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Review Article

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Ultrasound-Guided Nerve Blocks for Emergency Fracture Analgesia in China: Advances and Future Challenges

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Abstract

Fractures represent a common global injury with rising incidence. Elderly patients aged ≥65 years constitute a substantial proportion of emergency fracture cases, frequently presenting with severe pain and serious complications such as fat embolism syndrome. Traditional intravenous opioid analgesia poses risks of respiratory depression and delirium, particularly detrimental in geriatric populations, while blind nerve blocks lack precision and safety. Accumulating evidence demonstrates that Ultrasound-Guided Nerve Block (UGNB), utilizing high-frequency ultrasound for real-time neural visualization, enables precise blockade, significantly reduces onset time, prolongs analgesic duration, decreases opioid consumption, and shortens emergency department length of stay. Multiple studies have validated its expanding application across diverse fracture sites, including clavicular, proximal humeral, distal radial, hip, femoral shaft, tibial/fibular, and rib fractures, offering a precise and efficient analgesic alternative that is especially valuable for elderly and high-risk patients by minimizing opioid-related adverse effects. Nevertheless, widespread clinical adoption remains hindered by inadequate procedural training and absence of standardized protocols. Future directions should emphasize interprofessional education to enhance emergency physicians' independent procedural competence and emergency management capabilities, facilitate integration into routine emergency department practice, and establish a seamless analgesia continuum from prehospital care through the perioperative period.

Keywords: Analgesia, Emergency department, Fracture, Nerve block, Ultrasound-guided

Abbreviations: GBD: Global Burden of Disease; IPE: interprofessional education; LAST: Local Anesthetic Systemic Toxicity; NRS: Numeric Rating Scale; PENG: Pericapsular Nerve Group; UGNB: Ultrasound-Guided Nerve Block

Introduction

Fractures represent one of the most prevalent injury types globally and constitute a key clinical entity in emergency department practice. The Global Burden of Disease (GBD) database demonstrates that the global incidence of fractures increased by more than one-third between 1990 and 2019, with lower limb fractures becoming the most common type [1]; domestic data similarly reveal a significant rise in the incidence of forearm and hip fractures [2,3]. Fractures are frequently complicated by serious complications such as severe pain [4] and fat embolism [5,6]; in the emergency setting, rapid and effective pain relief represents not only the primary patient need [7] but also a critical factor for subsequent treatment. Ultrasound-Guided Nerve Block (UGNB) involves the precise injection of local anesthetic around target nerve trunks or plexuses under real-time ultrasound guidance to reversibly block sensory and motor nerve conduction [8,9]. Although equipment and technical factors have limited its widespread adoption, the application value of UGNB in emergency scenarios has been increasingly recognized for its precise localization, rapid onset, and safety profile [10-14]. This article aims to systematically review the research progress and clinical experience of UGNB in emergency fracture analgesia, providing a theoretical framework and practical guidance for its scientific and standardized clinical application.

Technical Principles of UGNB and Its Advantages in Emergency Fracture Analgesia

The technical principles of UGNB are based on the differential echogenic reflection of high-frequency ultrasound (typically 5

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15MHz) within tissues of varying densities. This technology enables real-time visualization of neural structures (typically appearing as hyperechoic dots or bundle-like formations against a hypoechoic background) and adjacent vascular, muscular, fascial, and other tissues [15,16]. The puncture needle, as a hyperechoic object, displays a clearly visible trajectory under ultrasound; by adjusting the insertion angle and depth, the operator can precisely position the needle tip adjacent to the target nerve under real-time imaging guidance and observe the hypoechoic spread of local anesthetic, confirming perineural drug distribution to achieve precise blockade [17,18]. This visualization technique offers multiple advantages: ①enabling precise injection; ②avoiding injury to vital vessels and organs; and ③reducing local anesthetic consumption. Therefore, UGNB represents not merely a technological upgrade to nerve block procedures, but also significantly enhances procedural safety and precision.

Compared with traditional analgesic methods, UGNB demonstrates unique advantages in analgesia for emergency department fracture patients. Domestic studies have reported that compared with blind nerve block, UGNB exhibits a shorter onset time (11.6±2.6min vs. 17.4±3.9min) and a longer block duration (157±32min vs. 115±24min) [19]. International studies suggest that although there is no difference in anesthetic efficacy between blind nerve block and UGNB, the injection process with UGNB is more comfortable and less painful [20].

Furthermore, compared with intravenous opioid analgesia, UGNB also offers distinct advantages. Multiple studies have indicated that common adverse effects of opioids include respiratory depression, cognitive dysfunction, delirium, and gastrointestinal dysfunction [21-23]. Particularly noteworthy is that elderly patients exhibit higher sensitivity to opioids, with a significantly increased incidence of adverse reactions [24,25]; patients aged ≥65 years account for 30% 35% of emergency department fracture cases [26], and opioid use may increase the risk of falls and refracture due to delirium or excessive sedation [27]. Furthermore, both domestic and international studies have demonstrated that patients aged ≥65 years comprise up to 30 35% of fracture cases treated in emergency departments [26]. UGNB can effectively circumvent these risks, significantly reducing pain scores at 2 hours post emergency department presentation (NRS: 3.5 vs. 5.3, P=0.002), decreasing opioid consumption by 33% 40% [28], and shortening emergency department length of stay [12].

In summary, UGNB offers significant advantages in precision, efficacy, and safety, making its application crucial for optimizing emergency fracture analgesia strategies (see Table 1 for details).

Table 1: Comparative advantages of UGNB versus conventional analgesia in emergency department fracture patients.

Comparison Parameter	Ultrasound-guided Nerve Block	Blind Nerve Block	Intravenous Opioid Analgesia
Analgesic Mechanism	Precise blockade of target nerve conduction	Nerve location estimated based on anatomical landmarks	Systemic effect via blood circulation
Procedure Safety	High (real-time visualization, avoids accidental vessel/nerve puncture)	Low (no real-time guidance, high risk)	High (non-invasive)
Patient Suitability	Broad (including elderly and high-risk patients)	Limited (restricted by anatomical variations)	Limited (caution advised in elderly and high-risk patients)
Complication Risk	Low (precise technique reduces accidental injury)	High (high risk of accidental vessel/nerve puncture)	Moderate to high (risk of respiratory depression, addiction, etc.)
Ease of Procedure	Moderate (requires ultrasound equipment and training)	High (simple tools required)	High (simple intravenous injection)
Clinical Applicability	High (suitable for various fracture types)	Moderate (dependent on operator experience)	Low to moderate (unsuitable for regional blockade)

Applicability and Protocols of UGNB for Emergency Department Fracture Analgesia

The application of UGNB is based on well-defined anatomical principles: anybody region innervated by single or multiple peripheral nerves that can be clearly identified by ultrasound and offers a safe puncture pathway may serve as a target for UGNB [29,30]. Current evidence demonstrates that UGNB has been extensively applied to most common fracture types involving the upper extremity [31-45], lower extremity [46-57], and trunk [58-66], with perioperative and emergency department analgesic protocols summarized in Table 2. Overall, UGNB techniques suitable for emergency department use should be characterized by ease of performance, rapid onset, and minimal complications.

Table 2: Common fracture types by anatomic site and ultrasound-guided nerve block analgesia protocol.

Fracture site	Common types of fractures	Existing Perioperative Protocols (etc.)	Emergency Department UGNB Analgesia Protocols (etc.)
Upper Limb			
Clavicle	Mid-shaft, lateral end, medial end fractures	Supraclavicular nerve + clavipectoral fascial plane block [45]	Clavipectoral fascial plane block [43]

Proximal humerus	Surgical neck, greater tuberosity fracture	Brachial plexus block (interscalene approach) [31]	Brachial plexus block (interscalene approach) [32,33], shoulder inter-fascial plane block [34]
Humeral shaft	Mid-shaft, distal fracture	Ultrasound-guided upper trunk block [35]	Not reported
Distal humerus	Supracondylar, intercondylar fracture	Peri-humeral block [36]	Not reported
Distal radius fracture (with or without distal ulna fracture)	Colles or Smith fractures	Brachial plexus block (axillary approach [40]	Periosteal nerve block [38,39]
Hand fracture	Metacarpal, phalangeal fracture	Brachial plexus block (axillary approach) or distal peripheral nerve block (ulnar, radial, or median nerve) [41]	Ulnar nerve block (5th metacarpal fracture) [42]
Lower Limb			
Hip fracture	Femoral neck, intertrochanteric fracture	Pericapsular nerve group block (PENG) [46]	Pericapsular nerve group block (PENG) [47,48], fascia iliaca compartment block [49]
Femoral shaft fracture	Mid-shaft, distal fracture	Femoral nerve block [50]	Femoral nerve block or fascia iliaca compartment block [51,52]
Patella fracture	Transverse, comminuted fracture	Femoral + lateral femoral cutaneous + obturator + sciatic nerve block [53]	Not reported
Tibia and fibula fracture	Mid-shaft, distal fracture	Popliteal sciatic nerve block [54]	Popliteal sciatic nerve block [55]
Ankle fracture	Medial, lateral, posterior malleolar fracture	Popliteal sciatic nerve block [56]	Not reported
Foot fracture	Calcaneal, metatarsal fracture	Ankle block or popliteal sciatic nerve block combined with saphenous nerve block [57]	Not reported
Trunk			
Rib fracture	Single or multiple fractures	Erector spinae plane block [58]	Serratus anterior plane block [59,60], erector spinae plane block [61,62]
Sternal fracture	Transverse, longitudinal fracture	Parasternal intercostal plane block (PIP) [63]	Bilateral parasternal block [64]
Scapular fracture	Body fracture	Thoracic paravertebral nerve block [69]	Rhomboid-intercostal nerve block [68]
Pelvic fracture	Acetabular, pubic ramus fracture	Iliac hypogastric and ilioinguinal nerve block [70]	Pericapsular nerve group block (PENG) [66]

Table Abbreviations: UGNB: Ultrasound-Guided Nerve Block; PENG: Pericapsular Nerve Group Block; PIP: Parasternal Intercostal Plane Block

Upper Extremity Fractures

UGNB is widely applied in emergency analgesia for upper extremity fractures. As shown in Table 2, from proximal clavicular fractures (pectoralis-intercostal fascial plane block [43]) to distal radius and ulna fractures (periosteal nerve block [38,39]), validated analgesic protocols based on case reports have been established for most sites; proximal humeral fractures can also be managed with interscalene brachial plexus block [32,33] or inter-fascial plane block of the shoulder [34]. However, UGNB for mid- and distal humeral fractures remains unreported in emergency settings, and hand fractures have only been explored through isolated case reports [42], yielding weak evidence. The absence of applications in these areas likely stems from their complex innervation patterns, which often require combined block techniques, thereby increasing the difficulty of emergency implementation.

Lower Extremity Fractures

The emergency application of UGNB for lower extremity fractures is gradually expanding. For hip and femoral shaft fractures, protocols such as Pericapsular Nerve Group (PENG) block [47,48] and fascia iliaca compartment block [49,51,52] have demonstrated favorable outcomes. Tibial and fibular fractures can be directly managed with popliteal sciatic nerve block [55]. However, as shown in Table 2, direct emergency UGNB case reports for patellar, ankle, and foot fractures are still lacking. For ankle and foot fractures, combined femoral nerve block and popliteal sciatic nerve block can

achieve effective analgesia, with its feasibility confirmed by perioperative studies [67]. For patellar fractures, however, complete analgesia requires simultaneous blockade of the femoral, lateral femoral cutaneous, obturator, and sciatic nerves [53]; this complex combined block protocol may have limited practicality and applicability in the emergency setting. In summary, although emergency UGNB application for lower extremity fractures has covered hip, femoral shaft, and tibial/fibular fractures, direct evidence for patellar and ankle/foot fractures remains lacking, and the clinical practicality of combined block techniques warrants further validation.

Trunk Fractures

UGNB can now be applied to various trunk fractures ranging from ribs to pelvis. As shown in Table 2, for rib fractures, both serratus anterior plane block [59,60] and erector spinae plane block [61,62] have been applied in actual emergency cases. For sternal fractures, parasternal block represents a viable analgesic regimen [64]. Rhomboid-intercostal nerve block can be employed for emergency analgesia of scapular fractures [68-70]. Additionally, Pericapsular Nerve Group (PENG) block can also be utilized for emergency analgesia of pelvic fractures [66]. Currently, corresponding emergency UGNB analgesic protocols have been established for various trunk fractures from ribs to pelvis, demonstrating high technical maturity and strong clinical feasibility (Table 2).

Current Application Status of UGNB in Emergency Fracture Analgesia

UGNB was initially dominated by anesthesiologists for perioperative analgesia, with its application in the perioperative period having a robust evidence base and its technical feasibility widely validated [71-73]. In recent years, given its unique advantages in achieving precise and efficient analgesia, the clinical application of UGNB has progressively shifted toward the emergency department, providing a novel solution for fracture pain management in this setting. However, current domestic practice remains in its infancy, with the predominant model involving emergency departments inviting anesthesiologists to perform UGNB for analgesia via consultation [74,75]. Although studies have reported successful cases performed independently by emergency physicians (e.g., femoral nerve block for 87 cases of mid-to-distal femoral fractures) [76], such cases remain in the minority. Therefore, it can be concluded that this technology possesses substantial potential for promotion and development within the domestic emergency medicine field.

International experience demonstrates that through systematic training, emergency physicians can safely and effectively master UGNB. The American College of Emergency Physicians formally incorporated UGNB into its emergency multimodal analgesia strategy in 2021[77]. Driven by this initiative, the proportion of emergency departments in the United States implementing this technology increased significantly between 2016 and 2021 (by 16%) [11]. Concurrent data from other countries have shown similar trends: at a tertiary hospital in Pune, India during 2022 2023, only 16.4% of 274 fracture patients who received UGNB required additional analgesics, further validating the analgesic value of this technology in the emergency setting [78]. Canadian case reports have also confirmed its feasibility and effectiveness in the emergency department [79]. These international advancements provide valuable evidence-based justification and implementation paradigms for promoting this technology in China's emergency departments.

Main Challenges of UGNB in Emergency Fracture Analgesia

UGNB, as an ideal fracture analgesia technique, still faces challenges at two levels for its comprehensive promotion and routine application in the emergency department: technical proficiency and safety assurance. These challenges are particularly pronounced in the clinical scenario of analgesia for emergency fracture patients.

Technical Proficiency Level

The UGNB technique imposes high comprehensive skill requirements on emergency physicians and entails a long learning curve. This technique requires operators to possess solid knowledge of regional anatomy, precise interpretation skills for ultrasound imaging, and refined hand-eye coordination, all of which necessitate systematic training to achieve competency [80,81]. The procedural environment for analgesia in emergency fracture patients is often complicated by multiple factors, including severe pain, positional limitations (e.g., inability to lie supine in hip fracture), soft tissue swelling, and traumatic anatomical variations. This complexity places higher demands on physicians' technical proficiency. However, emergency department work itself is already high-load and high-intensity, making it difficult for physicians to allocate sufficient time for specialized skill training within their existing workload [82,83], creating a conflict between "skill demand" and "lack of training time."

Safety Assurance Level

The risks are compounded by insufficient experience in complication management and the complexity of injury patterns. Local Anesthetic Systemic Toxicity (LAST) and puncture-related nerve injury constitute potential complications of UGNB; although their incidence is low (0.04% 0.3%) [84,85], once they occur, intralipid emulsion should be administered within 5 minutes [86,87], with simultaneous airway management and circulatory support [88]. A Turkish study of 178 emergency physicians revealed relative deficiencies in LAST management training and drills: only 20.8% of physicians could correctly identify all symptoms, and over 40% had never used intravenous lipid emulsion [89]. This is not an isolated phenomenon; another study covering non-anesthesiologist physicians also showed that while 79.2% were aware of LAST risk, only 43.4% could correctly diagnose and identify the affected system [90]. These studies collectively demonstrate a general deficiency among emergency physicians in both recognition and management of such complications. In polytrauma fracture patients, seizures or

circulatory depression caused by LAST may be confused with manifestations of traumatic brain injury or haemorrhagic shock, leading to misdiagnosis and mistreatment [91]; furthermore, the neurological function of the fractured limb may already be compromised, posing a major challenge for emergency physicians to differentiate whether deficits result from block effect, puncture injury, or primary trauma [92,93].

Promotion Strategies for UGNB in Emergency Fracture Analgesia

Despite numerous challenges, direct mastery and application of UGNB technology by emergency physicians-the primary receiving clinicians-is crucial for achieving early rapid analgesia in fracture patients and improving the patient care experience. Currently, UGNB has not yet been widely implemented in emergency departments in China, but it can be gradually promoted through multi-level training and corresponding strategies. Interprofessional Education (IPE)-a teaching model emphasizing interprofessional collaboration to solve clinical problems, where learners from different specialties teach and learn from each other in shared tasks to improve collaboration and patient outcomes [94]-provides novel approaches for UGNB training and promotion.

Introducing IPE at the Residency Training Level

IPE can be integrated into teaching rounds and simulation-based education components of residency training. It is recommended that senior emergency and anaesthesiology physicians co-facilitate sessions, designing typical emergency fracture cases using high-fidelity simulators or standardized patients. During this process, anaesthesiology physicians lead UGNB technical instruction, including ultrasound anatomy identification, puncture essentials, and complication prevention; emergency physicians focus on integrating the emergency context, explaining how to rapidly assess indications, seize optimal analgesia timing, and apply the technique in complex trauma environments. Similar practices have emerged in Singapore: through designing online pre-learning plus offline training programs, 30 trainees were instructed and all passed the minimum competency assessment [95]. Through this collaboration, residency trainees can not only master the technique but also develop comprehensive clinical reasoning.

Introducing IPE at the Department Collaboration and Clinical Practice Level

At the clinical department level, deepening collaboration represents a direct pathway for UGNB promotion. Currently, the predominant model in China involves emergency departments inviting anaesthesiology consultation to perform UGNB [76,96]. However, to achieve earlier analgesia, independent operation by emergency physicians is the superior solution. Based on IPE principles, physicians from both departments should jointly develop standard operating procedures for UGNB, clarifying indications, operational protocols, complication management, and division of responsibilities. Building upon this, regular joint simulation drills should be conducted to enable team members to master the procedures thoroughly and develop seamless coordination, ultimately achieving a smooth transition from anaesthesiology-led to emergency department-independent operation.

Summary and Outlook

This study provides a systematic analysis of the application value, current practice status, and challenges of Ultrasound-Guided Nerve Block (UGNB) in emergency fracture analgesia. Although the technology faces practical difficulties during widespread implementation, including high technical requirements and insufficient experience in emergency management of complications, its advantages in providing precise and efficient analgesia have firmly established its important role in emergency fracture analgesia, particularly for elderly patients and those at high risk for opioid-related adverse effects. Looking ahead, with the refinement of standardized training systems and widespread adoption of portable ultrasound equipment, UGNB application is poised to advance into the prehospital emergency setting, establishing a seamless high-quality analgesia continuum from 'field rescue' through 'in-hospital emergency care' to 'perioperative management', thereby providing core impetus for innovation in modern emergency analgesia paradigms.

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Conflict of Interest

None.

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