Review Article

Regional anesthesia for hip surgery: A review of current approaches and their application to clinical practice

ABSTRACT

Hip surgery is extremely common and ranges from surgery for hip fracture to elective procedures in younger adults. Pain can mark the postoperative period and compromise functional recovery. Nevertheless, major comorbidities may occur in the perioperative period, especially in elderly fragile patients. The approach to patients undergoing hip surgery has significantly evolved, focusing on multimodal strategies to optimize pain control while minimizing side effects, prompting patients' recovery. The seek for motor-sparing, analgesic techniques with a better risk benefit profile has promoted the application of new peripheral nerve blocks, with special attention paid to the newest fascial plane blocks. However, significant interest is addressed toward other outcomes (such major comorbidities and deaths) that may influence intermediate and long-term recovery. Specific strategies have been investigated to improve outcomes after hip surgery in elderly patients, considering the higher risk for complications, including delirium. In this narrative review, we aim to summarize the role of regional anesthesia and analgesia in the context of hip surgery by detailing on the effects of regional anesthesia on major outcomes. Considering the specific innervation of hip joint, we summarize the available evidence on newer peripheral nerve blocks for hip patients by focusing on potential complications associated with each technique, especially the occurrence of motor block. In this review, we aim to provide an updated and concise overview of the available evidence to help the reader planning the most appropriate strategy for hip surgery.

Key words: Analgesia, complications, enhanced recovery, hip surgery, motor block, postoperative pain, regional anesthesia

Introduction

Hip surgery is extremely common and ranges from surgery for hip fracture to elective procedures in younger adults: Total hip arthroplasty (THA) is one of the most common and successful surgical procedures in modern orthopedic surgery,[1] offering excellent outcomes in terms of improved quality of life, pain relief, and restored mobility for patients with degenerative or traumatic hip joint conditions. However, the postoperative period can be marked by significant pain, which may compromise functional recovery and increase the risk of complications, including delayed rehabilitation and chronic pain development.[2]

Over the years, the approach to patients undergoing hip arthroplasty has significantly evolved, focusing on multimodal strategies that combine different methods and

Access this article online	
	Quick Response Code
Website: https://journals.lww.com/sjan	
DOI: 10.4103/sja.sja_68_25	

How to cite this article: Evangelista T, Pugno C, Finazzi S, Colombi A, Bugada D. Regional anesthesia for hip surgery: A review of current approaches and their application to clinical practice. Saudi J Anaesth 2025;19:164-73.

Tiberio Evangelista, Camilla Pugno, Simone Finazzi, Alessandro Colombi[1], Dario Bugada

Emergency and Intensive Care Department, [1]Orthopedics and Traumatology, ASST Papa Giovanni XXIII, Piazza OMS, Bergamo, Italy

Address for correspondence: Dr. Dario Bugada, Emergency and Intensive Care Department, ASST Papa Giovanni XXIII, Piazza OMS, 1 24127, Bergamo, Italy.
E-mail: dariobugada@gmail.com

Submitted: 26-Jan-2025, **Accepted:** 28-Jan-2025, **Published:** 25-Mar-2025

pharmacological agents to optimize pain control, minimize side effects, and promote rapid recovery.[3] Among the key components of this approach, regional anesthesia and lower limb nerve blocks play a primary role. These techniques provide effective analgesia while reducing opioid requirements, thereby lowering the incidence of opioid-related adverse effects such as nausea, vomiting, sedation, and respiratory depression. Furthermore, targeted regional nerve blocks contribute to early patient mobilization, a critical element of Enhanced Recovery After Surgery (ERAS) protocols: Regional anesthesia is considered a pivotal component of modern updated protocols for postoperative pain management.[4,5]

This narrative review aims to summarize the role of regional anesthesia with focus on risks and benefits of various procedures. The goal is to provide an updated overview of the available evidence, helping the reader choosing the most appropriate analgesic strategy to optimize perioperative outcomes.

Hip Anatomy and Implications for Regional Anesthesia and Analgesia

The hip joint is a spheroidal synovial joint, consisting of the firm union of bony and ligament structures.

Bones are the pelvis and the head of the femur. The pelvis is made up of three parts – ilium, ischium and pubis – joined together in the triradiate cartilage to form the cup-shaped socket known as the acetabulum. The acetabulum covers approximately 40% of the femoral head in any position of hip movement. Further stability is provided by the labrum, a rim composed of circumferential collagen fibers that surrounds the acetabulum and acts to enlarge the hip socket and limit the extreme range of motion of the femoral head. The labrum contributes approximately 22% of the articular surface of the hip and increases the volume of the acetabulum by 33%.[6]

The hip joint capsule is made of three main ligaments: the iliofemoral, pubofemoral, and ischiofemoral ligaments. The capsular ligaments run spirally preventing extension of the hip and are surrounded by thick longitudinal fibers that provide additional stability in the lateral plane. The capsule is thicker in the anterior-superior part: In this part, the main mechanical stress occurs due to loading.[7]

The innervation of hip joint is complex with variations in terms of both nerves involved and disposition of nociceptors/mechanoceptors.[8] However, the main sensory and nociceptive innervation is covered by the lumbar plexus and its terminal rami: femoral (FN), obturator (ON), and lateral femoral cutaneous nerve (LFCN).

FN and ON are the main suppliers of sensory innervation in the hip joint. The accessory obturator nerve can also contribute.[9] These nerves provide articular branches mainly to the anteromedial aspect of the hip joints, with significant overlap. Articular branches from the femoral nerve are also supplied to the knee joint and derive from the same femoral nerve bundle: Ross anatomical findings suggest that dichotomized peripheral sensory fibers innervate the hip and knee joints,[10] suggesting a close correlation between hip and knee joint pain. The obturator nerve also gives sensory branches to the antero-medial thigh and to the knee: This may explain why patients with hip osteoarthritis often report knee pain. LFCN innervates the skin of the lateral thigh: This nerve is not directly involved in hip joint innervation but deserves attention when hip surgery is performed (since most of surgical access will cross the LFCN's territory of innervation).

The hip joint is also partially innervated by the sacral plexus: Branches from the sciatic nerve, superior gluteal nerve, and nerve to the quadratus femoris muscle[11] join in the sensory innervation of the posterior-lateral part of the joint (and need to be covered by nerve blockade when surgical anesthesia is required).

Receptors in the hip joint have a peculiar distribution: Nociceptors are mainly in the anterior and medial parts of the joint, while mechanoreceptors are denser posteriorly. This concept reflects in the different choice in terms of the regional anesthetic technique for analgesia rather than anesthesia.

For analgesic purposes, the main target is the antero-medial joint, that is, femoral, obturator, and accessory obturator nerves. Posterior nerve branches may contribute to analgesia in some cases but need to be blocked when complete surgical anesthesia of the hip joint wants to be achieved.

General and Regional Anesthesia: Difference in Perioperative and Long-Term Outcomes

Although hip surgery is expected to improve quality of life, complications are still a common concern (especially in elderly frail patients with hip fractures).

Regional anesthesia displays documented benefits in the perioperative period, and it is considered a pivotal item ERAS: Reduction in surgical stress improves key perioperative outcomes, such as gut function, early nutrition, mobilization, and blood losses.[12] A recent meta-analysis has confirmed that neuraxial anesthesia (NA) is superior to general anesthesia (GA) in decreasing length of hospital stay (LOS) with quicker hospital discharge.[13] Decreased LOS with NA is probably explained by better pain control with less side effects (such as nausea, vomiting, drowsiness, and fatigue), which finally lead to early mobilization and discharge.[14] Improved analgesia with NA has been evaluated by early narcotic consumption and pain scores in the post-anesthesia care unit (PACU), these trends remaining consistent when controlling for age, gender, BMI, and American Society of Anesthesiologists (ASA) status.[15]

In a retrospective cohort study, it was shown that the type of anesthesia for THA has changed in the past 15 years, with a decrease in the number of GA (72.7% vs 69.8%) as compared to an increased use of NA (10.7% vs 25.7%[16]), showing the growing interest in NA for the favorable risk–benefit ratio. Nevertheless, the superiority of one approach should not be resumed to pain and LOS only: Other outcomes are of strong interest and not strictly confined to the immediate perioperative period. Recent studies have focused their attention on the effect of different anesthesia modalities on morbidity and mortality in hip patients. However, these outcomes are difficult to study and methodological issues exist: Univocal definitions of outcomes are lacking, which makes it difficult to standardize and compare different types of anesthesia.[17]

To the best of the current knowledge, relevant differences between different anesthetic approaches are still far from being elucidated. A recent metanalysis including up to 202.000 patients does not highlight any statistically significant difference in mortality at 30 days, acute myocardial infarction, pneumonia, and delirium. A small statistically (but not clinically) significant difference in LOS is reported, shorter with spinal anesthesia.[17] These results are confirmed by another systematic review based on a consensus-based core-outcome set for patients with hip fracture: Except for a slight reduction in the risk for acute kidney injury, none of the relevant outcomes (delirium, mortality, hypotension, acute myocardial infarction) are influenced by NA versus GA.[18] A recent study created much criticism and must be interpreted with caution. This trial (1600 patients) identifies no difference in outcome between patients undergoing spinal anesthesia and GA.[14] However, relevant bias exists that precludes the generalization of these results: First, patients are healthier than those who are generally involved in this type of surgery; second, the 15% failure rate in spinal anesthesia is not in line with clinical practice, where expert anesthesiologists are supposed to give patients with anesthesia (with lower failure rates). A recent meta-analysis confirms that NA and GA are not correlated to statistically significant differences in perioperative outcomes in hip fracture surgery. NA is superior in terms of less intraoperative hypotension, but no differences were identified for other outcomes (duration of surgery, LOS, 30- and 90-day mortality, postoperative complications such as delirium, pneumonia, heart attack, and pulmonary embolism[15]).

However, avoiding hypotension reduces the probability of developing serious postoperative complications and should be regarded as an important endpoint in all surgeries, especially in comorbid and frail patients.[19] Furthermore, benefits of RA have been documented in joint arthroplasties (not only for femur fracture). The International Consensus on Anesthesia-Related Outcomes after Surgery Group (ICAROS) reports that among all hip arthroplasty patients, was associated with lower odds of complications in most categories: all-cause mortality, respiratory complications, thrombo-embolic complications, acute kidney failure, all cause infections, rate of blood transfusions, and falls. In general, the use of NA improves outcomes or gives no difference but is not associated with higher odds of complications. RA offers significant advantages for patients, especially for comorbid patients (less neuromuscular blockade, avoidance or airway manipulation, preservation of pulmonary dynamics, reduced release of inflammatory mediators). With this rational, the current strong recommendation is toward the use of NA in unilateral THA in the absence of significant contraindication or special circumstance to preclude its use.[20] Similarly, recommendations from the Enhanced Recovery After Surgery (ERAS®) Society also favor NA over GA in THA.[3]

As regards of peripheral nerve blocks, they also have effect in outcomes in terms of pain reduction, regardless of the type of anesthesia. For this reason, Procedure Specific Postoperative Pain Management (PROSPECT) Working Group recommend the use of PNB for analgesia in THA and in femur fracture surgery, combined with other pharmacological strategies as part of multimodal analgesic protocols.[4] Also, a recent meta-analysis shows that PNB are associated with lower odds for cognitive dysfunction, respiratory failure, cardiac complications, surgical site infections, pulmonary embolism, and blood transfusions: Peripheral nerve blocks (with NA or GA) are recommended, except when contraindications preclude their use.[20]

Another outcome of interest, especially in hip fracture patients or elderly patients requiring nonurgent procedures, is postoperative delirium (POD). POD is defined as a postoperative cognitive disturbance, generally after 2–5 days from surgery, with sudden and variable impairment in attention and awareness.[21] The incidence of POD varies from 4.7% to 74%, and it is associated with increased LOS, impaired functional and cognitive recovery, and a higher risk of morbidity and mortality.[22-24] The pathophysiology of POD in geriatric patients is still unclear, but some studies underline the role of neuroinflammation, neurotransmitters, and metabolism abnormality.[21] No specific therapy for POD exists: Prevention (aimed to reduce risk factors) plays a pivotal role.[25] Risk factors include different conditions in the preoperative (i.e. male sex, advanced age, ASA classification, comorbidities, electrolyte disorder, cognitive impairment or dementia, malnutrition), intraoperative (THA, intraoperative bleeding, and transfusion), and postoperative periods (pneumonia or urinary infections, pain, use of morphine, postoperative acute kidney injury).[21] Pooling these factors together, it is easy to understand why elderly patients receiving hip surgery are at peculiar risk of POD. The main features of prevention are optimization of nutrition, management of comorbidities/complications, and control of fluid imbalances.[21] Of course, correct pharmacological management is mandatory: Benzodiazepines and opioids are commonly used for sedation and pain control before and after surgery but are associated with increased risk of delirium and should be used with caution (or abolished[21,26]).

A lot of studies have tried to identify any association between the type of anesthesia/analgesia and the occurrence of delirium. A strong rationale exists toward the choice of regional techniques. On one hand, the use of PNB is recommended for earlier treatment of pain with opioid-sparing effects[27,28]: Intuitively, the use of PNB offers significant advantages in the management of elderly patients receiving hip surgery, but they have not yet been clearly associated to a reduction in delirium rate.[29,30] On the other hand, specific drugs (that may be part of GA) should be avoided in patients at risk (such benzodiazepines) or should be used carefully and at the lowest possible amount (opioids),[31] even for sedation during RA. Although a rationale exists to reduce POD by using RA, multiple metanalyses over years have substantially failed to demonstrate any clear protective role of RA versus GA. Nevertheless, as for mortality and other perioperative outcomes, demonstrating the superiority of one technique over the other may be difficult, and important methodological issues exist in trials that warn to generalize any result to clinical practice.[32] Of note, GA has been changing over years: Advanced monitoring and new pharmacologic compounds (like dexmedetomidine[33]) offer new strategies to target GA to the single patient, reducing the impact on patient physiology and (arguably) mitigating the imbalance between GA and RA that we may expect by only basing on theoretical beliefs.

In other words, the occurrence of delirium may not be associated to a specific type of anesthesia (GA vs RA). When high risk of POD is expected (considering the multifactorial origin[21]), a proper planning and conduction of anesthesia is crucial rather than choosing one or the other (with early and effective pain management, proper drugs choice and dosages, monitoring of hypnosis, avoidance of hypotension).

Generally speaking, multiple benefits of NA have been shown in joint arthroplasties. Although a clear superiority for NA for some outcomes has not been reported, this fact may rely on methodological issues and bias in different studies rather than on a real lack of benefits and should not refrain anesthesiologists from promoting the use of NA as a primary choice for hip surgery, especially in patients at high risk of complications from GA.[34] However, the choice between GA and NA[35] may depend on multiple factors (patient-, surgeon- and institution- related factors), and future trials are required to assess differences in outcomes between different anesthetic techniques in different types of patients.

Peripheral Nerve Blocks for Hip Analgesia

Lumbar plexus block

Lumbar plexus block has been widely used for hip surgery over the past decades. The clinical efficacy of LBP in hip surgeries has been widely demonstrated as it reduces analgesic use during hip arthroplasty both intra- and postoperatively and reduces pain assessed by pain scales compared to placebo.[36] When compared with the classic epidural analgesia, it has shown noninferiority in terms of analgesia within the first 24 hours.[37]

However, LBP has non-negligible risk and is not currently considered as a primary indication for hip surgery. LBP is a deep block, with high risk for potential spread of the anesthetic into the epidural and spinal space and of intravascular injection: Severe complications, including cardiac arrest, respiratory failure, seizures, and death, have been reported.[38] The depth of the block also accounts for the contraindication in anticoagulated patients.[39]

Alternatives have therefore been sought that provide equivalent analgesic efficacy but with superior safety profiles. Over the years, alternatives in peripheral regional analgesia have been numerous. Thanks to the increasing use of ultrasound, these techniques have taken on a primary role, relegating epidural analgesia and lumbar plexus block to secondary roles on the scene.

Femoral nerve block

The femoral nerve block (FNB) was one of the first alternatives to the lumbar plexus block, becoming one of the most used techniques for pain control in hip surgery. Its quick learning curve, ease of execution, and few adverse effects make it an extremely effective block.

Technically, it is performed using a linear probe to identify, below the inguinal ligament, the triad of femoral nerve, artery, and vein. The femoral artery should be observed before its bifurcation into deep and superficial femoral arteries to visualize medially the femoral vein and laterally the nerve. It is possible to identify two fascia layers above the femoral triad: fascia lata and fascia iliaca, with the latter surrounding the triad. The nerve typically appears as a hyperechoic oval structure lateral to the artery, below the fascia iliaca (although anatomical variations exist). The procedure involves injecting the local anesthetic around the nerve after crossing both fascia layers. The use of ultrasound and a nerve stimulator reduces the possibility of intravascular puncture or drug release away from the nerve.

The effectiveness of this technique is proven in terms of both intraoperative and postoperative analgesia. Providing early FNB in patients with neck of femur fracture reduces pain during radiological examinations and manipulations.[40] FNB is more effective and safer than opioids in such scenarios.[41] FNB also helps positioning patients for spinal anesthesia and decreases the time needed to perform spinal anesthesia.[42] When compared with placebo, FNB can extend the time from anesthetic emergence to the first request for analgesia after hip surgery,[43] with decreased systemic analgesics, improved pulmonary functions, and faster achievement of post-anesthesia care unit (PACU) discharge criteria.[44]

The safety profile is high, with a few possible complications: Femoral artery puncture, intravascular injection, or errors in nerve identification were the most common, but the routine use of ultrasound has reduced their incidences. Additionally, injecting a local anesthetic in this location does not affect hemodynamic stability, even in traumatized subjects.[45] Randomized group comparisons[46] receiving GA with or without femoral nerve block showed greater intraoperative hemodynamic stability and significantly reduced VAS up to 24 hours postoperatively in the nerve block group. However, a common side effect of femoral nerve block is motor block of the quadriceps femoris muscle, which may delay early mobilization or result in falls with significant consequences.[47,48]

Fascia iliaca block (FIB)

FIB is a fascial block involving the injection of a large volume of local anesthetic below the fascia iliaca to achieve concurrent analgesia of the femoral, lateral femoral cutaneous, and obturator nerves.[49] However, the involvement of the obturator nerve has been reevaluated due to inconsistent results.[50,51]

The block can be performed using two approaches relative to the inguinal ligament: infra-inguinal (IFIB) or supra-inguinal (SIFIB).[50] In the infra-inguinal approach, the probe is placed transversely below the inguinal ligament. After visualizing the femoral neurovascular bundle, the probe is moved laterally to reveal the sartorius muscle overlying the iliacus muscle. The needle is inserted in a lateral-to-medial direction, targeting the space where the fascia iliaca meets the sartorius muscle. Correct needle placement is confirmed by hydrodissection and spread of anesthetics medially and laterally.[49]

The supra-inguinal approach involves placing the probe on the sagittal plane along the inguinal ligament and sliding toward the anterior superior iliac spine (ASIS). The "bowtie sign," formed by the iliacus, sartorius, and internal oblique muscles is used as a landmark. The local anesthetic is injected cranially within the fascia iliaca, aiming for cephalad spread toward the lumbar plexus. Studies on cadavers suggest that 40 ml of anesthetic is necessary to achieve consistent coverage of the femoral and lateral femoral cutaneous nerves.[52]

Among the two approaches, the supra-inguinal technique is more likely to achieve the desired "3-in-1 block" effect as it facilitates cranial anesthetic spread to involve the obturator nerve. Despite this, challenges in reproducibility remain, and fascia iliaca may be more accurately described as a "2-in-1 block," targeting the femoral and lateral femoral cutaneous nerves in most of the cases.[53] This could be the reason why various meta-analyses have not shown any or little differences between the FIB and FNB in terms of opioid sparing, reported pain, nausea and vomiting, or differences in hospital stay duration.[54,55]

However, the SIFIB is recognized as an analgesic technique of proven efficacy. Clinical studies have shown that SIFIB is superior to placebo in both reducing perceived pain and promoting early mobilization within the first 48 hours postoperatively when applied to patients undergoing general or spinal anesthesia.[56] This approach is particularly beneficial in orthopedic contexts, such as hip or femoral surgery, where optimal pain management is crucial to improving functional recovery. SIFIB is recommended by the 2021 PROSPECT guidelines as a peripheral block of choice for hip arthroplasty.[4]

Although effective, potential problems may arise in specific conditions and during rehabilitation. First of all, the risk of motor impairment and the consequent risk of falls are not eliminated and should therefore be carefully considered.[57,58] Second, large volumes of local anesthetic are required, necessitating careful monitoring and in specific subgroups of patients at higher risk of local anesthetics systemic toxicity. However, in the average patients, 200 mg of ropivacaine for FIB has been reported to be safe (with local anesthetic levels remaining within safety limits in the bloodstream), but additional risk factors in patients undergoing hip arthroplasty or femur fracture repair warrant caution.[59]

As FIB does not overcome the limitations of FIB and LPB (or it only partially does), clinicians are seeking alternative nerve blocks to deal with hip analgesia. In the past decade, the development of newer fascial plane blocks has granted attention because of their potential to provide effective analgesia by meanwhile fixing some (or all issues) associated with traditional approaches. These new techniques include quadratus lumborum block (QLB), erector spinae plane block (ESPB), and PENG block.

Quadratus lumborum block (QLB)

The quadratus lumborum is a dorsal muscle that assists in lateral flexion of the trunk on the pelvis and extension movements. It is situated postero-laterally to the psoas major muscle and is superficially covered by the terminal part of the latissimus dorsi muscle and the erector spinae muscles. It originates posterior-medially from the iliac crest and inserts cranially into the 12th rib and the transverse processes of the lumbar vertebrae. The anatomical rationale of QLB is based on utilizing the spread of local anesthetic between muscle layers to reach the lumbar plexus roots caudally.

There are different approaches to this anesthetic technique, classified based on the injection site relative to the muscle.[60] These include lateral, posterior, and anterior (trans-muscular) approaches. The patient is positioned on the contralateral side of the block (which is performed on the ipsilateral side of surgery), with a convex probe placed transversely above the iliac crest to intercept the transverse process of the fourth lumbar vertebra, until the convergence of the abdominal wall muscles with the quadratus lumborum muscle is visualized. A recurring anatomical landmark for identifying structures is the "shamrock sign": the vertebral transverse process surrounded by the quadratus lumborum proximally, the erector spinae posteriorly, and the psoas anteriorly.

- **Anterior approach**: The needle is advanced medio-laterally until its tip is located between the QL and the psoas major muscle.
- **Lateral approach:** The needle is inserted latero-medially, targeting the lateral side of the QL, where the abdominal wall muscles converge.
- **Posterior approach:** A procedure similar to the lateral approach, but the anesthetic target is posterior to the QL muscle.[60]

When evaluating individual approaches, the anterior approach appears most suitable for lower limb analgesia due to its consistent and reproducible anesthetic spread to the lumbar plexus. Some studies show that this approach provides superior analgesia compared to placebo in hip surgery.[61] *Takeda et al*. demonstrated reduced postoperative morphine consumption, comparing it to femoral nerve block. This approach was not found inferior when compared to the infra-inguinal fascia iliaca block[62,63] and LBP.[61]

Despite the efficacy, relevant risks are associated with this technique that may limit the applicability in the clinical context. First, the highly vascularized area favors anesthetic absorption. Second, the hemorrhagic risk associated is unclear, but clinicians must be mindful of the abdominal branches of the lumbar arteries that run within the fascia targeted in the lateral and posterior approaches. The anterior approach is classified as a deep block with equivalent hemorrhagic risks in an incompressible zone.[39] Third, needle placement risks damaging organs such as the kidney or pleura. Finally, muscle weakness and hypotension may occur due to the spread of the anesthetic.[64]

Lumbar Erector Spinae Block (ESPB)

ESPB is gaining popularity due to its effectiveness and safety profile. Initially developed for thoracic use, it has recently been applied at the lumbar level.

Anatomically, the term *erector spinae* refers to a group of dorsal muscles, also known as "intrinsic dorsal muscles," that extend from the cervical to the sacral regions. At the lumbar level, the erector spinae group includes the *longissimus dorsi*, *iliocostalis*, and *multifidus* muscles. This group of muscles is located postero-laterally to the spinous processes, adhering ventrally to the transverse processes.

The spinal nerves in the lumbar region, as they exit the intervertebral foramina, divide into anterior and posterior nerves. The anterior nerves form the lumbar and sacral plexuses, while the posterior nerves further divide into medial, intermediate, and lateral branches, which move posteriorly through the fascial layers separating the muscles of this compartment.

The technique involves injecting a local anesthetic close to the vertebral transverse process and utilizing its spread among the fascial planes. In this location, the local anesthetic may spread:

- posteriorly, among the fascial planes of different muscles, reaching the dorsal branches;
- anteriorly, crossing the transverse process to involve the

anterior spinal branches;
- cranio-caudally, thus affecting multiple spinal levels.

At the lumbar level, the use of a low-frequency probe can facilitate visualization, although the use of a linear probe is also described. The probe can be placed transversely to visualize the profile of a single vertebra or sagittally in the paraspinous region to visualize multiple adjacent vertebrae. The needle can be inserted either in-plane or out-of-plane. If in the lateral position, the probe can be placed transversely to visualize the "Shamrock sign" (see QLB).[65] In hip surgery, ESPB is usually performed at L3-L4 level.[23]

ESPB has demonstrated good analgesic efficacy in hip procedures. A recent meta-analysis of five RCTs[66] highlighted that the use of ESPB, compared to control groups, resulted in better postoperative analgesia, reduced opioid consumption within 24 hours, and no increased risk of complications. Both *Flaviano et al*.[67] and *Kaciroglu et al*.[68] compared this technique with the current "gold standard" FIB demonstrating no differences in terms of analgesia and morphine consumption. However, reduced incidence of quadriceps weakness was shown, which is an additional advantage in the context of enhanced rehabilitation. From the perspective of potential complications, the ESBL block offers several advantages: It is superficial, performed in a compressible area, and has a low hemorrhagic risk. The main complication could be related to the systemic absorption of local anesthetic, particularly in at-risk populations.[69]

PENG (PEricapsular nerve group) BLOCK

PENG block is a technique that has gained attention in the past 5 years as it is claimed to completely avoid motor block of the quadriceps muscle by providing selective analgesia to the hip joint.

This block involves the injection of a local anesthetic in a location proximal to the joint capsule with the rationale of anesthetizing the sensory articular branches that originate from the femoral nerve, obturator nerve, and accessory obturator nerve without involving the motor branches of the thigh muscles (which branch off earlier).[70] The technical approach involves positioning the patient supine and placing the curvilinear low-frequency probe over the anterior inferior iliac spine, rotating it approximately 45° to align with the pubic ramus. By tilting the probe, it is possible to optimize a circular structure that is more echogenic compared to the surrounding muscle (the tendon of the iliopsoas and the homonymous muscle), the inferior-superior iliac spine (ISIS), and the ileo-pubic eminence. Injection should take place in between the tendon and the ISIS above the bony structures. Lifting of the tendon is often visualized, which means that injection is taking place outside the tendon (injection within the tendon should be avoided). Care must also be taken to avoid the femoral artery, which will appear pulsating superficially, to prevent vascular injury.[71]

Theoretically, the local anesthetic spreads around the capsule, involving branches of the femoral and obturator nerves. However, recent studies have challenged this theory as neither cadaveric studies[72] nor *in vivo* studies[73] have been able to demonstrate consistent spread to the obturator nerve and its branches or to the accessory obturator[74] nerve. Although the mechanism of action of the PENG block is still not clearly delineated, its clinical efficacy has been proven by numerous studies published in recent years. *Pascarella et al*.[32] demonstrated the effectiveness of the PENG block (in combination with LFCN block) reporting a reduction in opioid consumption, faster mobilization, and a greater range of motion, without motor block.

Comparative studies with other types of blocks have confirmed comparable analgesic efficacy to other blocks but with a greater motor-sparing effect, which is increasingly sought in modern ERAS strategies. Allard *et al*.[75] showed no differences with PENG block compared to FNB in terms of postoperative pain intensity, mobilization time, or opioid-related effects in femur fracture surgery, but a significant motor-sparing effect was observed with PENG group. PENG block showed[76,77] similar or superior efficacy compared with FIB, with reduced postoperative opioid consumption at 24 hours. The PENG block also offers some advantage over ESPB,[78,79] showing superiority in terms of patient satisfaction and facilitation of assuming the sitting position for spinal anesthesia, with comparable or slightly superior analgesia depending on the studies. Finally, when comparing the PENG block with the quadratus lumborum block, the analgesic effect appears slightly superior in the PENG group, with less motor block.[80]

PENG block plays an increasingly important role in the context of modern ERAS approaches due to the potential for motor-sparing effect. However, there is a percentage of undesired and unexpected motor block that develops in certain individuals, which seems to be associated with the spread to the femoral nerve. This has currently been attributed to excessive anesthetic diffusion that may reach the femoral nerve by moving up through the fascial layers.[81] Other causes or contributing factors are under investigation, such as the risk of rupture of the iliopsoas bursa located inferior to the psoas tendon. Rupture due to accidental puncture or anesthetic injection may promote the diffusion of anesthetic into the iliac fascia, involving the femoral nerve.[72] Another potential risk factor could be intramuscular diffusion of the anesthetic, which may facilitate spread toward superficial planes.[82] Currently, the appropriate anesthetic volume to eliminate the risk of motor weakness is not clearly defined. Although 20 ml is the standard volume used, a randomized study compared different volumes and concentrations and showed that reducing the volume to 10 ml seems to better preserve motor function without altering analgesia.[83] Further studies are required, but refining the technique may contribute to promote PENG block as one of the most promising approaches to hip surgery.

Lateral Femoral Cutaneous Nerve (LFCN) Block

Both FNB and FIB can be combined with a block of the LFCN, composed of purely sensory fibers innervating the skin of the lateral thigh. This combination is useful for posterior-lateral access in total hip arthroplasty to cover surgical incision pain, although studies have not demonstrated conflicting results on clinical efficacy.[32,84,85] Limited clinical efficacy may depend on the surgical incision that (at least in part) may be outside the skin area innervated by LFCN.[86] A local anesthetic is injected around the lateral femoral cutaneous nerve, located in a subcutaneous space along the sartorius muscle border as it courses above the iliac muscle. The use of ultrasound can help to identify this nerve running into the superficial layer of thigh.[87]

Conclusions

Regional anesthesia plays a pivotal role in modern hip surgery, offering enhanced pain control and reduced opioid usage. The integration of advanced nerve block techniques demonstrates significant potential for motor-sparing benefits and improved recovery. Also, regional anesthesia may improve perioperative outcomes in specific subgroup of patients, namely, the frail elderly receiving hip surgery for fractures. Future research is warranted to refine techniques and validate long-term benefits, ensuring optimal care strategies.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future young patient demand for primary and revision joint replacement: National projections from 2010 to 2030. Clin Orthop Relat Res 2009;467:2606-12.
2. Kehlet H, Dahl JB. Anaesthesia, surgery, and challenges in postoperative recovery. Lancet 2003;362:1921-8.
3. Wainwright TW, Gill M, McDonald DA, Middleton RG, Reed M, Sahota O, *et al*. Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Acta Orthop 2020;91:3-19.
4. Anger M, Valovska T, Beloeil H, Lirk P, Joshi GP, Van de Velde M, *et al*. PROSPECT guideline for total hip arthroplasty: A systematic review and procedure-specific postoperative pain management recommendations. Anaesthesia 2021;76:1082-97.
5. Lavand'homme PM, Kehlet H, Rawal N, Joshi GP. Pain management after total knee arthroplasty: PROcedure SPEcific postoperative pain management recommendations. Eur J Anaesthesiol 2022;39:743-57.
6. Bowman KF, Fox J, Sekiya JK. A clinically relevant review of hip biomechanics. Arthroscopy 2010;26:1118-29.
7. Martin HD, Savage A, Braly BA, Palmer IJ, Beall DP, Kelly B. The function of the hip capsular ligaments: A quantitative report. Arthroscopy 2008;24:188-95.
8. Laumonerie P, Dalmas Y, Tibbo ME, Robert S, Durant T, Caste T, *et al*. Sensory innervation of the hip joint and referred pain: A systematic review of the literature. Pain Medicine (United States) 2021;22:1149-57.
9. Akkaya T, Comert A, Kendir S, Acar HI, Gumus H, Tekdemir I, *et al*. Detailed anatomy of accessory obturator nerve blockade. Minerva Anestesiol 2008;74:119-22.
10. Sakamoto J, Manabe Y, Oyamada J, Kataoka H, Nakano J, Saiki K, *et al*. Anatomical study of the articular branches innervated the hip and knee joint with reference to mechanism of referral pain in hip joint disease patients. Clin Anat 2018;31:705-9.
11. Birnbaum K, Prescher A, Heßler S, Heller KD. The sensory innervation of the hip joint - An anatomical study. Surg Radiol Anat 1997;19:371-5.
12. Carli F, Kehlet H, Baldini G, Steel A, McRae K, Slinger P, *et al*. Evidence basis for regional anesthesia in multidisciplinary fast-track surgical care pathways. Reg Anesth Pain Med 2011;36:63-72.
13. Pu X, Sun JM. General anesthesia vs spinal anesthesia for patients undergoing total-hip arthroplasty. Medicine (United States) 2019;98. doi: 10.1097/MD.0000000000014925.
14. Neuman MD, Feng R, Carson JL, Gaskins LJ, Dillane D, Sessler DI, *et al*. Spinal anesthesia or general anesthesia for hip surgery in older adults. N Engl J Med 2021;385:2025-35.
15. Liu S, Chen J, Shi H, *et al*.. Comparing perioperative outcomes between regional anesthesia and general anesthesia in patients undergoing hip fracture surgery: A systematic review and meta-analysis. Can J Anesth 2024;71:849-69.
16. Illescas A, Cozowicz C, Zhong H, Reisinger L, Liu J, Poeran J, *et al*. Comparative effectiveness of neuraxial versus general anesthesia in total joint replacement surgery: An updated retrospective analysis using more recent data. Reg Anesth Pain Med 2024:1-10. doi: 10.1136/rapm-2024-105438.
17. Hopkins AM, McDonnell C, Breslin NP, O'Morain CA, Baird AW. Omeprazole increases permeability across isolated rat gastric mucosa pre-treated with an acid secretagogue. J Pharm Pharmacol 2002;54(3):341-347.
18. Kunutsor SK, Hamal PB, Tomassini S, Yeung J, Whitehouse MR, Matharu GS. Clinical effectiveness and safety of spinal anaesthesia compared with general anaesthesia in patients undergoing hip fracture surgery using a consensus-based core outcome set and patient-and public-informed outcomes: A systematic review and meta-analysis. Br J Anaesth 2022;129:788-800.
19. White SM, Moppett IK, Griffiths R, Johansen A, Wakeman R, Boulton C, *et al*. Secondary analysis of outcomes after 11,085 hip fracture operations from the prospective UK anaesthesia sprint audit of practice (ASAP-2). Anaesthesia 2016;71:506-14.
20. Memtsoudis SG, Cozowicz C, Bekeris J, Bekere D, Liu J, Soffin EM,

et al. Peripheral nerve block anesthesia/analgesia for patients undergoing primary hip and knee arthroplasty: Recommendations from the International Consensus on Anesthesia-Related Outcomes after Surgery (ICAROS) group based on a systematic review and meta-analy. Reg Anesth Pain Med 2021;46:971-85.
21. Chen Y, Liang S, Wu H, Deng S, Wang F, Lunzhu C, *et al*. Postoperative delirium in geriatric patients with hip fractures. Front Aging Neurosci 2022;14:1-13. doi: 10.3389/fnagi.2022.1068278.
22. Maldonado JR. Acute brain failure: Pathophysiology, diagnosis, management, and sequelae of delirium. Crit Care Clin 2017;33:461-519.
23. Flikweert ER, Wendt KW, Diercks RL, Izaks GJ, Landsheer D, Stevens M, *et al*. Complications after hip fracture surgery: Are they preventable? Eur J Trauma Emerg Surg 2018;44:573-80.
24. Connolly KP, Kleinman RS, Stevenson KL, Neuman MD, Mehta SN. Delirium reduced with intravenous acetaminophen in geriatric hip fracture patients. J Am Acad Orthop Surg 2020;28:325-31.
25. Pieri M, De Simone A, Rose S, De Domenico P, Lembo R, Denaro G, *et al*. Trials focusing on prevention and treatment of delirium after cardiac surgery: A systematic review of randomized evidence. J Cardiothorac Vasc Anesth 2020;34:1641-54.
26. Panel UE. American Geriatrics Society 2023 updated AGS Beers Criteria® for potentially inappropriate medication use in older adults. J Am Geriatr Soc 2023;71:2052-81.
27. Guay J, Kopp S. Peripheral nerve blocks for hip fractures in adults. Emergencias 2022;34:388-9.
28. Guay J, Johnson RL, Kopp S. Nerve blocks or no nerve blocks for pain control after elective hip replacement (arthroplasty) surgery in adults. Cochrane Database Syst Rev 2017;10:CD011608.
29. Kim SY, Jo HY, Na HS, Han SH, Do SH, Shin HJ. The effect of peripheral nerve block on postoperative delirium in older adults undergoing hip surgery: A systematic review and meta-analysis of randomized controlled trials. J Clin Med 2023;12:2459. doi: 10.3390/jcm12072459.
30. Exsteen OW, Svendsen CN, Rothe C, Lange KHW, Lundstrøm LH. Ultrasound-guided peripheral nerve blocks for preoperative pain management in hip fractures: A systematic review. BMC Anesthesiol 2022;22:192. doi: 10.1186/s12871-022-01720-7.
31. 2019 American Geriatrics Society Beers Criteria® Update Expert Panel, Fick DM, Semla TP, Steinman M, Beizer J, Brandt N, *et al*. American Geriatrics Society 2019 updated AGS beers Criteria® for potentially inappropriate medication use in older adults. J Am Geriatr Soc 2019;67:674-94.
32. Pascarella G, Costa F, Strumia A, Ruggiero A, Remore LM, Lanteri T, *et al*. Lateral femoral cutaneous nerve block or wound infiltration combined with pericapsular nerve group (PENG) block for postoperative analgesia following total hip arthroplasty through posterior approach: A randomized controlled trial. J Clin Med 2024;13:1-11. doi: 10.3390/jcm13092674.
33. Shin HJ, Woo Nam S, Kim H, Yim S, Han SH, Hwang JW, *et al*. Postoperative delirium after dexmedetomidine versus propofol sedation in healthy older adults undergoing orthopedic lower limb surgery with spinal anesthesia: A randomized controlled trial. Anesthesiology 2023;138:164-71.
34. Stone AB, Poeran J, Memtsoudis SG. There remains a role for neuraxial anesthesia for hip fracture surgery in the post-REGAIN era. Reg Anesth Pain Med 2023;48:430-2.
35. Pissens S, Cavens L, Joshi GP, Bonnet MP, Sauter A, Raeder J, *et al*. Pain management after hip fracture repair surgery: A systematic review and procedure-specific postoperative pain management (PROSPECT) recommendations. Acta Anaesthesiol Belg 2024;75:15-31.
36. Tsen LC, Segal S, Pothier M, Bader AM. Alternative medicine use in presurgical patients. Anesthesiology 2000;93:148-51.
37. Sharma H, Mitra S, Singh J, Gupta S, Garg S. A randomized study comparing the efficacy of ultrasound guided lumbar plexus block and epidural anesthesia for postoperative analgesia in patients undergoing total hip replacement. Asian J Anesthesiol 2020;58:131-7.
38. Bugada D, Allegri M, Grossi P, Manassero A, Pinciroli RL, Zadra N, *et al*. Regional anesthesia: The best is yet to come. Minerva Anestesiol 2017;83:774-5.
39. Kietaibl S, Ferrandis R, Godier A, Llau J, Lobo C, Macfarlane AJ, *et al*. Regional anaesthesia in patients on antithrombotic drugs: Joint ESAIC/ESRA guidelines. Eur J Anaesthesiol 2022;39:100-32.
40. Somvanshi M, Tripathi A, Meena N. Femoral nerve block for acute pain relief in fracture shaft femur in an emergency ward. Saudi J Anaesth 2015;9:439-41.
41. Riddell M, Ospina M, Holroyd-Leduc JM. Use of femoral nerve blocks to manage hip fracture pain among older adults in the emergency department: A systematic review. Can J Emerg Med 2016;18:245-52.
42. Hartmann FVG, Novaes MRCG, de Carvalho MR. Femoral nerve block versus intravenous fentanyl in adult patients with hip fractures – A systematic review. Braz J Anesthesiol (English Edition) 2017;67:67-71.
43. Fournier R, Van Gessel E, Gaggero G, Boccovi S, Forster A, Gamulin Z. Postoperative analgesia with “3-in-1” femoral nerve block after prosthetic hip surgery. Can J Anaesth 1998;45:34-8.
44. Wiesmann T, Steinfeldt T, Wagner G, Wulf H, Schmitt J, Zoremba M. Supplemental single shot femoral nerve block for total hip arthroplasty: Impact on early postoperative care, pain management and lung function. Minerva Anestesiol 2014;80:48-57.
45. Hsu YP, Hsu CW, Chu KCW, Huang WC, Bai CH, Huang CJ, *et al*. Efficacy and safety of femoral nerve block for the positioning of femur fracture patients before a spinal block – A systematic review and meta-analysis. PLoS One 2019;14:1-20. doi: 10.1371/journal.pone.0216337.
46. Kratz T, Dette F, Schmitt J, Wiesmann T, Wulf H, Zoremba M. Impact of regional femoral nerve block during general anesthesia for hip arthoplasty on blood pressure, heart rate and pain control: A randomized controlled study. Technol Health Care 2015;23:313-22.
47. Grevstad U, Mathiesen O, Valentiner LS, Jaeger P, Hilsted KL, Dahl JB. Effect of adductor canal block versus femoral nerve block on quadriceps strength, mobilization, and pain after total knee arthroplasty: A randomized, blinded study. Reg Anesth Pain Med 2015;40:3-10.
48. Kandasami M, Kinninmonth AW, Sarungi M, Baines J, Scott NB. Femoral nerve block for total knee replacement - A word of caution. Knee 2009;16:98-100.
49. O’Reilly N, Desmet M, Kearns R. Fascia iliaca compartment block. BJA Educ 2019;19:191-7.
50. Capdevila X, Biboulet P, Bouregba M, Barthelet Y, Rubenovitch J, D’Athis F. Comparison of the three-in-one and fascia lliaca compartment blocks in adults: Clinical and radiographic analysis. Anesth Analg 1998;86:1039-44.
51. Bendtsen TF, Pedersen EM, Moriggl B, Hebbard P, Ivanusic J, Børglum J, *et al*. Anatomical considerations for obturator nerve block with fascia iliaca compartment block. Reg Anesth Pain Med 2021;46:806-12.
52. Vermeylen K, Soetens F, Leunen I, Hadzic A, Van Boxtael S, Pomés J, *et al*. The effect of the volume of supra-inguinal injected solution on the spread of the injectate under the fascia iliaca: A preliminary study. J Anesth 2018;32:908-13.
53. Niemann CU, Biancofiore G. Transplant anesthesia and critical care: Current research and possible future developments. Best Pract Res Clin Anaesthesiol;34:1-2.
54. Fan X, Cao F, Luo A. Femoral nerve block versus fascia iliaca block for pain control in knee and hip arthroplasties: A meta-analysis. Medicine (United States) 2021;100:E25450. doi: 10.1097/MD.0000000000025450.
55. Wang YR, Bian HL, Wang Q. Atropine 0.5% eyedrops for the treatment of children with low myopia: A randomized controlled trial. Medicine 2017;96:e7371.
56. Carella M, Beck F, Piette N, Denys S, Kurth W, Lecoq JP, *et al*. Effect of suprainguinal fascia iliaca compartment block on postoperative opioid consumption and functional recovery in posterolateral-approached total hip arthroplasty: A single-blind randomized controlled trial. Reg Anesth

Pain Med 2022. doi: 10.1136/rapm-2021-103427.

57. Behrends M, Yap EN, Zhang AL, Kolodzie K, Kinjo S, Harbell MW, *et al*. Preoperative fascia iliaca block does not improve analgesia after arthroscopic hip surgery, but causes quadriceps muscles weakness: A randomized, double-blind trial. Anesthesiology 2018;129:536-43.
58. Vamshi C, Sinha C, Kumar A, Kumar A, Kumari P, Kumar A, *et al.* Comparison of the efficacy of pericapsular nerve group block (PENG) block versus suprainguinal fascia iliaca block (SFIB) in total hip arthroplasty: A randomized control trial. Indian J Anaesth 2019;49:257-62.
59. Desmet M, Vermeylen K, Van Herreweghe I, Carlier L, Soetens F, Lambrecht S, *et al*. A longitudinal supra-inguinal fascia iliaca compartment block reduces morphine consumption after total hip arthroplasty. Reg Anesth Pain Med 2017;42:327-33.
60. Elsharkawy H, El-Boghdadly K, Barrington M. Quadratus Lumborum Block: Anatomical Concepts, Mechanisms, and Techniques. Anesthesiology 2019;130:322-35. [doi: 10.1097/ALN.0000000000002524]. Erratum in: Anesthesiology. 2024 Dec 1;141:1226. [doi: 10.1097/ALN.0000000000005221].
61. Kukreja P, MacBeth L, Sturdivant A, Morgan CJ, Ghanem E, Kalagara H, *et al*. Anterior quadratus lumborum block analgesia for total hip arthroplasty: A randomized, controlled study. Reg Anesth Pain Med 2019. doi: 10.1136/rapm-2019-100804.
62. Takeda Y, Tsujimoto K, Okamoto T, Nakai T, Fukunishi S, Tachibana T. Efficacy of Anterior Quadratus Lumborum Block and Pain After Total Hip Arthroplasty: A Randomized Controlled Trial. J Arthroplasty 2023;38:2386-92.
63. Hashmi J, Cusack B, Hughes L, Singh V, Srinivasan K. Transmuscular quadratus lumborum block versus infrainguinal fascia iliaca nerve block for patients undergoing elective hip replacement: A double-blinded, pilot, randomized controlled trial. Local Reg Anesth 2022;15:45-55.
64. Kukreja P, MacBeth L, Sturdivant A, Morgan CJ, Ghanem E, Kalagara H, *et al*. Anterior quadratus lumborum block analgesia for total hip arthroplasty: A randomized, controlled study. Reg Anesth Pain Med 2019;44:1075-9.
65. Tulgar S, Aydin ME, Ahiskalioglu A, De Cassai A, Gurkan Y. Anesthetic techniques: Focus on lumbar erector spinae plane block. Local Reg Anesth 2020;13:121-33.
66. Huda AU, Ghafoor H. The use of erector spinae plane block reduces opioid consumption and pain score in postoperative period after hip surgery: A meta-analysis. Cureus 2023;15:e47477. doi: 10.7759/cureus.47477.
67. Flaviano E, Bettinelli S, Assandri M, Muhammad H, Benigni A, Cappelleri G, *et al*. Erector spinae plane versus fascia iliaca block after total hip arthroplasty: A randomized clinical trial comparing analgesic effectiveness and motor block. Korean J Anesthesiol 2023;76:326-35.
68. Kaciroglu A, Ekinci M, Dikici M, Aydemir O, Demiroluk O, Erdogan D, *et al*. Lumbar erector spinae plane block versus infrainguinal fascia iliaca compartment block for pain management after total hip arthroplasty: A randomized clinical trial. Pain Medicine (United States) 2024;25:257-62.
69. De Cassai A, Bonanno C, Padrini R, Geraldini F, Boscolo A, Navalesi P, *et al*. Pharmacokinetics of lidocaine after bilateral ESP block. Reg Anesth Pain Med 2021;46:86-9.
70. Del Buono R, Padua E, Pascarella G, Costa F, Tognù A, Terranova G, *et al*. Pericapsular nerve group block: An overview. Minerva Anestesiol 2021;87:458-66.
71. Girón-Arango L, Peng PWH, Chin KJ, Brull R, Perlas A. Pericapsular nerve group (PENG) block for hip fracture. Reg Anesth Pain Med 2018;43:859-63.
72. Joo MK, Park JJ, Kim SH, Kim KH, Jung W, Yun JW, *et al.* Prevalence and endoscopic features of eosinophilic esophagitis in patients with esophageal or upper gastrointestinal symptoms. J Dig Dis 2012;13:296-303.
73. Balocco AL, Gautier N, Van Boxstael S, López AM, Carella M, Corten K, *et al*. Pericapsular nerve group block: A 3D CT scan imaging study to determine the spread of injectate. Reg Anesth Pain Med 2024. doi: 10.1136/rapm-2024-105459.
74. Diwan S, Shivamallappa S, Timane R, Pai P, Gupta A. Anatomic evaluation to compare the dye spread with ultrasound-guided pericapsular nerve group (PENG) injection with or without an additional suprainguinal fascia iliaca (SIFI) injection in soft embalmed cadavers. J Anesth 2024;38:445-54.
75. Allard C, Pardo E, de la Jonquière C, Wyniecki A, Soulier A, Faddoul A, *et al*. Comparison between femoral block and PENG block in femoral neck fractures: A cohort study. PLoS One 2021;16:1-11. doi: 10.1371/journal.pone.0252716.
76. Prakash J, Rochwerg B, Saran K, Yadav AK, Bhattacharya PK, Kumar A, *et al*. Comparison of analgesic effects of pericapsular nerve group block and fascia iliaca compartment block during hip arthroplasty: A systematic review and metaanalysis of randomised controlled trials. Indian J Anaesth 2019;49:257-62.
77. Andrade PP, Lombardi RA, Marques IR, Braga ACDNAE, Isaias BRS, Heiser NE. Pericapsular nerve group (PENG) block versus fascia iliaca compartment (FI) block for hip surgery: A systematic review and meta-analysis of randomized controlled trials. Braz J Anesthesiol 2023;73:794-809.
78. Medhat MM, Kamel AAF, Salem DAE, Alagamy SA, Fathi HM. The analgesic effects of preemptive ultrasound-guided pericapsular nerve group block in comparison with erector spinae plane block in elderly undergoing hip arthroplasty: A randomized controlled trial. Anesth Pain Med 2023;13:e138623. doi: 10.5812/aapm-138623.
79. Küçük O, Sağ F, Eyrice A, Karadayı S, Alagöz A, Çolak A. Comparison of the analgesic effect of pericapsular nerve group block and lumbar erector spinae plane block in elective hip surgery. Medicina (Lithuania) 2024;60. doi: 10.3390/medicina60050799.
80. Et T, Korkusuz M. Comparison of the pericapsular nerve group block with the intra-articular and quadratus lumborum blocks in primary total hip arthroplasty: A randomized controlled trial. Korean J Anesthesiol 2023;76:575-85.
81. Yu HC, Moser JJ, Chu AY, Montgomery SH, Brown N, Endersby RVW. Inadvertent quadriceps weakness following the pericapsular nerve group (PENG) block. Reg Anesth Pain Med 2019;44:611-3.
82. Giron Arango L, Peng P. Reply to Dr Yu *et al*..: Inadvertent quadriceps weakness following the pericapsular nerve group (PENG) block. Reg Anesth Pain Med 2019;44:613-4.
83. Huang Y, Lu Y, Wang J, Lu Q, Bao HF, Liu L, *et al*. Effect of pericapsular nerve group block with different concentrations and volumes of ropivacaine on functional recovery in total hip arthroplasty: A randomized, observer-masked, controlled trial. J Pain Res 2024;17:677-85.
84. Thybo KH, Schmidt H, Hägi-Pedersen D. Effect of lateral femoral cutaneous nerveblock on pain after total hip arthroplasty: A randomised, blinded, placebo-controlled trial. BMC Anesthesiol 2016;16:1-7. doi: 10.1186/s12871-016-0183-4.
85. Thybo KH, Mathiesen O, Dahl JB, Schmidt H, Hägi-Pedersen D. Lateral femoral cutaneous nerve block after total hip arthroplasty: A randomised trial. Acta Anaesthesiol Scand 2016;60:1297-305.
86. Davies A, Crossley AP, Harper MW, O'Loughlin EJ. Lateral cutaneous femoral nerve blockade-limited skin incision coverage in hip arthroplasty. Anaesth Intensive Care 2014;42:625-30.
87. Nielsen TD, Moriggl B, Barckman J, Kølsen-Petersen JA, Søballe K, Børglum J, *et al*. The lateral femoral cutaneous nerve: Description of the sensory territory and a novel ultrasound-guided nerve block technique. Reg Anesth Pain Med 2018;43:357-66.