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REVIEW

The Utilization of Ultrasound-Guided Regional Nerve Blocks in Anesthetic Management for Fracture Surgery

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Abstract: Fracture surgeries are frequently accompanied by severe pain, necessitating efficacious pain management strategies to enhance postoperative recovery. Nerve block techniques, which are critical in mitigating pain, involve the targeted administration of local anesthetics to disrupt nerve signal transmission, thereby achieving significant analgesia. Traditionally, these techniques rely on anatomical landmarks and the clinician's expertise, which can introduce variability and potential risks. The adoption of ultrasound-guided nerve blocks has increased, facilitated by advancements in imaging technology. This approach enables precise placement of anesthetics through real-time visualization of neural structures and adjacent tissues, significantly improving the accuracy and safety of the procedure. This review summarizes recent advancements in the application of ultrasound-guided nerve block techniques in fracture surgeries, particularly for rib, upper limb, thoracic, lumbar, and hip fractures. By precisely placing local anesthetics, these techniques not only improve the safety and efficiency of surgeries but also significantly reduce postoperative pain and recovery time. The widespread application of ultrasound-guided nerve blocks offers an efficient and low-side-effect anesthesia management strategy, enhancing post-surgical patient experience and recovery quality.

Keywords: ultrasound-guided nerve blocks, fracture surgery, postoperative pain management, anesthetic precision and safety

Introduction

Effective anesthetic management and analgesia are foundational to the successful execution of fracture-related surgical procedures.[1] Fracture surgeries invariably involve intense pain, which, if inadequately managed, can significantly impede postoperative recovery.[2] Consequently, the selection of a reliable, efficacious, and controlled anesthetic technique is pivotal in enhancing surgical outcomes. Nerve blocks, which directly interrupt pain transmission pathways, are extensively utilized in clinical settings due to their direct impact on pain perception.[3]

Depending on the location of the fracture, different nerve block techniques, like intercostal, sciatic, or femoral nerve blocks, are commonly used. These methods work by injecting local anesthetics near specific nerve trunks, which blocks nerve signals and provides significant pain relief.[4] This approach helps manage pain during and after surgery, improves patient comfort, and supports faster recovery. However, traditional nerve block techniques often rely on anatomical landmarks and the clinician's experience, which can lead to variability and potential risks.[5]

With the integration of technological advancements, ultrasound-guided methods have increasingly been adopted to enhance the precision and safety of nerve blocks.[6] Ultrasound imaging facilitates real-time and detailed visualization of nerve structures, vascular formations, and adjacent tissues, thereby allowing for exact placement of local anesthetics.[6] This precision reduces both the required dosage of anesthetics and the risk of complications, enhancing the overall safety profile of the procedure.[7] Moreover, the consistency in analgesic effectiveness provided by ultrasound-guided techniques

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ensures a superior patient experience both during and following the surgical intervention.[8] This review will collate recent advancements and explore the application, effectiveness, and future prospects of ultrasound-guided nerve blocks in anesthesia management for fracture surgeries.

Clavicle and Upper Limb Fractures

The brachial plexus primarily consists of the anterior branches from C5 to C8 and T1, occasionally including contributions from C4 and T2.[9] With the widespread adoption of ultrasonography, new approaches and methods for continuous brachial plexus blocks (CBPB) have been developed, enhancing the traditional approaches and catheter placement techniques.[10] Currently, approaches for CBPB include interscalene, supraclavicular, infraclavicular, and axillary routes, which are selected based on the anatomical course of the nerves.[11] CBPB not only improves the efficacy of brachial plexus anesthesia but also offers distinct advantages in postoperative analgesia and pain management due to its precise analgesic effects, minimal systemic side effects, and the ability to improve local blood circulation through vasodilation.[12] It is routinely employed for the diagnosis and treatment of acute and chronic pain, pain management in upper limb vascular reconstructions or ischemic conditions, treatment of cancer pain, and management of phantom limb syndrome in the upper extremities.[13] Ultrasonography ensures accurate catheter placement, enhances the certainty of anesthesia and analgesia, and reduces the incidence of associated complications, potentially increasing patient satisfaction.[14] The effectiveness of CBPB varies with the approach used, and there is a plethora of ongoing research on its methods and clinical applications.

Ultrasound-Guided Continuous Interscalene Brachial Plexus Block for Analgesia in Shoulder and Upper Humeral Surgeries

The interscalene brachial plexus block targets the upper trunk formed by C5-C6, extending to the middle and lower trunks, offering profound analgesia particularly suitable for shoulder and upper arm surgeries.[15] This technique utilizes an ultrasound-guided anterolateral approach to accurately place the catheter, enhancing the efficacy and duration of analgesia beyond that provided by single-shot blocks.[16] Studies have demonstrated its effectiveness not only in routine shoulder surgeries but also in specialized procedures like finger reattachment and pectoralis major tendon repairs.[17]

While the classic anterolateral approach remains standard, the posterior approach has gained favor for its stability and reduced risk of catheter displacement, crucial in dynamic regions.[18] This approach navigates through deeper muscle layers, offering sustained analgesia with minimal risk of dislodgment.

Advanced Techniques in Upper Limb Anesthesia: Supraclavicular and Costoclavicular Blocks

The supraclavicular block and the costoclavicular approach are both effective techniques for providing anesthesia for upper limb surgeries, each with unique advantages and specific use cases. A randomized study compared the diaphragmatic and pulmonary functions following these blocks, showing that the costoclavicular approach preserves diaphragmatic function and pulmonary capacity better than the supraclavicular approach while maintaining similar efficacy.[19] The costoclavicular block has also shown high success rates in pediatric populations, demonstrating excellent visualization and ease of application with minimal complications.[20] Furthermore, in emergency settings, the costoclavicular block has proven to be an effective analgesic tool, providing dense, surgical anesthesia for upper extremity procedures, thereby avoiding the need for procedural sedation and reducing opioid use.[21] Meta-analyses confirm the lower incidence of hemidiaphragmatic paralysis with the costoclavicular approach compared to other brachial plexus blocks, while maintaining comparable block performance parameters.[22]

Continuous Infraclavicular and Axillary Brachial Plexus Blocks

The infraclavicular block, axillary block, and supraclavicular block each have specific advantages and considerations for upper limb surgeries. A comparative study on ultrasound-guided infraclavicular block using bupivacaine alone versus bupivacaine combined with dexmedetomidine showed that the addition of dexmedetomidine hastened the onset and prolonged the duration of both sensory and motor blocks, providing better analgesia.[23]

The supraclavicular block's effectiveness for upper limb surgeries has been enhanced by combining bupivacaine with ketamine.[24] Ketamine, known for its NMDA receptor antagonism, may reduce central sensitization and inhibit pain signal transmission.[25] When used as a perineural adjuvant, ketamine has been shown to improve the onset time and prolong the duration of nerve blocks, possibly by stabilizing nerve membranes and enhancing local anesthetic action through anti-inflammatory effects.[24] While studies indicate these benefits, the exact mechanism of ketamine in prolonging regional anesthesia remains under investigation, and its efficacy compared to intravenous administration warrants further exploration. An observational study validated the use of the perfusion index (PI) as a reliable measure for postoperative pain assessment in patients undergoing upper limb surgeries under supraclavicular block.[26] A comparison between ultrasound-guided supraclavicular and infraclavicular approaches found that the infraclavicular block had a faster onset of sensory blockade, although the block performance time was longer.[27] Additionally, dexmedetomidine added to ropivacaine in supraclavicular blocks resulted in earlier onset and prolonged duration of sensory and motor blocks, enhancing postoperative analgesia.[28]

In conclusion, ultrasound-guided continuous interscalene brachial plexus blocks emerge as the preferred choice for shoulder and upper humeral surgeries due to their enhanced stability, especially with the posterior approach which mitigates the risk of catheter displacement (Table 1). Although the interscalene nerve block remains the gold standard for shoulder anesthesia due to its superior efficacy, the use of continuous supraclavicular brachial plexus blocks is expanding in shoulder surgeries attributed to their reduced risk of ipsilateral diaphragmatic paralysis, although they demonstrate limited efficacy in managing pain for elbow and more distal surgeries compared to continuous infraclavicular blocks. Meanwhile, continuous costoclavicular brachial plexus blocks excel in providing effective anesthesia and analgesia for elbow and distal procedures, surpassing the performance of supraclavicular, infraclavicular, and axillary approaches in terms of stability and effectiveness. The continuous axillary blocks, while easy and safe, are seeing a decline in usage due

Table 1 Comparative Overview of Ultrasound-Guided Nerve Blocks Across Various Fracture Types

Fracture Type	Anesthesia Technique	Advantages	Disadvantages
Clavicle and Upper Limb	Ultrasound-Guided Continuous Interscalene Block	Profound analgesia for shoulder surgeries	Risk of diaphragmatic paralysis
	Supraclavicular and Costoclavicular Blocks	Costoclavicular approach preserves diaphragmatic function	Supraclavicular may impair pulmonary function
	Continuous Infraclavicular and Axillary Blocks	Stable analgesia, minimized risk of catheter displacement	Requires precise anatomical knowledge
Thoracic and Lumbar	Medial Branch Block	Directly targets pain centers for spine surgeries	High anatomical knowledge required
	Thoracolumbar Interfascial Plane Block	Extensive coverage for severe pain management	Risk of incomplete blockade
	Erector Spinae Plane Block	Simpler to perform, effective for thoracic surgeries	Limited data on efficacy in lumbar surgery
Hip Fracture	Lumbar Plexus Block	Prolonged pain control for extensive surgeries	Risk of kidney and intestinal injury
	Femoral Nerve Block	Reduces opioid requirement, effective pain control	May cause muscle weakness, increasing fall risk
	Fascia Iliaca Compartment Block	Long duration of analgesia, eases positioning pain	May cause hypotension before lumbar anesthesia
	Quadratus Lumborum Block	Extends analgesia, reduces opioid consumption	Variable effectiveness in different studies
	Fascia Obturator Nerve Block	Targets pain from hip to medial thigh effectively	Requires high precision and anatomical knowledge
	PENG Block	Targets pericapsular nerves effectively	Risk of inadvertent motor blockade

to anatomical constraints that affect their efficacy. CBPB remain a vital anesthesia and analgesia technique. Clinically, the choice of block technique and approach should be strategically selected based on the specific surgical requirements and patient conditions. Ultrasonography plays a critical role in enhancing the precision of catheter placement and block efficacy, significantly minimizing the potential for adverse effects and complications, thereby underscoring the need for broader clinical adoption and ongoing refinement in practice.

Thoracic and Lumbar Fractures

The incidence of lumbar spine disorders, including fractures, has risen significantly in recent years, prompting the use of invasive surgeries that often lead to severe postoperative pain, impairing physiological functions and hindering early mobilization.[29] To address this, a multimodal analgesia (MMA) strategy, incorporating various analgesic methods targeting different pain mechanisms, has become essential in managing acute postoperative pain effectively.[30] This approach, particularly regional nerve blocks, has shown considerable success in reducing complications and facilitating quicker recovery in patients undergoing surgeries for spinal fractures (Table 1).

Medial Branch Block

The anatomical structure of the posterior branches of the spinal nerves is still under active investigation. Historically, the anatomy of these nerves was not precisely described for an extended period, and most anatomical textbooks depicted the posterior spinal nerve branches as consisting of two major subdivisions: the medial and lateral branches. Kozera et al[31,32] building on a review of the literature, described the positioning and function of these branches, subdividing the posterior spinal nerve branches into posterior medial and lateral branches. Subsequently, dissections of eight cadavers from T1 to L5 confirmed that the posterior branches of the spinal nerves could consist of three primary branches: medial, lateral, and intermediate.[33] The medial branch innervates the spinous muscles and the multifidus muscles, covering the area from the midline to the zygapophysial joints; the lateral branch innervates the area corresponding to the iliocostalis muscle; the intermediate branch covers the area between the medial and lateral branches, terminating at the longissimus muscle.[34] The surgical treatment of lumbar spine disorders, including midline and paramedian approaches through the paraspinal muscles, may inadvertently damage or stimulate the posterior spinal nerve branches, leading to nerve root congestion, edema, and adhesion, which can result in postoperative muscle atrophy and subsequent lower back pain.[35] Therefore, understanding the anatomical structure of the posterior spinal nerve branches is crucial for preserving the functionality of the paraspinal muscles. Despite ongoing debates over the anatomy of these branches, considering the distribution of thoracolumbar back muscles, the notion of three main branches in the posterior spinal nerve branches appears more plausible in practical applications.

The traction and stimulation of nerve roots during surgery can directly transmit to the pain centers, causing central pain.[36] Selective blockade of the posterior spinal nerve branches at the site of injury can eliminate aseptic inflammation and interrupt pain transmission, providing effective analgesia.[37] Five cases of posterior spinal nerve branch block used in lumbar spine laminectomy and internal fixation surgery involved surgical incisions positioned at the posterior midline of the L1 to L4 vertebrae.[38] Under planar ultrasound guidance, patients in the prone position received 5 mL of 0.33% ropivacaine at each transverse process from T10 to L2, with five injections administered by moving the probe head or tail to change the needle direction without removing the needle from the skin, completing the injections at two skin puncture sites.[39] The dosage of intravenous anesthetics and inhalation anesthetics used intraoperatively was reduced, and patients did not experience pain requiring remedial analgesia within 6 hours postoperatively; no adverse reactions associated with the blockade were observed.[40] The report did not mention the impact of the blockade on postoperative analgesic medication dosage or prognosis. Considering the temporary effect of a single nerve block, a combination of local anesthetic infiltration around the surgical incision with the spinal nerve blockade can extend the effective duration of postoperative analgesia.

The clinical application of medial branch block is extensive, and apart from analgesia, it also plays a significant role in the treatment of lower back pain.[41] However, the execution of medial branch block should consider the challenges of the blockade. Ultrasound-guided blocks require high anatomical knowledge from the practitioner and care should be taken to avoid injury due to the anatomical position and course of the posterior spinal nerve branches.[42] For multi-segment surgeries, the demand for multiple block points increases the complexity of the procedure and the risk of infection. In contrast, direct visualization during nerve blocks appears safer, dependent on the surgeon, but concentrates local anesthetics around the nerves. No clear reports yet exist on the safe concentration of local anesthetics, and there is a risk of motor blockade from the infiltration of local anesthetics into the subarachnoid space. Further research is needed to explore the optimal dosage and minimum concentration of local anesthetics.

Thoracolumbar Interfascial Plane Block

The Thoracolumbar Interfascial Plane (TLIP) block, a novel interfascial blockade technique, has primarily been utilized in surgeries involving the lumbar and lower back regions.[43] Initially reported in 2015 under ultrasound guidance, the TLIP block involves the injection of local anesthetics between the multifidus and longissimus muscles' fascial planes, effectively blocking the posterior branches of the spinal nerves through fascial diffusion, thereby providing adequate analgesia for midline incisions in lumbar surgeries.[43] In subsequent years, a series of studies demonstrated that local anesthetic injections into this interfascial plane effectively block the posterior spinal nerve branches.[44,45] The bilateral TLIP block, when combined with general anesthesia, has been shown to significantly alleviate perioperative pain in patients undergoing lumbar laminoplasty, surpassing the analgesic efficacy of general anesthesia alone.[46]

However, the clinical application of TLIP blocks revealed challenges in accurately identifying the interfascial gap between the multifidus and longissimus muscles under ultrasound.[47] This led researchers to propose a modified TLIP block, which involves ultrasound-guided injection of local anesthetics between the longissimus and iliocostalis muscles. The modified TLIP block offers several advantages, including a reduced risk of spinal cord injury by changing the needle trajectory from external to internal, and easier identification of the interfascial plane between the longissimus and iliocostalis, resulting in higher success rates of puncture.[47] Subsequent studies have applied the modified TLIP block to various lumbar surgeries, such as multilevel lumbar surgery and posterior lumbar fusion, showing effective relief from static pain at 48 hours post-operation and dynamic pain at 24 hours post-operation, along with a reduction in opioid consumption at 24 hours.[48] Ueshima et al reported on the successful use of combined conventional and modified TLIP blocks in surgeries, addressing the issue of incomplete blockade often encountered with a single blockade technique.[49] The combined approach proved to be safer and easier to perform than the original TLIP block alone, suggesting its potential as a part of multimodal analgesic strategies for patients undergoing extensive lumbar surgeries.

While clinical data on TLIP block applications are sparse, primarily consisting of case reports with few complications related to the block reported, a retrospective study involving 175 cases noted only a single instance of hematoma with no reports of inadvertent vascular entry, infection, or other complications, underscoring its safety.[50] The effectiveness of TLIP blocks largely depends on adequate diffusion of local anesthetics between the muscle fascial planes; common agents used include ropivacaine, levobupivacaine, and bupivacaine.[51] Optimal volumes, concentrations, and types of local anesthetics for TLIP blocks have yet to be determined. Given its superficial injection site, the TLIP block is easy to implement and an excellent option for multimodal postoperative analgesia, particularly in patients with severe renal impairment.[52] However, as a new technique, it demands high proficiency from the practitioner to accurately identify the fascial layers under ultrasound and ensure precise injection and sufficient diffusion of the anesthetic.

Erector Spinae Plane Block

The Erector Spinae Plane (ESPB) block, guided by ultrasound, represents a novel interfascial plane blockade technique that has been gaining prominence alongside the Thoracolumbar Interfascial Plane (TLIP) block.[53] As the longest muscle in the back, the erector spinae lies adjacent to the spinal column's spinous processes.[54] Local anesthetics are injected deep into the erector spinae, where they can diffuse cranially and caudally through the potential spaces between muscles, effectively infiltrating and blocking both the dorsal and ventral branches of the spinal nerves.[55] The use of ESPB for neuropathic pain achieved favorable outcomes and observing dye diffusion to the ventral and dorsal spinal nerve branches in dissections of fresh cadavers.[56]

In the years following, the clinical applications of ESPB have expanded, being employed for postoperative analgesia in various surgeries including abdominal,[57] thoracic,[58] and breast surgeries.[59] As ESPB techniques have evolved, researchers have begun comparing ESPB with other regional nerve block techniques such as the transversus abdominis plane block for post-cholecystectomy pain management,[60] and with local anesthetic infiltration around the shoulder joint for post-arthroscopy pain control.[61] Randomized controlled trials have confirmed that ESPB provides more effective pain relief compared to other methods.[62]

There is growing clinical research on the use of ESPB for postoperative analgesia following lumbar surgery,[63,64] yet extensive clinical studies are still required to explore its effectiveness comprehensively. Under ultrasound guidance, the injection of local anesthetics between the deep erector spinae and the transverse processes of the vertebrae allows for safer and more feasible observation of anesthetic spread.[65,66] Compared to TLIP blocks, ESPB is simpler to perform under ultrasound as the transverse processes are easier to identify than the muscular interfascial gaps, where the spread of local anesthetics might be more restricted and the blockade range narrower.[67] However, both techniques lack extensive randomized controlled trial data for post-lumbar surgery analgesia, mostly limited to case reports. Experiments comparing both techniques are warranted based on their proven benefits in managing postoperative pain.[68] Furthermore, optimal protocols for the volume, concentration, and type of local anesthetics in ESPB remain undefined, necessitating extensive clinical research. There are case reports of continuous ESPB,[69] but randomized controlled trials are yet to be seen; continuous ESPB may hold potential for opioid-free postoperative analgesia in the future. For patients undergoing single-segment lumbar surgeries, ESPB could potentially serve as the sole anesthetic technique, providing effective post-incisional pain relief while avoiding the incomplete blockade associated with local anesthetics and reducing medical resource waste and costs associated with general anesthesia, significantly advancing the development of patient-centered care.[70]

Hip Fracture

In recent years, the frequency of hip joint surgeries has steadily increased, establishing it as a common orthopedic procedure.[71] A significant concern associated with these surgeries is perioperative pain, which can lead to a broad spectrum of complications, increased morbidity, and diminished overall patient satisfaction.[72] This pain not only adversely affects surgical outcomes, such as intraoperative blood pressure fluctuations triggered by nociceptive stimuli but also negatively impacts long-term prognoses and the quality of life for patients.[73] A prospective survey found that approximately 8% of patients were dissatisfied with the outcomes of total hip arthroplasty, with pain being the principal complaint, accounting for about 39% of all dissatisfaction factors.[74]

In the realm of anesthesia for hip surgeries, regional anesthesia facilitated by ultrasound-guided nerve blocks has become a recognized safe practice.[75] The primary mechanism of nerve blocks is to interrupt the pathways of pain transmission and the associated vicious cycles, thereby improving blood circulation, nourishing nerves, and providing anti-inflammatory effects.[76] Common nerve blocks utilized in hip surgeries include lumbar plexus block, femoral nerve block, quadratus lumborum block, obturator nerve block, and periarticular hip capsule block[77] (Table 1).

Lumbar Plexus Block

The lumbar plexus, composed of the anterior branches of the T12 nerve and L1 to L4 spinal nerves embedded within the psoas major muscle, not only innervates the quadratus lumborum and iliacus muscles but also gives rise to branches such as the iliohypogastric, ilioinguinal, femoral, obturator, genitofemoral, and lateral femoral cutaneous nerves.[78] These branches predominantly supply the anterior and medial aspects of the thigh, as well as the inguinal region. For lumbar plexus block (LPB), patients are typically positioned in the lateral decubitus position with the affected side up and hips and knees flexed for unilateral blocks; a prone position with a pillow under the abdomen to flatten the lumbar curvature is used for bilateral blocks. In the sagittal plane of the lumbar plexus, the ultrasound probe is placed parallel to the spine at the L3/4 spinous process level and scanned laterally.[79] The psoas major muscle can be visualized in the space between adjacent transverse processes, with the lumbar plexus located deep within it. The spacing between the index, middle, and ring fingers can help locate the three transverse processes and the intermuscular septum of the psoas major, where a high-echoic region indicates the lumbar plexus and allows for measurement of the approximate distance from the skin to the nerves, thus minimizing the risk of adverse reactions and complications associated with nerve blocks.[80] However, many clinicians consider this an out-of-plane technique that could potentially harm the kidneys and intestines.[81] On the transverse section of the lumbar plexus, the position of the abdominal muscles is initially confirmed, then the probe is slowly moved dorsally and caudally inclined until a typical cloverleaf image comprising the L4 transverse process, psoas major, erector spinae, and quadratus lumborum is observed.[82] At this point, within the posterior quarter quadrant of the psoas major, a high-echoic structure representing the lumbar plexus nerves can be seen. The probe is then stabilized, and the local anesthetic is injected 4 cm lateral to the L4 spinous process.[83] LPB offers hemodynamic stability and prolonged postoperative maintenance, making it a preferred option for patients with unstable circulation.[84] Compared to general anesthesia alone or epidural anesthesia, lumbar plexus nerve block has proven to be an effective method for controlling postoperative pain following hip joint reconstruction in cerebral palsy populations.[85] Additionally, LPB combined with infiltration anesthesia can also reduce stress responses and postoperative pain in elderly patients undergoing hip replacement, enhancing anesthetic comfort.[86] However, due to the deep placement of the lumbar plexus, the approach is prone to peritoneal injury during needle insertion and can occasionally result in unintended bilateral blocks causing epidural diffusion.[87] Besides, due to the deep placement of the lumbar plexus and the requirement for relatively large volumes of local anesthetic, there is an elevated risk of local anesthetic systemic toxicity (LAST) if the anesthetic is inadvertently injected into vascular structures.[88] Hence, although LPB provides effective analgesia in regional blocks for hip joint procedures, the operational risks and insufficient early postoperative mobility in patients necessitate further exploration of more effective blocking techniques.

Femoral Nerve Block

The femoral nerve, originating from the L2 to L4 nerve roots, descends between the psoas major and iliacus muscles, passing beneath the inguinal ligament into the femoral triangle.[89] For ultrasound-guided femoral nerve blocks (FNB), the patient is positioned supine with the affected limb slightly externally rotated.[90] The probe is placed at the midpoint of the inguinal ligament to locate a prominently pulsating artery, and the needle is inserted 1 cm laterally within the plane.[91] The femoral nerve can be identified by a high-echoic shadow lateral to the femoral artery, where the local anesthetic is administered.[92] FNB effectively alleviates pain while substantially reducing the need for opioid analgesics.[92] Chul-Ho Kim demonstrated that FNB can prevent perioperative delirium in elderly patients with hip fractures who do not have pre-existing cognitive impairments.[93] However, the blockade of the quadriceps muscles can increase the likelihood of postoperative falls, which is disadvantageous for early mobility recovery.

Fascia Iliaca Compartment Block

The iliofascial compartment represents a potential space in the inguinal region, bordered anteriorly by the iliac fascia, posteriorly by the iliacus muscle, medially by the lower lumbar and sacral vertebrae, and laterally by the inner lip of the iliac crest.[94] Within this space, branches of the lumbar plexus, including the femoral nerve, the lateral femoral cutaneous nerve, and the obturator nerve, traverse. During ultrasound-guided Fascia Iliaca Compartment Block (FICB), the ultrasound probe is positioned horizontally just inferior to the inguinal ligament, lateral to the femoral artery where the broad fascia and iliac fascia appear as two distinct high-echoic lines.[95] Special sonographic signs such as the “hourglass”, “bow-tie”, and “hill” help in rapidly locating the iliofascial space. The needle is inserted laterally to the thigh, extending 1 cm beyond the edge of the probe, using an in-plane technique from either the medial or lateral side of the femur, avoiding the femoral artery.[96] A characteristic “pop” sensation felt twice, as the needle penetrates the fascia lata and iliac fascia, indicates entry into the iliofascial space.[96] FICB can be performed via either a medial or lateral approach, with Tengchen Feng’s research on different approaches for FICB in total hip arthroplasty indicating that the medial approach provides better anesthesia, postoperative analgesia, reduced postoperative analgesic requirements, and a lower incidence of postoperative delirium compared to the lateral approach.[97] In elderly patients undergoing hip replacement surgery, FICB is typically used before spinal anesthesia to alleviate the pain associated with positioning. A study investigating pre-spinal FICB found that the Visual Analogue Scale (VAS) scores decreased from 8.02 to 2.28.[98] While FICB offers extended analgesia duration, it is noteworthy that it may reduce postoperative muscle strength and lead to hypotension before lumbar anesthesia.[14] Additionally, studies have found that FICB can effectively reduce the incidence of early postoperative cognitive dysfunction in elderly, high-risk patients undergoing hip replacement.[99] FICB not only reduces the reliance on opioid analgesics but also enhances patient satisfaction with pain management.[100]

Quadratus Lumborum Block

Depending on the injection site relative to the quadratus lumborum muscle, various approaches to quadratus lumborum block (QLB) are distinguished.[101] The lateral QLB (QLB1) involves the deposition of local anesthetic laterally to the quadratus lumborum.[102] The posterior QLB (QLB2) entails injections posterior to the quadratus lumborum muscle. The anterior QLB (QLB3), also known as the transmuscular approach, typically involves injecting at the level of the L4 vertebra, anterior to the quadratus lumborum muscle.[102] The intramuscular QLB (QLB4) consists of injecting the local anesthetic within the quadratus lumborum muscle itself.[102]

The precise mechanism by which QLB provides analgesia is not fully understood; however, it is hypothesized that local anesthetics diffuse through the thoracolumbar fascia and intrathoracic fascia into the paravertebral space to exert their analgesic effects.[103] Research suggests that QLB3 facilitates the spread of anesthesia through the medial and lateral arcuate ligaments into the thoracic paravertebral space, whereas the lumbar plexus nerves between the transversus abdominis and the psoas major are not affected.[104] During ultrasound-guided QLB3, patients are positioned in the lateral decubitus position, with a low-frequency convex probe placed perpendicularly above the iliac crest.[105] The puncture needle is inserted from the anteromedial direction through the quadratus lumborum until the tip lies between the quadratus lumborum and psoas major muscles, followed by the injection of the local anesthetic into the fascia.[105]

Moderate evidence suggests that the use of QLB in hip joint surgeries can significantly reduce pain scores and opioid consumption within the first 24 hours postoperatively, making QLB a viable option for postoperative analgesia following hip surgery.[106] However, some argue that as part of a multimodal analgesic approach, QLB does not significantly benefit patients undergoing hip replacement in terms of opioid consumption or pain scores during rest and activity, and carefully designed trials are needed to validate these findings.[107] A study evaluating the benefits of QLB in total hip arthroplasty within randomized controlled trials found that incorporating QLB with general or spinal anesthesia did not confer substantial benefits, thus not supporting the routine use of QLB as part of a multimodal analgesic regimen for total hip arthroplasty.[108]

Fascia Obturator Nerve Block

The obturator nerve, originating from the anterior branches of the second, third, and fourth lumbar nerves, descends through the psoas major muscle, traversing the obturator canal to extend to the anterior portion of the thigh.[109] This nerve is a critical component of the lumbar plexus, providing sensory and motor innervation to the medial thigh.[110] The Femoral Obturator Nerve Block (FONB) is a technique used to control pain by blocking the obturator nerve, which can be performed using either a distal or proximal approach.[111] The distal approach involves injecting local anesthetic between the pectineus and the adductor brevis muscles, or between the long and short adductor muscles, using in-plane ultrasound guidance to block the anterior branch of the obturator nerve, followed by an injection between the adductor brevis and adductor magnus to block the posterior branch.[112] The proximal approach, under ultrasound guidance, involves injecting the local anesthetic into the fascial plane between the pectineus and obturator externus muscles, effectively blocking both the anterior and posterior branches of the obturator nerve.[113] Compared to the distal approach, the proximal approach requires a smaller volume of local anesthetic and is more likely to achieve successful nerve blockade.[114]

Both FONB and the Fascia Iliaca Compartment Block (FICB) offer effective pain control for elderly patients with hip fractures Notably, FONB has been shown to provide superior pain relief compared to FICB, significantly reducing pain levels and lowering the reliance on analgesic medications.[115] These advantages highlight FONB as a valuable technique for managing pain in elderly patients with hip fractures, particularly when incorporated into a multimodal analgesic strategy.

PENG Block

The Pericapsular Nerve Group (PENG) block, first introduced in 2018 by Giron-Arango et al, represents a novel local analgesic technique primarily targeting the sensory branches of the femoral, obturator, and accessory obturator nerves that innervate the peri-capsular region of the hip joint.[116] This technique is advantageous for perioperative analgesia in hip surgeries. Under ultrasound guidance, the PENG block involves positioning the probe transversely above the anteroinferior iliac spine and moving it downward to visualize the pubic ramus, subsequently displaying the femoral artery and ilium.[117] Using an in-plane approach, the needle is advanced from lateral to medial, and local anesthetic is injected between the anterior aspect of the iliopsoas tendon and the posterior aspect of the ilium.[118] PENG can serve as an alternative to femoral or lumbar plexus blocks, mitigating the risks of quadriceps weakness associated with these blocks and increasing patient comfort due to the supine position.[119] Some studies have reported that extensive anesthetic injection during a PENG block might lead to obturator muscle motor blockade.[120] Considering the proximity of the femoral nerve relative to the iliopsoas tendon, substantial volumes of local anesthetics might diffuse superficially, inadvertently resulting in a femoral or fascia iliaca compartment block (FICB).[121] A meta-analysis comparing single-shot FNB with continuous FNB underscored the superiority of the continuous technique, enhancing the duration of analgesia and reducing opioid consumption.[122] Prado-Kittel et al conducted continuous PENG blocks by placing a catheter between the pubic ramus and the iliopsoas tendon, finding that continuous PENG provided excellent analgesia, extending pain relief to the distal femoral region.[123] However, the clinical efficacy of continuous or multi-dose PENG blocks requires further exploration. While anterior capsular innervation is the source of most hip joint-related pain, PENG blocks primarily provide analgesia to the anterior hip capsule, neglecting the posterior capsule. The posterior capsule, innervated by the nerve to the quadriceps and superior gluteal nerve from the sacral plexus, also plays a crucial role in complete analgesia of the hip joint.[124] As some scholars have recently suggested, combining PENG blocks with sciatic nerve blocks or local infiltration analgesic techniques to enhance perioperative pain management in hip surgeries may gain wider application in the future.[125]

Conclusion and Perspective

In managing shoulder and upper limb fractures, the use of continuous brachial plexus blocks (CBPB) including interscalene, supraclavicular, infraclavicular, and axillary blocks has markedly enhanced the scope and efficacy of regional anesthesia. Employing ultrasound-guided techniques has catalyzed a significant shift towards more precise, effective, and safe anesthesia practices. This has improved the specificity of nerve targeting for different fracture types, offering tailored analgesia that enhances patient recovery and comfort while minimizing systemic side effects. Each anatomical route—interscalene, supraclavicular, infraclavicular, and axillary—has been fine-tuned to optimize post-operative outcomes through targeted analgesia, thus directly impacting surgical recovery trajectories and pain management strategies. Such specificity not only accelerates patient rehabilitation but also aligns closely with personalized medical care approaches.

For thoracic and lumbar fractures, the Thoracolumbar Interfascial Plane (TLIP) and Erector Spinae Plane (ESPB) blocks stand out for their extensive coverage and deep penetration of anesthesia, crucial in managing the severe pain associated with these fractures. These newer techniques provide extensive coverage and deep penetration of anesthesia, crucial for managing the severe pain associated with spinal fractures. By diffusing anesthetic effectively across multiple layers of back musculature, these blocks facilitate comprehensive postoperative pain control, which is pivotal in promoting early mobilization and reducing the risk of long-term disability.

In emergency medicine, where rapid and effective pain management is essential, supraclavicular and infraclavicular blocks, along with ESPB blocks, are frequently utilized due to their efficacy in both pre and post-operative care for patients with fracture surgeries. These blocks are preferred for their quick onset and effective management of pain, making them particularly useful in acute settings where treatment speed is critical. This tailored approach to anesthesia for fractures across different anatomical regions not only ensures effective pain management but also supports faster and safer recovery, embodying the advancements in ultrasound-guided nerve block techniques.

As we look to the future, the trajectory of regional anesthesia is poised to leverage the ever-evolving ultrasonography technology to further enhance the precision and efficacy of nerve blocks. Anticipated advancements are expected to refine these already sophisticated techniques and introduce novel anesthetic compounds that could offer longer durations of pain relief with minimal side effects. The ongoing integration of these advanced regional anesthesia techniques into multimodal analgesia strategies is set to revolutionize pain management in orthopedic surgeries. This progression will likely lead to a significant reduction in opioid dependency, aligning with broader healthcare goals of enhancing patient outcomes, optimizing surgical recovery, and personalizing pain management strategies.

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