Musculoskeletal Sonopathology and Ultrasound-Guided Regional Anesthesia

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Received: 20 January 2010/Accepted: 11 June 2010/Published online: 17 August 2010
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Abstract The use of real-time ultrasound guidance has revolutionized the practice of regional anesthesia. Ultrasound is rapidly becoming the technique of choice for nerve blockade due to increased success rates, faster onset, and potentially improved safety. In the course of ultrasound-

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Each author certifies that his or her institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participating in the study was obtained.

Level of evidence: level IV: retrospective case series evidence

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guided regional anesthesia, unexpected pathology may be encountered. Such anomalous or pathological findings may alter the choice of nerve block and occasionally affect surgical management. This case series presents a variety of musculoskeletal conditions that may be encountered during ultrasound-guided regional anesthesia practice.

Keywords anesthesia · ultrasound · regional anesthesia

Introduction

Regional anesthesia (RA) involves depositing local anesthetic around peripheral nerves or the neuraxis in order to provide anesthesia and analgesia. Within the specialty of anesthesiology, RA is undergoing a renaissance largely due to the development of ultrasound (US) guidance, which allows for direct visualization of the nerves, surrounding structures, needle, and local anesthetic spread [7]. Rapidly emerging evidence suggests that US reduces block onset time, increases success rate, and prolongs block duration compared to traditional “blind” methods of nerve localization [1]. Further emerging evidence supports improved safety with the use of ultrasound guidance and recently established national guidelines in the UK already recommend using US for both peripheral nerve and neuraxial blockade [1, 16–18].

As the international experience with US-guided regional anesthesia continues to grow, so too does our appreciation and respect for the benefits and limitations of this important technology [24]. For example, multiple reports in the literature now describe the incidental discovery of abnormal anatomy, including venous thrombosis, arterial plaques, lymphadenopathy, or fluid collections, during scanning with US prior to performing the block [6, 8, 10, 26, 28]. Importantly, these unexpected findings (herein referred to as “sonopathology”) have in some cases led to alterations in the anesthetic plan, nerve block approach, and even surgical

management [26, 27]. Such information would not have been available using traditional “blind” nerve localization techniques such as nerve stimulation.

The purpose of this case series is to demonstrate the variety of musculoskeletal conditions that an anesthesiologist might incidentally encounter during pre-procedural scanning for US-guided regional anesthesia. Specifically, we address the following questions: (1) what types of musculoskeletal pathology may be encountered within the scope of US-guided RA practice, and (2) what are some of the important sonographic features that characterize normal and abnormal musculoskeletal tissue? Presenting an anatomical collection of sonopathology images that were acquired over a 7-year period at five separate institutions, these two questions are sequentially addressed in a purposefully organized, reference-friendly format according to musculoskeletal tissue type.

Bones

Ultrasound is not the imaging modality of choice for bone. The cortex is highly echogenic and visualized as an intensely hyperechoic line with characteristic posterior acoustic shadowing due to a high attenuation coefficient. Despite these technical limitations, bony pathology may still be encountered and identified. Ultrasound has been demonstrated in children to be useful in detecting fractures and guiding reduction in place of X-ray [5]. It has also been used for prehospital care of fracture reductions where X-ray technology is not available [15]. Small breaks in the continuity of the cortical surface, as suggested by ultra-

sound, may indicate a fracture. As an example, ultrasound can be used to detect fractures of the humerus (Fig. 1). In practice, however, it is almost certain that the anesthesiologist will not be the first clinician to detect a new fracture. It is useful to remember that breaks in the cortical surface may also occur where nutrient vessels penetrate the bone, where bone tunnels have been created in ligament reconstructive surgery, or if screws have been removed.

Tendons

Tendons commonly lie in the immediate vicinity of nerves and, along with blood vessels and bone, can serve as useful landmarks to orient the anesthesiologist towards the target nerve. In the short axis, normal tendons appear as bright, stippled echoes. In the long axis, a fibrillar pattern is created by the many fine, tightly packed linear echoes [14]. A variety of tendon-related pathologies might be encountered by anesthesiologists performing US-guided regional anesthesia including tears, degenerative changes, tenosynovitis, tumors, ganglia, and inflammatory conditions.

In tendons with a synovial sheath, inflammation may occur secondary to repetitive microtrauma, overuse, osseous friction, foreign bodies, infection, or arthritis. In acute serous tenosynovitis, fluid may be visible within the tendon sheath, encircling the tendon, forming a halo sign [23]. Other signs of tenosynovitis include swollen and irregularly hypoechoic tendons. This can be dramatically illustrated in cases of tibialis posterior tenosynovitis (Figs. 2 and 3). In subacute or chronic disease, the effusion is often associated with sheath thickening [14].

Fig. 1. **a** A panoramic longitudinal ultrasound image of the lateral aspect of the proximal humerus. Bony structures are outlined by a bright hyperechoic line followed more deeply by an acoustic shadow as bone is impermeable to the ultrasound waves. The irregular outline of the lateral bony cortex is seen at the level of the fracture depicting

callus formation consistent with a healing fracture. **b** A plain anterior-posterior radiograph of the left shoulder joint in the same patient shows a healing fracture at the neck of humerus suggested by callus bone formation

Fig. 2. This is a short axis image of the tibialis posterior tendon with transducer placement on the posterior–medial aspect of the ankle demonstrates tibialis posterior tenosynovitis. The tendon is surrounded by a cuff of inflammatory tissue (hypoechoic ring) reflecting tenosynovitis

Wrist blocks are often performed in combination with general anesthesia for post-operative analgesia or as the sole anesthetic for short hand procedures with or without a tourniquet. A variety of tendinous structures traverse the carpal tunnel and may develop tenosynovitis (Figs. 4 and 5), which may be scanned during a median nerve block. Underneath the roof formed by the transverse carpal ligament lies the median nerve, which is medial to the flexor pollicis longus and superficial to the four tendons of the flexor digitorum superficialis. The flexor digitorum superficialis lies on the four tendons of the flexor digitorum profundus.

Fig. 3. This axial intermediate-weighted MRI image through the ankle is of the same patient in Fig. 2, demonstrating tenosynovitis of the tibialis posterior tendon. Note the close proximity of the inflammation to the neurovascular bundle

Fig. 4. This short axis image through the volar aspect of the wrist demonstrates extensive peritendinous fluid surrounding the flexor tendons extending into the carpal tunnel with resultant mass effect on the median nerve and is indicative of carpal tunnel tenosynovitis. Sonographic appearance of neural structures can be similar to a tendon at the level of the wrist. This particular patient presented with complaints of tenderness and inflammation of the wrist suggesting a clinical picture of carpal tunnel syndrome

Fig. 5. Axial T1 (a) and T2 (b)-weighted MRI images of the same patient showing tenosynovitis of the flexor digitorum tendons and the median nerve

Fig. 6. This image is a long axis view of the distal calf demonstrating a complete rupture of the Achilles tendon, as marked by the caliper. AT Achilles tendon, FHL flexor hallucis longus tendon

In contrast to tenosynovitis, in which fluid is often distributed in a circumferential pattern, fluid present in bursae or ganglion cysts is typically located eccentrically to the tendon. Fluid related to tendon inflammation can easily distract the anesthesiologist into assuming that the tendon is actually the nerve [24]. This is secondary to the fluid acting as a contrast agent, in which the hypoechoic fluid highlights and emphasizes the tendon (Fig. 2). “Tracing” a nerve proximally and distally to ensure it does not disappear (as a tendon would) may be instructive in this scenario. Nerve stimulation combined with ultrasound can also be used, but false negatives may still occur with this technique [19].

A tendon tear or rupture is commonly a result of trauma, degenerative change, or systemic disease. Ultrasound can provide an accurate assessment of the extent of tendon tears, and in some cases, be as accurate as magnetic resonance imaging [30]. In a complete rupture, a focal defect between torn tendon edges is visible, sometimes with posterior acoustic shadowing created by the refraction of the beam at the ragged tendon edges [13]. In acute cases, a hypoechoic area created by local hematoma may be visualized between the two ruptured ends of the tendon. This can become hyperechoic over time as the clot organizes. Tears of the Achilles tendon (Figs. 6 and 7)

are relatively common and may be encountered during the performance of ultrasound-guided ankle blocks for unrelated foot surgery. Incidental tears at the elbow, albeit of possibly less clinical significance, may be encountered during imaging for nerve blocks at the elbow when such blocks are performed for post-operative analgesia in hand surgery or to supplement inadequate brachial plexus blocks.

Muscles

Characteristic muscle group patterns are often used as landmarks to identify target nerves, especially for interscalene, musculocutaneous, and popliteal nerve blocks [4]. Ultrasound has the ability to visualize real-time muscle movements, such as contractions and fasciculations, which can sometimes further facilitate target nerve visualization [22]. A variety of musculoskeletal pathologies may be encountered during US-guided regional anesthesia, including hereditary diseases, anomalous lesions, tumors, myopathies, and infections. The differential diagnosis of a muscle mass includes benign or malignant tumor, abscess, granuloma, vascular malformation, a hematoma, Baker's cyst, or myositis ossificans. Some of these, such as abscess and hematoma, are less likely to present unexpectedly.

Normal muscle appears grossly hypoechoic, divided by hyperechoic connective tissue, which is visualized as focal intense echoes in the short axis or linear structures in the long axis [20]. Diseased or infected muscles may have an increased adipose and fibrous content. Due to the different acoustic impedances, the number of reflective interfaces increases, therefore making the image more echogenic (Fig. 8). This particular patient had a history of a spinal cord injury and subsequent incomplete paraplegic state and was undergoing a mid thigh saphenous nerve block. Superficial to the saphenous nerve was a thick layer of adipose tissue, likely due to inactivity. The sartorius muscle was hyperechoic, presumably due to muscle atrophy. Of interest, the superficial femoral artery was barely visible due to attenuation of the ultrasound beam through the pathologic muscle layer. In general, ultrasound is relatively insensitive to the detection of early muscle changes.

Fig. 7. This is a panoramic longitudinal view of the distal calf demonstrating a complete rupture of the Achilles tendon in the same patient as in Fig. 6

Fig. 8. This image illustrates sartorius muscle atrophy imaged in a patient with incomplete paraplegia in which the anesthesiologist had a difficult time performing a mid-thigh saphenous nerve block. In this image, notice the increased adipose tissue and the abnormal hyperechoic nature of the sartorius muscle. This hyperechogenicity persisted even with an aggressive reduction in the image gain. *SFA* superficial femoral artery

A sarcoma such as a malignant fibrous histiocytoma in the posterior thigh is a malignant tumor that may develop from fat, nerve, muscle, or fibrous tissue (Fig. 9). Such a lesion may be visible when blocking the sciatic nerve. In general, the most common soft tissue sarcomas are malignant fibrous histiocytomas, liposarcomas, leiomyosarcomas, and synovial sarcomas [31]. Sonographic features, however, are non-specific and so the primary use of ultrasound in this setting is guidance for fine needle biopsy.

Fig. 9. **a** Short axis image of the posterior aspect of the mid thigh, showing a hypoechoic mass posterior to the femur consistent with a soft tissue sarcoma. The sciatic nerve is seen in close proximity to the

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 [29]. Foreign bodies may be present in the subcutaneous tissues as the result of traumatic injuries or therapeutic procedures.

Wood fragments are the most frequently found foreign bodies, followed by glass and metal fragments [2]. If not removed, foreign bodies can result in granuloma formation, secondary infection with formation of an abscess, fistula, purulent tenosynovitis, and septic arthritis. Bone destructive changes and damage to adjacent nerves may also occur. The ultrasound appearance of foreign bodies varies depending on the object [12]. Wood fragments may exhibit posterior acoustic shadowing, as shown in Fig. 10. Figure 10a originates from a patient who had an untreated pine splinter that resulted in cellulitis of his forearm. In this instance, intraoperative ultrasound was utilized by an anesthesiologist to identify the incision site (requested by the surgeons), identify proximity to the median nerve, and confirm the complete removal of the foreign body. Ultrasound was also useful in characterizing an abscess associated with a cactus thorn embedded in a patient's leg (Fig. 11). Ultrasound can also confirm the dislodgement of implantable subcutaneous devices, help to localize injection ports for tissue expanders, and diagnose suture granulomas.

Ganglia, cysts, and fluid collections

Ganglia are benign thin-walled cysts containing mucinous material which develop in relation to joints or tendon sheaths. Commonly, ganglia are present in the tendon sheath rather than intratendinously [3]. The hand and wrist are the most frequent sites of development, and therefore, incidental ganglia may be encountered during the performance of wrist and forearm blocks. Such blocks may be used for minor hand surgery or for post-operative analgesia in

tumor. On further evaluation, this mass was found to be a sarcoma. **b** The structures seen on a T1 MRI image of the mid thigh depicting the same relationship to the femur and the sciatic nerve

Fig. 10. **a** These ultrasound images illustrate a wood splinter with associated inflammatory change. **b** A pine splinter in the forearm (*short arrows*) generates a dropout shadow from its high acoustic impedance

combination with general anesthesia if surgery is major and a tourniquet is required. Ganglia generally appear on ultrasound as round or oval hypoechoic structures with regular borders. There is an absence of blood flow when evaluated with color Doppler. As is true for other low impedance structures (i.e., blood vessels), posterior acoustic enhancement may occur. A Guyon tunnel ganglion can be imaged with both ultrasound and the corresponding magnetic resonance image (Figs. 12 and 13). The ulnar nerve at the wrist traverses Guyon's tunnel, which lies ulnar and superficial to the carpal tunnel. Guyon tunnel syndrome (an ulnar neuropathy) is rare compared to carpal tunnel syndrome. The leading cause of a Guyon tunnel syndrome is the presence of a ganglion. These ganglia originate from either the hamate-triquetrum or the piso-triquetrum joints. Other causes include injuries to the ulnar artery causing thrombosis and pseudoaneurysm formation, primary ulnar artery aneurysm, and anomalous muscles within the tunnel, which can lead to ulnar nerve compression. If the ulnar or median nerve appears to be in close proximity to a ganglion cyst, careful consideration should be made to performing a more proximal brachial plexus block.

The posterior knee area is a predominant site for cystic masses and is also where popliteal nerve blocks are performed for foot and ankle surgery [32]. A popliteal cyst can be defined as a cystic lesion located on the posterior aspect of the knee joint. The most common such cyst is a Baker's cyst, which arises from distension of the semimembranosus–gastrocnemius bursa and, therefore, is not technically a true cyst. Five percent of patients undergoing MRI of the knee for unrelated problems have Baker's cyst [11] (Fig. 14). In some cases, a tail of fluid can be seen extending between the semimembranosus and gastrocnemius tendons, confirming the diagnosis. Baker's cysts may rupture or dissect tissues. Compression of the tibial or peroneal nerves secondary to a compartment syndrome has been reported [9, 21]. Because the neurovascular bundle also transverse the popliteal fossa, direct compression of nerves by an unruptured cyst can also lead to a neuropathy.

Seromas are pockets of clear serous fluid that sometimes develop after surgery (Fig. 15). The sonographic character-

Fig. 11. This image depicts a cactus thorn in a patient's leg with its corresponding inflammatory change

Fig. 12. This is a short axis ultrasound image through the ulnar border of the wrist, demonstrating a ganglion cyst (GC) within the Guyon's canal. Pisiform bone (P) and the ulnar nerve (U) are seen medially and laterally, respectively

Fig. 13. This is the same patient illustrated in Fig. 12 demonstrating T1-weighted MRI images through the wrist, showing the ganglion cyst (GC) in relation to the pisiform (PISI) and the ulnar nerve (U) in the Guyon's canal

istics that distinguish this from an abscess are that it is homogenous, anechoic, and has no septae. The lack of color flow confirms that it is not a blood vessel. Aspiration can be used to check the nature of the collection and, in this case, it was confirmed to be a seroma. A hematoma with its heterogeneous pattern should be considered in the setting of any fluid collection (Fig. 16).

Summary

As the popularity of US-guided RA continues to grow, so too will the frequency of abnormal findings and detection of incidental pathology that may influence anesthetic, and even surgical, management. Indeed, US-guided RA often relies on pattern recognition of the location of the target nerve relative to the surrounding “landmark” vascular and

Fig. 15. This is a short axis image of a seroma in the upper arm of a patient presenting with pain. Characteristics that distinguish it from an abscess are that it is homogenous, anechoic, and contains no septae. It is not a blood vessel because on multiple angles and views, no flow is demonstrated with color Doppler. Fluid aspirated from this structure was clear and sterile. The axillary artery serves as a convenient reference structure

musculoskeletal structures, thus representing a unique opportunity to uncover anomalous and/or pathological anatomy. There is ongoing debate concerning the training of regional anesthesiologists for the purposes of interpreting the significance of abnormal sonographic findings. This is in part addressed by new US-guided RA educational guidelines [25], one key task of which is recognizing normal anatomy and anatomic variations. We are hopeful that this case series will add to the anesthesiologists' knowledge base with a view towards ever improving patient-centered care.

Fig. 14. This is a short axis ultrasound image through the medial aspect of the popliteal fossa, showing an anechoic cystic structure, a Baker's cyst lying superficial to the medial head of the gastrocnemius muscle (GCM). AE acoustic enhancement

Fig. 16. This is a short axis ultrasound image through the posterior aspect of the calf, demonstrating a large intramuscular heterogeneous mass consistent with a hematoma. This patient presented with a history of trauma. Note that there is distinct echogenicity associated with the center of the lesion. This is most likely consistent with areas of coagulation and organizing clot

Acknowledgment The authors wish to thank Mr. James Liang, BMSc, Research Fellow, Department of Anesthesia, Toronto Western Hospital, Toronto for his assistance in formatting and editing of images during the preparation of this manuscript.

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