Clinical Sonopathology for the Regional Anesthesiologist

Part 2: Bone, Viscera, Subcutaneous Tissue, and Foreign Bodies

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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 bone, viscera, and subcutaneous tissue.

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In part 2, we expand our presentation of sonopathology to include bone, viscera, subcutaneous tissue, and medicinal foreign bodies. As in part 1, we attempt to highlight clinical correlations that emphasize the relevance to anesthesiologists participating in ultrasound-guided regional anesthesia (UGRA).

BONE

Cervical Rib

A cervical rib is present in approximately 1 in 200 people. Thoracic outlet syndrome may occur when the brachial plexus (particularly the lower trunk), the subclavian artery, or the subclavian vein is compressed by a cervical rib as these structures pass through 1 of the 3 anatomic spaces that comprise the thoracic outlet.1 Although plain x-ray, computed tomography, or magnetic resonance imaging is generally used to image the thoracic outlet, ultrasound can also detect a cervical rib. A cervical rib will most likely present incidentally as a superficial hyperechoic linear structure while imaging the divisions of the brachial plexus for a supraclavicular block. Dynamic Doppler imaging may be useful in measuring the extent of vascular obstruction on hyperaducting the arm, which is one factor precipitating symptoms.2 The incidental detection of an accessory rib may also occur during an interscalene or astellate ganglion block. Given that a dropout shadow is likely to occur inferior to the accessory bone, the image of the brachial plexus may be compromised if contained within this artifact. Typical sonographic views may be further altered if the neurovascular anatomy is distorted. For example, a cervical rib can fuse with the first rib and displace the subclavian artery anteriorly. Furthermore, fibrous bands, commonly associated with cervical ribs, can insert onto the rib and compress neural structures. Finally, the subclavian artery may actually pass above the cervical rib.3 Figure 1 demonstrates a dramatic image of a cervical rib that was unexpectedly found during scanning of the supraclavicular fossa. Further questioning of this subject revealed a subtle neuropathic pain syndrome, which was not surprising given the physical distortion of the brachial plexus. The presence of a cervical rib should prompt consideration of alternatives in the block approach, such as choosing an infraclavicular block or modifying the needle approach.

Absent First Rib

The hyperechoic first rib and its dropout shadow provide useful landmarks during an ultrasound-guided supraclavicular block.4 When the first rib is absent, then the pleura is fully visible underneath the artery, and both the comen tail sign and double-barreled subclavian artery artifacts may appear.5 An ultrasound-guided supraclavicular block in such cases may be challenging, if not dangerous, because the first rib is not present to act as the typical “back stop” to prevent unintentional pleural puncture. Figure 2 is the supraclavicular region of a patient presenting for wrist surgery who had undergone a complete first rib resection 3 years previously. Of interest, this particular supraclavicular block was successful but had a slow onset, possibly because of the scar tissue impeding the spread of local anesthetic.

VISCERA

The thyroid gland is seen often and in significant detail when performing interscalene and stellate ganglion blocks. The anesthesiologists may be the first to identify incidental thyroid lesions.

Thyroid Nodules

Thyroid nodules (Fig. 3) occur in up to 50% of the population.6 Ultrasound is the diagnostic imaging modality of choice for thyroid nodules. The thyroid has 2 lobes connected by an isthmus. Although up to 30% of people have an extra (pyramidal) lobe, this is rarely seen on ultrasound. Ultrasound scanning reveals the thyroid parenchyma to be a fine, homogeneous, hyperechoic structure compared with the adjacent muscles. Diffuse thyroid diseases such as Grave disease or Hashimoto thyroiditis (Fig. 4) alter the appearance of the parenchymal tissue, producing more subtle changes that may be challenging to detect. Surrounding the parenchyma is the echogenic thyroid capsule. Posterior to the gland is the hypoechoic air space inside the trachea, which is recognizable by interspersed distinct hyperechoic cartilaginous rings.

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For trained diagnostic sonographers, it can be challenging to distinguish between benign and malignant nodules based on sonographic features alone. Although microcalcifications (punctuate echogenic spots without posterior acoustic shadowing), lack of hypoechoic “halo” (seen around most benign nodes), irregular margins, hypoechoogenicity, and increased intranodular flow may all raise suspicion, no one is pathognomonic for malignancy. In combination, however, the likelihood of malignancy is increased. The number and size of nodules are nonspecific characteristics of malignancy, whereas lymphadenopathy and local invasion of adjacent structures are highly specific features of thyroid malignancy but are far less commonly seen.

Thyroid nodules may be encountered during the performance of an ultrasound-guided interscalene, cervical plexus, or facet blocks. If an incidental thyroid lesion is encountered during routine scanning for a peripheral nerve block, further consultation should be requested. The presence of a thyroid lesion(s), without clinical signs of hyperthyroidism or hypothyroidism, is unlikely to change the anesthetic management.

**Lung: Pneumothorax**

The pleura is identified as a linear and hyperechoic structure that slides during respiration. The comet tail sign is a useful artifact generated by multiple beam reverberations emanating from the pleural interface.

**FIGURE 1.** Cervical rib. This accessory bone was identified during scanning for a supraclavicular brachial plexus block. Identification of the accessory bone allowed the operator to guide the needle over the bone and into the brachial plexus. SA indicates subclavian artery; BP, brachial plexus.

**FIGURE 2.** Ultrasound-guided supraclavicular brachial plexus nerve block in a patient with an absent first rib. The pleura is evident; however, no first rib was identified. In this image, the labeled hyperechoic line is the pleura. Normally, this would be the location to image the first rib. Dynamically, under real-time ultrasound, one could appreciate the sliding of the pleura at this labeled location.

**FIGURE 3.** Thyroid nodules. This is a case where a multinodular thyroid was found during the performance of a stellate ganglion block. Figure 4 is a short-axis image at the level of the C7 showing multiple hypoechoic nodules (unlabeled arrows) in the thyroid gland parenchyma. Ultrasound-guided stellate ganglion blocks necessitate the deposition of local anesthetic at the level of the cervical sympathetic chain which usually lies posterior or posteromedial to the carotid artery (CA) and anterior to the prevertebral fascia (PF) covering the anterior border of longus colli muscle (LC). C7TP indicates transverse process of the C7 vertebral body; Cerv symp, cervical sympathetic chain; Eso, esophagus; IJV, internal jugular vein; SCM, sternocleidomastoid muscle; ThG, thyroid gland.
from the pleura, which acts as a strong specular reflector. Another important sign is the lung sliding sign, which is generated by the real-time countermovements of the visceral and parietal pleurae.

Pneumothorax is a potential complication of brachial plexus, paraverterbral, and intercostal nerve blocks. Pneumothorax can be diagnosed by ultrasound, and it is already being incorporated in the focused abdominal sonography for trauma scan in some emergency centers. One important presenting feature of a pneumothorax is the loss of the lung sliding sign. The analysis for a pneumothorax is best accomplished with M-mode ultrasound. M-mode (Motion) is the diagnostic ultrasound presentation of the temporal changes in echoes in which the depth of the echo-producing interfaces is displayed along one axis and time is displayed along the second axis, recording motion of the interfaces toward and away from the transducer. This is, in essence, B-mode ultrasound presented over time. M-mode was the first display used, and this continues to be useful for the precise timing of cardiac valve opening and correlating valve motion with electrocardiography, phonocardiography, and Doppler echocardiography. In comparison to real-time 2-dimensional ultrasound, M-mode offers a higher frame rate, which is the reason why it is useful for the evaluation of moving structures. The hallmark sign of a pneumothorax is the visualization of the M-mode "stratosphere" sign, indicating the absence of pleural sliding (Fig. 5A). The "seashore sign" (Fig. 5B) confirms pleural sliding and no pneumothorax.

It is good practice to image the lung during ultrasound-guided supraclavicular, infraclavicular, intercostal, and paraverterbral blocks to note the distance of the pleura relative to the proposed needle trajectory as well as to avoid pleural puncture in real-time. Lung sliding may be absent in patients without a pneumothorax but have lung fibrosis, scarring, or adult respiratory distress syndrome. Comet tail artifacts should be distinguished from other artifacts such as "horizontal artifacts." These are internal reverberation artifacts that do not spread to the bottom of the image as comet tail artifacts do. In subcutaneous emphysema, reverberation artifacts are also seen, but these are generated above the pleural line, which can make visualization of the pleura difficult, if not impossible.

**Bowel: Hernia**

Intestinal hernias are focal protrusions of tissue through fascial defects. Ten percent of the population will develop a hernia in their lifetime, 70% of which are inguinal. Femoral hernias are visible medial to the femoral vein below the inguinal

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**FIGURE 4.** Hashimoto thyroiditis. These images come from a patient with tachycardia and hypertension. A, Short-axis view at the level of the thyroid isthmus. Both lobes of the thyroid gland are heterogeneous in echogenicity and contain hypoechoic nodules. B, Right lobe demonstrating the increased vascularity consistent with thyroiditis. Of note, the patient’s diagnosis of Hashimoto thyroiditis was confirmed by biopsy.

**FIGURE 5.** Pneumothorax and normal lung. A, “Stratosphere sign.” This image was generated by placing the transducer in the midclavicular line over ribs 2 and 3 and scanning with M-mode. In the case of pneumothorax, and thus absent pleural sliding, horizontal lines are visualized throughout, representing a laminar pattern (stratosphere sign) both above and beyond the pleural line (white arrow). B, “Seashore sign.” This is a M-mode ultrasound image in a patient without a pneumothorax. The pleural line is once again indicated by the white arrow, and above it, the motionless parietal structures are localized first. Below the pleural line, lung sliding appears as a homogenous granular pattern, showing a laminar pattern above pleural line (stationary chest wall) and granular appearance (seashore sign) deep into the pleural line, representing pleural sliding. (Images courtesy of Dr. Michael B. Stone, Department of Emergency Medicine, Kings County Hospital Center/SUNY Downstate, Brooklyn, NY.)
ligament, whereas inguinal hernias are located more cephalad. A variety of structures may herniate through the fascial defect including the soft tissue, the peritoneal sac, or the intestines (Fig. 6). Compared with other imaging modalities, real-time ultrasound has the advantage of allowing dynamic examination of hernias during the Valsalva maneuver. Ultrasound may also help differentiate indirect from direct inguinal hernias by identifying the inferior epigastric artery. Herniated bowel contents may show peristalsis, with herniated adipose tissue appearing distinctly hyperechoic. Figure 7 demonstrates a hernia in the midline developing below the umbilicus. Bowel is clearly seen adherent to the linea alba.

Hernias would most likely be identified during the performance of a femoral, obturator, rectus sheath, transversus abdominus plane, or ilioinguinal nerve block. It is conceivable that hernia contents could be damaged by needle advancement. If a hernia is suspected (previous multiple surgeries or history), increase the depth and search for the peritoneum and peristaltic

![FIGURE 6.](image1)

**FIGURE 6.** Inguinal hernia. This is a short-axis image of the region just proximal the inguinal ligament. Evident in this picture is a hypoechoic circular structure penetrating deeper through the tissue into the subcutaneous region. This structure is a hernia sac consisting of bowel contents. On dynamic ultrasound imaging, the radiologist could see peristalsis in this sac. The plus signs represent the calipers used for measuring. IA indicates iliac artery. The dropout shadow once again is a helpful clue to potential pathology. This image was obtained 1 cm proximal (suprainguinal) to where a femoral nerve block would normally be conducted. It is conceivable that hernia sacs could be present infrainguinally as well.

![FIGURE 7.](image2)

**FIGURE 7.** The beginnings of a midline hernia. This is a short-axis image just below the umbilicus. Note the linea alba that marks the midline. The bowel loops are easy to appreciate adherent to the posterior rectus sheath. RM indicates rectus muscle.

![FIGURE 8.](image3)

**FIGURE 8.** Normal breathing. This is an M-mode image through the liver with the transducer placed in the midaxillary line below the diaphragm. The M-mode cursor can be seen bisecting the diaphragm (image top). The M-mode image is seen at the bottom of the figure. This image is consistent with the normal diaphragmatic excursion pattern during tidal volume breathing. White arrows indicate the start of an inspiratory effort. The normal diaphragmatic breathing pattern is caudad movement of the diaphragm. This results in movement of the diaphragm line more superficially on the screen because it represents movement of the diaphragm toward the transducer.

![FIGURE 9.](image4)

**FIGURE 9.** Impaired diaphragm. This is the same patient as Figure 9, except 20 mins after an interscalene block. The diaphragmatic paralysis is evident, with demonstrable qualitative diminution in the magnitude of diaphragmatic excursions. The white arrow indicates the static diaphragm despite breathing. (Images courtesy of Dr. Sheila Riazi, Department of Anesthesia, Toronto Western Hospital, University of Toronto, Toronto, Ontario, Canada.)
motion of bowel before needle insertion. As an example, the operator may choose not to perform a rectus sheath block (Fig. 7) in favor of a more lateral transversus abdominus plane block.

Diaphragm

Ultrasound enables the assessment of diaphragmatic movement through the use of M-mode ultrasound. Figures 8 and 9 demonstrate a patient who was scanned before and shortly after completing a right interscalene nerve block. One can clearly appreciate the dramatic absence of diaphragmatic excursion.

Preblock scanning of the contralateral diaphragm in patients with a history of a spinal cord injury or phrenic nerve palsy may be helpful in formulating a final anesthetic plan when considering an interscalene or supraclavicular block. If the M-mode reveals contralateral diaphragmatic pathology, then consideration should be made to performing another block or aborting the procedure entirely.

SUBCUTANEOUS TISSUES

High-frequency ultrasound transducers commonly used during superficial nerve blockade enable the identification of a variety of pathologic structures. Ultrasound examination of the subcutaneous tissue involves dynamic application of different degrees of transducer pressure, finger palpation, and manual mobilization of the skin to help distinguish among masses, fluid collections, and fibrosis. Normal subcutaneous tissue is visualized on ultrasound as a discrete layer, characterized by a hypoechoic background of adipose tissue, with interposed linear echoes generated by the connective septa. Subcutaneous veins may be seen as elongated or rounded anechoic structures that run inside the larger septa that collapse with transducer pressure. Small sensory nerves may be seen coursing alongside the superficial veins, usually in the deep subcutaneous tissue. Lymphatics, which are also contained within the connective septae, are not typically visualized with ultrasound unless distended by fluid as in the case of subcutaneous edema.

Lymphadenopathy

Normal lymph nodes appear as flattened oval structures with a thin hypoechoic cortex and an echogenic, hypovascular hilum. Ultrasound is useful for imaging superficial nodes such
Ultrasound is superior to palpation alone in detecting lymphadenopathy. Although sonographic features can help differentiate malignant from benign nodes, the combination with fine-needle aspiration increases the sensitivity and specificity. Enlarged nodes may be benign or malignant, so nodal size alone is not a reliable method for characterizing lymph nodes. The ultrasound characteristics of malignant infiltration include enlarged nodes that are usually rounded and show peripheral or mixed vascularity. They may have thickened outer wall, internal echoes, cystic formations, internal nodularity, and septations. Finally, malignant nodes are usually noncompressible.

In the axilla, lymph nodes often have a similar appearance as nerves and can potentially confuse the operator. In the inguinal region, lymph nodes are commonly encountered in the context of performing femoral nerve blocks (Fig. 10). Anesthetic management in the patient depicted in Figure 10A was changed empirically from a continuous femoral catheter to a single-shot injection to reduce the possibility of infection. Femoral catheters appear to be at particular risk of colonization compared with other locations. Although guidelines exist on minimizing the risk of infection during placement of continuous catheters, it remains unclear whether an indwelling continuous...
Edema

Edema has a variety of causes, and this will inevitably be encountered by anesthesiologists participating in UGRA. In the early stages, edematous changes tend to involve the deep layer of the subcutaneous tissue. This is visualized on ultrasound as hypoechoic areas of fluid accumulation, whereas the most superficial layers of the subcutaneous tissue remain normal. As fluid accumulates, the connective septa enlarge and become anechoic strands caused by distension of the superficial network of lymphatic channels. As seen in Figure 11, fat lobules ultimately become individualized structures separated from one another by fluid. Edema may interfere with peripheral nerve blockade by distorting the neural anatomy, increasing the depth, masking hypoechoic structures, diluting local anesthetic injection, and possibly altering nerve stimulation thresholds. Conversely, hypoechoic fluid may actually facilitate imaging of the hyperechoic nerve by effectively outlining the target.

Abscess

The anesthesiologist may be one of the first members of the care team to identify a loculated fluid collection in a patient presenting for anesthesia. Ultrasound can facilitate differentiating between an abscess and cellulitis by demonstrating the spread of infection into deeper skin layers as well as into tendons, muscle, or joints. Cellulitis is visualized as an irregular, ill-defined hyperechoic appearance of fat with blurring of tissue planes, progressing to hypoechoic strands reflecting edema. This pattern can be difficult to distinguish from simple edema. Figure 12 demonstrates a subcutaneous abscess that was noted in an intravenous drug user who presented for drainage. Abscesses are characterized by irregular fluid-filled hypoechoic areas with posterior acoustic enhancement, containing a variable amount of echogenic debris that represents purulent material. In highly echogenic collections, pressure with the transducer may cause fluctuation of the particles, which can help confirm the liquid nature of the mass. The formation of gas is possible in advanced disease or with gas-forming organisms such as Clostridium. The presence of gas may be suggested by scattered bright foci in the tissues (Fig. 13). The presence of an abscess near a nerve would likely preclude the placement of a continuous catheter and possibly even a single injection.

FOREIGN BODIES AND HARDWARE

Ultrasound is an excellent tool for detecting and evaluating foreign bodies. Unlike plain radiography, it can accurately determine the relationship of the foreign body to surrounding soft tissue structures. Foreign bodies may be present in the subcutaneous tissues as the result of traumatic injuries or therapeutic procedures. We will focus on foreign bodies placed medicinally because they have the most relevance to UGRA.

Spinal Hardware

The role of ultrasound in central neuraxial procedures has been slower to develop because structures of interest lie relatively deep and are encased in bone, with only narrow acoustic windows available for imaging. Despite these limitations, ultrasound can provide prepuncture information on the appropriate spinal interspace and depth of the various targets. Scanning the spine in both midline short-axis and paramedian long-axis...
Evidence of previous spine surgery, such as in postlaminectomy patients, detailed imaging of the spinal structures is possible (Fig. 15).

**Clavicle Hardware**

The clavicle is a common location for operative interventions. Figure 16 originates from a patient in whom a supravacular block was being considered. In this image, the edge of the clavicular hardware effectively prevented the ability to image the typical structures of the supravacular fossa. This procedure was aborted.

**Tubes and Drains**

There are an endless number of medical devices that may present themselves in the context of performing regional anesthesia. More common devices would include pacemaker wires (Fig. 17), pacemaker generators, vascular grafts, prosthetic material, chest tubes, and ventricular-peritoneal shunts (Fig. 18). Although a thorough history and physical is arguably the best way to identify potential objects that could complicate a nerve block, the anesthesiologist may be initially confronted with a foreign object during preprocedure scanning for a planned regional anesthetic. Figure 18 comes from a patient undergoing an interscalene nerve block. A small hyperechoic circle was seen with a distinct acoustic dropout shadow. On further questioning of the patient, it was discovered that the patient had a ventricular-peritoneal shunt. Given the proximity of the shunt to the brachial plexus, the nerve block was aborted.

**CONCLUSIONS AND SCOPE OF PRACTICE ISSUES**

Nerves and the tissues surrounding the nerves are commonly involved with pathology and/or atypical anatomy. The anesthesiologist will inevitably encounter some of these situations during the conduct of UGRA. This library of images and descriptions of sonopathology will hopefully add to the anesthesiologist’s role as the perioperative physician. As anesthesiologists become increasingly familiar with ultrasound technology and sonographic anatomy, inevitably we will begin investigating our own patients at the point-of-care, detecting incidental occult pathology, and call on to assist our surgical colleagues in the operating room and beyond. We are nonetheless hopeful that this review will broaden the awareness of common sonopathology such that ultrasound can be used most effectively to advance knowledge and skills of regional anesthesiologists.

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