Images in Anesthesia

Cadaveric ultrasound imaging for training in ultrasound-guided peripheral nerve blocks: lower extremity

THIS Images in Anesthesia feature demonstrates the image quality obtainable from scanning the lower extremity of a cadaver in order to facilitate ultrasound-guided peripheral nerve blocks (PNB). Training methods to improve the performance of ultrasound-guided PNB are required, but have yet to be standardized.¹ A novel approach is to use cadaveric model simulations, which provide the learner with anatomic examination and the ability to practice nerve blocks in a stress-free environment without time constraints and the potential for patient discomfort. Cadaveric ultrasound imaging can also help the learner of these techniques to acquire an in-depth knowledge of the relevant regional anatomy in order to facilitate successful identification of nerve structures under ultrasound guidance, and to acquire expertise and confidence in performing these blocks.² Dissections can be performed to confirm nerve or blood vessel identity whenever uncertainty exists (e.g., small nerves of the periphery). The cadaver model can also be used to acquire the critical skills necessary to accurately align the needle and probe to ensure visibility of the entire needle,^{3,4} while tracking or following the needle to the target nerve.⁵

In order to successfully practice these needle insertion techniques, it is beneficial to have a knowledge of the ultrasonographic anatomy of both cadavers and living patients. This imaging article serves as a guide for this important initial process. A recently-published companion Images in Anesthesia feature demonstrated the similarities of ultrasound images obtained from cadaveric and live subjects, and identified the relevant regional anatomy and clinical issues for upper extremity blocks.⁶ Here, we consider these issues for the most common nerve blocks of the lower extremity, namely those of the femoral and sciatic nerves.

Ultrasound images (MicroMaxx, SonoSite Inc, Bothell, WA, USA; HFL38 13-6MHz linear probe for femoral and popliteal and C60 5-2 MHz curved probe for sciatic) were obtained from the lower extremity of a male adult cadaver (embalmed six months previously in the usual manner⁶ at the authors' institution) and were compared with the images from a living adult male. The cadaver was in legal custody of the Division of Anatomy of the authors' institution at the time of the imaging. The embalming and imaging procedures were performed with permission from the Division of Anatomy and in compliance with the institutional ethical standards for the use of human material in medical education. Ethics approval was obtained from the local Institutional Research Ethics Board for ultrasound scanning on the volunteer (one of the authors).

Gaining an appreciation of the correlation between ultrasound appearance and histological findings of muscles and tendons is important for interpreting ultrasound images. Silvestri *et al.* reported that nerve fascicles generally appear hypoechoic, where the hyperechoic background usually represents the connective tissue within and surrounding the nerves (including the bright adipose tissue).⁷ The connective septa surrounding the muscles is also hyperechogenic, as is the fascia of the compartmental membranes.⁸ This difference in echogenicity is likely due to the higher acoustic impedance of the denser connective tissue. In the periphery, the nerves tend to appear more hyperechoic which may be due to relatively more connective tissue than nerve tissue (i.e., fewer fascicles in periphery than centrally). However, the distinction between fascia and connective septa or perimysium will be challenging in most cases.

There are several common elements related to the accompanying images. With many portable ultrasound

FIGURE 1 Ultrasound images of the femoral artery and nerve at (a) the profunda femoris artery branch off site and (b) the inguinal crease. Arrowheads: nerve; FA and FV = femoral artery and vein. The femoral nerve appears slightly brighter than the surrounding muscle tissue and abuts the fascial tissue superficially.

systems such as the one reported here, a specific frequency cannot be selected, as the system automatically adjusts frequency depending on the depth of scanning. The number in the lower right corner of each ultrasound image represents the tissue depth of beam penetration, and display of the needle is limited to the clinical images to highlight potential technique, with probe alignment similar to that used clinically. Needles were not used during the scanning process since the purpose was to illustrate the initial scanning performed for anatomical overview and nerve localization, rather than scanning during the block. Indeed, the needle may have caused a disparity between images of the cadaver and the healthy live subject. All photographs of the sciatic nerve blocks were taken with the patient in the left lateral decubitus position.

Femoral nerve block (Figure 1)

The probe for this block is positioned to capture the transverse axis of the femoral nerve in the proximal

thigh, approximately 2–3 cm inferior to the inguinal ligament and along the inguinal crease. It is sometimes difficult to determine the exact location of the inguinal ligament due to anatomic distortion or obesity, and in these cases we recommend using a “traceback” approach to identify the nerve adjacent to the femoral artery. This involves movement of the ultrasound probe cephalad (from above the mid thigh) along the course of the femoral artery until the profunda femoris branch becomes visible and re-unites with the femoral artery (Figure 1a). This junction usually occurs about 4 cm inferior to the inguinal ligament.⁹ By adopting this traceback approach and commencing with the needle positioned at or above the origin of the profunda femoris artery, optimal needle placement can be achieved to within 4 cm from the inguinal ligament.

In both cadaveric and live subjects (Figure 1b), the femoral nerve appears about 1 cm lateral and deep to the large, circular and anechoic (black) femoral artery. Despite the inability to use a colour Doppler in the

FIGURE 2 Ultrasound images of the sciatic nerve deep within the gluteal region. Arrowheads = nerve; GMM = gluteus maximus muscle.

cadaver for confirming the identity of the artery and vein in this region, the vessels are clearly distinguishable from the surrounding tissues in the ultrasound image. The hyperechoic (bright) and distinct linear pattern of the deep connective tissue (presumably fascia lata) is also easily identifiable in both images, immediately superficial to the neurovascular structures. In contrast, the fascia iliaca separating the nerve and vessels was difficult to visualize clearly in these subjects. The femoral nerve appears somewhat triangular in cross section in the live subject, but has an oblong shape in the cadaver. Of note, a large clot was present in the femoral artery of the cadaver.

Sciatic nerve block

The large sciatic nerve traverses deep within the gluteal region and may be difficult to locate using currently available portable ultrasound systems. Each block location described below has useful landmarks that can be identified during ultrasound scanning to help confirm the nerve's identity. In general, images (e.g., field of view) of the sciatic nerve block regions vary considerably from one subject to another depending on the scanning angle, the amount of subcutaneous tissue, the degree of pressure applied to the probe, and indeed whether the probe is of linear or curved array. In addition, scanning in the gluteal and subgluteal regions generally requires a lower frequency probe (2–5 MHz) to allow deeper tissue penetration (i.e., reduced resolution) of the ultrasound beam. The combination of these factors sometimes makes recognition of the target structures in these ultrasound images quite challenging.

Gluteal approach (Figure 2)

Initial scanning in both cadaveric and live subjects with cephalad and caudad movements of the probe in the mid-gluteal region (proximal to the classical Labat's landmark-based block site) localizes the ischium (body or spine) as a hyperechoic line with shadowing underneath. After locating the widest portion of this bone and placing it at the medial edge of the image, the sciatic nerve is seen in the middle of the screen, overlaid by the bulky, more uniformly hypoechogenic gluteus maximus muscle.

The greater trochanter of the femur appears laterally. The nerve appears predominantly hyperechoic (bright), with few internal echoes, and is relatively wide and flat on its short axis. Both images confirm that the nerve appears with limited delineation and clarity at this deep location.¹⁰ Although not used here, a colour Doppler can be helpful (depending on probe angle and patient size) in confirming the identity of the nerve by illuminating the inferior or superior gluteal arteries which lie medial to the nerve.¹⁰ In addition, the tissues of the cadaver were compressed in this region, necessitating the use of a large quantity of gel in order to maintain adequate skin-probe contact.

Subgluteal approach (Figure 3)

The highly hyperechoic bony structures, the ischial tuberosity medially and the femur (presumably the greater trochanter) laterally, with their underlying dense hypoechoic shadows are useful landmarks for localization of the sciatic nerve at this location. These bones can be identified with broad scanning and the nerve will be found at approximately the midpoint

FIGURE 3 Ultrasound images from scanning the subgluteal region. Arrowheads = nerve.

of a line joining these two landmarks (depending on probe angle and patient size, both bones do not always appear in the scan with the nerve). The lower gluteal region of the cadaver was compressed and flattened with large folds at this location, and the tissues had to be firmly manipulated for smooth contact with the probe. When it is difficult to localize the sciatic nerve in this region, it is very useful to utilize a “trace-back” approach in which the sciatic nerve is traced proximally (‘backwards’) from its point of bifurcation at or near the apex of the popliteal fossa (Figure 4).¹¹ Consideration should be given to the fact that the bifurcation of the sciatic nerve may be quite proximal in some cases.

Posterior popliteal block site (Figure 4)

Scanning the popliteal fossa to locate the sciatic nerve is most successful when using a proximal ‘traceback’ approach.¹¹ This includes initial identification of the tibial and common peroneal (fibular) nerves at the popliteal crease (where they are superficial and in close relation to the popliteal vessels) and subsequently scanning cephalad towards the sciatic nerve bifurcation. Placement of the probe transversely over the skin surface of the popliteal fossa allows easy identification of the popliteal blood vessels in both the cadaver and live subject. The round hyperechoic tibial nerve can be identified lying near the midline, superficial and lateral to the popliteal artery and vein. The common peroneal (fibular) nerve is vaguely identifiable in both subjects lateral to the tibial nerve. Scanning proximally, the ultrasound image changes sequentially from showing a distinct common peroneal (fibular) nerve laterally and tibial nerve medially, to one displaying a

single bilobular structure, and finally to an image of the large and oval hyperechoic sciatic nerve (b and c). The nerves often contain small internal hypoechoic areas (fascicles) interspersed between hyperechoic (fascia and adipose) connective tissues.⁷ At the mid-posterior thigh, the belly of the biceps femoris muscle may be seen lying superficial to the nerves, and appearing as a larger, hypoechoic oval-shaped structure with fewer internal punctuate areas than in the nerves; this is more evident in the cadaver. The typical changes in the neurovascular relationships are evident in both the cadaver and live subject during the distal-to-proximal scan: both vessels become deeper and farther away from the tibial nerve, while the common peroneal (fibular) nerve merges towards the tibial nerve, forming the sciatic nerve.

In conclusion, ultrasound imaging of the relevant anatomy for simulated PNBs of the lower extremity in cadaveric specimens provides image quality similar to that obtainable from live subjects. Cadaveric imaging may thus be very beneficial for those learning ultrasound-guided anatomic correlates, as well as various scanning and needling techniques. Not all block locations (e.g., subgluteal, axillary) possess ideal imaging characteristics, but most will be suitable. Fresh cadaveric specimens may provide several advantages over conventional preparations, particularly as their higher water content may improve image quality due to the optimal echogenic properties and easy manipulation of the tissue. Given the high resolution which can be obtained with currently-available portable ultrasound machines, nerve, bone and blood vessels can all be reasonably well visualized, even in the suboptimal conditions of the embalmed cadaver. Thus, in our opinion,

FIGURE 4 Ultrasound images during a proximally-directed scan from the popliteal crease (a), to a mid-popliteal location (b), and finally at the traditional block location at the sciatic nerve bifurcation (c). Arrowheads: nerves; T and CP = tibial and common peroneal nerves; PA and PV = popliteal artery and vein. The picture in the middle of (b) is a magnetic resonance image of the live subject at the same level as the ultrasound scan.

the cadaver model presents an effective educational tool for teaching approaches to PNBs of the lower extremity, either in small group settings in the anatomy laboratory, or at larger workshops. Increasing the specialty's repertoire of teaching models and strategies

for PNBs will be essential for the training of residents during the coming years, given the unprecedented speed of technological advances in the field of regional anesthesia.

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