Ankle blocks are routinely indicated for surgical anesthesia and postoperative analgesia of procedures involving the foot. Traditionally, ankle blocks have been performed by relying on landmark identification of nerves. The literature regarding the performance and efficacy of ankle blocks is inconsistent. This can be attributed to several variables, such as provider technique, differences in patient populations, and the type and volume of local anesthetics administered. As with other peripheral nerve blocks originally performed using landmark technique, ultrasound imaging is now being incorporated into these procedures. Ultrasound guidance provides the anesthetist with several advantages over landmark techniques. The ability to identify peripheral nerves, view needle movements in real-time, and observe the spread of local anesthetic has been shown to result in greater block efficacy, even with reduced volumes of local anesthetic. Additionally, ultrasound imaging gives the provider the option to perform regional anesthesia in specific patient populations not considered possible when using landmark technique. Despite the limited literature on ultrasound-guided ankle blocks, outcome metrics seem to be consistent with those of other peripheral nerve blocks performed using this technology.

Keywords: Ankle blocks, landmark nerve identification, ultrasonography, ultrasound, ultrasound-guided blocks.
not so efficacious. McLeod et al found that 16% of patients required rescue analgesics and 11% described postoperative pain as severe. Palmisani et al reported a 17% failure rate of ankle blocks performed for hallux valgus surgery. Russell et al found pain scores acceptable in their study of outpatient surgery of the forefoot. However, 8% of the study patients required block augmentation during the case, and 80% required oral analgesics in the postoperative period (first 24 hours), with 5% receiving intravenous administration of opioids. Singh et al investigated whether the timing of ankle block using ALG would influence efficacy. Conducting a prospective, randomized study, the authors demonstrated that when performed following inflation of the tourniquet, ankle blocks were more efficacious postoperatively than those done before inflation.

As with numerous other peripheral nerve blocks traditionally accomplished with ALG, ankle blocks are now described in the literature using ultrasound guidance (USG). Ultrasound (US) imaging affords the provider 3 advantages over landmark technique: (1) the ability to determine the location of nerves, (2) real-time needle visualization, and (3) observation of local anesthetic spread. Reduced volumes of local anesthetic, increased efficacy, shorter procedure times, and greater patient satisfaction using US in the performance of other peripheral nerve blocks are reported in numerous studies.

Despite the paucity of literature involving US-guided
ankle blocks, the outcome metrics appear consistent with other US-guided peripheral nerve blocks.

**Ultrasound Technique**

Ultrasound-guided ankle blocks are performed with the patient in either the supine or prone position. The lower extremity can be either supported under the calf or positioned off the stretcher to provide greater access to the ankle as required when blocking the sural and tibial nerves. A high-frequency, linear array transducer (≥ 9 MHz) is used when performing US-guided ankle blocks, because the nerves are usually superficial (< 2 cm) to the skin. (The Table contains a list of definitions for commonly used US terms.)

Peripheral nerves in the ankle appear as small, circular, bright echogenic structures (hyperechoic) with brightness mode (BMode) US and are best visualized when the US beam is perpendicular to them. However, because peripheral nerves rarely course consistently parallel to the skin surface, tilting the transducer may improve visualization.

Except for the superficial peroneal nerve, nerves in the ankle are in close proximity to arteries and/or veins. In contrast to nerves, blood vessels are anechoic and appear as dark circles with BMode US, making them easy to identify. This contrast provides a good reference point for nerve identification. A tourniquet placed at the proximal tibia will dilate veins, facilitating their identification. Additionally, blood flow in a vessel can be confirmed using color flow Doppler ultrasonography. Once the nerve is visualized next to the corresponding vessel, it can be reliably blocked by achieving circumferential spread with as little as 3 mL of local anesthetic (Figure 2).16

Air artifact encountered during these blocks is due to the limited surface area and bony prominences of the ankle. A high-frequency, linear array transducer with a smaller footprint will eliminate this artifact. Some authors have described using a low-frequency (5-MHz), curvilinear transducer to facilitate transducer-to-skin contact17; however, image resolution is greatly reduced (Figure 3). An assistant is helpful in maintaining external and internal rotation of the lower extremity during tibial and sural nerve blocks, and in injecting local anesthetic while the provider obtains an in-plane image of the needle with US.

The tibial nerve provides most of the sensation to the foot, and blocking it is critical for providing sufficient anesthesia and analgesia. The tibial nerve is the larger of 2 terminal branches of the sciatic nerve in the proximal popliteal fossa. It courses distally through the popliteal fossa beneath the popliteal fascia, taking a posterior and medial path between the gastrocnemius muscles to the ankle. At the level of the ankle, it lies behind the posterior tibial artery and veins, and between the tendons of

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Anechoic</td>
<td>A structure that does not generate an echo when contacted by an ultrasound beam and the sound continues through it unimpeded</td>
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<tr>
<td>Brightness mode (BMode)</td>
<td>Ultrasound technology in which echoes generated from sound-tissue interaction are used to create images on a gray scale</td>
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<td>Curvilinear transducer</td>
<td>Ultrasound imaging device in which the transmitting surface is curved</td>
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<tr>
<td>Doppler ultrasonography</td>
<td>Ultrasound technology that uses a change in frequency as a result of motion between the sound source and receiver; a positive shift results when the source and receiver are approaching each other, and a negative shift occurs when they are moving away from each other</td>
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<tr>
<td>Echogenic</td>
<td>Degree to which a structure generates an echo when it interacts with sound</td>
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<tr>
<td>Herz (Hz)</td>
<td>Unit of frequency; 1 cycle per second</td>
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<tr>
<td>High-frequency ultrasound</td>
<td>Ultrasound frequencies greater than 7 MHz</td>
</tr>
<tr>
<td>Hyperechoic</td>
<td>A structure that has a high degree of reflectivity when contacted by an ultrasound beam, such as bone or fascia</td>
</tr>
<tr>
<td>Hypoechoic</td>
<td>A structure that has a low degree of reflectivity when contacted by an ultrasound beam, such as blood or adipose tissue</td>
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<tr>
<td>In-plane</td>
<td>Ultrasound-guided needle technique in which the entire length of the needle is viewed during the procedure</td>
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<tr>
<td>Linear transducer</td>
<td>Ultrasound imaging device in which the transmitting surface is flat</td>
</tr>
<tr>
<td>Low-frequency ultrasound</td>
<td>Ultrasound frequencies less than 7 MHz</td>
</tr>
<tr>
<td>MHz</td>
<td>Abbreviation for megahertz (1 million cycles per second)</td>
</tr>
<tr>
<td>Out-of-plane</td>
<td>Ultrasound-guided needle procedure in which only the tip of the needle is viewed during the procedure</td>
</tr>
<tr>
<td>Transverse view</td>
<td>Cross-sectional image of anatomical structures</td>
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Table. Ultrasound Terms
the long flexor muscles of the toes and great toe. Several branches emerge from the tibial nerve at the level of the medial malleolus, most notably the medial and lateral plantar nerves that provide innervation to the sole of the foot. In addition, the medial calcaneal nerve provides sensation to the heel.

With the patient supine and slight external rotation of the lower extremity, a high-frequency, small-footprint transducer is placed in a transverse orientation just superior to the medial malleolus. The nerve appears as a hyperechoic circle just inferior to the posterior tibial artery and veins (see Figure 2). Doppler ultrasonography can be used to verify the location of the artery. As the scan is performed cephalad, the nerve becomes larger and more easily identifiable. Once all anatomical structures are located and the US image is optimized, a block needle is inserted using an in-plane technique, posterior to the vessels at the cephalad portion of the medial malleolus. A minimum volume of local anesthetic is injected so that circumferential spread around the nerve is achieved.

Several authors describe improved outcomes when performing tibial nerve blocks with USG. Redborg et al showed greater efficacy and patient satisfaction when tibial nerve blocks were performed with US imaging. However, the US-guided blocks took almost twice as long to perform (159 vs 79 seconds) and required more needle redirections to complete the procedure. Soares et al found that as little as 2 to 5 mL of local anesthetic was sufficient to achieve blockade as long as circumferential spread was achieved.

The deep peroneal nerve is a branch of the common peroneal nerve. The common peroneal nerve is the smaller of 2 terminal branches of the sciatic nerve in the proximal popliteal fossa. As it travels distally below the knee,
it takes a lateral path around the head of the fibula, then divides into the superficial and deep peroneal nerves. The deep peroneal nerve courses between the anterior tibial muscle and the long extensor muscle of the great toe into the ankle. At the level of the ankle, it lies lateral to the anterior tibial artery and medial to the long extensor muscle of the great toe. It is responsible for innervating the short extensors of the toes, providing sensory innervation to the skin on the lateral side of the hallux and medial side of the second digit.

With the patient in a supine position, a high-frequency, linear array transducer is placed in transverse orientation on the anterior aspect of the ankle at the level of the extensor retinaculum.\(^2\) The deep peroneal nerve appears as a small hyperechoic circle adjacent to the anterior tibial artery. However, because of its small size, the deep peroneal nerve is often difficult to discern from surrounding tissue. Once all anatomical structures are identified, the US image is optimized (Figure 4). Using an out-of-plane technique, local anesthetic is deposited near the nerve. Antonakakis et al\(^{20}\) noted that if the nerve is not visualized, local anesthetic should be deposited just lateral to the artery. The injection of 5 mL of local anesthetic with US substantially improved onset time of the block, and no significant difference in motor function, temperature, or pinprick sensation was seen compared with ALG.\(^{20}\) However, as the sural nerve offers only a small contribution to the forefoot, it is procedure specific. Coe and Ram\(^4\) completed a series of 30 ankle blocks that excluded the sural nerve, finding that in patients undergoing surgery medial to the third toe, excellent pain relief was achieved in all cases.

The sural nerve is composed of branches from the tibial and peroneal nerves. The medial sural nerve is a branch of the tibial nerve that travels between the heads of the gastrocnemius muscle, then becomes superficial halfway down the calf. At this point, it joins with the sural communicating nerve, a branch of the common peroneal nerve, before traveling superficially behind the lateral malleolus of the ankle. The sural nerve provides sensation to the posterior portion of the heel and sole of the foot, as well as part of the Achilles tendon above the ankle.

Redborg et al\(^{21}\) created a protocol for blocking the sural nerve at the ankle with US. The patient is placed in the prone position, and a tourniquet is applied around the proximal tibia to distend the lesser saphenous vein. A high-frequency, linear array transducer is placed in a transverse orientation 1 cm proximal to the lateral malleolus (Figure 5), and the lesser saphenous vein is imaged in cross-sectional view. No attempt is made to locate the sural nerve. The needle is inserted using an out-of-plane technique with the primary goal of achieving circumferential spread with 5 mL of local anesthetic around the lesser saphenous vein. Using this method on 18 healthy volunteers, the authors demonstrated that USG results in a more complete and longer-lasting sural nerve block than with ALG.\(^{21}\) However, as the sural nerve offers only a small contribution to the forefoot, it is procedure specific. Coe and Ram\(^4\) completed a series of 30 ankle blocks that excluded the sural nerve, finding that in patients undergoing surgery medial to the third toe, excellent pain relief was achieved in all cases.

The saphenous nerve is the terminal branch of the femoral nerve and courses subcutaneously along the medial aspect of the lower leg below the knee. At the ankle, it follows the greater saphenous vein distally along the anterior aspect of the medial malleolus. It provides sensory innervation to the medial aspect of the lower extremity below the knee, ankle, and part of the forefoot.

With the patient in the supine position, the lower extremity is slightly externally rotated. The transducer is placed in transverse orientation approximately 10 cm proximal to the medial malleolus, with the greater

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**Figure 4. Ultrasound-Guided Deep Peroneal Nerve Block**

Left: Lower extremity is positioned off the stretcher, and the transducer is placed in transverse orientation on the anterior aspect of the distal tibia. Right: Flow through the anterior tibial artery (A) appears as a red circle using Doppler ultrasonography. Deep peroneal nerve (DP) appears as a small, bright (hyperechoic) circle just lateral to the artery. Often it is difficult to discern the DP. In this instance, local anesthetic should be deposited just lateral to the artery. Once the injection begins, the nerve often becomes more apparent. (Right image courtesy of Virginia Commonwealth University, Department of Nurse Anesthesia.)
The saphenous vein used as a landmark. A tourniquet can be placed on the proximal calf to better visualize the vein. The saphenous nerve appears as a small hyperechoic structure medial to the vein (Figure 6). The needle is inserted medial to lateral for an in-plane technique, or the needle can be inserted using an out-of-plane technique. A total of 3 to 5 mL of local anesthetic is injected until circumferential spread is achieved.

As with the sural nerve, the saphenous nerve provides limited sensory innervation to the foot and can be excluded for certain procedures. In a prospective study using US-guided ankle blocks for hallux valgus surgery, López et al. examined the contribution of the saphenous nerve and found that 97% of patients would not have benefited from a saphenous nerve block.

The superficial peroneal nerve provides cutaneous innervation to the dorsum of the foot and toes. It is a branch of the common peroneal nerve that courses laterally along the tibia to the ankle. With use of US, the transducer is placed in a transverse plane approximately

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**Figure 5. Sural Nerve Block**
Left: Lower extremity is placed on a foam bolster with slight internal rotation, creating greater access to perform the block. Some authors advocate performing this block with the patient in the prone position. Right: Sural nerve (SN) is a small, bright (hyperechoic) circle inferior to the lesser saphenous vein (LSV), which appears blue with Doppler ultrasonography. A tourniquet applied to the proximal calf will distend the vein making it easier to visualize. Because of limited sensory innervation of the lateral foot, the sural nerve block may not be indicated for every procedure.

(Right image courtesy of Virginia Commonwealth University, Department of Nurse Anesthesia.)

**Figure 6. Saphenous Nerve Block Using an Out-of-Plane Technique**
Left: Lower extremity is elevated on a foam bolster, and slight external rotation allows more access to perform the block. Right: Saphenous vein (SV) is identified using Doppler ultrasonography. Saphenous nerve (N) appears as a small hyperechoic circle medial to the SV. A tourniquet applied to the proximal calf will distend the vein, making it easier to identify. Because of limited sensory innervation to the medial aspect of the foot, the saphenous nerve block may not be indicated for every procedure.

(Right image courtesy of Virginia Commonwealth University, Department of Nurse Anesthesia.)
5 cm proximal to the lateral malleolus. The superficial peroneal nerve appears as a small hyperechoic structure in the subcutaneous tissue superficial to the fascia in the prominent groove created by the peroneus brevis longus and extensor digitorum longus muscles that lead to the fibula (Figure 7). Because the nerve is not located near vascular structures and it is small, imaging with US is not always possible. At present, there are no studies comparing the efficacy of US-guided superficial peroneal nerve blockade and the ALG technique, and traditional infiltration ALG is advocated by some authors.

Discussion
In most studies comparing USG with ALG for ankle blocks, efficacy appears to be superior, block onset faster, and patient satisfaction greater when USG is used. However, not all authors corroborate these results. Fredrickson et al compared low-volume USG and high-volume landmark technique ankle blocks, finding that although US-guided ankle blocks provided a high block success rate, they were associated with marginally inferior analgesia during the next 24 hours. In their study, USG was performed with a low-frequency curvilinear array transducer to identify the adjacent vascular structures and not the nerves themselves, and the superficial peroneal nerve was blocked using subcutaneous infiltration.

Currently there is only one large retrospective study investigating the clinical efficacy of US-guided ankle blocks. In a review of more than 700 patients who received either unilateral or bilateral ankle blocks, Chin et al showed that successful surgical anesthesia was more likely achieved using USG compared with ALG.

Patients who had ankle blocks with USG were less likely to require supplemental local anesthesia, undergo an unplanned general anesthetic, or require supplemental fentanyl. These findings involved blocks performed mostly by trainees (80%), inferring that USG improves clinical efficacy compared with traditional ALG, especially in the hands of less-experienced practitioners.

Other practitioners have used USG to perform ankle blocks in unique circumstances that would not have been possible using landmark technique. Schober et al demonstrated the benefits that needle visualization afforded with US imaging when performing a US-guided ankle block on a patient with “stone man” syndrome, fibrodysplasia ossificans progressiva, requiring the resection of bone and soft tissue secondary to osteomyelitis. Minimal trauma to skeletal muscle and connective tissue in these patients may induce ectopic bone formation; therefore, regional anesthesia is often contraindicated in this population. However, in this case the authors used USG in a patient with distorted anatomy due to skeletal malformation and osteomyelitis-induced swelling so that they could identify structures and successfully perform the ankle block with minimum trauma.

Conclusion
Peripheral nerve blocks performed with USG allows the anesthetist to determine the location of peripheral nerves, visualize needle movements in real-time, and observe local anesthetic spread, providing greater management options. Additionally, the volume of local anesthetic injected around each nerve can be reduced, increasing the safety profile of these procedures. In nearly all studies, USG results in increased efficacy, decreased postop-
ervative analgesic requirements, and increased patient satisfaction. Authors have demonstrated the versatility of USG in special circumstances where regional anesthesia would otherwise not be indicated. Although procedure times and needle redirections can be greater, these do not appear clinically significant and should not be seen as a contraindication to using US imaging when performing ankle blocks.

REFERENCES

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