Pericapsular Nerve Group Block for Pre- and Post-Operative Analgesia in Elderly Patients with Hip Fracture

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Abstract

Background: Hip fracture in elderly patients represents a major challenge for anesthesiologists due to the high incidence of severe pain, physiological frailty, and increased risk of postoperative complications. Optimal pain management in this population requires techniques that provide effective analgesia while minimizing systemic opioid exposure and related adverse effects. The pericapsular nerve group (PENG) block has recently emerged as a promising motor-sparing regional anesthesia technique specifically targeting the articular branches that innervate the anterior capsule of the hip joint. By selectively anesthetizing the articular branches of the femoral, obturator, and accessory obturator nerves, the PENG block achieves focused analgesia in the region with the highest density of nociceptors within the hip capsule, thus providing substantial pain relief both pre- and post-operatively.

This review explores the anatomical rationale, sonoanatomy, technical performance, pharmacological considerations, and clinical efficacy of the PENG block in elderly patients undergoing hip fracture surgery. It highlights the significance of this block in reducing perioperative opioid consumption, improving patient comfort, and facilitating early mobilization and rehabilitation. In addition, it discusses the physiological challenges of pain management in geriatric patients, including age-related cardiovascular, respiratory, renal, and neurological changes that affect anesthetic pharmacokinetics and pharmacodynamics. The integration of the PENG block into multimodal analgesic pathways aligns with enhanced recovery principles and supports safer anesthetic care in a vulnerable patient group.

Furthermore, the review addresses the safety profile of the PENG block, potential complications, and strategies to prevent local anesthetic systemic toxicity through appropriate dosing and vigilant monitoring. Future directions include the evaluation of optimal anesthetic volumes, comparative outcome data across surgical types, and innovations such as liposomal bupivacaine formulations and point-of-care ultrasound refinements. Through the combination of anatomical precision and clinical practicality, the PENG block has become an essential component of perioperative pain management in elderly patients with hip fracture, offering a balance between analgesic efficacy and preservation of motor function essential for early postoperative recovery.

Keywords: *Pericapsular Nerve Group Block, Analgesia, Elderly, Hip Fracture*

Introduction

Hip fracture in the elderly remains one of the most common and debilitating orthopedic emergencies worldwide. It is associated with significant pain, loss of independence, prolonged hospitalization, and a one-year mortality that may reach up to 30%. The rapid institution of effective analgesia is not only essential for humane care but also for minimizing complications such as delirium, thromboembolism, and cardiopulmonary deterioration. Elderly patients present a unique physiological vulnerability due to reduced organ reserve, multiple comorbidities, and altered drug metabolism, making traditional systemic analgesics less effective and potentially harmful. Consequently, regional anesthesia has become a cornerstone of perioperative pain control, offering site-specific analgesia and a superior safety profile compared to opioid-based regimens [1–5].

The pericapsular nerve group (PENG) block, first described in 2018, represents a significant development in regional anesthesia for hip-related pain. It is designed to target the articular branches of the femoral, obturator, and accessory obturator nerves, which provide sensory innervation to the anterior hip capsule. This region of the capsule contains the highest concentration of nociceptors, making it the primary source of pain following hip fracture and during surgical manipulation. By precisely depositing local anesthetic in the myofascial plane between the psoas tendon and the superior pubic ramus, the PENG block can achieve profound analgesia with minimal impact on motor function, thereby enabling early mobilization and rehabilitation [6–10].

Pain management in elderly patients with hip fractures is challenging due to age-related physiological and anatomical changes. Decreased renal and hepatic clearance prolongs the half-life of many drugs, while diminished cardiac compliance and altered autonomic responses increase susceptibility to hypotension and bradycardia. Moreover, cognitive dysfunction and frailty complicate postoperative recovery, emphasizing the importance of analgesic techniques that reduce systemic sedative exposure. The PENG block provides a motor-sparing alternative that aligns with the principles of enhanced recovery and geriatric anesthesia, where maintaining hemodynamic stability and functional independence are paramount goals [11–15].

Despite its growing popularity, the PENG block remains relatively new, and its full clinical potential continues to be explored. Current evidence supports its efficacy in reducing perioperative pain and opioid requirements, but further research is needed to optimize dosing regimens, duration of analgesia, and safety protocols. The present review aims to provide a comprehensive analysis of the anatomical basis, technical considerations, pharmacology, safety, and clinical applications of the PENG block for pre- and postoperative analgesia in elderly hip fracture patients. Through an integration of anatomical insight and clinical evidence, it seeks to establish a framework for its safe and effective use in modern anesthetic practice [16–20].

Anatomical and Pathophysiological Basis of Hip Fracture Pain

The hip joint is a classic ball-and-socket synovial joint formed by the articulation of the femoral head with the acetabulum. It possesses a strong fibrous capsule, reinforced by ligaments and muscles that allow stability and wide range of motion. The joint capsule itself is richly innervated, particularly its anterior and superolateral portions, which contain a dense network of nociceptive fibers. These fibers are responsible for transmitting pain signals following capsular distension, inflammation, or mechanical trauma such as fracture. Understanding the nerve supply of the hip is crucial to designing regional anesthesia techniques that effectively block the primary sensory pathways contributing to pain in hip fractures [21–24].

The anterior capsule of the hip joint receives its sensory innervation predominantly from the femoral nerve, the obturator nerve, and, when present, the accessory obturator nerve. The femoral nerve provides articular branches that course deep to the iliopsoas muscle, while the obturator nerve contributes branches that penetrate the anteromedial capsule. The accessory obturator nerve, present in nearly half

of individuals, adds variable articular branches traversing near the iliopubic eminence. These branches converge near the anterior inferior iliac spine, creating a consistent target zone for pericapsular infiltration of local anesthetic. In contrast, the posterior capsule is supplied by the nerve to quadratus femoris and by articular branches from the sciatic nerve, which explains why posterior hip pain may persist even after anterior capsule blocks if these posterior nerves are not addressed [25–29].

Following a hip fracture, pain arises initially from periosteal disruption and capsular stretch. Periosteal nociceptors, being highly mechanosensitive, generate acute sharp pain, while subsequent inflammatory mediators induce peripheral sensitization and hyperalgesia. Persistent afferent input can also lead to central sensitization within the dorsal horn of the spinal cord, amplifying pain perception beyond the local injury site. This pathophysiological cascade is particularly deleterious in the elderly, as reduced descending inhibitory control and altered pain thresholds augment sensitivity to nociceptive stimuli. Regional techniques that interrupt nociceptive transmission early in this cascade, such as the PENG block, may therefore prevent the establishment of central sensitization and reduce the risk of chronic postoperative pain [30–34].

The anatomic foundation for the PENG block stems from detailed cadaveric and imaging studies demonstrating that the articular branches to the anterior hip capsule share a consistent spatial relationship to the iliopubic eminence and psoas tendon. This anatomic corridor provides a practical and reproducible target for ultrasound-guided needle placement. By bathing the area between the psoas tendon and superior pubic ramus with local anesthetic, the block achieves selective coverage of the relevant sensory branches while sparing the motor components of the femoral nerve located more laterally. Consequently, patients retain quadriceps strength, facilitating earlier mobilization and decreasing the risk of falls, a vital consideration in geriatric rehabilitation [35–38].

The PENG block thus represents a technique born directly from anatomical precision and an understanding of the pathophysiology of hip pain. Its focus on the anterior capsule, where nociceptive density is greatest, provides targeted analgesia with minimal motor impairment. This specific anatomical insight differentiates it from broader plexus or compartment blocks, which may induce unnecessary motor weakness. By addressing the anatomical source of pain and avoiding motor blockade, the PENG block aligns ideally with the goals of elderly perioperative care—effective pain control, early mobilization, and functional recovery [39–43].

Anatomical Basis and Sonoanatomy of the Pericapsular Nerve Group (PENG) Block

The PENG block is anatomically designed to target the pericapsular region of the anterior hip, where the articular branches of the femoral, obturator, and accessory obturator nerves converge. This region lies between the anterior inferior iliac spine (AIIS) laterally and the iliopubic eminence (IPE) medially, forming a consistent and accessible window for ultrasound-guided injection. The femoral artery serves as a reliable sonographic landmark, positioned medial to the AIIS and lateral to the pubic ramus. The local anesthetic is deposited in the myofascial plane between the psoas tendon and the superior pubic ramus, allowing the drug to spread medially and laterally to bathe the articular branches supplying the anterior capsule [44–47].

The femoral nerve contributes its articular branches near the level of the inguinal ligament, coursing deep to the iliacus and psoas major muscles. The obturator nerve, originating from the lumbar plexus (L2–L4), exits the pelvis through the obturator canal and sends articular twigs that penetrate the anteromedial capsule. When present, the accessory obturator nerve arises from L3–L4 and traverses near the IPE before supplying the capsule. These three neural contributions lie within close proximity to the psoas tendon, explaining why anesthetic injection into this plane provides broad anterior capsular coverage. The success of the PENG block thus relies on recognizing this convergence and accurately targeting the interfacial space where these branches course [48–51].

Ultrasound guidance has greatly improved the precision and safety of the PENG block. A low-frequency curvilinear probe (2–5 MHz) is generally preferred to visualize the deep pelvic structures. The probe is first positioned transversely over the AIIS, then rotated obliquely to align with the pubic ramus,

producing a characteristic image showing the femoral artery medially, the IPE centrally, and the psoas tendon anterior to the pubic ramus. The needle is inserted in-plane from lateral to medial, advancing under real-time ultrasound visualization until it reaches the plane between the psoas tendon and the superior pubic ramus. The injection of local anesthetic—typically in 5 mL increments—creates an anechoic hypoechoic spread confirming correct placement [52–55].

The sonoanatomy of the PENG block offers distinct advantages over traditional anterior hip blocks. Unlike the femoral nerve block or the fascia iliaca compartment block, which may inadvertently anesthetize the motor branches to the quadriceps, the PENG block's more medial injection plane avoids direct contact with motor fibers. This selective sensory blockade provides effective pain control for hip fracture and arthroplasty without compromising the patient's ability to perform postoperative physiotherapy or ambulation. In elderly patients, where early mobilization correlates with reduced morbidity and shorter hospital stays, this motor-sparing property has significant clinical value [56–60].

Understanding anatomical variations is critical for reproducibility. The presence or absence of the accessory obturator nerve, variations in the course of the femoral artery, or hypertrophy of the psoas tendon may influence local anesthetic spread. Preprocedural scanning allows the clinician to identify these differences and adjust needle trajectory accordingly. Awareness of these variations minimizes the risk of incomplete analgesia or vascular puncture. The combination of precise anatomical targeting and real-time ultrasound confirmation ensures both the safety and efficacy of the PENG block, making it a robust addition to modern regional anesthesia practice [61–64].

Technique of Ultrasound-Guided Pericapsular Nerve Group (PENG) Block

The PENG block is a technically straightforward but anatomically precise regional anesthesia technique. It can be performed in the emergency department, operating room, or postoperative care unit, making it highly adaptable for the perioperative management of hip fracture pain in elderly patients. The patient is positioned supine with the lower limb extended and slightly abducted. This position relaxes the iliopsoas muscle and improves sonographic visualization of the target area. A low-frequency curvilinear probe is preferred due to the depth of pelvic structures in most adults. The block area is aseptically prepared, and a sterile cover is applied to the probe before the procedure begins [65–68].

The ultrasound probe is initially placed transversely over the anterior inferior iliac spine to identify this bony landmark. It is then rotated caudally approximately 45 degrees to align with the pubic ramus. On this oblique plane, the key structures visualized from lateral to medial include the iliopsoas muscle and tendon, the iliopubic eminence, the superior pubic ramus, and the femoral artery. The target injection plane lies between the psoas tendon anteriorly and the superior pubic ramus posteriorly. A 22-gauge, 80–100 mm block needle is inserted in-plane from lateral to medial, ensuring the tip is advanced under continuous ultrasound visualization to avoid vascular puncture [69–72].

After negative aspiration to exclude intravascular placement, 1–2 mL of local anesthetic is injected to confirm the correct plane by observing separation of the psoas tendon from the pubic ramus. When an appropriate hypoechoic spread is visualized, the remainder of the anesthetic—usually 15–20 mL of 0.25–0.5% bupivacaine—is administered incrementally. Adequate dispersion along the pericapsular plane is essential for complete anterior capsule coverage. Clinically, patients often report significant pain relief within 10–20 minutes, and the sensory blockade may last 8–12 hours, depending on the concentration and agent used [73–76].

An important technical advantage of the PENG block is its reproducibility and relative safety. Unlike deeper plexus blocks, the injection site is superficial to major neurovascular structures, and the needle trajectory is easily visualized with ultrasound. Additionally, because the PENG block targets articular sensory branches rather than the femoral nerve trunk, the risk of quadriceps weakness is minimal. This characteristic is especially valuable in elderly patients, as preserved motor function promotes safer transfers and early postoperative mobilization [77–80].

To optimize outcomes, meticulous attention to detail is required during needle advancement and

injection. Excessive pressure during local anesthetic deposition should be avoided to prevent fascial disruption or misdirection of injectate. Maintaining a shallow needle angle helps ensure deposition remains in the correct myofascial plane. Following injection, continuous observation of the hypoechoic fluid spread confirms success, while post-block assessment for sensory relief and motor preservation provides functional confirmation. Standard monitoring, including heart rate, blood pressure, and oxygen saturation, should be maintained throughout and after the procedure, given the potential for systemic absorption of local anesthetic [81–84].

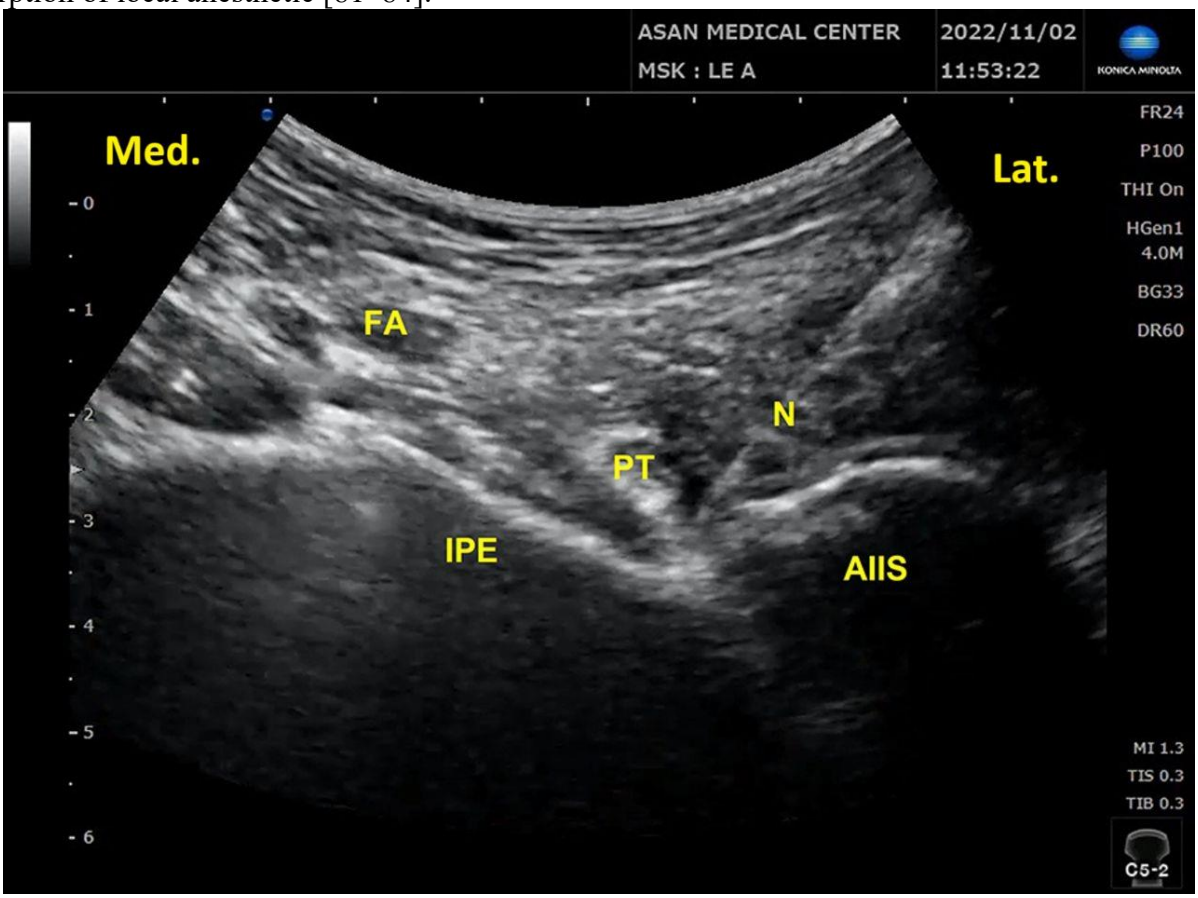

Fig. 1: Sonoanatomy of the Pericapsular Nerve Group Block. Pericapsular nerve group (PENG) block. AIIS, anterior inferior iliac spine; FA, femoral artery; IPE, iliopubic eminence; N, needle; PT, psoas tendon [77].

Indications, Contraindications, and Clinical Applications of the PENG Block

The PENG block was originally described for analgesia following hip fracture and arthroplasty, but its application has since expanded to a variety of conditions involving the anterior hip capsule. It is now widely used for preoperative pain management in patients awaiting surgical fixation of femoral neck or intertrochanteric fractures and for postoperative analgesia following hip replacement, hemiarthroplasty, or open reduction and internal fixation. The technique is also useful in managing non-surgical hip pain syndromes such as osteoarthritis, avascular necrosis, or acetabular pathology where anterior capsular nociception predominates [44, 45].

Beyond its orthopedic utility, the PENG block has gained interest in emergency and trauma settings due to its relative simplicity, rapid onset, and safety in frail or anticoagulated patients who may not tolerate neuraxial anesthesia. In elderly patients presenting with hip fractures, performing the block in the emergency department can significantly reduce pain scores before imaging or transfer to the operating room. The resulting analgesia also facilitates positioning for spinal anesthesia, which can be particularly challenging in patients with severe pain or kyphoscoliosis. Thus, the block serves both diagnostic and procedural purposes, improving patient comfort throughout the perioperative continuum [46].

Absolute contraindications to the PENG block include patient refusal, local infection at the injection site, and documented allergy to local anesthetics. Relative contraindications include coagulopathy, preexisting neuropathy, or severe deformity that distorts local anatomy. Because the PENG block is performed near vascular structures such as the femoral artery, care must be taken in patients with bleeding risk or on anticoagulants, adhering to current regional anesthesia safety guidelines. In such cases, risk–benefit evaluation should guide decision-making, as the analgesic benefit may still outweigh the procedural risk when performed under meticulous ultrasound control [45].

The PENG block complements multimodal analgesia protocols and is often used alongside acetaminophen, nonsteroidal anti-inflammatory drugs, or low-dose opioids. It can also be combined with other regional techniques, such as the suprainguinal fascia iliaca block or the lateral femoral cutaneous nerve block, when more extensive sensory coverage is required. In geriatric patients, the PENG block's selective sensory action minimizes motor blockade, reducing the risk of falls and expediting early rehabilitation. This functional preservation represents one of its most compelling clinical advantages, aligning well with enhanced recovery and geriatric anesthesia principles [47, 48].

Pharmacology of Local Anesthetics in the PENG Block (with Emphasis on Bupivacaine)

Local anesthetics used for the PENG block must provide long-lasting analgesia with a favorable safety profile. **Bupivacaine** is the most widely employed agent due to its potency, lipophilicity, and prolonged duration of action. It blocks voltage-gated sodium channels within neuronal membranes, thereby preventing depolarization and transmission of nociceptive impulses. Its high protein binding and lipid solubility enable a sustained effect, making it ideal for prolonged postoperative pain control in elderly patients who benefit from single-injection techniques that avoid frequent dosing [57, 60].

Following injection, bupivacaine is absorbed at a rate dependent on tissue vascularity and total dose. The pericapsular region, being moderately vascular, allows gradual systemic absorption that supports a steady duration of action of up to 12 hours. The agent undergoes hepatic metabolism via cytochrome P450 enzymes, producing water-soluble metabolites excreted by the kidneys. In elderly patients, both hepatic clearance and renal excretion are often reduced, increasing the potential for systemic accumulation. Therefore, careful attention to maximum dosage—generally not exceeding 2.5 mg/kg without epinephrine—is essential to avoid toxicity [58].

The onset and quality of the block depend on drug concentration and volume. For the PENG block, 15–20 mL of 0.25–0.5% bupivacaine typically achieves adequate anterior hip capsule coverage. Adding epinephrine (1:200,000) can modestly prolong duration by reducing systemic absorption, though it must be used cautiously in elderly patients with cardiac disease. Recent interest in liposomal bupivacaine formulations suggests potential to extend analgesia beyond 24 hours, but data specific to PENG application remain limited, warranting further clinical evaluation [59, 61].

Bupivacaine's pharmacodynamic characteristics—potent sensory blockade with relative motor-sparing at lower concentrations—align well with the aims of the PENG block. Unlike larger-volume plexus blocks, which may impair quadriceps strength, the PENG block uses smaller, focused volumes directed at articular sensory branches. This targeted delivery minimizes the risk of motor inhibition while providing sufficient capsular analgesia. Such precision is crucial for elderly patients, allowing pain-free mobilization without compromising muscle power, an essential determinant of recovery and fall prevention [62].

Adverse effects are uncommon when correct technique and dosage are observed. The most serious risk remains **local anesthetic systemic toxicity (LAST)**, which can manifest with neurological symptoms such as perioral numbness, tinnitus, or seizures, and progress to cardiovascular collapse. Preventive strategies include fractionated injection under aspiration, continuous patient monitoring, and immediate access to lipid emulsion therapy per ASRA guidelines. In frail geriatric patients, heightened vigilance and early recognition of subtle toxicity signs are imperative to ensure safety and maximize the therapeutic benefit of the block [69, 70].

Physiological and Pharmacological Considerations in Geriatric Patients

Elderly patients with hip fractures present unique physiological challenges that influence anesthetic management. Aging is accompanied by a decline in cardiovascular reserve, reduced baroreceptor sensitivity, and increased arterial stiffness, all of which predispose patients to hypotension during anesthesia. Diastolic dysfunction and diminished responsiveness to β-adrenergic stimulation further limit compensatory mechanisms. These factors underscore the importance of regional blocks like the PENG, which provide profound analgesia without the hemodynamic instability often associated with systemic opioids or neuraxial anesthesia [22, 24].

Respiratory function also declines with age due to reduced lung elasticity, decreased vital capacity, and impaired response to hypoxia and hypercapnia. Systemic opioids exacerbate these vulnerabilities by depressing the respiratory drive and increasing the risk of postoperative pulmonary complications. The PENG block, by offering opioid-sparing analgesia, contributes to better respiratory stability and reduced need for supplemental oxygen in the perioperative period. This effect is particularly important for patients with chronic obstructive pulmonary disease or restrictive chest wall disorders, which are prevalent among the elderly [25].

Renal and hepatic changes in geriatric patients alter the pharmacokinetics of most anesthetic agents. Reduced hepatic blood flow and cytochrome enzyme activity slow the metabolism of amide-type local anesthetics such as bupivacaine. Similarly, age-related decline in glomerular filtration rate prolongs drug elimination, increasing the risk of systemic accumulation. Dose adjustments and careful adherence to maximum recommended limits are therefore mandatory. Moreover, comorbidities such as diabetes and hypertension can exacerbate end-organ vulnerability, making a motor-sparing, low-dose regional technique like the PENG block highly suitable for this patient group [28, 32].

The aging nervous system also displays increased sensitivity to anesthetic agents. Structural and biochemical changes, including neuronal loss and reduced receptor density, may heighten susceptibility to central nervous system effects. Furthermore, the prevalence of cognitive impairment and delirium in elderly surgical patients complicates postoperative pain assessment and management. The PENG block offers a solution by delivering effective, localized analgesia without significant systemic sedation or confusion, thereby supporting clearer mental status and facilitating participation in physiotherapy [27, 40].

Finally, sarcopenia, frailty, and decreased bone density affect both positioning and recovery following anesthesia. Motor weakness induced by femoral or lumbar plexus blocks can worsen mobility and increase fall risk. The PENG block avoids these complications by sparing the motor branches of the femoral nerve while providing robust sensory blockade. This enables safe transfers and early ambulation, reducing complications related to immobility such as thromboembolism, pressure ulcers, and deconditioning. In this context, the PENG block not only improves analgesia but also aligns with the holistic goals of geriatric anesthetic care—safety, stability, and functional recovery [29, 33, 47].

Advantages of the PENG Block in Elderly Hip Fracture Patients

The PENG block offers multiple advantages that make it particularly suitable for elderly patients with hip fractures. Foremost among these is its **motor-sparing effect**, achieved by selectively anesthetizing the articular sensory branches of the femoral, obturator, and accessory obturator nerves while avoiding blockade of the femoral motor fibers. Preservation of quadriceps strength enables early mobilization, which is crucial for reducing postoperative complications such as pneumonia, deep vein thrombosis, and muscle deconditioning. For elderly patients, maintaining mobility translates directly into improved functional recovery and shorter hospital stays, making this technique a cornerstone of enhanced recovery protocols [44, 47].

Another major advantage is the **high degree of analgesic specificity**. The PENG block targets the anterior capsule of the hip joint, the region with the greatest density of nociceptors responsible for acute post-fracture pain. This focused action provides rapid and significant pain relief both preoperatively and postoperatively. Unlike systemic opioids, which produce widespread sedation, nausea, and respiratory depression, the PENG block delivers localized analgesia without systemic compromise. This specificity

enhances patient comfort, improves positioning for spinal anesthesia, and supports early participation in rehabilitation exercises after surgery [45, 46].

The **safety profile** of the PENG block further reinforces its clinical value. Because the needle trajectory and target site are visualized clearly with ultrasound, the risks of vascular puncture, intraneural injection, or local anesthetic systemic toxicity are low. Additionally, the injection site is distant from major nerves and vessels, reducing the likelihood of hematoma formation in anticoagulated patients—a common scenario in elderly populations receiving antithrombotic therapy. The block can be performed with minimal patient repositioning, an important consideration in those with pain, spinal deformity, or hemodynamic instability [65].

From a **perioperative workflow perspective**, the PENG block is practical and efficient. It can be performed in the emergency department, preoperative holding area, or operating theatre using portable ultrasound equipment. Its implementation has been associated with reduced opioid requirements, improved hemodynamic stability during positioning and anesthesia induction, and better postoperative satisfaction. This flexibility allows anesthesiologists to integrate the block seamlessly into existing perioperative pathways without delaying surgery, which is critical for optimizing outcomes in hip fracture management [46, 47].

Lastly, the PENG block aligns with the broader goals of **geriatric and multimodal analgesia**. It enables effective pain control while minimizing polypharmacy and the risk of drug interactions. When combined with non-opioid analgesics such as acetaminophen and NSAIDs, it contributes to balanced analgesia and enhances the overall quality of perioperative care. By improving pain relief, promoting mobility, and reducing systemic complications, the PENG block embodies the principles of patient-centered, functional recovery in elderly surgical patients—a paradigm shift toward safer and more effective anesthesia [48, 49].

Contextual Overview of the PENG Block Among Other Regional Techniques

The management of hip fracture pain has traditionally relied on a variety of regional techniques aimed at interrupting nociceptive transmission from the hip capsule. Among these, femoral nerve blocks, three-in-one blocks, and fascia iliaca compartment blocks have been the mainstay for decades. While these methods provide good analgesia, they often produce significant quadriceps weakness due to motor involvement, delaying postoperative mobilization. The PENG block represents an evolution from these earlier approaches, offering a more refined and anatomically targeted option that achieves equivalent or superior analgesia without compromising motor function [44, 47].

In contrast to lumbar plexus or femoral nerve blocks, the PENG block deposits local anesthetic in a pericapsular fascial plane, directly adjacent to the articular branches innervating the anterior hip capsule. This precise placement ensures selective sensory blockade while minimizing diffusion to motor nerves. Clinically, this translates to improved ability for patients to move and bear weight early after surgery—a vital aspect of recovery for geriatric patients. Furthermore, because the injection site lies more medial and deeper than in the fascia iliaca approach, the PENG block is less affected by variations in fascial continuity, resulting in more consistent analgesia for hip-specific pain [45, 48].

Another advantage of the PENG approach is its reproducibility under ultrasound guidance. The sonoanatomy of the anterior inferior iliac spine, iliopubic eminence, and femoral artery provides reliable landmarks across a wide range of body types. In elderly patients, anatomical distortions caused by muscle atrophy or prior surgery can complicate other blocks; however, the PENG block's reliance on deep bony and vascular structures that are easily visualized reduces the chance of failure. Its performance also requires smaller volumes of local anesthetic, thereby reducing systemic absorption risk, an important factor in patients with limited hepatic or renal clearance [46].

From a functional standpoint, the PENG block fits well within enhanced recovery and opioid-sparing anesthesia protocols. By achieving effective sensory blockade without the motor impairment associated with more extensive plexus blocks, it helps maintain patient independence and reduces the need for postoperative opioids. This approach not only minimizes sedation and respiratory depression but also

decreases the incidence of postoperative delirium—a key goal in geriatric anesthesia. Consequently, the PENG block stands as a refined technique that bridges the gap between efficacy, safety, and functional preservation [49].

Ongoing studies continue to evaluate the PENG block's role across surgical disciplines. Early data suggest comparable analgesic efficacy to established techniques for procedures involving the hip, yet with greater patient satisfaction and earlier ambulation. Its application is expanding to include combination protocols, where it serves as a foundation for multimodal regional anesthesia targeting the hip and proximal femur. While further research is needed to define optimal drug volumes and refine technique parameters, clinical experience supports the PENG block as a valuable addition to the anesthetic armamentarium for elderly hip fracture patients [50].

Safety Considerations and Complications

The PENG block is generally considered a safe and well-tolerated regional anesthesia technique when performed under ultrasound guidance. Its safety is attributed to both the superficial nature of the injection and the absence of direct proximity to major neurovascular structures. Nonetheless, as with all regional anesthesia procedures, complications can occur and must be anticipated. A detailed understanding of relevant anatomy, adherence to aseptic technique, and continuous ultrasound visualization throughout the procedure are essential to minimize risks. Pre-procedural scanning to identify anatomical variations, particularly in frail or cachectic elderly patients, enhances procedural safety and reliability [45, 65].

Potential mechanical complications include vascular puncture, hematoma formation, and local tissue trauma. Although the femoral artery lies near the medial margin of the ultrasound field, its location is easily identified, allowing safe needle advancement in a lateral-to-medial trajectory. Aspiration before injection should always be performed to avoid inadvertent intravascular delivery. The use of a blunt-tip echogenic needle and real-time visualization reduces the likelihood of arterial or venous injury. Infection at the injection site is exceedingly rare with standard aseptic precautions. The use of sterile gel, probe covers, and disposable needles further minimizes this risk [66, 67].

Local anesthetic systemic toxicity (LAST) represents the most serious potential complication associated with the PENG block. Because the pericapsular region is moderately vascular, systemic absorption may occur if excessive volumes or concentrations of local anesthetic are used. Elderly patients, with reduced hepatic metabolism and lower plasma protein binding capacity, are particularly susceptible. Early recognition of toxicity symptoms—such as circumoral numbness, tinnitus, or confusion—is vital. Management involves immediate cessation of injection, airway support, and administration of 20% lipid emulsion therapy as per current ASRA guidelines. Strict adherence to recommended dose limits, incremental injections with aspiration, and continuous monitoring during and after the procedure are the best preventive strategies [68, 69].

Nerve injury following a PENG block is exceedingly uncommon. Because the technique targets a fascial plane rather than a discrete nerve, direct intraneural injection is unlikely. However, inadvertent penetration of the psoas tendon or excessive pressure during injection can cause transient pain or incomplete analgesia. The use of low-pressure, incremental injections under visualization ensures accurate spread and reduces this risk. Transient quadriceps weakness has been reported in isolated cases, usually due to excessive lateral spread of local anesthetic toward the femoral nerve trunk. This can be mitigated by using lower injection volumes and maintaining the needle tip in close proximity to the iliopubic eminence [46, 70].

Overall, the PENG block demonstrates a favorable safety profile, particularly in elderly patients who often cannot tolerate the systemic side effects of opioids or the hemodynamic shifts of neuraxial anesthesia. Its use requires appropriate training, vigilance, and preparedness for rare complications such as LAST. When these standards are observed, the block provides an excellent balance between efficacy and safety, underscoring its suitability for fragile geriatric populations undergoing hip fracture repair [47, 69].

Integration of the PENG Block into Multimodal Analgesia Pathways

Modern perioperative care emphasizes multimodal analgesia—using different classes of analgesic agents and techniques to target various components of the pain pathway while minimizing reliance on opioids. In the context of hip fracture surgery, the PENG block represents a key regional component of this strategy. When integrated effectively, it complements systemic analgesics such as acetaminophen, nonsteroidal anti-inflammatory drugs, and low-dose opioids, providing synergistic pain relief with fewer adverse effects. The PENG block's capacity to selectively anesthetize the anterior hip capsule allows significant pain reduction while preserving motor function, making it ideally suited to early mobilization protocols and enhanced recovery after surgery (ERAS) programs [44, 47].

In preoperative settings, the block offers substantial benefit by enabling pain-free positioning for spinal or epidural anesthesia. Many elderly hip fracture patients struggle to tolerate flexion or lateral decubitus positioning due to severe pain. Administering a PENG block in the emergency department or induction room can greatly improve patient comfort and procedural success rates for neuraxial anesthesia. Postoperatively, maintaining this regional analgesia translates into reduced opioid consumption, lower incidence of postoperative nausea and vomiting, and a decreased risk of respiratory depression—factors that directly impact recovery quality and hospital length of stay [48].

The PENG block can also be used in combination with other regional techniques as part of a tailored analgesic plan. For example, adding a lateral femoral cutaneous nerve block provides supplementary cutaneous analgesia for lateral incisions used in hemiarthroplasty, while combining the PENG block with a suprainguinal fascia iliaca block may enhance coverage in extensive surgical approaches. These combinations must, however, respect cumulative dose limits of local anesthetics to prevent systemic toxicity. The individualized application of multimodal regional techniques aligns with contemporary anesthesia goals that emphasize safety, precision, and rapid rehabilitation, particularly in the elderly [45].

Another important dimension of multimodal integration is the block's role in reducing opioid-related delirium. Delirium remains one of the most common postoperative complications in geriatric hip fracture patients, closely linked to opioid exposure and poorly controlled pain. By providing continuous, stable analgesia, the PENG block reduces the need for systemic narcotics, thereby mitigating both delirium incidence and severity. The resulting improvement in cognitive stability supports earlier participation in physical therapy and improved long-term functional outcomes [49].

Implementation of PENG-based multimodal protocols requires structured institutional pathways, training, and interdisciplinary collaboration among anesthesiologists, orthopedic surgeons, and nursing staff. Standardized checklists, availability of ultrasound machines in emergency and orthopedic wards, and education about local anesthetic safety are essential for widespread adoption. When integrated into ERAS pathways, the PENG block not only enhances analgesic outcomes but also represents a paradigm shift toward safer, patient-centered perioperative care for the aging population [46, 50].

Postoperative Outcomes and Functional Recovery

Effective postoperative analgesia is a cornerstone of recovery following hip fracture surgery, particularly in the elderly, where pain can impede mobilization and prolong rehabilitation. The PENG block contributes significantly to early postoperative comfort by providing focused sensory blockade of the anterior hip capsule. Patients frequently report rapid pain relief, often within minutes of injection, and sustained analgesia lasting up to 12 hours depending on the agent used. This immediate reduction in pain enables smoother transfer from bed to chair, improved participation in physiotherapy, and reduced reliance on systemic opioids, which are well-known contributors to postoperative delirium, respiratory depression, and constipation in the elderly [44, 46].

Several clinical studies have demonstrated that incorporating the PENG block into perioperative care protocols for hip fracture patients leads to improved functional recovery. Patients who receive the block are more likely to ambulate earlier and require fewer rescue opioid doses in the first 24 hours after surgery. Early ambulation is a critical determinant of postoperative outcomes, as it helps prevent venous

thromboembolism, pulmonary complications, and muscle wasting. Moreover, enhanced comfort and reduced opioid exposure contribute to better sleep patterns and overall cognitive clarity during recovery, both of which are essential for rehabilitation success [45, 47].

The preservation of quadriceps strength following PENG block administration offers a key functional advantage. Traditional blocks such as the femoral or lumbar plexus blocks can cause transient lower limb weakness, delaying physical therapy initiation. In contrast, the PENG block's selective analgesia allows patients to retain sufficient muscle power to perform early mobility exercises under supervision. This feature aligns perfectly with the goals of enhanced recovery after surgery (ERAS) programs that prioritize early weight-bearing, independence, and shorter hospitalization. Improved functional independence also reduces the risk of secondary complications such as pressure ulcers and joint stiffness [48].

Beyond physical recovery, the cognitive and psychological benefits of adequate analgesia in elderly patients cannot be overstated. Pain and opioid-induced sedation are major contributors to postoperative delirium and cognitive dysfunction. The PENG block minimizes these risks by offering effective pain relief without systemic sedation, enabling clearer communication and cooperation with healthcare providers. This cognitive preservation enhances overall patient satisfaction and contributes to smoother transitions from acute hospital care to rehabilitation facilities or home environments [49].

Overall, the PENG block promotes a holistic model of recovery that extends beyond pain control. By fostering mobility, stability, and mental clarity, it directly impacts long-term outcomes such as return to baseline function and reduced institutionalization rates. As part of a multidisciplinary perioperative strategy, the PENG block represents not merely an anesthetic technique but a functional enabler—transforming pain management into an integral component of restorative care for elderly patients with hip fractures [50].

Conclusion

The pericapsular nerve group (PENG) block has emerged as a transformative regional anesthesia technique for the management of hip fracture pain in elderly patients. Its anatomic precision, ease of performance under ultrasound guidance, and selective sensory blockade make it ideally suited to the frail geriatric population, in whom maintaining mobility and physiological stability is paramount. By targeting the articular branches of the femoral, obturator, and accessory obturator nerves, the PENG block provides focused analgesia of the anterior hip capsule—the principal source of nociceptive input following hip injury—while preserving quadriceps motor strength.

Incorporating the PENG block into perioperative care pathways supports the goals of enhanced recovery and geriatric-friendly anesthesia. It enables pain-free positioning for neuraxial anesthesia, reduces perioperative opioid consumption, and minimizes adverse effects such as delirium and respiratory depression. Moreover, the technique promotes early mobilization and functional independence, factors that significantly improve overall outcomes and reduce hospitalization duration. These benefits are particularly valuable in a population at high risk for morbidity and mortality following hip fracture surgery. The safety profile of the PENG block is favorable when performed with proper ultrasound visualization and adherence to safe local anesthetic dosing. With its relatively straightforward technique and reproducible landmarks, it is accessible to clinicians across a variety of care settings—from emergency departments to operating theatres. Education, institutional support, and continued research will be essential to establish standardized protocols and optimize the use of this block within multimodal analgesia strategies. In summary, the PENG block represents an important advancement in regional anesthesia, combining anatomic accuracy with clinical practicality. It exemplifies the shift toward patient-centered, function-preserving analgesia that prioritizes recovery and quality of life for elderly patients with hip fractures. As evidence continues to expand, the PENG block is poised to become a cornerstone of perioperative pain management in orthopedic and geriatric anesthesia practice.

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