Clinical Sonopathology for the Regional Anesthesiologist

Part 1: Vascular and Neural

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Abstract: The use of ultrasound to facilitate regional anesthesia is an evolving area of clinical, education, and research interests. As our community’s experience grows, it has become evident that anesthesiologists performing “routine” ultrasound-guided blocks may very well be confronted with atypical or even pathologic anatomy. As an educational resource for anesthesiologists, the following articles present examples of common sonopathology that may be encountered during ultrasound-guided regional anesthesia. This present article describes sonopathology related to blood vessels and nerves.

(Reg Anesth Pain Med 2010;35: 272–280)

When an anesthesiologist scans a patient with ultrasound during the performance of a peripheral nerve block, there is a distinct possibility that a “textbook image” will not be present. Nerves and key reference structures may be hard to distinguish from surrounding soft tissues. There are many potential reasons for this including the laws of physics (e.g., artifacts), incorrect machine settings, musculos of patient anatomy, incorrect scanning techniques, and pathologic conditions. Many of the educational objectives and training efforts occurring on national and international levels focus on image optimization through “anatomy” issues and scanning techniques. However, little information exists in the literature describing abnormal findings that may be encountered during the conduct of ultrasound-guided regional anesthesia (UGRA). Such pathology or atypical anatomy as seen with ultrasound is referred hereon as sonopathology.

This 2-part article presents a collection of sonopathology that was acquired during a 7-year period at 5 separate institutions. Part 1 addresses common pathologic conditions affecting the tissues most central to UGRA; that is, blood vessels and nerves. Part 2 describes important pathology related to surrounding structures including the viscera and subcutaneous tissues. The information can be considered an extension of the content offered in the 2 articles previously published on ultrasound-related artifacts.7 The primary objective was to expand the educational resources available to anesthesiologists participating in UGRA. The cases and discussions provided in the article will hopefully support the notion that anatomic variation and pathology do occur and will be encountered within the context of our scope of practice. The authors do not support the use of ultrasound as a mass screening examination by anesthesiologists. We recognize that not every case presented in the article will be seen or be relevant to all practitioners. We do believe, however, that the identification of abnormal tissue or challenging anatomy presents a distinct opportunity for anesthesiologists to alter the anesthetic plan, contribute to the medical care of the patient, and potentially avoid certain complications.

VASCULAR

Blood vessels are commonly used as landmarks for UGRA. Short-axis imaging of blood vessels reveals round anechoic structures that are either pulsatile (arteries) or compressible (veins). Blood vessels are generally easy to identify and the target nerve(s) usually lie in close proximity. Vascular lesions, however, can create difficulties for the anesthesiologist either by impeding the intended needle trajectory to the nerve or by displacing the nerve.3 Both intervascular and perivascular pathology may be encountered during preprocedural scanning. Color Doppler imaging complements 2-dimensional findings and can help to determine patency, vessel narrowing, and perturbations in blood flow. The identification of vascular pathology may have important implications for anesthetic management.

Atherosclerosis

Atherosclerosis affects up to 10% of the Western population older than 65 years, although the true incidence is difficult to quantify because it is often asymptomatic. Up to 10% of adults older than 80 years have greater than 50% carotid artery stenosis.9 The carotid bifurcation, the most common site for carotid plaques, occurs at the level of the thyroid cartilage. Plaques are often calcified and, therefore, may create distinct acoustic dropout shadows (Fig. 1). Some plaques may be hypoechoic and only noticeable if there is an area absent of color flow within the vessel circumference. Plaques that appear echolucent are lipid-rich, whereas echogenic plaques have a higher content of fibrous tissue and calcification. Diagnostic scanning for plaques is generally performed using vascular long-axis imaging to search for a stenotic lesion along the length of the vessel. Short-axis scanning, as is performed for interscalene blocks, still allows for detection of an eccentric plaque. In the lower limb, the superficial femoral artery (Figs. 2 and 3) is the most common location for atherosclerosis, with popliteal arteritis being less prevalent.3
Carotid thrombosis can complicate a preexisting atherosclerotic plaque, as seen in Figure 4. Of note, the thrombosis is not fully appreciated until the operator transitions from the short-axis view (Fig. 4A) to the long-axis view (Fig. 4B). Arterial thrombosis tends to appear homogenous and hypechoic. However, thrombosis is usually less echogenic than calcified plaques. This difference is clearly evident by comparing Figures 1 and 4B.

Figure 5 is an example of a Doppler phenomenon called aliasing. Aliasing can be identified when using color Doppler in areas of stenosis that generate turbulent and high-velocity flows. Aliasing appears as a mosaic of colors representing flow that exceeds the scale set on the ultrasound machine. Aliasing can be a distinct clue that there is vascular pathology present.

Formal quantification of vascular stenosis by ultrasound is highly accurate and involves standard 2-dimensional imaging, analysis of Doppler waveform, and blood velocity measurements. Ultrasound can also provide information on plaque morphology, giving insight into the risk of embolism (ie, mobile plaque).

The incidental detection of both femoral and carotid arterial plaques has already been reported during scanning for femoral and interscalene nerve blocks, respectively. In each instance, the anesthetic and/or surgical management was altered. Figure 1 is an example of a carotid plaque incidentally found during the performance of an interscalene block. The detection of this lesion in a hypertensive patient scheduled for shoulder surgery resulted in cancellation with a view to improving blood pressure control and arranging a formal investigation. The case later proceeded with invasive arterial monitoring, strict perioperative blood pressure control, altered patient positioning, and the use of intraoperative electroencephalography monitoring. In another example, on detecting a femoral artery plaque in a patient presenting for total knee arthroplasty, it was jointly decided by the surgery and anesthesia teams not to use a tourniquet during the procedure.

The most useful (and simplest) clue for the anesthesiologist indicating the presence of vascular pathology is the identification of a hypechoic area within the lumen of a blood vessel that is associated with a dropout shadow. If a dropout shadow is noted, consider changing the machine settings from a musculoskeletal application to a vascular-specific setting and lowering the gain to help reduce artifactual speckles within the vessel lumen. These adjustments may help to exclude a false-positive
FIGURE 5. Long-axis view demonstrating the obstruction to blood flow in the internal carotid artery causing aliasing on color Doppler. Aliasing can be a sign that indicates turbulent and high-velocity flow associated with a stenosis. This carotid artery is also being analyzed with pulse wave Doppler. Pulse wave Doppler simply measures blood flow velocity at a particular point, as indicated by the cursor on the screen that the operator could move. The velocities instead of being mapped with color (color Doppler) are presented as a spectral display (bottom part of image). In such a spectral display, the x-axis is time and the y-axis is velocity in centimeters per second (cm/sec).

Diagnosis of a vessel lesion. Also, long-axis imaging of suspected vascular pathology will provide more information than the standard short-axis view.

Deep Venous Thrombosis

The venous drainage system of the lower limb consists of the superficial (great and small saphenous veins) and the deep (lateral, peroneal, popliteal, and femoral veins) systems, connected by perforating and transcutaneous veins. The occurrence of deep venous thrombosis (DVT) varies between particular patient populations. The femoral and popliteal deep veins are commonly imaged by radiologists and can contain acute thrombus. Classically, a venous thrombus presents (in short-axis) as a non-compressible and often dilated circle of variable echogenicity. There will likely be an absent or obstructed blood flow. Sonographic findings will change depending on the age of the thrombosis. In general, a fresh thrombus is hypoechoic and homogeneous with an associated dilated, incompressible vein. A chronic thrombus may shrink and become more hyperechoic and heterogeneous.

The incidental finding of a DVT during ultrasound scanning for regional anesthesia has already been documented. In 1 case, an inferior vena cava filter was inserted before surgery. Figure 6 demonstrates a dramatic thrombosis of the common femoral vein as seen in long-axis imaging. This DVT

FIGURE 6. Long-axis image demonstrating a large thrombus extending from the superficial femoral vein to the common femoral vein. CFV indicates common femoral vein; PFV, profundus femoral vein; SFV, superficial femoral vein.

FIGURE 7. Doppler analysis of the same patient as in Figure 6. This image demonstrates obstruction to blood flow as suggested by color Doppler. The large thrombus is evident, extending from the superficial to the common femoral vein.

FIGURE 8. Venous thrombus in the SFV. Notice the lack of vessel compressibility and absent blood flow with Doppler analysis. Lack of dynamic compressibility with the transducer during ultrasound analysis is considered a hallmark of a DVT.

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has extended proximally from the superficial femoral vein to the common femoral vein. Doppler analysis can help confirm the lack of blood flow secondary to an obstruction (Fig. 7). Noncompressibility (Fig. 8) or intraluminal echogenicity are features of DVT that will likely be most evident during scanning for regional anesthesia. If suspicion exists that a thrombus is present, scanning with color Doppler may be helpful in identifying obstruction to or absent blood flow. The anesthiologist must be mindful of the limitations and artifacts related to color Doppler. Most importantly, the Doppler equation precludes the detection of blood flow when the angle of incidence of the ultrasound beam is 90 degrees. Further, when analyzing low-velocity structures such as the superficial femoral vein, the velocity scale should be turned down. In the case provided (Fig. 7), the scale was set at 11 cm/sec to evaluate venous flow. In the case of the carotid artery, velocity scales will need to be set higher (30 cm/sec) to help prevent aliasing (see above).

Aneurysms

Excluding the aorta, the reported incidence of peripheral aneurysms in hospitalized patients is only 0.007%. However, peripheral aneurysms most commonly occur in the popliteal artery as shown in Figure 9. The femoral artery, visualized when locating the femoral nerve, is less frequently involved with aneurismal disease. Aneurysms are saccular or spindle-shaped
dilatations of the vessel lumen. Ultrasound examination is the initial investigation of choice and can reveal information on diameter, as well as the presence of thrombosis. False or pseudoaneurysms occur in up to 4% of cases after percutaneous transluminal angioplasty. Aneurysms can be differentiated from other perivascular hypoechoic structures such as hematoma, seroma, or lymphocele by the bidirectional "to and fro" flow through the neck of the aneurysm, as visualized best by color Doppler.\(^{15}\)

**Elevated Central Venous Pressure**

The internal jugular vein is commonly imaged during brachial plexus blockade above the clavicle. Raised central venous pressure occurs in a variety of pathologic conditions and may be noticed in the internal jugular or even subclavian vein during an interscalene or supraclavicular block. Figure 10B is an example of a dilated subclavian vein that is looping anterior to the supraclavicular brachial plexus in a patient with tricuspid regurgitation, chronic right-sided heart failure, and elevated central venous pressure. Given that the transducer was positioned in the supraclavicular fossa, a supraclavicular nerve block would be technically challenging, with a higher risk of vessel puncture, hematoma formation, and possible intravascular injection. It should be noted that in the standard view for a supraclavicular block (as in this example), the subclavian vein is usually not visualized.

**FIGURE 11.** Unintentional puncture of a branch of the subclavian artery. The needle is seen through and through a structure believed to be the transverse cervical artery. This puncture resulted in a postsupraclavicular block hematoma that was controlled with compression. SA indicates subclavian artery, and the triangles mark the long-axis view of the transverse cervical artery. The arrow indicates the needle puncturing the transverse cervical artery.

**FIGURE 12.** Atypical location of the brachial plexus. This image depicts the brachial plexus in the midneck crossing directly through the anterior scalene muscle. Notice that the "empty" interscalene groove is located just posterolateral to the actual nerves. The anesthesiologist recognized this variant anatomy and performed the injection into the anterior scalene muscle. AS indicates anterior scalene muscle; BP, brachial plexus (roots); MS, middle scalene muscle.

**FIGURE 13.** "Rainbow" arrangement of the supraclavicular brachial plexus. This is a short-axis image of the subclavian artery (SA), pleura, and the first rib. In this patient, the neural structures (likely the divisions and cords) are seen surrounding the subclavian artery in a rainbow-like fashion. That is, they are located on either side (medial and lateral) as well as superiorly. Arrows indicate the individual neural elements. Classically, the brachial plexus lies lateral to the subclavian artery (Fig. 10A). The authors believe that the appreciation and identification of such neural variation will likely improve the quality of the block.

**FIGURE 14.** Atypical femoral nerve. This is a case of the femoral nerve that appears to be embedded in the iliohypogastric muscle. Classically, the femoral nerve is an oval structure that is found under the fascia iliaca and adjacent to the iliohypogastric muscle. It would be reasonable to conclude that an injection extramuscular may result in a suboptimal block. FA indicates femoral artery; FI, fascia iliaca; FN, femoral nerve; IPM, iliohypogastric muscle.
Anatomic Variants

Neural anatomic variants are commonplace, potentially undermining the success of UGRA. For example, the anatomy of the upper nerve roots of the brachial plexus is anomalous in 13% to 35% of cases. Figure 12 demonstrates neural tissue directly penetrating the anterior scalene muscle of an 80-year-old man presenting for a rotator cuff repair. Of note, the interscalene groove has no neural tissue present and is easy to identify past anterior to the anterior scalene muscle.

The resurgence in popularity of supraclavicular blockade and the recent description of the "corner-pocket" ultrasound-guided technique rely on the normal location of the divisions of the brachial plexus immediately lateral to the subclavian artery and above the first rib. Anomalous nerve locations can compromise the success and safety of ultrasound-guided supraclavicular techniques (Fig. 13). Variations in the anatomy of the cords and nerves relative to the axillary artery are also well recognized.

Reports of anomalous nerve anatomy in the lower extremity are less common, possibly reflecting the scope of modern regional anesthetic practice. Nonetheless, Figure 14 demonstrates a case of what we believe to be the femoral nerve embedded in the iliofemoral muscle. Classically, the femoral nerve divides into the anterior and posterior divisions below the inguinal ligament. Descriptions, however, do exist of this branching occurring more proximally, above the inguinal ligament. In 1 cadaver study, psoas or iliacus muscle slips were noted to cover the femoral nerve in 7.9% of cases.

Inflammatory Neuritis

Compressions by hematoma or trauma from a retractor are the most common causes of perioperative inflammatory neuritis, but other mechanisms include sepsis and intraoperative limb positioning. The incidence of femoral nerve palsy after total hip arthroplasty is less common than sciatic nerve injury, and this has been reported to be 0.7%. Figure 15 depicts a femoral

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NERVES

Ultrasound can now rival magnetic resonance imaging as an imaging modality for peripheral nerves. Nerves can be hypoechoic or hyperechoic depending on the nature of the surrounding tissue and the amount of connective tissue within the nerve itself. Most often, a honeycomb pattern is evident in short-axis view, with hypoechoic nerve fascicles surrounded by the echogenic epineurium. A variety of relatively common pathologies such as axillary neuropathies, nerve compression, nerve entrapment, neurologic disorders, infections, tumors, and anatomic variants may be encountered during the conduct of UGRA. If intrinsic or extrinsic nerve abnormalities are encountered, an alternative anesthetic management should be considered because neural pathology is a contraindication to nerve blockade. Perioperative nerve injury is a complex and multifactorial process. The use of ultrasound guidance does not necessarily prevent or reduce the incidence of nerve injury.

![Image of femoral neuropathy](image1)

**FIGURE 15.** Femoral neuropathy. These are short-axis images of femoral nerve that come from the same patient. Normal right-side femoral nerve. B, Swollen and left femoral nerve. This patient sustained a dramatic right femoral neuropathy after a total hip revision on the left side. An injury was noted on ultrasound examination by a radiologist t a comprehensive diagnostic evaluation. The dotted white line outlines the femoral nerve as seen by the radiologist. The decision where to draw this line may seem arbitrary to some readers. However, the line drawn was based on the observed presence of a fascicular pattern (internal morinchnal circles). This pattern is clearly evident within the ing and absent adjacent to it.

![Image of femoral anatomy](image2)

**CULAR ANATOMY**

It should be noted that normal anatomic variation in blood vessels can also create an obstacle to needle insertion and cause block placement. Examples of typical vascular anomalies that may impede typical needle approaches would include the dorsal scapular artery and the transverse cervical artery in the brachial plexus blocks above the clavicle. In the forearm, the lateral femoral circumflex artery can be a venous to avoid during the performance of femoral nerve blocks. Figure 11 depicts an unintentional puncture of what was thought to be a large transverse cervical artery during a scapular nerve block. This puncture resulted in a postprocedure hematoma that was controlled with compression. This case underscores the importance of conducting a preprocedure scan or Doppler.

![Image of femoral block](image3)

**FIGURE 16.** Swollen sciatic nerve. This is a short-axis image of an enlarged sciatic nerve with swollen fascicles in a patient with a diabetic peripheral neuropathy. The image was acquired approximately 5 cm proximal to the popliteal crease. The anesthetic plan for this patient was a combined sciatic and proximal saphenous nerve block to act as a surgical anesthetic for a below-the-knee amputation. The anesthesiologist recognized the abnormal nerve before the injection. However, given the potential morbidity of a general anesthetic (secondary to the patient's severe cardiopulmonary disease), the decision was made to proceed with the block. The decision where to draw the nerve outline is supported by the same process as described for Figure 15. In addition, the hypoechoic adipose tissue surrounding the sciatic nerve clearly demarcates the border of the neural tissue.
nerve of a patient who developed a left-sided femoral nerve palsy after a total hip arthroplasty. The nerve appears swollen and enlarged, particularly when compared with the contralateral side. Postoperatively, the patient developed a dense motor deficit of the quadriceps muscle, as well as sensory loss in the anterior thigh and knee. It is important to note that this patient did not receive a femoral nerve block.

If an abnormality in the target nerve is suspected, scan the contralateral side as a control. If swelling or distorted architecture is identified, there is significant chance that the nerve is abnormal. Careful thought should be given to altering the anesthetic plan. Figure 16 demonstrates an enlarged sciatic nerve as imaged 5 cm proximal to the popliteal crease in a patient with diabetes with known peripheral neuropathy. In this image, swollen fascicles are noted with a grossly abnormal diameter. Given this patient's severe coexistent cardiopulmonary condition, a decision was made to still proceed with the nerve block as a surgical anesthetic for a below-the-knee amputation.

Nerve Tumors

Peripheral nerve tumors are infrequent in comparison with other primary neurologic tumors. Indeed, malignant tumors have an incidence of only 0.1 per 100,000. Both schwannomas and neurofibromas can be detected by ultrasound, although it is difficult to distinguish between these 2 pathologies. In both cases, hypochoic masses may be seen originating from the nerves, sometimes with posterior acoustic enhancement. Figure 17 represents a dramatic example of a large schwannoma originating from the sciatic nerve in the popliteal fossa. In this particular patient, the anesthesiologist was requested by the surgeons to help identify an incision site that would provide direct access to the middle of the tumor.

Neurofibromas can sometimes have hypoechoic tissue layers, which, when alternating with hypoechoic layers, create a "target" sign. Other masses such as hemangiomas, lymphomas, and ganglia may also develop inside nerves. Nonneural tumors may also invade peripheral nerves. Ultrasound can help to define its size and its relationship to the surrounding tissue and may also be used for needle-guided biopsy.

Nerve Entrapment

Nerves are generally compressible and alter their shape depending on the volume of the anatomic space that they traverse. Although short periods of compression usually produce only a temporary neuropraxia, prolonged severe pressure can distort the nerve architecture. Extrinsic compression of a nerve may occur anywhere in the body. Nerve flattening, with fusiform swelling of the nerve proximal to the lesion, may be encountered on ultrasound imaging. In such entrapment neuropathies, the nerve may also become hypoechoic at and proximal to the compression site. This loss of echogenicity occurs because of swelling of the fascicles and decreased echogenicity of the epineurium. Figure 18B demonstrates the lateral antecubital cutaneous (LABC) nerve of a patient who presented with a neuropathic syndrome of his anterior lateral forearm. Lateral antecubital cutaneous nerve entrapment is a diagnosis, which, in such circumstances, should be considered. This patient was referred to one of the authors by a plastic surgeon, requesting a trial block of this nerve in the antecubital fossa. The goal was to diagnose a lesion at this level. By tracing distally from the musculocutaneous nerve in the axilla (Fig. 18A), the LABC was found. In the author's experience, the nerve appeared fusiform.
and swollen. An injection of local anesthetic around the nerve resulted in relief of the neuropathic pain and so a decision was made to proceed to decompressive surgery. Intraoperatively, however, the surgeons could not find the LABC nerve. Therefore, under ultrasound guidance, a spinal needle was inserted next to the nerve (Fig. 19). With this guidance, the surgeons were able to dissect a small fascial band from the nerve. Postoperatively, the patient was pain-free.

In summary, part 1 examines common pathologic conditions affecting the tissues critically involved with UGRA: blood vessels and nerves. Part 2 will expand our discussion of sonopathology to include interesting cases associated with bone, viscera, subcutaneous tissue, and foreign bodies. As in part 1, we emphasize potential clinical connections to anesthesiologists practicing regional anesthesia.

ACKNOWLEDGMENTS

The authors thank Mr. Liang Liang, BPhSc, Research Fellow, Department of Anesthesia, Toronto Western Hospital, Toronto, for his assistance in formatting and editing of images during the preparation of the article.

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