.	Hip arthroscopy, in all age groups.	Supra-inguinal FICB block (275 patients) with 20 mL of 0.2% ropivacaine.	Pain scores: low (24% vs 18%), moderate (40% vs 46%), high (36% vs 36%) in block versus nonblock groups. Decreased opioid consumption in block group (0.28 vs 0.35 mg/kg ME). Decreased emesis (0.7% vs 4.3%) and shorter PACU stay (93 vs 108 minutes) in block group.
DeLong L *et al*.[15]	RCT, 15 patients, 7-16 years of age.	Orthopedic procedures of hip, upper thigh, or femur.	LPB (n=7) vs. SIFI (n=8). 0.5% ropivacaine (0.6 mL/kg) with 0.2 mg/mL dexamethasone and 1:200,000 epinephrine.	Similar pain scores in PACU, but decreased during postoperative period (median of 4 vs. 2). Similar opioid requirements. SIFI as effective or better than LPB in providing analgesia for hip, femur and upper thigh surgery in children and adolescent. Decreased time to place block.
Quan J *et al*.[18]	RCT, 60 patients, 6-14 years of age.	Hip surgery for developmental hip dysplasia.	Supra-inguinal FICB with sub-gluteal sciatic nerve block vs. PCB with sub-gluteal sciatic nerve block. Ropivacaine (0.25%) total volume <35 mL.	PCB patients had lower pain scores and decreased requirement for opioids. Fewer patients received sufentanil (13.8% vs 63.8%) and had less opioid use by patient-controlled analgesia. PCB provided better postoperative pain control than FICB for developmental hip dysplasia surgery.
Arce Villalobos M *et al*.[39]	Retrospective study including 26 patients with intervention	Femoral limb lengthening surgery between 10 to 40 years of age.	Suprainguinal FICB catheter with postoperative bolus of 0.2% ropivacaine followed by infusion of 0.1% ropivacaine at 0.1 ml/kg/hr	Patients with a suprainguinal FICB catheter had reduced postoperative opioid consumption and decreased hospital length of stay compared to patients with no regional anesthesia. (0.4 versus 2.1 mg/kg ME and 32 hours versus 53 hours, respectively). Pain scores were similar between the two cohorts.

FICB=Fascia iliaca compartment block (SIFI block); ASA=American Society of Anesthesiologist; RCT=randomized controlled trial; OR=operating room; PACU=postanesthesia care unit; ME=morphine equivalents; LPB=lumbar plexus block; PCB=psoas compartment block

have described the use of the SIFI block in approximately 326 pediatric-aged patients, the majority of whom were in the adolescent age group. The first description of the SIFI block in children was a case series published in 2011 that included three patients, who were 8, 13, and 14 years of age and who underwent surgical procedures involving the hip, femur, and thigh. Local anesthetic dosing included 10, 40, and 40 mL of 0.2% ropivacaine. The authors reported that the patients had low pain scores with minimal opioid requirements during the perioperative period. Physical examination revealed effective sensory coverage of the distribution of the FN, LFCN, and ON and the inability to move the leg with motor blockade of the hip adductors and quadriceps muscle.[16]

Subsequently, the SIFI block has been evaluated in five other studies in children and adolescents, including three retrospective studies and two prospective studies for patients undergoing hip and femur surgery. The three retrospective studies compared the SIFI block to patients not receiving a regional anesthetic technique.[10,17,39] In the two studies that examined single-shot SIFI block, the largest of which included a SIFI block in 275 patients, the SIFI block resulted in decreased opioid requirements and improved outcomes (decreased incidence of postoperative emesis, shorter PACU stay in the study of Alrayashi *et al*., and decreased pain scores in the study of Eastburn *et al*.)[10,17]

The third retrospective study conducted by Arce Villalobos and colleagues was a matched cohort investigation of continuous SIFI local anesthetic infusion compared to no regional anesthesia for postoperative analgesia following femoral limb lengthening procedures.[39] A total of 26 patients with a median age of 15 years (IQR 12, 17) received a continuous SIFI local anesthetic infusion compared to 11 matched patients without regional anesthesia. Median opioid consumption in the first postoperative 48 hours and hospital length of stay were significantly reduced in the regional anesthesia group compared to the no regional anesthesia group

(0.4 vs 2.1 mg/kg ME and 32 hours vs 53 hours, respectively). Pain scores were similar between the two cohorts.

The two prospective studies compared the SIFI block to other regional techniques including a lumbar plexus block (LPB) or a psoas compartment block (PCB), resulting in somewhat different conclusions.[15,18] In the prospective study of DeLong *et al*. that included 15 adolescents, eight in the SIFI group and seven in the LPB group, the authors demonstrated that the SIFI block was at least as effective as the LPB with modestly improved pain scores (median score of 2 versus 4 on postoperative day 1 and similar opioid requirements).[15] Additionally, the time to perform the SIFI block was decreased compared to LPB and the authors noted the SIFI block was easier to perform.

Different outcomes were reported by Quan and colleagues in their prospective, randomized trial comparing a SIFI block to a psoas compartment block (PCB) in 60 pediatric aged patients ranging from 6 to 14 years, presenting for surgery for developmental dysplasia of the hip.[18] To provide better analgesia to the posterior dermatomes involved in the surgery, the investigators combined the two blocks with a subgluteal sciatic nerve block. Patients who received a PCB had lower intraoperative and PACU requirements for sufentanil and decreased postoperative opioid needs using patient-controlled analgesia (PCA). The patients who received an SIFI block required an average of 5 PCA demands in first 24 hours compared to 2 in the PCB group.

The small number and heterogeneity of studies examining SIFI block in the pediatric population limit conclusions regarding the efficacy of the technique in children. Furthermore, each of the reviewed studies had specific limitations or qualifications that may have impacted the conclusions. The retrospective study by Eastburn and colleagues demonstrated that the SIFI block results in sensory changes in the distribution of the FN and LFCN but was unable to show its efficacy in the distribution of the ON.[10] Alrayashi and colleagues' investigation of children undergoing hip arthroscopy revealed comparable pain scores regardless of whether they had received a nerve block or not.[17] A limitation of the prospective study by DeLong and colleagues was the small number of subjects (the study was interrupted by COVID-19).[15] The initial sample size to power the analysis was determined to be 70, but the study was ultimately reported as a case series as recruitment ceased at 17 patients. Moreover, this study did not specify the types of hip or femur surgery where the two regional anesthetic techniques were applied. The one randomized controlled trial in the pediatric population conducted by Quan and colleagues concluded that the SIFI block is inferior to PSB for postoperative analgesia after surgery for hip dysplasia.[18]

Quan and colleagues described using the SIFI block technique by Hebbard *et al*.,[30] which involves entering the fascia iliaca compartment underneath the inguinal ligament, unlike the modified technique described by Desmet *et al*.[11] and utilized in the study by DeLong and colleagues.[15,18] The modified technique may confer a more proximal spread of local anesthetics as the point of injection is superior to the inguinal ligament, possibly increasing block effectiveness. However, given the heterogeneity of study designs and the limited number of investigations, no definitive conclusions can be made about which of these suprainguinal approaches provides superior analgesia.

Finally, the study by Arce Villalobos and colleagues is limited by the retrospective design which did not primarily aim to evaluate the effectiveness of continuous SIFI blockade.[39] In this study, the SIFI block was one of three types of regional anesthetics which were compared to no regional anesthesia for postoperative pain management after either femoral osteoplasty or tibial-fibular osteoplasty.

Current evidence in the pediatric population suggests that the SIFI block provides at least partial sensory coverage of the hip and thigh and has the potential to be an effective regional anesthetic technique for postoperative analgesia after surgery of the hip, femur, and lateral thigh. However, the aggregate data do not support the superiority of the SIFI block over other regional anesthetic techniques. Of specific interest is the unanswered question of whether the SIFI block in children similarly increases the rate of capture of the ON when compared to the infrainguinal technique, as has been reported in adults. Despite this, certain advantages of the SIFI block have been proposed in the pediatric literature, including the speed and simplicity of the block and avoidance of the usual adverse effect profile associated with neuraxial blockade. Opposed to these potential advantages is the proximity of the block location to the site of a hip surgery. If a continuous SIFI block technique is indicated, the catheter dressing may interfere with the surgical field or be directly beneath adhesive drapes, increasing the risk of catheter dislodgement.

Summary

The FICB has seen significant clinical use over the past several decades for surgical procedures involving the hip, femur, and thigh. The suprainguinal approach compared to the infrainguinal approach has aimed to provide improved analgesia by increasing the frequency of concomitant blockade of the three primary nerves of the lumbar plexus, the FN, LFCN, and ON. Current evidence supports that the suprainguinal approach is a volume-dependent regional anesthetic that mainly targets the FN and LFCN with variable effects on the ON. The predominance of evidence supports that the SIFI block does not reliably block the ON, indicating that this regional anesthetic technique may have limited utility when the primary surgical manipulation is in the territory of this nerve. In the adult population, the SIFI block may be applied to surgery for proximal femoral fractures, neck of femur fracture, proximal femoral osteotomy and osteoplasty, hip joint arthroscopy and hip joint osteoplasty, and acetabular reconstruction, although data supporting use in hip arthroscopy are mixed.

To date, there are only a limited number of reports of the SIFI block in the pediatric literature, with the most common listed surgeries being hip arthroscopy or surgery for developmental dysplasia of the hip. These studies are limited by their retrospective design, a small number of patients, or negative study outcomes and do not provide strong evidence to support the superiority of the SIFI block over alternative regional anesthetic techniques. Despite this, purported benefits of SIFI block in children include the simplicity of the block and shorter time to perform. In general, clinical studies in both adults and children have demonstrated a relatively low complication rate.

The SIFI block is an evolution of the infrainguinal approach made possible by the advent of high-resolution ultrasonography at the bedside and increased knowledge of fascial plane anatomy. Investigations involving sensory testing and MRI studies examining local anesthetic spread indicate that the suprainguinal approach may improve cephalad spread of the local anesthetic agent within the FI compartment, leading to more widespread blockade of the nerves of the lumbar plexus compared with the infrainguinal approach. Nonrandomized investigations using the SIFI block in the pediatric population suggest that it may be a promising alternative to more invasive regional anesthesia techniques for hip and thigh surgery. However, given the paucity of data with only two prospective, randomized studies, the true efficacy of the SIFI block when compared to other regional anesthetic techniques for hip and femur surgery requires further investigation.

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Conflicts of interest
There are no conflicts of interest.

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