Perioperative Precision Medicine
eISSN: 2957-5443

Review Article https://doi.org/10.61189/601268tfpowt

Progress of ultrasound-guided nerve block in foot and ankle arthroscopy

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Acknowledgement: This work was supported by Young Scientist Fund of National Natural Science Foundation of China (81700078) and Xuzhou Medical Key Talents program (XWRCHT20220051).

Declaration of conflict of interest: None.

Received November 5, 2023; Accepted January 30, 2024; Published June 30, 2024

Highlights

- Foot and ankle arthroscopic techniques are vital for diagnosing and treating foot and ankle disorders.
- Ultrasound-guided nerve blocks in the foot and ankle provide precise nerve selection.

Abstract

Foot and ankle arthroscopy frequently results in severe perioperative swelling and pain. The ultrasound-guided nerve block technique stands out for its ability to offer reliable and potent pain relief. This technique not only promotes early functional exercise, but also realizes enhanced recovery after surgery, which has demonstrated significant advantages in the realm of foot and ankle arthroscopy. In recent years, blocking techniques targeting different nerve planes have been reported to expand the options available for clinical use. This article primarily describes the current application of foot and ankle arthroscopy, detailing various local nerve blocks under innervation and ultrasound guidance. By doing so, this review intends to provide insights for the selection of clinical anesthesia in foot and ankle arthroscopy.

Keywords: Nerve block, ultrasound guidance, foot and ankle arthroscopy, high ankle block, sciatic nerve block

Introduction

The foot and ankle region is characterized by intricate interactions among muscles, tendons, and bones [1]. Initially, the foot and ankle arthroscopic techniques were applied to the ankle joint and then gradually expanded to small joints such as the first metatarsophalangeal joint and talar joint, as well as tendon (tendoscopy) [2]. Technological developments, alongside enhancements in arthroscopic equipment, and surgical methods, have significantly advanced the field of foot and ankle arthroscopy, which has evolved as a vital tool for both diagnosing and treating foot and ankle diseases.

Along with the increasing demand for surgery and rapid recovery, the focus on controlling postoperative pain, reducing the reliance on sedatives and opioids, and avoiding the side effects associated with spinal or general anesthesia has intensified [3, 4]. In recent years, ultrasound-guided nerve block has emerged as a noteworthy advancement in foot and ankle arthroscopy, which benefits of providing visual guidance and delivering precise analgesic effect.

Review of research progress

Innervation of the foot and ankle

The sensory and motor innervation of the foot and ankle is provided by branches derived from the sciatic nerve (SN) and femoral nerve (FN), which mainly include the tibial nerve (TN), deep

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Table 1. Optional nerve blocks for different arthroscopies

Foot and ankle arthroscopy	SNB	FNB	ACB	GPB	High ankle block	Classical ankle block	Modified deep peroneal nerve block
Ankle arthroscopy	√	√	√	√	√		
Tendoscopy	√	√	√	√	√		
Subtalar arthroscopy	√	√	√	√	√	√	
Foot mini-arthroscopy	√	√	√	√	√	√	√

Note: SNB, sciatic nerve block; FNB, femoral nerve block; ACB, adductor canal block; GPB, gastrocnemius plane block.

peroneal nerve (DPN), superficial peroneal nerve (SPN), sural nerve and saphenous nerve (SaN) [5].

The SN, recognized as the most substantial nerve in human body, emerges from the sacral plexus, and traverses the pelvis region through the inferior foramen of the pyriformis muscle, descending into the gluteal region. Proceeding beneath the gluteus maximus, the nerve intricately passes sequentially through the obturator internus, flanking the upper and lower segments of trapezius. It then aligns with the posterior boundary of the vastus muscle, eventually extending towards the lower limb, specifically to the semitendinosus, semimembranosus, and biceps femoris muscle. Before reaching the popliteal fossa, the SN divides into TN and common peroneal nerve (CPN), which innervates all the muscles of the calf and foot as well as skin sensation in the calf and foot except for the area innervated by the SaN [6]. The TN, as a direct extension of the SN, progresses along the posterior part of the calf, nestles between the layers of superficial-deep muscles, and bifurcates into the medial and lateral plantar nerves just posterior to the medial ankle. The muscular branch is distributed to the posterior calf muscle groups. The cutaneous branch encompasses the medial sural cutaneous nerve, which extends sensation to the posterior lateral calf and plantar aspect of the foot [7]. The CPN descends along the upper outer edge of the popliteal fossa, passes through the inner edge of the biceps femoris to the posterior side of the fibular head, bypasses the neck of the fibula, and then goes forward through the beginning of the peroneus longus muscle, and divides into two terminal branches, SPN and DPN. The sural nerve, formed by the conjunction of a cutaneous medial branch from the TN and a lateral cutaneous branch from the CPN, innervates the lateral border of the plantar aspect of the foot and the outer part of the heel. This includes sensory control over the lateral aspect of the foot, the lateral ankle, the posterior lateral skin of the distal third of the calf, and the sensation of the fifth toe [8].

The FN originates from the lumbar plexus, descending along the lateral border of the psoas major muscle and the iliacus muscle. It travels beneath the deep surface of the inguinal ligament to reach the femoral triangle, with a muscular branch that distributes to the anterior group of the thigh muscles, including the pubococcygeus muscle, the suture muscles, and the quadriceps muscle. The cutaneous branch distributes to the skin of the anterior femur. Its terminal branch evolves into the SaN, a pure sensory nerve that traverses through the retractor canal. Accompanying the descending genicular artery, it surfaces from beneath the medial aspect of the knee joint. Here, the SaN navigates past the adductor magnus tendon and through the vastus medialis muscle, continuing subcutaneously. It then travels along with the saphenous vein from the knee to the ankle, providing sensory innervation to the medial part of the calf and the medial part of the foot [9].

Foot and ankle arthroscopy

Foot and ankle arthroscopy enables direct visualization of the ankle, subtalar joints, and adjacent structures through small incisions, which allows targeted lesion management while minimizing postoperative pain, complications, and facilitating quicker recovery. Anesthesia and analgesia for different arthroscopic procedures involve various nerve blocks based on the innervation and ultrasound guidance (**Table 1**).

Ankle arthroscopy

The ankle joint comprises the distal ends of the tibia and fibula as well as the talus. The anterior and posterior walls of joint capsule are thin and lax, complemented by ligamentous enlargements on both sides to bolster stability. Indications for ankle arthroscopy include bone and soft tissue impingement syndromes, arthrofibrosis, arthritis, osteochondral injuries, post-traumatic ossification and free bone, chronic synovitis, ankle instability, tarsal coalition, tarsal sinus pain, and hindfoot fracture [10]. In a comprehensive review involving 150 studies, Arshad et al. highlighted ankle arthroscopy as a safe treatment with low overall complication rates and most of which are mild [11]. The standard techniques for ankle arthroscopy encompass anteromedial, anterolateral, and posterolateral approaches, with the anteromedial approach positioned posteromedially behind the tibialis anterior tendon, the anterolateral approach positioned posterolaterally to the third gastrocnemius muscle, and the posterolateral approach positioned between the Achilles tendon and the peroneal tendon [12].

Tendoscopy

Tendoscopy can be used to diagnose and treat disorders of the Achilles tendon, tibialis posterior tendon, bunion flexor tendon, and peroneal longissimus tendon, with indications for symptomatic tenosynovitis and tendon tears [13]. Stornebrink et al. evaluated surgical tendoscopy with a 2-mm diameter scope on cadaveric model of the posterior tibialis, peroneus brevis, and Achilles' tendons, and underscored tendoscopy's capability to provide a safe and efficient surgical view that was significantly less invasive compared to traditional methods [14]. For the Achilles tendoscopy procedure, patients were placed in the prone position, with surgical approaches including the posterior medial and the posterior lateral routes. The peroneal tendoscopy approach is located proximal and distal to the central region of the tendinopathy. Caution was advised during the establishment of the approach and the tendon resection process due to the risk of peroneal nerve injury [15].

Subtalar arthroscopy

The subtalar joint consists of the posterior articular surface of the talus and the calcaneus. The joint capsule is thin and lax, and surrounded by the anterior, posterior, medial, and lateral talocalcaneal ligaments. The development of subtalar arthroscopy was initially hindered by the constrained space within the joint, confining its primary usage to diagnostic purposes. However, its use has been progressively extended to therapeutic interventions. Lauf et al. after evaluating and treating 22 patients with tarsal sinus syndrome, reported that subtalar arthroscopy yielded favorable outcomes in the long-term follow-up and facilitated the motion restoration and recovery rate [16]. Furthermore, studies conducted by Rungprai et al. and Oshba et al. evaluated the outcomes of either arthroscopic or open joint fusion surgery, and found that patients who underwent arthroscopic procedures experienced shorter recovery time [17, 18].

The standard approaches for talar arthroscopy are anterolateral, central, and posterior approaches. The anterolateral approach is located approximately 1 cm anterior to the tip of the lateral ankle and 2 cm below the tarsal sinus. The central approach is located at the tip of the lateral ankle and anterior to the peroneal tendon. The posterior lateral approach can be found 1 cm below the tip of the lateral ankle and posterior to the peroneal tendon. It is important to note that establishing access through these approaches carries the risk of causing damage to the peroneal nerve branches, SPN, and peroneal tendon [19].

Foot mini-arthroscopy

Arthroscopy for the small joints of the foot has advanced with improvements in surgical equipment and innovative techniques broadening the scope of its applications while also minimizing complications. This form of arthroscopy encompasses procedures on the first metatarsophalangeal joint, the lesser metatarsophalangeal joint, tarsometatarsal joint, calcaneal dice joint, and intermetatarsal joint, with the arthroscopy of first metatarsophalangeal joint being the most widely applied [20, 21]. There are three approaches to first metatarsophalangeal arthroscopy: medial, dorsomedial, and dorsolateral. The medial dorsal and lateral dorsal approaches are localized to the medial and lateral sides of the extensor digitorum longus tendon, respectively, while the medial approach is positioned anteriorly and inferiorly to the terminal branch of the SPN [22].

Nerve blocking modalities

Sciatic nerve block (SNB)

Frequently used accesses comprise the parasacral approach, subgluteal space approach, anterior approach, and popliteal approach [23].

The hallmark para sacral SNB was first described by Mansour et al. in 1993, and involves blocking the SN distal to the sacrum's lateral edge and caudal to the sacroiliac joint [24]. This technique not only effectively block the branches of the SN, which include the TN and CPN, but also encompasses the posterior cutaneous nerve of the thigh as well as both sensory and motor functions of the buttocks. However, it is worth noting that it may produce postoperative incontinence if the parasacral approach SNB is bilateral [25]. The subgluteal space is a well-defined anatomical space between the anterior surface of the gluteus maximus and the posterior surface of the quadratus femoris. Subgluteal SNB has a superficial depth of puncture entry, allowing ultrasound to more distinctly reveal the alignment and structural features of the SN. An anterior approach to the SNB targets the nerve at the proximal thigh, with research suggesting that the optimal position for ultrasound-guided anterior SNB involves externally rotating the hip joint by 45° and flexing the knee joint by 15° or 45° [26]. The advantage of the anterior approach is that it can be performed in the lying position to minimize discomfort associated with positional changes. However, the puncture point is very close to the femoral nerve, femoral vein, and femoral artery, and attention must be paid to avoid potential damage to these related structures.

Popliteal sciatic nerve block (PSNB) is performed for SN in the popliteal region, including TN and CPN. When carrying out PSNB, it is crucial to ascertain whether the SN has branched at the puncture site to avoid incomplete block [27]. Cutaneous innervation of the medial calf is provided by the SaN, which must be blocked separately to ensure complete anesthesia below the knee. SNB combined with SaN block can provide anesthesia for the entire foot and ankle surgery. However, popliteal blocks may result in calf muscle paralysis, foot drop, and more pronounced dyskinesia than distal ankle blocks, as well as weakness of knee motion, increasing the risk of ankle sprains and inpatient falls [28].

Femoral nerve block (FNB)

The FN consists of a lumbar 2-4 anterior branch of the posterior femur within the femoral triangle. It bifurcates into anterior and posterior divisions, each further branching into muscular and dermatomal segments. FNB is usually performed after the completion of SNB. The FN is generally located in a triangular, hyperechoic area located lateral to the femoral artery, on the surface of the iliopsoas muscle, which is usually hyperechoic and roughly triangular or ovoid. When performed, FNB results in the loss of quadriceps motor function (hip flexion, knee extension), inability to straighten the calf, loss of knee tendon reflexes, dullness or loss of sensation in the anterior femoral region, and may be associated with an increased risk of postoperative falls [29]. For procedures involving the foot or medial ankle, blockade of the SaN, an extension branch of the femoral nerve is essential. Besides, it has been noted that its effect can reach the distal tibial periosteum, the medial and ventral regions of the medial ankle capsule, and, in some cases, the medial region of the talar joint capsule [30].

Adductor canal block (ACB)

The anatomy of the adductor canal has been described in detail by JÆGer et al. [31]. The adductor canal, also known as Hunter's canal or the infraspinatus canal, is located in the anterior medial third of the thigh, nestled deep within the adductor muscle layer. The canal is surrounded by the vastus medialis, vastus intermedius, vastus longus, and vastus lateralis muscles. It is a tendinous channel of about 15-17 cm in length with a roughly triangular cross-section, the anterior wall of which is the tendinous plate of the vastus lateralis muscle straining between the vastus lateralis muscle and the vastus medialis muscle, covered by the suture muscle, the lateral wall of the vastus medialis muscle, as well as the posterior wall of the vastus longus and vastus lateralis muscles. The retractor canal contains the femoral artery, femoral vein, branches of the femoral nerve and the posterior branch of the obturator nerve (especially the SaN and the nerve innervating the medial femoral muscle), as well as lymphatic vessels and loose connective tissue.

In a study comparing the anesthetic analgesic effects of ACB versus FNB combined with SNB in posterior foot and ankle surgery, Joe et al. discovered that ACB significantly preserved quadriceps strength from 30 minutes up to 2 hours postoperatively and was not inferior to FNB in terms of pain scores, need for analgesia, and duration, making it an effective alternative to FNB for patients undergoing posterior foot and ankle surgery [32]. A majority of studies of ACB have focused on arthroscopic knee surgery or total knee arthroplasty [33, 34]. Nonetheless, given its lower muscular impact compared to conventional FNB, ACB is anticipated to gain broader acceptance and application in clinical practice.

Gastrocnemius plane block (GPB)

Due to the high incidence of nerve complications, including the potential nerve injury following the PSNB, coupled with anatomical observations showing that branches of the popliteal sciatic nerve either penetrate or are adjacent to the gastrocnemius muscle, it is theorized that administering local anesthetics at on the surface of the gastrocnemius muscle can achieve a similar effect as a PSNB [35-37]. Li et al. initiated the approach by conducting ultrasound-guided planar staining on the peroneal muscles of two amputated limbs destined for incineration, and the results of the staining highlighted the common PN, the medial and lateral peroneal cutaneous nerves, as well as the TN below the peroneal muscle, successfully meeting anesthesia prerequisites [38]. Subsequently, a study involving 60 patients undergoing foot and ankle surgery demonstrated that GPB could provide good postoperative analgesia, reduce the use of opioids, and improve patient satisfaction.

Ultrasound-guided GPB is a novel approach for precise blockade of the tibial nerve, common peroneal nerve, and medial and lateral peroneal cutaneous nerves. Ma et al. suggested that postoperative analgesia for foot and ankle surgery should be provided by PSNB in combination with ACB [39]. Consequently, integrating GPB with a SaN block can offer safe and effective postoperative analgesia to patients.

Classical ankle block

An ankle nerve block involves five nerves: tibial, deep peroneal, superficial peroneal, peroneal, and saphenous [40]. The tibial nerve is found posterior to the tibial artery with block executed by positioning the probe in cross-section on the medial aspect of the calf. Ultrasound-guided techniques allow for selective blocking of the pudendal nerve while conserving the heel branch, thereby facilitating early post-operative walking. The DPN, lying superficially near the dorsalis pedis artery in the ankle, is blocked anteriorly at the anterior ankle joint in front of the tibia [28]. Located between the peroneus brevis muscle and the intermuscular septum of the distal lateral calf, the SPN emerges through the calf fascia to become the distal superficial nerve, which can be blocked either subfascially or immediately after puncturing the fascia. Furthermore, the PN, which innervates sensation in the lateral aspect of the foot, is in the same superficial fascial sheath as the lesser saphenous vein at the level of the ankle joint, and perivascular local anesthetics can be injected on either side of the lesser saphenous vein to produce an adequate block [40]. In the distal 1/3 of the calf, there is a fascial sheath encasing SaN alongside the saphenous vein. Extending from the posterior tibia to its medial side, the saphenous vein is locatable proximally and anteriorly to the ankle, permitting a focused block on the SaN [41].

Korwin-Kochanowska et al. conducted a comprehensive review including 55 randomized controlled trials and 1 systematic review for the optimal pain management regimen after bunion revision and concluded that ankle blocks were currently the preferred analgesic technique [42]. Similarly, Ravanbod et al. in a systematic review comparing the analgesic effects of local nerve blocks for bunion surgery, noted that ankle blocks were as effective as popliteal blocks in controlling postoperative pain [40, 43]. Given the impact of popliteal blocks on lower extremity motion, ankle blocks emerged as a superior choice. It should be emphasized that ankle blocks are predominantly applied in anterior midfoot surgery, with a cautionary note regarding their potential inadequacy for hindfoot procedures. If the surgery extends beyond the midfoot or requires a thigh tourniquet, studies have shown that a “double block” of the femoral and sciatic nerves can be used, which can also provide better surgical anesthesia and good postoperative pain control [9].

High ankle block

The high ankle block emerges as an advanced technique for surgeries situated around the ankle joint. For surgery around the ankle joint, SNB is widely used, but it affects calf motor function, delays postoperative functional exercise and ambulation, and poeses a higher risk of nerve injury [1, 35]. Addressing these concerns, Hofmann-Kiefer et al. proposed the concept of “high ankle block” for the first time and initially proved that blocking the SPN, SaN, and peroneal nerve through subcutaneous infiltration at a distance of 15-20 cm proximal to the ankle joint, combined with ultrasound-guided blocks of the DPN and the TN, could achieve the required nerve coverage [44]. Marko et al. shared findings at the 2023 Annual Meeting of the American Society of Regional Anesthesiology and Pain Medicine from a preliminary trial involving 17 patients undergoing foot and ankle surgery, which demonstrated noteworthy benefits in postoperative pain relief and motor recovery [45].

The high ankle block provides adequate anesthesia and pain management for ankle surgery and is less time-consuming than the distal SNB. Executed beneath the site of the “distal” SNB, this technique superiorly maintains the motor function of the lower leg, and helps to preserve ankle motion, allowing for early rehabilitation and fast patient recovery [45]. The block is particularly well suited for mild-to-moderate surgical patients who do not require delicate catheter-based long-term regional anesthesia, and the block is easy to administer and guarantees effective pain relief within the first 24 hours after surgery.

Modified DPN block

Nerves innervating below the plane of the ankle include the tibial, superficial peroneal, saphenous, peroneal, and DPNs. These nerves, often running alongside blood vessels and encased in the sheaths, navigate through confined spaces, rendering them susceptible to compression and injury [46]. Particularly, the DPN and the anterior tibial artery share a tight compartment at the front of the ankle joint, where they are prone to compression and trauma, potentially leading to anterior tarsal tunnel syndrome. Fu et al. altered the traditional DPN block site and instead used ultrasound guide to locate the dorsal pedicle artery in the proximal end of the second phalanx and metatarsal gap, and then performed a nerve block after determining that the DPN was located around the dorsal pedicle artery [47]. It was found that there was no significant difference between this block and the traditional anterior tibial block. The modified new block point could avoid narrowing the internal drug injection space and reduce the risk of compression, and the modified peroneal nerve block combined with the ankle nerve block could meet the anesthesia needs of foot surgery in the ankle plane.

Conclusion

Ultrasound-guided nerve blocks have become an important adjunctive analgesic technique for foot and ankle arthroscopy, significantly relieving patients' postoperative pain, facilitating their early functional exercise, and accelerating recovery. The foremost clinical justification for employing ultrasound guidance lies in its prowess to pinpoint the precise nerve location. By providing real-time and dynamic visualization of the needle and observation of the spread of the local anesthetic, this technique offers immediate feedback to the clinician, and therefore reduces the risk of unintentional intravascular injections and incorrect needle placement [48, 49]. The use of regional anesthesia has been promoted for its positive impact on patient comfort and safety, and advances in ultrasound technology have enabled anesthesiologists to perform more selective and precise nerve blocks.

In recent years, the concept of enhanced recovery after surgery has been widely proposed in clinical settings, emphasizing the need to minimize the preoperative wait time, incorporate perioperative multimodal analgesic programs, and carry out timely functional exercises, thus reducing the risk of complications and improving the patient recovery and satisfaction [50]. Within the framework of enhanced recovery after surgery, the precision of ultrasound-guided nerve blocks in choosing specific nerves becomes increasingly significant. Particularly for the foot and ankle procedures, understanding the relationship between the surgical site and its corresponding innervation area allows for potential substitution of higher-position blocks with sensory branch blocks. This tailored approach aims to minimize patient discomfort and expedite postoperative rehabilitation.

Author Contributions: Huanjia Xue contributed to the conception of the study and wrote the manuscript. Shengze Yang performed the analysis with constructive discussions. Guangkuo Ma performed the analysis with constructive discussions. Ziwei Xia performed the analysis with constructive discussions. Liwei Wang critically reviewed the content of the article. Kai Wang reviewed the content and provided guidance and funding.

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