Ultrasound-Guided Interventional Procedures in Pain Management

Evidence-Based Medicine

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Abstract: Recently, there has been a growing interest in the application of ultrasonography in pain medicine because ultrasound provides direct visualization of various soft tissues and real-time needle advancement and avoids exposing the health care provider and the patient to the risks of radiation. The machine itself is more affordable and transferrable than a fluoroscopy, computed tomography scan, or magnetic resonance imaging machine. These factors make ultrasonography an attractive adjunct to other imaging modalities in interventional pain management especially when those modalities are not available or feasible.

The present article reviews the existing evidence that evaluates the role of ultrasonography in spine interventional procedures in pain management.

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The application of ultrasonography in pain medicine (USPM) is rapidly growing in the field of interventional pain management. Traditionally, spine interventional procedures for pain management have been performed with imaging guidance such as fluoroscopy and, rarely, computed tomography (CT) scan or magnetic resonance imaging. Over the last few years, there has been an overwhelming interest in USPM as evidenced by the multitude of published reports[1,2]; however, most of these publications are feasibility studies, case reports, or technical reports, with only 1 randomized controlled trial (RCT). It is therefore challenging to discuss evidence-based medicine for ultrasound (US)–guided pain procedures in comparison to those in regional anesthesia.

Because ultrasonography allows direct real-time visualization of various soft-tissue structures, it quickly became an established technique in peripheral nerve blocks in regional anesthesia when most of the conventional techniques are landmark based or "blind." On the other hand, ultrasonography faces unique challenges in spine injections when most of the established existing techniques require the use of fluoroscopy. Ultrasonography provides good visualization of bony surfaces, which may make it useful in various superficial spine injections such as the medial branch block, facet intraarticular injections, and nerve root blocks, but not as useful in neuraxial (epidural or intrathecal) blocks in adults because of limited resolution at deep levels and the presence of bony artifacts that limit the visualization of deep spinal structures. Accordingly, the spread of the injectate into the epidural space and intravascular injections are difficult to be detected with ultrasonography alone (contrary to the commonly used fluoroscopy in pain manage-ment practice).

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METHODS

We performed a literature search of the MEDLINE and PubMed databases from 1986 through July 2009. Search terms included *ultrasonography*, *ultrasound-guided*, *pain management*, *spine injections*, and different selected nerves or structures relevant in this review such as *transforaminal injections*, *facet intraarticular injections*, and *medial branch nerve block*.

Search included only human studies and was not limited to the English language. For the purpose of this review, only studies relating to interventional chronic pain management were included.

We excluded those publications that described peripheral nerve blocks in the perioperative setting, interlaminar neuroaxial injections, and musculoskeletal applications. Technical reports, case reports, and letters to the editor were also excluded.

RESULTS

Ultrasonography in interventional pain management is still a new field in evolution; therefore, most of the publications are within the past few years and come from a small number of centers, and most procedures have been performed by a very few experienced pain physicians. Twelve studies fit inclusion criteria for this review.

Based on the limited data available, it would be premature to make recommendations for practice at this point. Rather, the available evidence will be reviewed and classified according to the US Department of Health and Human Services Agency for Health Care Policy and Research.[3]

The existing evidence will be classified into the 2 main areas of interest: US-guided cervical and lumbar spine injections. We excluded peripheral applications (intercostal nerve block, suprascapular nerve block,…) because the available literature contains only proof-of-concept or feasibility studies.

Ultrasound-Guided Lumbar Spine Injections

Ultrasound-Guided Lumbar Facet Medial Branch Block

Greher et al[4] described the US-guided approach for lumbar facet medial branch block. They conducted a clinical case series of 28 US-guided facet nerve injections in 5 patients with US and fluoroscopic confirmation. Twenty-five of the 28 needle placements were accurate (level IV). The same group, in a cadaver study, reported the accuracy of the US technique confirmed with CT.[5]

Recently, Shim et al[6] in a nonrandomized crossover trial evaluated the success rate and validity of this US method by using fluoroscopy controls in patients previously diagnosed with lumbar facet joint–mediated pain. They initially performed

TABLE 1. Summary of the Evidence for Ultrasound in Lumbar Spine Injections

Study (Year)	No. Subjects	Study Design	Comparative Technique	Outcome
Shim et al[6] (2006)	20 Patients (101 injections)	Nonrandomized crossover trial	Fluoroscopy	95% Success
Galiano et al[8] (2007)	40 Patients, 20 in each group	RCT	CT scan	85% (17/20) Success

fluoroscopy-guided medial branch blocks in 20 patients. One month later, the same patients received another lumbar medial branch blocks with US guidance, and the needle-tip position was confirmed with fluoroscopy. They were able to place the needles in correct position under US guidance 95% of the time (level III).

The major limitation to this study was that the mean weight and body mass index of the patients in this study were only 51 kg and 22.8 kg/m^2, respectively. In fact, obesity is the major limiting factor in using US in lumbar spine injections, and although Shim et al[6] performed the procedure in lean patients, US could not detect intravascular injections in 2 patients.

Based on the above, US cannot be recommended to be the solo imaging technique while performing lumbar branch nerve blocks, especially in obese patients (level III-IV).

Ultrasound-Guided Lumbar Facet Intraarticular Injections

Galiano et al[7] reported the feasibility of US-guided facet joint injections in cadavers with a correlation coefficient of 0.86 between US- and CT-derived measurements. The same group then conducted the first prospective RCT comparing US-guided versus CT-guided lumbar facet intraarticular injections (Table 1).[8] Forty adult patients were consecutively enrolled and were assigned to either a US or CT group using a computer-generated randomization table. In the US group (20 patients), if the facet joints were visible, needle placement was attempted within the facet joint or at least within 5 mm of the joint and verified by CT. In the CT group (20 patients), the patients had an initial topogram, and then the needle was advanced under CT guidance to the target. In the US group, 16 patients had facets joints well visualized with accurate needle placement. Ultrasound-guided needle placement was faster compared with CT, with much less radiation. There was no difference in pain relief between the 2 groups.

This study involved a small sample size of 40 patients, and the facet joints could not be visualized in 2 patients with body mass index of 28.3 and 32.9 kg/m^2. They reported a success rate of 94% (17/18 patients with visualized joints) as defined by having the needle placed within 5 mm of the facet joint; however, the overall success rate in fact is 85% (17/20 patients); this is compared with 100% with fluoroscopy or CT. Placing the needle 5 mm away from the target may not lead to precise injection and accordingly may adversely affect the diagnostic and therapeutic value of such injection. The mean time for single joint injection was 14.3 (SD, 6.6) min, which is much longer than the widely used fluoroscopy-guided technique. To date, there is no RCT comparing US with fluoroscopy in lumbar facet injections.

Ultrasound is superior to CT-guided lumbar facer joint injections (level Ib) in regard to radiation exposure and time to perform the procedure. No recommendations can be given regarding if US is superior to fluoroscopy because no data exist.

Ultrasound-Guided Lumbar Nerve Root Injection

Contrary to the cervical area, lumbar nerve roots are usually not well seen with ultrasonography because of the depth and the presence of bony structures of different contours in the lumbar spine obscuring the visualization of the target structures in the neural foramen. Nevertheless, the technique was described before in cadavers as periradicular injections.[9] As one cannot accurately delineate the lumbar nerve root using US, the procedure is essentially the same as a paravertebral injection in terms of its selectivity and thus diagnostically not useful. Real-time fluoroscopy and contrast injection with digital subtraction—when available—should remain the standard of care.

No recommendations can be given if US is superior to fluoroscopy in lumbar selective nerve root block because no clinical data exist.

Cervical Spine Injections

Ultrasound-Guided Cervical Selective Nerve Root Injection

Galiano et al,[10] in an experimental cadaver study, described the use of US-guided periradicular injections in the middle and lower cervical spine confirmed with CT. Five of the 40 positioning attempts in 4 cadavers could not depict the spinal nerve because of reduced imaging conditions. However, all 8 needles placed in 1 cadaver (with the best imaging quality) were positioned accurately within 5 mm dorsal to the spinal nerve.

More recently, Narouze et al[11] reported a prospective observational study of 10 patients who received cervical nerve root injections using US as the primary imaging tool with fluoroscopy as the control (Table 2). The radiologic target point was the posterior aspect of the intervertebral foramen just anterior to the superior articular process (SAP) in the oblique view and

TABLE 2. Summary of the Evidence for Ultrasound in Cervical Spine Injections

Study/Year	Block Type	No. Subjects	Study Design	Comparative Technique	Outcome
Eichenberger et al[12] (2006)	Third occipital block	14 Volunteers/ 28 injections	Prospective observational cohort trial	Fluoroscopy	82% Success
Narouze et al[11] (2009)	Cervical nerve root	10 Patients	Prospective observational cohort trial	Fluoroscopy	100% Success
Kapral et al[14] (1995)	Stellate ganglion block	12 Patients	Nonrandomized crossover trial	N/A	100% Success
Gofeld et al[18] (2009)	Stellate ganglion block	7 Patients	Observational study	Fluoroscopy	100% Success

at the midsagittal plane of the articular pillars in the anteroposterior view. The needles were within 5 mm of the radiologic target in all patients as confirmed by fluoroscopy. Vessels at the anterior aspect of the foramen were identified in 4 patients by color Doppler, whereas 2 patients had critical vessels at the posterior aspect of the foramen. In these 2 cases, such vessels could have been injured in the pathway of a correctly placed needle under fluoroscopy alone. Thus, US might help avoid intravascular injection; however, it is not clear if it can help detect intravascular injection. This small feasibility study is inadequate to validate the safety of US guidance compared with fluoroscopy. Furthermore, the technique requires a highly experienced sonographer. It is worth mentioning that not detecting a small critical vessel with US does not necessarily mean it does not exist. Randomized controlled trials comparing US against other imaging techniques are needed before making any recommendations.

Thus, no recommendations can be given at this time if US is superior to fluoroscopy in cervical selective nerve root block because only limited data exist (level III).

Ultrasound-Guided Third Occipital Nerve and Cervical Medial Branch Block

Eichenberger et al[12] reported, in an observational study, the use of US guidance in blockade of the third occipital nerve (TON) in 14 volunteers. The needles (N = 28) were placed under US guidance and then confirmed by fluoroscopy. The TON was visualized in all volunteers and showed a median diameter of 2.0 mm. The C2-C3 facet joint was identified correctly by US in 27 of 28 cases, and 23 needles were placed correctly into the target zone. Then, local anesthetic (LA) versus normal saline was injected in a randomized, double-blind manner in 11 volunteers. Accuracy of needle position was confirmed by fluoroscopy in 82% of insertions, with 90% success of nerve blockade indicated by sensory anesthesia as the LA injected reached to the target. In this study, the randomization was with regard to the injectate (LA vs normal saline), not to the technique (US versus fluoroscopy). The report involves healthy volunteers, so it is not clear if the same applies to patients with degenerative changes and cervical spondylosis. This block is technically demanding and requires a high level of experience.

Although the above study reported the feasibility of identifying the medial branch of C3, there are no other feasibility studies regarding US-guided lower cervical medial branch block to date, only technical reports.

Based on the above, we have limited data to support the use of US in TON block (level III).

Ultrasound-Guided Cervical Facet Intraarticular Injections

Galiano et al[13] studied, in cadavers, the feasibility of US as a guiding tool for simulated cervical facet joint intraarticular injections. They were able to accurately identify the facet joints from C2-C3 to C6-C7 in 36 of 40 attempts. All 10 needle tips, placed in 1 cadaver, were located inside the joint space as verified by CT.

As the available data are limited only to cadaveric experimental studies, no recommendations can be made.

Ultrasound-Guided Cervical Sympathetic Block

Kapral et al[14] conducted a nonrandomized crossover trial to study the feasibility of US-guided stellate ganglion block. Twelve patients received the classic "blind" stellate ganglion block followed by a second US-guided block the next day. In this study, 5 mL of LA was administered, and all patients in the US-guided group developed sympathetic block within 10 mins compared with 10 of 12 in the blind group. Three patients developed asymptomatic hematoma with the blind technique (discovered during US examination), whereas no hematoma was reported with the US-guided technique.

The spread of the LA was observed under real-time scanning. The proximity of the LA to the recurrent laryngeal nerve and nerve root correlated well with complications such as hoarseness and paresthesia. This is one of very few reports of USPM that suggests the potential superiority of US guidance over the traditional approach. However, the study design did not allow for randomization between the 2 groups, and it involved only 12 patients. Also, they compared US with the classic blind technique and not to the more commonly performed fluoroscopy-guided technique (level III).

More recently, there have been few case reports and technical reports applauding the US-guided technique as US allows direct visualization of various soft-tissue structures, and this can be translated to fewer complications.[15–17]

Gofeld et al[18] reported, in an observational study, the feasibility of lateral in-plane approach with subfascial injection. All the 7 patients had a successful sympathetic block with spread of the injectate between C4 and T1 as confirmed by fluoroscopy (level III). However, it might not be feasible to prove that US-guided approach is safer than other techniques in regard to vascular injuries because the frequency of serious retropharyngeal hematoma after stellate ganglion block (SGB) was reported to be only 1 in 100,000 cases.[19] This will require an enormous number of patients in an RCT to come up with any statistically meaningful difference between different groups (blind, vs fluoroscopy, vs US). Still, RCTs are needed to comment on the incidence of other complications (recurrent laryngeal nerve [RLN] palsy, intravascular injections, etc).

CONCLUSIONS

Ultrasound is a valuable tool for imaging soft-tissue structures and bony surfaces, guiding needle advancement and confirming the spread of injectate around the target, without exposing health care providers and patients to the risks of radiation. There is a rapidly growing interest in USPM as evidenced by the surging number of publications in the last few years. However, most of these publications are small feasibility studies. Currently, we have only weak evidence that US is superior to CT in lumbar facet intraarticular injections (1 small RCT, level Ib). Although we do have a few reports suggesting that US-guided cervical injections have advantages over fluoroscopy-guided approaches (especially in stellate ganglion and cervical nerve root blocks), there are no RCT-driven data to support this.

Future research directions should focus on the cervical spine, peripheral pain blocks (intercostal nerve, suprascapular nerve, etc), and muscle and joint injections as US looks promising in these areas. We are in need for more studies to report on the efficacy and safety of US-guided techniques.

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Ultrasound-Guided Interventional Procedures in Pain Medicine: A Review of Anatomy, Sonoanatomy, and Procedures

Part I: Nonaxial Structures

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Abstract: Application of ultrasound in pain medicine is a rapidly growing medical field in interventional pain management. Ultrasound provides direct visualization of various soft tissues and real-time needle advancement and avoids exposing both the health care provider and the patient to the risks of radiation. The machine itself is more affordable than a fluoroscope, computed tomography scan, or magnetic resonance imaging machine. In the present review, we discuss the challenges and limitations of ultrasound-guided procedures for pain management, anatomy, and sonoanatomy of selected pain management procedures and the literature on those selected procedures.

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Application of ultrasound in pain medicine (USPM) is a rapidly growing component of interventional pain management. Traditionally, interventional procedures for pain management are performed either according to the description of surface landmarks or with imaging guidance such as fluoroscopy and computed tomography (CT) scan. In the last 5 years, there has been a tremendous growth in interest in USPM, as evidenced by the remarkable increase in the literature on ultrasound-guided injections. A search of the MEDLINE database revealed only 3 publications of ultrasound-guided or ultrasound-assisted injection techniques (excluding perioperative and various intra-articular, interlaminar, and trigger-point injections) between 1982 and 2002,[1–3] but there have been 42 publications since 2003. The first objective of this review was to describe and summarize the anatomy and sonoanatomy that are relevant to those specific interventional techniques. The second objective was to describe the limited reports and feasibility data published in the literature on the selected USPM procedures.

METHODS

We performed a literature search of the MEDLINE database from January 1982 to December 2008 using the search terms *ultrasound*, *ultrasound-guided*, *pain management*, and different selected nerves or structures relevant in this review such as *intercostal nerve*, *lateral femoral cutaneous nerve*, *pudendal nerve*, *piriformis muscle*, and *stellate ganglion*. We excluded those publications that described the use of the nerve blocks in the perioperative setting and those of intra-articular, interlaminar, and trigger-point injections.

Ultrasound Versus Conventional Imaging Techniques

One of the major problems with procedures relying on landmarks is the presence of anatomic variation, which can lead to a high failure rate.[4,5] Ultrasound provides direct visualization and imaging of various soft tissues: muscles, ligaments, vessels, nerve, joints, and bony surfaces. With the use of a high-resolution probe, thin nerves (<2 mm) can be visualized. Unlike fluoroscopy and CT scan, ultrasound does not expose the health care provider or the patient to the risks of radiation.[6] Fluoroscopy provides clear images of bone but not soft-tissue structures, limiting its use in those procedures involving peripheral structures or nerves. An ultrasound machine is generally more affordable than a fluoroscopy, CT scan, or magnetic resonance imaging machine. Unlike other imaging modalities, ultrasound equipment is portable and has limited supportive resource needs. Moreover, ultrasound imaging allows real-time needle advancement and appreciation of the spread of injectate, which improves the accuracy of the technique and minimizes the risk of intravascular injection. An added benefit of ultrasound is that it aids in the potential diagnosis of associated conditions that may be related to the patient's pain syndrome. These would include shoulder disorders,[7] various nerve entrapment syndromes,[8] joint pathology,[9] and pneumothorax (following intercostal nerve block).[10]

Limitations and Challenges of Ultrasound

Despite various advantages, ultrasound imaging also has several limitations. The technique and the image are quite operator dependent. The practitioner requires experience to obtain a good image and direct the needle safely to the target structure. Furthermore, the quality of the image in certain areas is poor. This is particularly true in the visualization of axial or spine structures where an acoustic shadow artifact is produced by bone, which has a high attenuation coefficient. Visualization of deep structures is also suboptimal because a low-frequency probe is commonly used in these situations, and the resolution is inferior to that provided by a high-frequency probe. Another limitation is the visualization of a thin needle or a needle inserted at a steep angle.[11] With the development of echogenic needles, this limitation may be overcome.[12]

Compared with ultrasound application in regional anesthesia, USPM is confronted with unique challenges. The targets are not limited to nerve structures (plexus or peripheral nerves) in the upper or lower limbs. Muscles, joints, ligaments, tendons, and bony structures (eg, the spine) are other anatomic structures

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that are targeted in USPM. For interventional techniques guided toward axial structures, the areas of interest are not limited to the interlaminar space for spinal or epidural injection. Structures of interest include the facet joints, facet (medial branch) nerves, spinal nerve roots, sacroiliac joint (SIJ), and caudal canal. Ultrasound in pain medicine demands extensive knowledge of the anatomy of different systems of the body, not to mention an extensive understanding of echogenicity and echotextures of various tissues and organs.

Similar to ultrasound-guided regional anesthesia, USPM is going through 2 phases. The first phase is a rapid increase in the reports of new USPM techniques and feasibility data in the literature. The second phase is an increase in publications of studies on efficacy and safety. Currently, USPM is in its infancy, and more studies on efficacy and safety are needed.

In general, the USPM techniques can be categorized as those belonging to nonaxial and axial structures. The former injection techniques mainly involve imaging of soft tissues, and in this respect, it is easy to see the advantage that ultrasound confers over the conventional techniques. The latter are used in patients with pain from the spine structures and are commonly performed by interventional practitioners under fluoroscopic guidance. At the present stage, the imaging capability provided by ultrasound is limited because of the acoustic shadow cast by bone and the limited window allowed to visualize the target structures for injections. In addition, fluoroscopy is the established technique, having been subjected to rigorous investigation. With this basic categorization in mind, we present a 2-part review: nonaxial and axial (spine) interventional techniques. The present article focuses on nonaxial interventional techniques.

Stellate Ganglion (Cervical Sympathetic) Block

Stellate ganglion block (SGB) is performed for the management of patients for a variety of pain conditions.[13,14] The most widely practiced approach to SGB is the paratracheal approach, in which the needle is inserted toward the anterior tubercle of cervical sixth vertebra (Chassaignac tubercle).[15] However, this landmark is actually in proximity to the middle cervical ganglion instead of the stellate ganglion, which is located opposite to the neck of first rib (Fig. 1).[16]

Anatomy

The sympathetic fibers for the head, neck, and upper limbs arise from the first few thoracic segments, ascend through the sympathetic chains, and synapse in the superior, middle, and inferior cervical ganglia. The stellate ganglion, formed by fusion of the inferior cervical and first thoracic ganglion, is located adjacent to the neck of the first rib, lateral to the longus colli muscle, and posterior to the vertebral artery (Fig. 1). The postganglionic fibers are sent from the stellate ganglion to the cervical nerves (seventh and eighth) and first thoracic nerve to provide sympathetic innervation to the upper limbs.[16–19] The preganglionic fibers of the head and neck region continue to travel cephalad to the superior and middle cervical ganglion through the cervical sympathetic trunk, which is located anterior to the prevertebral fascia.[20,21]

Limitations of the Existing Techniques

The dominant approach is an anterior paratracheal approach at the sixth cervical vertebral level with or without fluoroscopic guidance. A recent study showed the large anatomic variability between individuals in the size and location of Chassaignac tubercle.[15] Most concerning is the breadth of the transverse process in the cephalad-caudad dimension. The average minimum breadth is only 6 mm (Fig. 1). The implication is that a small deviation of the needle from the anterior tubercle will significantly increase the risk of the needle entry into the vertebral artery.[15] Furthermore, with the "blind" technique, the needle may be directed to the posterior tubercle, resulting in local anesthetic spreading around the spinal nerve root. With fluoroscopy, the needle can be accurately directed to the bony landmark, especially using the oblique approach.[22] However, the anterior tubercle is only a surrogate marker because the location of the cervical sympathetic trunk is defined by the fascial plane of the prevertebral fascia, which cannot be visualized with fluoroscopy. Vascular structures (inferior thyroidal, vertebral, and carotid arteries) and soft tissues (thyroid and esophagus) are also not seen with fluoroscopy and are therefore at risk for puncture with the fluoroscopy-guided technique.[23]

Sonoanatomy

The key structures in the ultrasound-guided injection are vessels within the carotid sheath, prevertebral fascia, longus colli muscle, anterior tubercle of the sixth cervical vertebra, and the thyroid (Fig. 2A). When performing the classic approach, the needle is inserted in the vicinity of the cervical sympathetic trunk, which occupies a space anterior and lateral to the cervical vertebral bodies and which is covered by the posterior fascia of the carotid sheath anteriorly and by the prevertebral and alar fascia posteriorly.[24] Contrary to the fluoroscopy-guided method, the end point of the needle is not the contact with bone but the prevertebral fascia.[23,25] This fascia lies over the vertebral bodies, their anterior transverse processes, the longus colli, capitis, and anterior scalene muscles (Fig. 2B). Ultrasound allows direct visualization of vessels and soft tissues (thyroid, esophagus, and muscle) and potentially minimizes the damage of these structures (Figs. 2B, C).[23] Although the vertebral artery enters

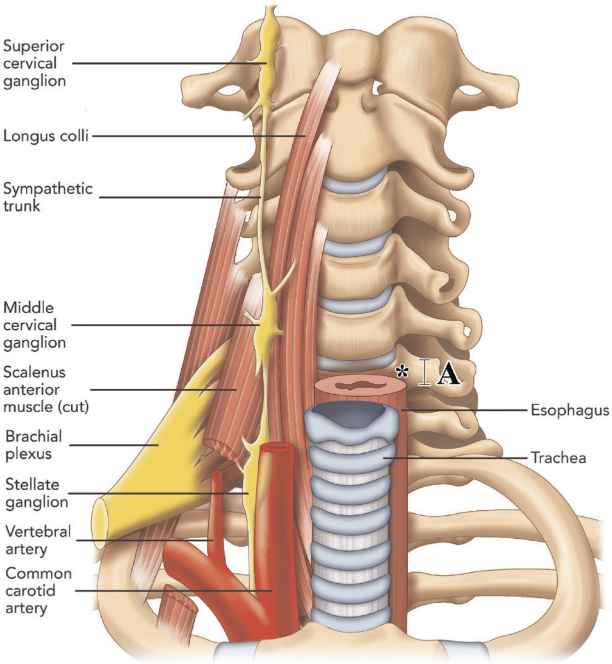

FIGURE 1. Prevertebral region of the neck. The target site for needle insertion in classic approach is marked as asterisk. The breadth of the transverse process is marked as A. Reproduced with permission from Ultrasound for Regional Anesthesia (www.usra.ca).

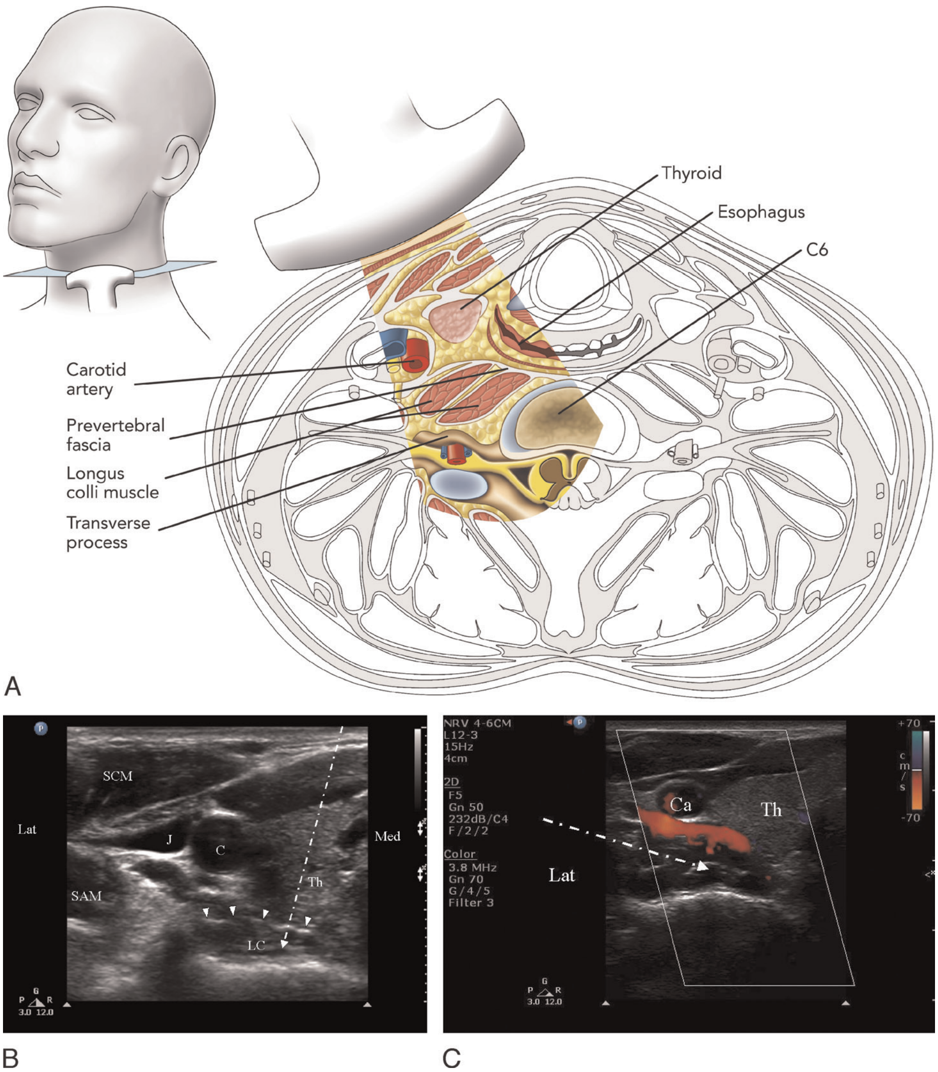

FIGURE 2. A, Cross section of the neck at the sixth cervical vertebral level correlating with the ultrasonographic image. B, Ultrasonographic image of neck at C6. C, Ultrasonographic image with color Doppler. C6 indicates sixth cervical vertebra; C, carotid artery; J, internal jugular vein; SCM, sternocleidomastoid muscle; SAM, scalenus anterior muscle; Th, thyroid; LC, longus colli muscle. The prevertebral fascia is marked by solid arrowhead. The needle path is marked by dotted arrow. Panel A was reproduced with permission from USRA (www.usra.ca).

the foramen of the C6 transverse process in about 90% of cases, it implies that vertebral artery is "exposed" at the level of C6 in the remaining 10% of the population.[26] This variation in anatomy can be detected by ultrasound. Injection under real-time guidance allows the visualization of spread of local anesthetic anterior or posterior to the prevertebral fascia. The absence of the spread of local anesthetic during the real-time injection raises the suspicion of intravascular injection.

Technique for Ultrasound-Guided Injection

Ultrasound-guided approach to SGB was first reported by Kapral et al[2] in 1995. In their case series, 12 patients received the classic blind SGB followed by ultrasound-guided block the next day. Three patients who had received the blind technique developed a hematoma, which did not occur with the ultrasound-guided technique. The spread of the local anesthetic was observed under real-time scanning. The proximity of the local anesthetic to the recurrent laryngeal nerve and nerve root correlated well with complications such as hoarseness and paresthesia. In this study, 5 mL of local anesthetic was administered, and all patients in the ultrasound-guided group developed sympathetic block compared with 10 of 12 in the "blind" group. The authors did not mention specifically whether the needle was directed suprafascial or subfascial. In another study, the investigators deliberately placed the needle in the subfascial plane (26 patients) except in 7 patients because the needles were too short.[25] The change in the temperature of the ipsilateral upper arm was significant compared with that of the contralateral arm with the subfascial injection, whereas the difference in temperature changes between arms was minimal in the suprafascial group. Hoarseness was absent in the subfascial group but occurred in 4 of the 7 patients in the suprafascial group.

The literature suggests that the spread of medication using the classic technique differs, depending on the needle tip position anterior or posterior to the prevertebral fascia. With injection anterior to the prevertebral fascia, the solution tends to spread around the carotid sheath with medial, posterior, or anterior extension.[24] In this case, the risk of hoarseness is higher, probably secondary to contact of the solution with the recurrent laryngeal nerve medial to the carotid and lateral to the trachea.[24,25] When compared with suprafascial injection, subfascial injection results in more extensive caudad spread of solution to the stellate ganglion itself.[24,25] Further studies are required to investigate the advantages of subfascial injection.

There are minor variations in the scanning techniques described in the literature. In general, we prefer to perform the block, with the patient in supine position. A linear probe of high frequency (6–13 mHz) is placed at the level of the cricoid cartilage to obtain a transverse scan. The scan should reveal the important landmarks: the transverse process and anterior tubercle of the sixth cervical vertebra, longus colli muscle and the prevertebral fascia, carotid artery, and thyroid (Fig. 2B). A color Doppler scan will reveal if any vessel is close to the path of needle insertion (Fig. 2C). The needle insertion path should be planned to avoid puncturing important structures such as the esophagus.[23] The needle is targeted to the plane between the longus colli muscle in the subfascial plane and the prevertebral fascia. In the situation when the potential needle path could cause injury to those structures, the needle can be inserted on the lateral side of the ultrasound probe (Fig. 2C).[27]

Suprascapular Nerve Block

First described by Wertheim and Rovenstine[28] in 1941, suprascapular nerve (SSN) block has been performed by anesthesiologists, rheumatologists, and pain physicians to ameliorate the pain that follows trauma[29] or shoulder surgery[30,31] and the pain associated with various chronic shoulder pain syndromes,[32–36] as well as to aid in the diagnosis of suprascapular neuropathy.[37]

Anatomy

The SSN arises from the upper trunk of the brachial plexus, with contributions from the fifth and sixth cervical nerve roots (and also from fibers of the C4 root). The nerve courses laterally beneath the trapezius and the omohyoid muscles and enters the supraspinous fossa via the suprascapular notch beneath the suprascapular ligament. In the supraspinous fossa, it gives off a medial branch to the supraspinatus muscle, proceeds laterally curving around the lateral border of the spine of the scapula to the infraspinatus fossa, and terminates in branches to the infraspinatus muscle (Fig. 3). The SSN contains both motor and sensory branches: motor fibers to the supraspinatus and infraspinatus muscles and sensory fibers to the posterior shoulder joint capsule, acromioclavicular joint, subacromial bursa, coracoclavicular, and coracoacromial ligaments.[38] There is no reliable cutaneous innervation. The suprascapular artery and vein pass above the notch, separated from the SSN by the transverse ligament.

In adults, the suprascapular notch is located medial to the base of the coracoid process and is usually semicircular or V shaped. The size and contour of the notch are highly variable. A recent cadaver study of 423 dried scapula showed absence of the notch in 8.3% of the specimens and the presence of a bony foramen instead in another 7% of the dissections (Fig. 4).[39]

Limitations of the Existing Techniques

The existing techniques described can be summarized into posterior,[28] superior,[40] lateral,[41] and anterior[42] approaches. The targets for the SSN are either at the suprascapular notch itself[28,29] or in the suprascapular fossa.[40,41] To direct the needle to those targets, various methods have been used: a blind insertion using various landmarks,[28] a peripheral nerve stimulator[29] or electromyography,[33] or a direct insertion using fluoroscopic[43] or CT scan guidance.[44]

There are a few disadvantages to targeting the SSN at the notch using the blind or landmark-guided approach, including the risk of pneumothorax, intravascular injection, or nerve injury.[45] In an attempt to evaluate needle tip placement radiologically after blind needle placement, Brown et al[46] demonstrated that the proximity of the "needle tip-to-notch" was poor. The precision of the needle tip location can be improved by fluoroscopy or CT scan guidance. Placing the needle into the suprascapular fossa is a popular alternative.[40,41] The technique is easy to perform and further minimizes the risk of pneumothorax because of the direction of the needle. To ensure the SSN is blocked, an adequate volume of solution is injected into the suprascapular fossa compartment. Too low a volume will result in maldistribution, and too high will result in the spread of local anesthetic to the brachial plexus.[40,41,44,46] A recent CT scan study showed that 10-mL injectate spread to the brachial plexus in the axilla in 3 of 33 cadavers.[40] The authors suggested that 5 mL is the adequate volume for injection into the suprascapular fossa. They also showed that blind injection could lead to placement of the needle in, or even above, the supraspinatus muscle.[40]

Sonoanatomy

The suprascapular notch is a superficial structure always found medial to the coracoid process, having a skin-notch base

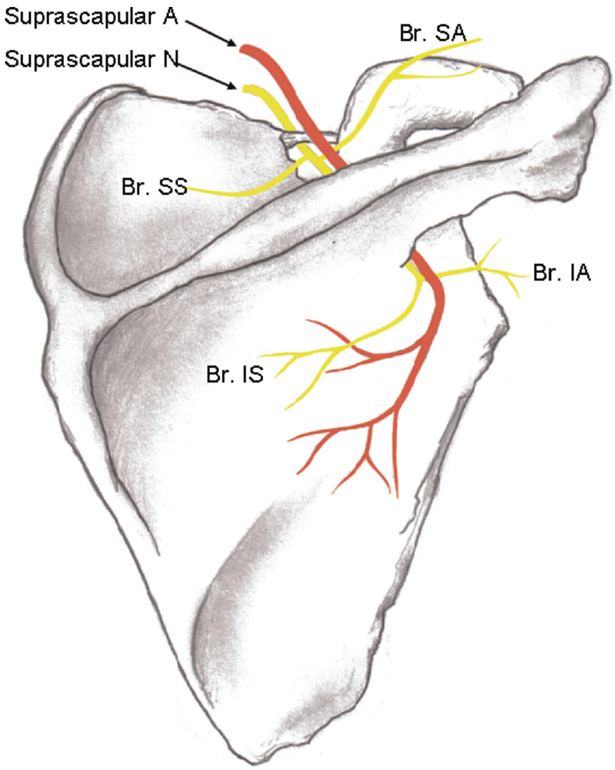

FIGURE 3. Suprascapular nerve and its branches. Superior articular branch (Br. SA) supplies the coracohumeral ligament, subacromial bursa, and posterior aspect of the acromioclavicular joint capsule; inferior articular branch (Br. IA) supplies the posterior joint capsule; Br. SS indicates branch to the supraspinatus muscle; Br. IS, branch to the infraspinatus muscle. Reproduced with permission from USRA (www.usra.ca).

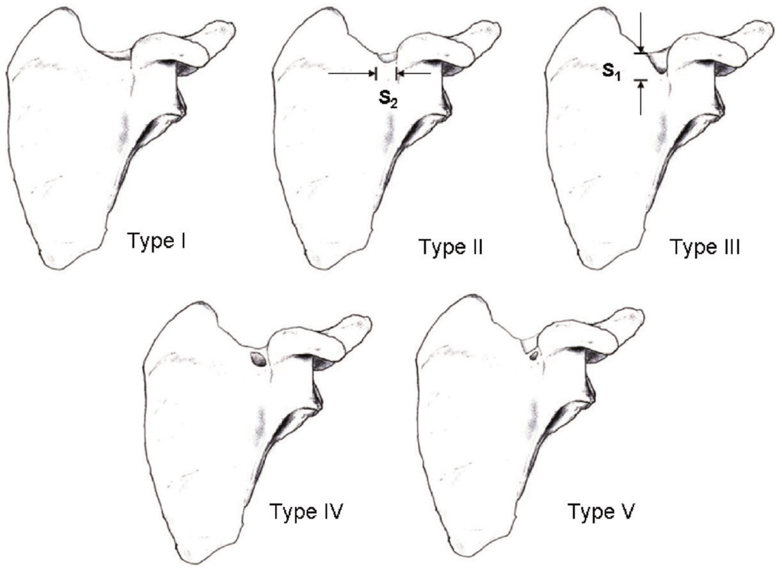

FIGURE 4. Variation of morphology of suprascapular notch. Type I—no notch (8.3%); type II—notch with greater transverse diameter, S_2 (41.85%); type III—notch with greater vertical diameter, S_1 (41.85%); type IV—bony foramen (7.3%); type V—notch with bony foramen (0.7%). Adapted from Ref. 43.

distance of less than 5 cm.[47] With the ultrasound probe tilting anteriorly and inferiorly in the suprascapular fossa, the notch is seen covered by trapezius and supraspinatus muscles (Fig. 5A). The maximum dimensions of the notch are approximately 14 mm wide and 7 mm deep. The suprascapular vasculature and suprascapular ligament were visualized in 86% and 96% of the subjects in a recent ultrasonographic morphometric study.[47] The diameter of the SSN is usually 2 to 3 mm.[48]

Technique for Ultrasound-Guided Injection

There is only 1 case report published on this subject.[49] The authors suggested placing the ultrasound probe initially parallel to the scapular spine and then moving the probe in a cephalad direction. However, the scapula floor forms a 40-degree angle to the scapula.[50] Thus, to visualize the floor and the notch, we recommend tilting the probe toward the coronal plane.[47] By adjusting the angle of the ultrasound probe in cephalad-caudad direction and toward the medial aspect of coracoid process, the SSN and the transverse ligament will be visualized. The scan is performed with the patient in sitting position. A linear probe with high frequency (6–13 Hz) is recommended because the nerve is quite superficial (<5 cm). Deep to the subcutaneous tissue, 2 muscles are clearly visualized: trapezius and supraspinatus muscles (Fig. 5A). Color Doppler of this area will show the suprascapular artery (Fig. 5B). The needle is inserted in-plane from the medial side of the probe. Five milliliters of solution (local anesthetic and steroid) is injected under real-time guidance. It is important to confirm the spread of injectate around the nerve. Absence of the spread suggests misplacement of needle (intramuscular or intravascular injection).

Intercostal Nerve Block

Intercostal nerve block has been in clinical use for more than 8 decades. Although the role of this nerve block is quite established in the management of acute pain after rib fractures[51] or thoracotomy,[52] the role in chronic pain management has yet to be defined.[53–55]

Anatomy

There are 3 layers of intercostal muscles: external, internal, and innermost intercostal muscles, which are all incomplete and thin layers of muscle and tendinous fibers (Fig. 6A).[56] The

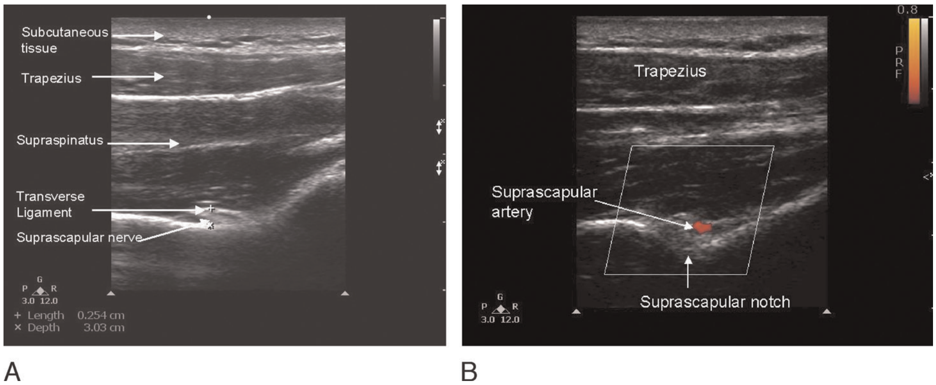

FIGURE 5. A, Ultrasound image of the suprascapular notch and the content. Measurement of the depth of the suprascapular notch from skin (3.03 cm) and the size of the SSN (0.25 cm) is shown. B, Color Doppler shows the suprascapular artery. Reproduced with permission from USRA (www.usra.ca).

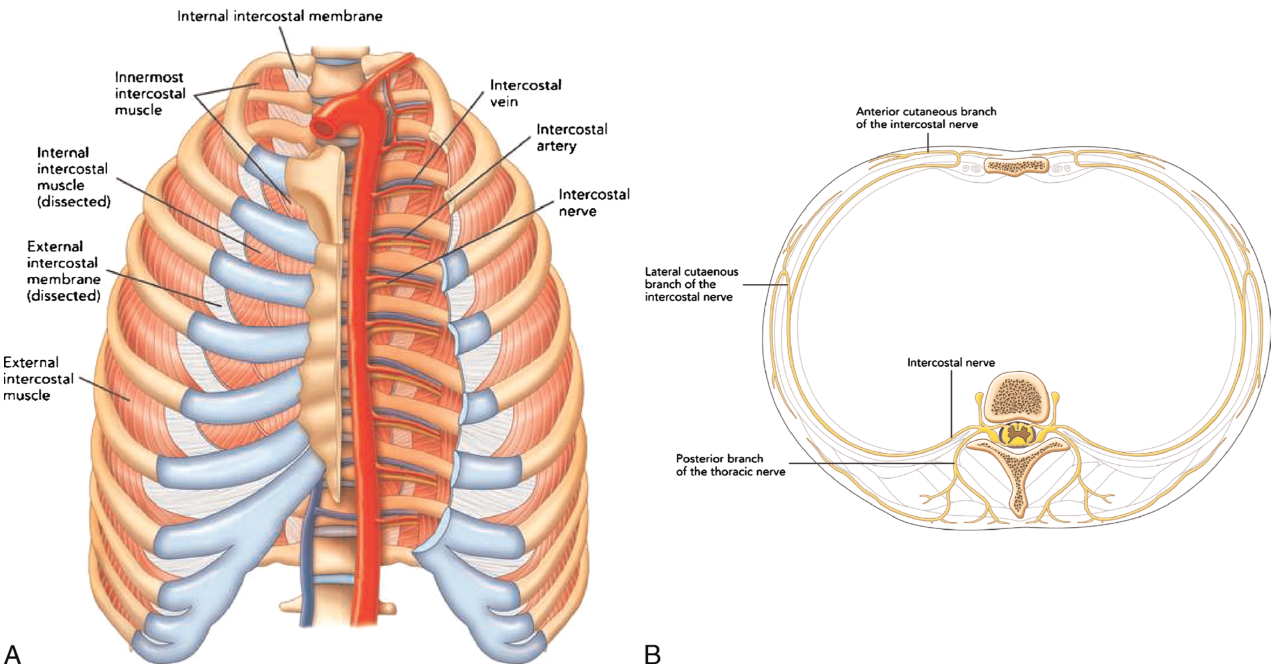

FIGURE 6. A, Intercostal muscles in the chest wall. B, Branches of the typical intercostal nerves. Reproduced with permission from USRA (www.usra.ca).

neurovascular bundle lies in between the internal and innermost intercostal muscles in the costal groove.[57] The neurovascular bundle enters the intercostal space between the parietal pleura and the internal intercostal membrane initially and then between the internal and innermost intercostal membrane. Although most of the textbooks describe the location of neurovascular bundle in the costal groove, 1 cadaver study showed that the neurovascular bundle was subcostal in only 17% of the cases, and in the remaining 73% of the cases, it was midway between the ribs (Fig. 7A).[58]

The intercostal nerves originate in the ventral rami of the 1st to 11th thoracic spinal nerves. The 12th thoracic spinal nerves give rise to the subcostal nerve. The second to sixth nerves are distributed within their intercostal spaces and are called thoracic intercostal nerves. They give rise to lateral and anterior cutaneous branches (Fig. 6B). The lateral cutaneous branches pierce the external intercostal muscle at approximately the level of the midaxillary line and supply the skin of chest wall, latissimus dorsi, and upper part of external oblique (EO) muscles.[56] This is the cutaneous branch that needs to be included in the nerve block for pain. The 7th to 11th intercostal nerves are named *thoracoabdominal nerves* as they continue anteriorly from the intercostal spaces into the abdominal wall. The 9th to 11th intercostal nerves, together with the subcostal (12th) nerve and first lumbar nerves, are widely connected and run within the transversus abdominis plane.[59]

Limitations of the Existing Techniques

The most feared complication with the existing blind technique is pneumothorax. The distance between the neurovascular bundles to the pleura in thin patients is usually within 0.5 cm.[60] Moore and Bridenbaugh[61] reported an incidence of pneumothorax of 0.09% in an analysis of 4333 patients who received 50,097 intercostal nerve injections. Injections were mostly performed by trainees under supervision (85%). However, 2 recent series have suggested a higher incidence of pneumothorax. In 1 study, intercostal nerve block was performed in patients receiving renal transplantation. Two patients (8%) developed pneumothorax, and both required chest drainage.[62] Another series described the incidence of pneumothorax after intercostal nerve block for rib fractures. Patients with pneumothorax, hemothorax, and/or subcutaneous air on initial chest radiograph were excluded.[63] Pneumothoraces were noted in 14 patients (8.7%)—11 of whom were treated with a thoracostomy tube.

Sonoanatomy

Ultrasound allows visualization of the pleura, different layers of the intercostal muscles, and the path of needle insertion when an in-plane technique is used (Figs. 7A, B). The neurovascular bundle cannot be visualized under normal circumstances, because it is covered by the rib. However, the location of the intercostal nerve can be estimated by directing the needle in between the internal and innermost intercostal muscle. After the injection, ultrasound can be used for diagnosing pneumothorax (see next section).[64] Diagnosis of pneumothorax by bedside ultrasonography has been validated, with a sensitivity of 100% and a specificity of 96.5%.[65] Ultrasound was found to be more sensitive than supine chest radiography in the detection of pneumothorax.[10]

Technique for Ultrasound-Guided Injection

There is limited literature describing the techniques of ultrasound-guided intercostal nerve injections.[60,66] The technique described below is similar to that described in the case report but has been modified by the authors. A linear probe with high resolution (6–13 Hz) is preferred. With the patient placed in a prone position, the ultrasound probe can be used to count the ribs. The angle of the rib is the preferred site of injection as the rib is thickest here, the costal groove (which no longer exists 15 cm from the spinous process) is at its broadest and deepest, and the intercostal nerve has not yet branched.[67] The angle of the

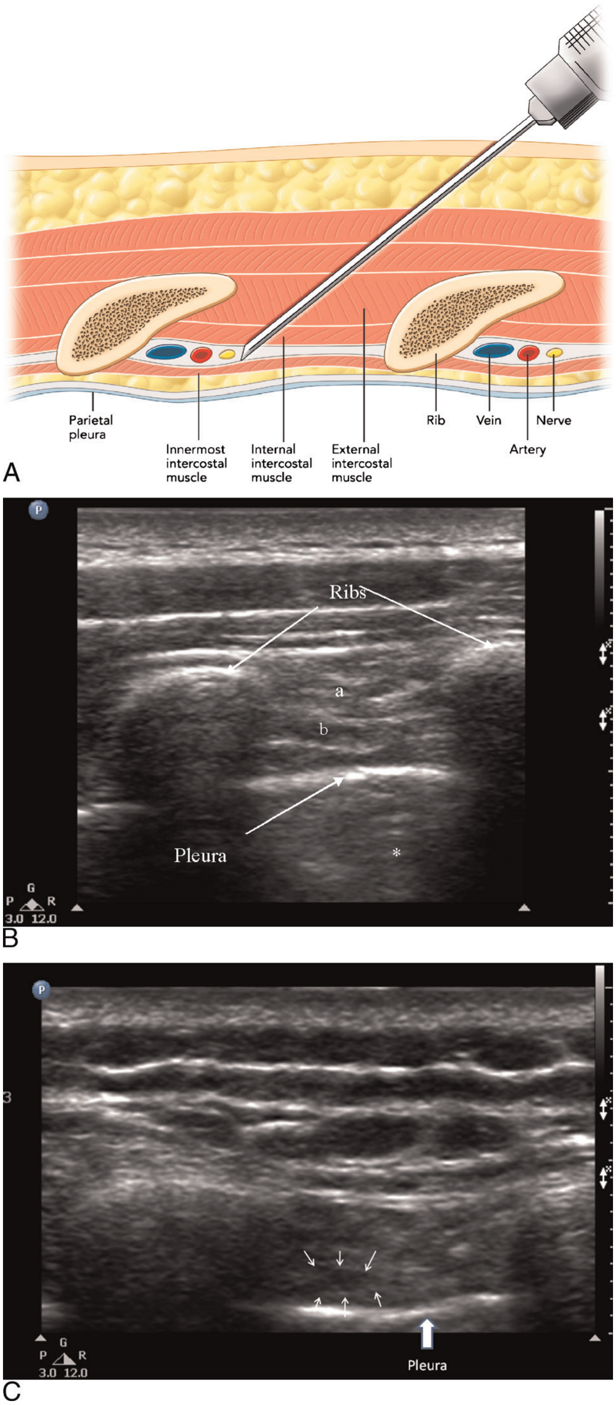

FIGURE 7. A, Cross section of chest wall showing intercostal muscles and neurovascular bundles. B, Corresponding ultrasound image. A, External intercostal muscle. B, Internal intercostal muscle. *Reverberation artifact. C, Ultrasonographic image after injection. The small arrows outline the collection of local anesthetic. Reproduced with permission from USRA (www.usra.ca).

rib is approximately 6 to 7.5 cm from the spinous process or on the lateral edge of the paraspinal muscle. The probe is placed in the short axis to the ribs, so the 2 consecutive ribs are in view (Fig. 7B). The depth and gain are adjusted so that the intercostal muscles and pleura are in view. Both in-plane and out-of-plane techniques for intercostal nerve block have been described,[60,66] and both have their advantages and disadvantages.[68] The authors prefer in-plane technique for various reasons: the direction of the needle is similar to the classic technique described for intercostal nerve block, and the complete needle path can be traced. The needle entry site is the upper margin of the rib 1 level caudad to the targeted intercostal nerves (Fig. 7A). Once the needle penetrates the skin, the ultrasound probe can be rolled over the needle, which is advanced deep to the internal intercostal muscle. One of the drawbacks for the in-plane technique is that when the probe is not perfectly in line with the needle, the practitioner may have a false impression of the location of the needle tip. Because the distance between the costal groove and the pleura is in the dimension of 0.5 cm, it is advisable to inject a small amount of injectate when the needle is in the external intercostal muscle to confirm the needle tip position. Under real-time injection, intravascular injection should be suspected if the spread of the medication is not visualized. Once the needle tip is confirmed deep to the internal intercostal muscle, the local anesthetic can be injected and spread of medication can be seen.

After the injection, ultrasound can be used to scan for the possible complication of pneumothorax while the patient is kept in the prone position. With the ultrasound probe placed longitudinally in the intercostal space, the pleura appears as a definite hyperechogenic line that glides with respiratory movement (Fig. 8). Normally, 2 types of artifacts can be visualized: reverberation artifacts appearing as a series of horizontal lines parallel to the pleural interface and vertical comet-tail artifacts. In patients with pneumothorax, the ultrasonographic features suggestive of the diagnosis are absence of lung sliding, broadening of the pleural line to a band, loss of comet-tail artifacts, and exaggeration of horizontal artifacts. Combining the signs of absent lung sliding and the loss of comet-tail artifact, ultrasound has a reported sensitivity of 100%, specificity of 96.5%, and negative predictive value of 100%.[65]

Ilioinguinal, Iliohypogastric, and Genitofemoral (Border) Nerve Block

Iliohypogastric (IH), ilioinguinal (IL), and genitofemoral (GF) nerves are known as "border nerves" because these nerves supply the skin "bordering" between the abdomen and thigh.[69] Because of the course of the nerves, they are at risk for injury in lower abdominal surgery (Pfannenstiel incision, appendectomy, inguinal herniorrhaphy) or laparoscopic surgery (trocar insertion).[70–72] As a result, patients may suffer from chronic

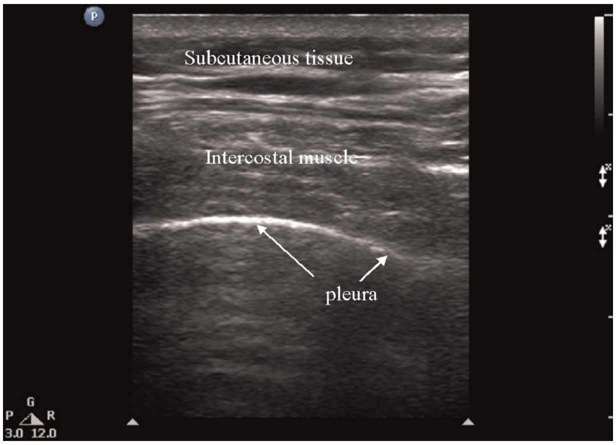

FIGURE 8. Longitudinal ultrasonographic view of pleura and lung. The pleura interface appears as an echogenic line.

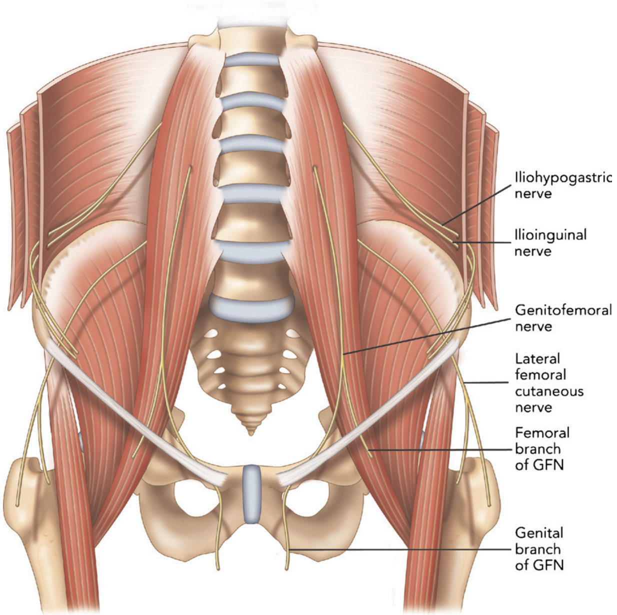

FIGURE 9. Schematic diagram showing the pathway of IL, IH, LFC, and GF nerves. Reproduced with permission from USRA (www.usra.ca).

postsurgical pain due to the nerve injury.[73,74] Patients with neuropathy after injury to these nerves will present with groin pain that may extend to the scrotum or the testicle in men, the labia majora in women, and the medial aspect of the thigh. Accurate diagnostic block of those nerves is important in understanding the etiology of the clinical problem.

Anatomy

Both the IL and IH nerves arise from the anterior rami of L1 with contributing filaments from T12 (Fig. 9). The nerves emerge from the lateral border of the psoas major muscle and run subperitoneally in front of quadratus lumborum muscle before piercing the transverse abdominis (TA) muscle above the iliac crest.[75]

The IH nerve runs downward and forward and pierces the internal oblique (IO) muscle above the anterior superior iliac spine (ASIS). It then travels between the IO muscle and the EO muscle. About an inch above the superficial inguinal ring, the IH nerve pierces the aponeurosis of the EO muscle and provides sensory fibers to the skin over the lower part of the rectus abdominis (the skin of the mons). The IL nerve runs parallel and below the IH nerve. After piercing the lower border of the IO muscle, the IL passes between the crura of the superficial inguinal ring in front of the spermatic cord. It supplies the skin of the superomedial area of the thigh and the skin over the root of the penis and anterior scrotum (the mons pubis and labium majus in females).

The GF nerve arises from the first and second lumbar nerve roots. After penetrating the psoas muscle at the level of the L3-4 intervertebral disk, the GF nerve comes to lie on its anterior surface, either as a single trunk or as separate genital and femoral branches (Fig. 9).[69] It divides into a femoral and genital branch at a variable distance above the level of the inguinal ligament. The femoral branch follows the external iliac artery and passes with it under the inguinal ligament. It penetrates the fascia lata to supply the skin overlying the femoral triangle. The genital branch of the GF nerve passes through the internal inguinal ring of the transversalis fascia and then continues into the inguinal canal. The relationship of the genital branch to the spermatic cord in the inguinal canal is highly variable. It can either run outside the spermatic cord in the ventral,[69] dorsal, and inferior locations[76] or incorporate with the cremaster muscle.[75]

It is important to note that there are many variations of the sensory nerve innervation patterns within the inguinal region, with free communication between the branches of the GF, IL, and IH nerves. The course of both IL and IH nerves described previously may apply to only 42% of dissections.[77] In a cadaver study, the IL nerve was solely responsible for the cutaneous component of the GF nerve in 28% of dissections and shared innervation with the genital branch of GF nerve in 8%.[75] The site where the IL and IH nerves penetrate the different layers of abdominal muscle is highly variable.[71] The size of the IL nerve is inversely proportional to the IH nerve. In 29% of patients, the IL nerve joins the IH nerve, or one of the nerves is entirely absent.[77]

Limitation of the Existing Techniques

The existing techniques based on landmarks are confusing. The needle entry points described vary in terms of their locations in the lower abdominal quadrant. Suggested entry points are 1 inch medial to the ASIS on a line joining the ASIS and umbilicus,[78] 3 cm medial and inferior to the ASIS,[79] or 2 inches medial and inferior to the ASIS (Fig. 10).[80] The direction of the needle in these described techniques can be completely opposite, and the authors often suggest infiltrating the local anesthetic in a fan-shape manner. Because the IL and IH nerves can be located at different fascial planes between the 3 muscles (IO, EO, and TA), these blind techniques have low success rates.[81] Furthermore, complications such as femoral nerve palsy[82] and bowel perforation[83,84] have been reported.

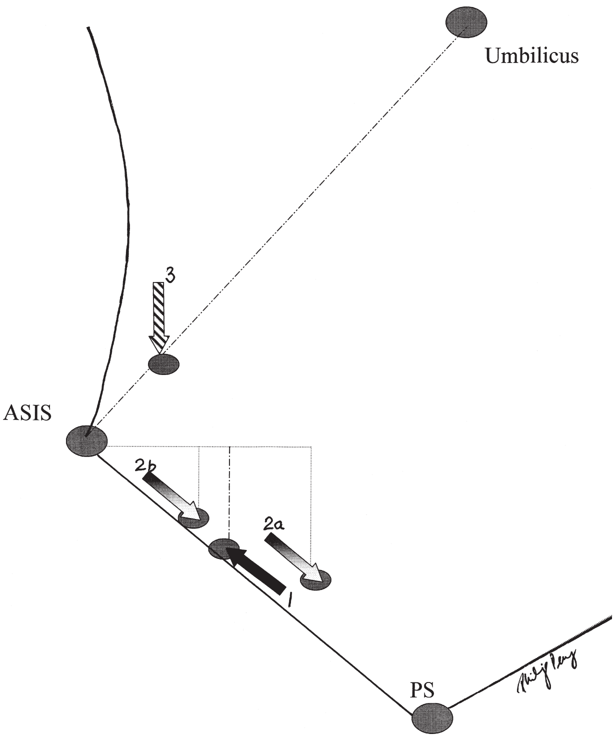

FIGURE 10. The 3 methods (4 landmarks) described for IL and IH nerve injections in Refs. 82, 83, and 84. PS indicates pubic symphysis. Reproduced with permission from the American Society of Interventional Pain Physician.[4]

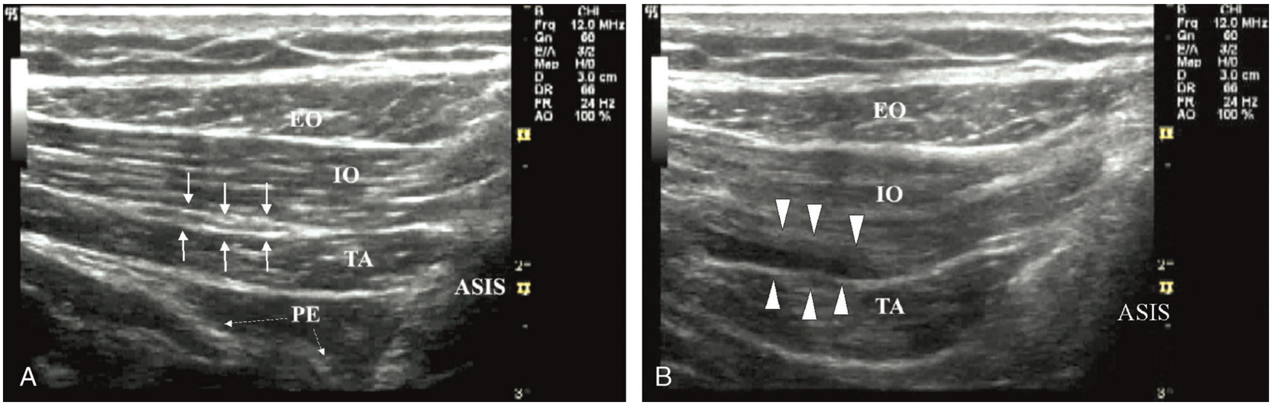

FIGURE 11. A, Ultrasound picture showing the 3 layers of abdominal muscles and the IL and IH nerves in the fascial split (arrows) between IO and TA muscles. PE indicates peritoneum. B, Presence of local anesthetic in the fascial split after injection. Reproduced with permission from the American Society of Interventional Pain Physician.[4]

The description of a GF nerve block mainly refers to the blockade of the genital branch, while ideally, the main nerve should be blocked at the level of the internal inguinal ring. The landmark described for the genital branch is the pubic tubercle.[80] It is suggested that the needle be directed to a point 1 cm superior and lateral to the tubercle with a field block. Although the basis of this landmark is not clear, the needle is likely directed toward the spermatic cord in the inguinal canal. With a blind technique, important structures of the spermatic cord (testicular artery and vas deferens) or the peritoneum are at risk.

Sonoanatomy

The area for optimal scanning is the area posterior and cephalad to the ASIS.[5] With the probe placed in an orientation perpendicular to the inguinal ligament, all the 3 layers of abdominal muscles (EO, IO, and TA), iliac crest, and peritoneum can be well visualized (Fig. 11A). In this plane, both nerves (IL, IH) may be found with 90% probability between the TA and IO muscles at this region.[85] At this region, both nerves should be within 1.5 cm from the iliac crest at this region, with the IL nerve closer to the iliac crest.[5,66] The 3 layers of abdominal muscles (EO, IO, and abdominis transversus) should be well visualized at this region as the EO muscle becomes thinner and forms its aponeurosis distally. Between the layers of TA and IO muscles, splitting of the fascial layer is usually observed. It is through this plane where the IL and IH nerves pass. Sometimes, both nerves pierce the IO and appear between the IO and EO muscles, especially when these 2 nerves travel more distally. Both nerves can run together[77] or run at a distance of approximately 1 cm apart. In this case, more than 1 fascial split will be seen. With color Doppler, the deep circumflex iliac artery is often seen accompanying the IL and IH nerves.

Technique for Ultrasound-Guided Injection

The technique for ultrasound-guided IL and IH injections in adults has only been reported as a single injection or the insertion of a catheter.[86–88] Unlike other ultrasound-guided techniques described previously, this nerve block has been validated by a cadaver study with 95% accuracy in localizing both nerves.[5] There are some variations of the techniques in those reports, but a few principles should be observed. Because of the superficial nature of the nerves, a linear probe of high frequency (6–13 MHz) is used. The orientation of the probe should be perpendicular to the inguinal line joining the ASIS and pubic tubercle, with the lateral end of the probe just above or posterior to the ASIS.[5] The probe is then tilted until all 3 layers of muscles (TA, IO, and EO) are visualized (Figs. 11A, B).

The nerve can be approached by an in-plane or out-of-plane technique. With out-of-plane techniques, a nerve-stimulating needle is inserted toward the splitting fascia. Sensory stimulation

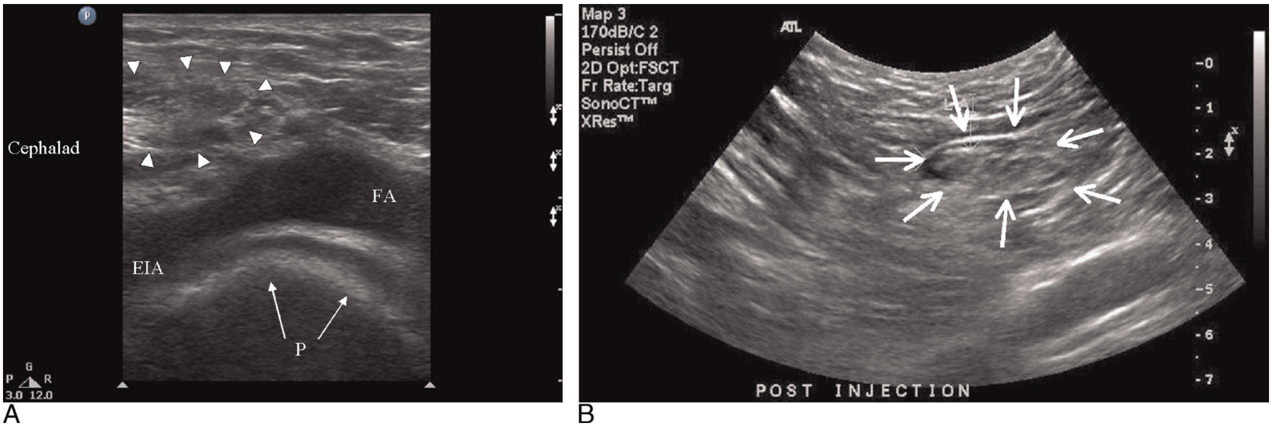

FIGURE 12. A, Longitudinal scan of the femoral artery and external iliac artery. The spermatic cord (indicated by solid arrowheads) appears superficial to the external iliac artery (EIA) at the inguinal canal. FA indicates femoral artery; P, superior ramus of pubis. B, Spermatic cord after injection. Panel B was reproduced with permission from the American Society of Interventional Pain Physicians.[4]

of the nerve may then produce paresthesia in the groin area. Five milliliters of local anesthetic is injected into the split fascia plane. If it is used for patients with chronic pain, steroids may be added. In some patients, both nerves may not be visualized, and injectate can be administered to the plane between TA and IO muscles.[87]

The technique for blocking the genital branch of the GF nerve under ultrasound guidance has only been described in a single review article.[4] A linear probe of high frequency (6–13 MHz) is used. The final position of the probe is about 2 finger-breadths lateral to the pubic tubercle, with the orientation perpendicular to the inguinal line. The GF nerve cannot be visualized directly. The key structure is the spermatic cord (round ligament of the uterus in a female), which is oval or circular in shape with 1 or 2 arteries within it (the testicular artery and the artery to the vas deferens). The vas deferens is often seen as a thick tubular structure also found within the spermatic cord. The recommended technique is to align the ultrasound probe in the internal inguinal ring, at which the femoral artery can be visualized in the long axis. By moving the probe in the cephalad direction, the artery is seen as diving deep toward the inguinal ligament and where it becomes the external iliac artery. At this point, an oval or circular structure can easily be seen superficial to the external iliac artery just opposite to the internal inguinal ring (Fig. 12A). The probe is then moved slightly in the medial direction away from the femoral artery in an attempt to trace the spermatic cord or round ligament. An out-of-plane technique is also used, with the needle approaching the skin from the lateral aspect of the probe. Local anesthetic without epinephrine is used to avoid the possible vasoconstrictive effect on the testicular artery. Because of the anatomic anomalies found with the location of the genital branch in the GF nerve, we suggest depositing 4 mL of local anesthetic inside and another 4 mL outside the spermatic cord (Fig. 12B).

Lateral Femoral Cutaneous Nerve Block

Meralgia paresthetica is a mononeuropathy of the lateral femoral cutaneous nerve (LFCN) characterized by paresthesia, numbness, and pain in a localized area on the anterolateral aspect of the thigh.[89,90] The incidence in a primary care setting was estimated at 4.3 per 10,000 person-years.[91] Diagnosis and management have been well reviewed elsewhere. Blockade of the LFCN is used for the diagnosis and conservative management of meralgia paresthetica.[89,90]

Anatomy

The LFCN is a pure sensory cutaneous nerve supplying the lateral aspect of the thigh as proximal as the greater trochanter.[92] It arises from the dorsal branches of second and third lumbar nerve roots. Emerging from the lateral border of the psoas muscle, the LFCN runs inferiorly and laterally across the iliacus muscle between the 2 layers of iliac fascia.[93,94] The LFCN reaches the thigh by passing beneath the inguinal ligament medial to the ASIS over the sartorius muscle into the thigh, where it divides into anterior and posterior branches (Fig. 9). When the LFCN passes medial to the ASIS, the distance from the nerve to ASIS varies between 6 and 73 mm.[93] Although this classic description holds true in most patients, LFCN has been observed passing over, or even posterior to, the ASIS in 4% to 29% of the cadavers.[95–97] In 28% of the cases, the LFCN divided before crossing the inguinal ligament (range, 0–5 nerve branches).[93] The diameter of the LFCN at the level of inguinal ligament is 3.2 mm (SD, 0.7 mm).[94] Below this level, the LFCN is sandwiched between the fascia lata and fascia iliaca (Fig. 13).[94,98] Nerve branches of the LFCN cross the lateral border of the sartorius muscle in distances ranging from 2.2 to 11.3 cm inferior to the ASIS.[93]

Limitation of the Existing Techniques

The most popular technique is a blind technique based on the landmark usually described as a point 2.5 cm medial and inferior to ASIS. Injection of local anesthetic can be performed using field block, a "pop" sensation (feeling of the needle passing through the fascia lata), or a loss-of-resistance technique.[92,98–100,105,106] A study correlating the needle placement by the classic landmark technique with both the cadaver dissection and localization of the nerve with transdermal nerve stimulation in volunteers showed a very poor correlation (5% and 0%, respectively).[101] A well-designed study suggested that the success rate of the blind technique was only 40%.[92] Furthermore, spread of local anesthetic to the femoral nerve occurred in 35% of subjects receiving LFCN block.[92] With the use of a nerve stimulator to elicit paresthesia, the success rate was improved to 85%. However, the nerve-stimulating technique achieves paresthesia, thus localization of the nerve, at the expense of added discomfort to the patient.[92]

With the wide variation in location of the LFCN distal to the inguinal ligament, a designated needle entry point medial to the ASIS is grossly inadequate. A recent study comparing the landmark- and ultrasound-guided technique for the LFCN block showed that the needle was in contact with the nerve in only 5% of the cadavers using the usual landmark, in contrast to 84% with ultrasound-guided technique.[101] The LFCN was approximately 2 cm medial and 8 cm caudad to the ASIS. The same group of investigators[101] also compared the use of ultrasound and landmark techniques to localize the LFCN in volunteers using a transdermal nerve stimulator to confirm the location. The accuracy in locating the LFCN was 80% and 0% for ultrasound and landmark techniques, respectively.

Sonoanatomy

The LFCN can be visualized proximal or distal to the inguinal ligament. In a patient with a low body mass index, the LFCN can be visualized proximal to the level of inguinal ligament lying over the iliacus muscles.[102] At the level of the inguinal ligament, the LFCN appears between the inguinal ligament and iliacus muscle medial to the ASIS. Distal to the level of inguinal ligament, the anatomic arrangement depends on the course of the nerve. If the LFCN continues to run superficial to the iliacus muscle, it can be

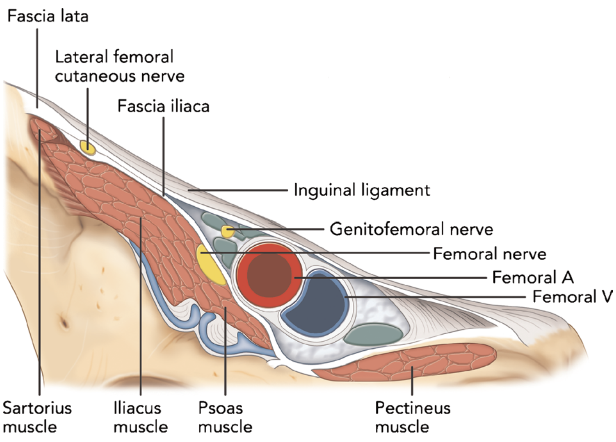

FIGURE 13. Nerves at the inguinal area. Reproduced with permission from USRA (www.usra.ca).

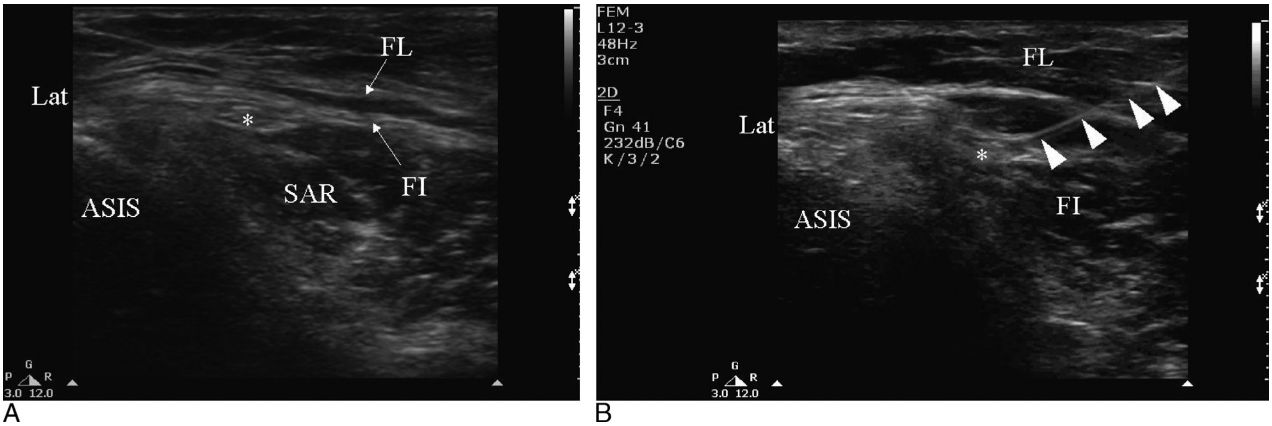

FIGURE 14. Ultrasonographic image of LFCN before (A) and after (B) injection. FL indicates fascia lata; FI, fascia iliaca; SAR, sartorius muscle. Solid arrowheads show the path of needle. Asterisk indicates LFCN.

found between the fascia iliaca and fascia lata.[94,98] The LFCN may course laterally over the sartorius muscle as soon as it runs distal to the inguinal ligament and can easily be found superficial to the sartorius muscle.[101,102]

Technique for Ultrasound-Guided Injection

The literature includes a case series, a feasibility study, and a validation study.[98,101–103] The literature suggests that the LFCN is best recognized when it courses laterally over the sartorius muscle, which has a typical triangular shape.[101,102] However, this implies the injection site distal to the usual site of entrapment, which is usually at the level of inguinal canal. To locate the LFCN proximally, the technical difficulty increases, and the success rate is reported at 70%.[102]

In the authors' experience, the scanning starts at the inguinal level, with the lateral end of the ultrasound probe on the ASIS. A linear high-frequency probe (8–13MHz) is used and moved in medial and inferior directions to allow a systematic anatomic survey. The LFCN appears as a hyperechoic "dot" between the fascia lata and fascia iliaca approximately 2 to 3 cm from the ASIS (Figs. 14A, B). In the case of difficult visualization of the nerve, one can inject dextrose solution deep to the fascia lata just medial to ASIS for hydrodissection. This will enhance the visualization of the LFCN. If the nerve cannot be recognized, the probe is then placed over the sartorius

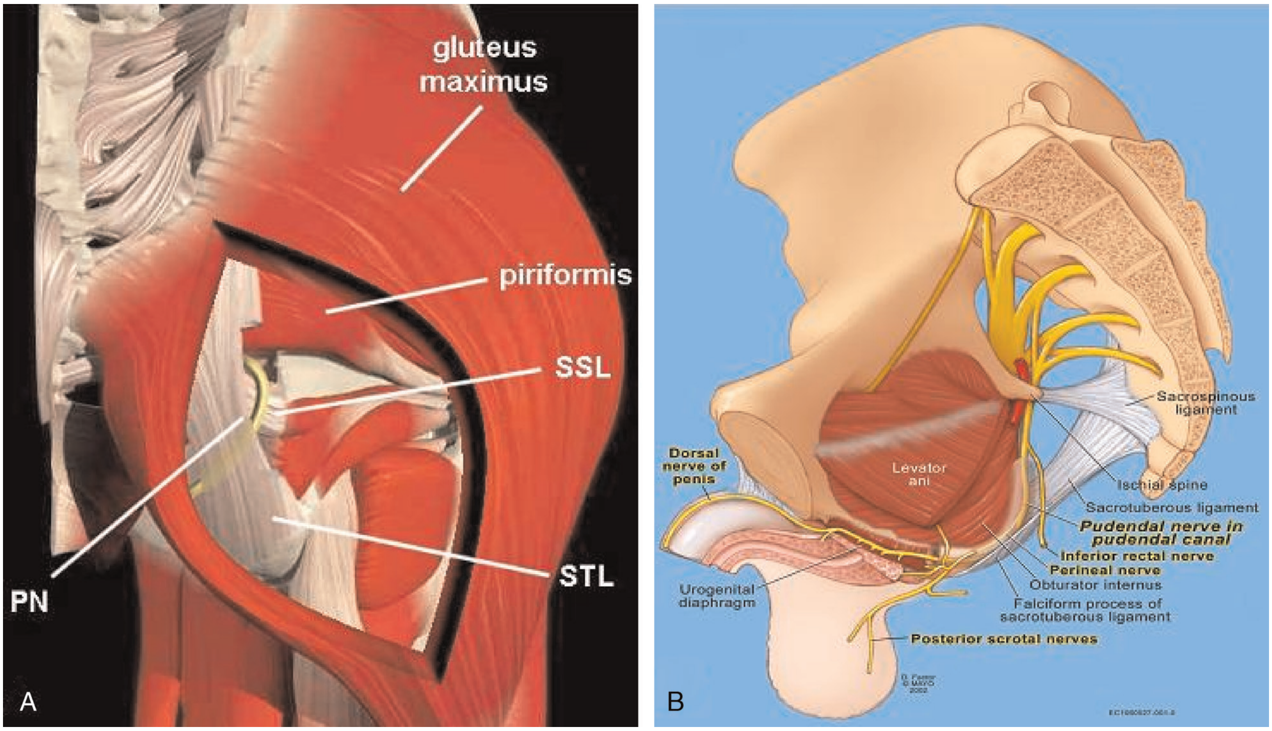

FIGURE 15. Piriformis and pudendal nerve. STL indicates sacrotuberous ligament; SSL, sacrospinous ligament; PN, pudendal nerve. Panel B was reproduced with permission from Mayo Foundation for Medical Education and Research. All rights reserved.[123]

muscles from the ASIS and then moved medially and distally to locate the nerve when it crosses superficially to the muscle. Once the nerve is located, the nerve is then traced as proximal as possible before the needle is inserted. When the nerve cannot be localized, it may be due to the anatomic variation: the nerve may pass through the sartorius muscle[94] and posterior to the ASIS.

Piriformis Muscle Injection

Piriformis syndrome is an uncommon and often underdiagnosed cause of buttock and leg pain. The diagnosis is made after exclusion of any other pathologic condition that could cause sciatica, and there is no consensus about the clinical findings, the laboratory studies, and the treatment.[104,105] The management of piriformis syndrome includes the injection of the piriformis muscle with local anesthetic and steroids[105] or the injection of botulinum toxin.[106]

Anatomy

Originating from the anterior surface of the second to the fourth sacral vertebrae and the capsule of the SIJ, the piriformis muscle runs laterally and exits the pelvis through the greater sciatic foramen, becomes tendinous, and inserts into the upper border of the greater trochanter (Fig. 15). It acts as an external rotator in the standing position and as an abductor in the supine position.

The piriformis muscle is a key landmark structure of the sciatic notch through which all neurovascular structures that enter the buttock from the pelvis pass either superior or inferior to the piriformis. The structures that pain physicians should know and that pass below the piriformis muscle are the inferior gluteal artery and nerve, the pudendal artery and nerve, and the sciatic nerve. Various anatomic relationships between the sciatic nerve and the piriformis muscle have been described. The most common arrangement is the undivided nerve passing below the piriformis muscle (78%–84%).[107,108] The second most common arrangement is the divided nerve passing through and below the muscle (12%–21%). The aberrant course of the sciatic nerve through the piriformis muscle can cause sciatic nerve irritation and may suggest the important role of a nerve stimulator in the injection of the piriformis muscle.

Limitation of the Existing Techniques

Various techniques have been described to assist in localizing the piriformis muscle. These include imaging techniques, such as CT scan and fluoroscopy, to guide the needle to the proximity of the muscle and electrophysiologic techniques, such as the use of the electromyography and nerve stimulation, to confirm the activation of the piriformis muscle or sciatic nerve. Quite often, physicians combine 1 component of both techniques to improve the accuracy of needle placement.[105,109,110]

Whereas CT scan and electromyography machines are not widely available to interventional physicians, fluoroscopy-guided technique is commonly used. Fluoroscopy displays the sciatic notch and SIJ, but not the piriformis muscle itself. When the needle placement within the piriformis muscle is required, such as in the situation of botulinum toxin injection, contrast is used to "outline"' the piriformis muscle (Fig. 16). A recent cadaver study demonstrated that the fluoroscopically guided, contrast-controlled injection was accurate in 30% of the injections.[111] Nerve stimulators can stimulate the muscle when the needle is in contact with or within the muscle itself. Neither approach offers direct visualization of the muscle, nor can it ensure the accurate placement of the needle within the piriformis muscle.

FIGURE 16. Radiographic contrast outlining the piriformis muscle. GT indicates greater trochanter. Reproduced with permission from the American Society of Interventional Pain Physician.[4]

Sonoanatomy

The key to successful needle placement is to locate the sciatic notch. Proximal to the sciatic notch is the ilium, which is visualized as a hyperechoic line running across the scan image from medial to lateral positions. Moving the probe medially, the sacrum and SIJ are visualized. When the scan is in the sciatic notch, the hyperechoic shadow of bone (ischium) is seen only in the lateral part of the scan image (Fig. 17C). At this level, 2 layers of muscles, gluteus maximus muscle dorsally and piriformis ventrally, will be visualized. By rotating the hip internally and externally with the knee flexed, the piriformis muscle will be seen gliding underneath the gluteus maximus muscle. By moving the probe in a medial-to-lateral position, the origin and the insertion of the piriformis muscle can be traced.

Technique for Ultrasound-Guided Injection

The ultrasound-guided techniques described in the literature are quite similar.[4,111–113,118,119] The patient is placed in the prone position. With the use of a curvilinear probe with low frequency (2–5 Hz), scanning is performed in the transverse plane with the probe placed caudad to the posterior superior iliac spine so that the SIJ can be seen (Figs. 17A, B). The probe is then moved caudally to the sciatic notch. The piriformis muscle is demonstrated by rotating the hip internally and externally with the knee flexed. The needle is inserted from medial to lateral using an in-plane technique. It is important to scan from the ilium and move the probe caudally to ensure the location of the sciatic notch, as an inexperienced practitioner may mistake the other external hip rotators (obturator externus, superior and inferior gemellus muscle forming the tricipital tendons below the ischial spine) for the piriformis.

Because of the anatomic anomalies of the sciatic nerve within and below the piriformis muscle, we strongly suggest the use of the nerve stimulator in preventing unintentional injection in the vicinity of the sciatic nerve. For injection outside the piriformis muscle, a small amount of normal saline (<0.5 mL) is

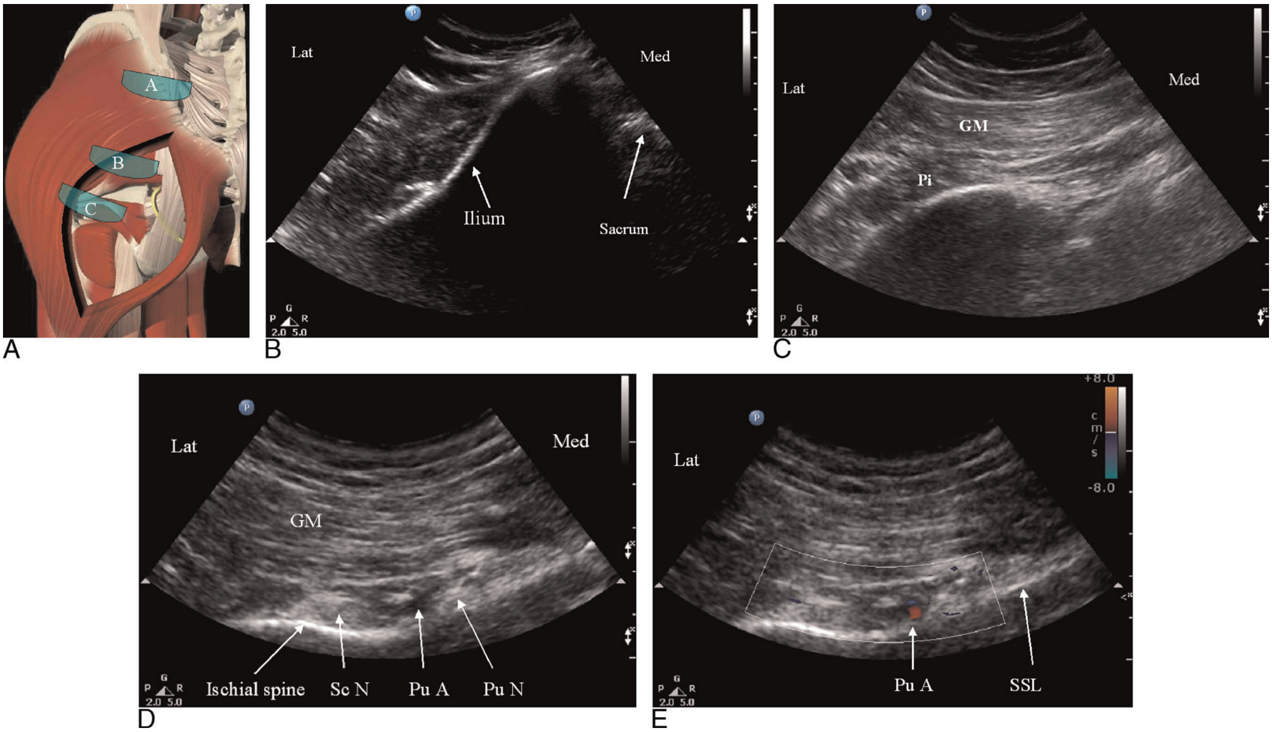

FIGURE 17. Ultrasonographic scan of the piriformis muscle and the pudendal nerve. A, Three different positions of ultrasound probe. B, Ultrasound image at probe position A. C, Ultrasound image at prone position B. D, Ultrasound image at probe position C. E, Color Doppler to show pudendal artery. Pu A indicates pudendal artery; Pu N, pudendal nerve, SSL, sacrospinous ligament; Sc N, sciatic nerve, GM, gluteus maximus muscle.

injected, which will confirm the location between the 2 muscle layers (gluteus maximus and piriformis). If intramuscular injection is attempted, the needle should be advanced further to elicit strong muscle contractions. A very small amount of normal saline (<0.5 mL) is injected to confirm the intramuscular location of the needle. It is not uncommon for sciatic nerve stimulation to be observed when the needle is advanced through the piriformis muscle.

Pudendal Nerve Injection

Chronic pelvic pain involving the sensory distribution of the pudendal nerve is termed *pudendal neuralgia*.[114,115] Classic presentation includes pain worse with sitting and relieved or diminished on standing, lying on the nonpainful side, or sitting on a toilet seat. Pudendal nerve block serves both diagnostic and therapeutic purposes.

Anatomy

The pudendal nerve is formed from the anterior rami of the second, third, and fourth sacral nerves (S2, S3, and S4). Exiting the pelvis through the greater sciatic notch, the pudendal nerve is accompanied by the internal pudendal artery on its medial side and travels dorsal to the sacrospinous ligament abutting the attachment of the latter to the ischial spine (Fig. 15). At this level, the nerve is situated between the sacrospinous and sacrotuberous ligament (interligamentous plane).[114,116,117] The nerve then swings ventrally to enter the pelvis through the lesser sciatic notch and Alcock canal.[124] The latter is the fascial tunnel formed by the duplication of the obturator internus muscle under the plane of the levator ani muscle on the lateral wall of ischiorectal fossa (Fig. 15). The pudendal nerve subsequently gives off 3 terminal branches: the dorsal nerve of the penis (clitoris), the inferior rectal nerve, and the perineal nerve, providing sensory branches to the skin of the penis (clitoris), perianal area, and posterior surface of scrotum or labia majora. It also innervates the external anal sphincter (inferior rectal nerve) and deep muscles of the urogenital triangle (perineal nerve).[118,119]

The path of the pudendal nerve either in between the sacrotuberous and the sacrospinous ligaments, or through Alcock canal, makes it susceptible to entrapment.[114,120] In Alcock canal, entrapment can be due to the falciform process of the sacrotuberous ligament and/or fascia of the obturator internus muscle. The course of the dorsal nerve of the penis under the subpubic arch or sulcus nervi dorsalis penis exposes the nerve to compression by the nose of the saddle of a bicycle.[121]

Limitation of the Existing Techniques

An important landmark for pudendal nerve injection is the interligamentous plane. Computed tomography scan allows visualization of the interligamentous plane reliably.[117] However, it is not usually available to interventional pain specialists. Fluoroscopy-guided injection is therefore a more popular technique.[114] Still, fluoroscopy reveals only the surrogate landmark, the ischial spine. Because the pudendal nerve is principally found medial to the pudendal artery (76%–100%) at the level of the ischial spine,[122,123] injection at this bony landmark may result in failure to disperse solution to the pudendal nerve.

Sonoanatomy

The most crucial technique is recognition of the ischial spine, which can be identified by the following features: (1) the spine appears as a straight hyperechoic line, whereas the ischium cephalad is seen as a curved line as it forms the posterior aspect of the acetabulum; (2) the sacrospinous ligament appears as a hyperechoic line in continuity with the medial end of the ischial spine, with lower echogenicity than bone; (3) the sacrotuberous ligament is seen as a light hyperechoic line ventral to the gluteus maximus muscle in the sciatic notch and appears parallel and dorsal to the sacrospinous ligament; and (4) the internal pudendal artery can be localized with the use of a color Doppler in close proximity to the ischial spine (Figs. 17D, E). Another arterial pulsation is often seen lateral to the tip of the ischial spine and is accompanied by the sciatic nerve. This is the inferior gluteal artery. Mistaking this artery for the pudendal artery will result in sciatic nerve block.

Technique for Ultrasound-Guided Injection

The use of ultrasound in the visualization of the pudendal nerve has been described,[122,123] but only 1 study describes the feasibility of the ultrasound-guided injection technique.[124]

A low-frequency, 2–5 MHz, curved array ultrasound probe is used, and scanning is performed in transverse planes to visualize the ischium forming the lateral border of the sciatic notch. By moving the ultrasound probe in a cephalad-caudad direction, the ischium appears as a progressively lengthening hyperechoic line that is widest at the ischial spine level. The most crucial technique is the recognition of the ischial spine, which is described previously. Once the ischial spine and the interligamentous plane are identified, an insulated peripheral nerve–stimulating needle is inserted from the medial aspect of the probe. It is advanced in line with the ultrasound probe to the medial aspect of the internal pudendal artery (Fig. 8B). Once the needle passes through the sacrotuberous ligament, a "click" is usually felt, and a small volume (1–2 mL) of normal saline is injected to confirm the spread within the interligamentous plane (Fig. 17). After satisfactory positioning of the needle tip, an admixture of local anesthetic and steroid is injected, and the adequacy of local anesthetic dispersion around the nerve during injection is assessed.

This visualization of the pudendal nerve is limited[124] for several reasons. The average diameter of the pudendal nerve at the level of the ischial spine is 4 to 6 mm.[114,122,125] Nerves of this size are generally difficult to detect with an ultrasound at a depth of 5.2 cm (SD, 1.1 cm).[124] At the level of the ischial spine, 30% to 40% of pudendal nerves are 2- or 3-trunked.[114,120,125] This reduces the chance of a direct depiction of the nerve with an ultrasound and may also account for the poor response to the nerve stimulator. Although visualization of the pudendal nerve is not possible in all cases, the 2 ligaments and the internal pudendal artery can be easily identified. The needle is inserted medially toward the pudendal artery where the pudendal nerve is principally known to lie (76%–100%).[122,123] With this technique, a sensory block can be reliably produced.

CONCLUSION

Ultrasound is a valuable tool for imaging peripheral structures, guiding needle advancement and confirming the spread of injectate around the target tissue, all without exposing health care providers and patients to the risks of radiation. There is a rapidly growing interest in USPM as evidenced by the expanding number of publications in the last 5 years. More studies on the efficacy and safety of ultrasound-guided techniques are required.

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Ultrasound-Guided Interventional Procedures in Pain Medicine: A Review of Anatomy, Sonoanatomy, and Procedures

Part II: Axial Structures

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Abstract: There is a growing trend in using ultrasonography in pain medicine as evident by the plethora of published reports. Ultrasound (US) provides direct visualization of various soft tissues and real-time needle advancement and avoids exposing both the health care provider and the patient to the risks of radiation. The US machine is more affordable and transferrable than fluoroscopy, computed tomography scan, or magnetic resonance imaging machine. In a previous review, we discussed the challenges and limitations of US, anatomy, sonoanatomy, and techniques of interventional procedures of peripheral structures. In the present review, we discuss the anatomy, sonoanatomy, and US-guided techniques of interventional pain procedures for axial structures and review the pertinent literature.

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Ultrasonography in pain medicine (USPM) is a rapidly growing medical field in interventional pain management. Traditionally, spine interventional procedures for pain management are performed with imaging guidance such as fluoroscopy and computed tomography (CT) scan. In the last few years, there has been tremendous growth in USPM interest as evidenced by the remarkable increase in the publication of literature on ultrasound (US)–guided injections.[1] A search of the MEDLINE database revealed only 3 publications published in US-guided or US-assisted injection techniques (excluding perioperative, intra-articular, interlaminar, and trigger-point injections) between 1982 and 2002, but there have been nearly 50 publications since 2003. The first objective of this review was to describe the relevant anatomy and sonoanatomy of those specific interventional techniques. The second objective was to describe and summarize various reports and feasibility data published in the literature on axial USPM procedures.

METHODS

We performed a literature search of the MEDLINE database from January 1982 to June 2009 using the search terms "ultrasound," "ultrasound-guided," "pain management," "spine injections" and different selected nerves or structures relevant in this review such as "transforaminal injections," "facet intra-articular injections," "medial branch nerve block," "caudal epidural," and "sacroiliac joint."

We excluded those publications that described the use of the peripheral nerve blocks in the perioperative setting and those describing intra-articular, interlaminar, and trigger-point injections.

US Versus Conventional Imaging Techniques

The advantages and shortcomings of US relative to other imaging modalities were described in detail in the previous review (Part I: Nonaxial Procedures).[1]

Ultrasonography allows direct real-time visualization of soft-tissue structures. Thus, it is an attractive alternative in nonaxial applications when most of the conventional techniques are landmark based or "blinded." However, USPM faces unique challenges in the spine or axial injections where most of the established techniques require the use of fluoroscopy. Although CT or magnetic resonance imaging guidance have been described, these procedures are most commonly performed with fluoroscopic guidance (which are discussed in the following sections).

Ultrasonography provides good visualization of bony surfaces that may make it useful in various superficial axial or spine injections such as the medial-branch block, facet intra-articular injections, nerve root blocks, and sacroiliac joint (SIJ) injection. However, US is not as useful in neuroaxial (epidural or intrathecal) blocks in adults as the major shortcomings of USPM are the limited resolution at deep levels and bony artifacts that affect image quality. If one cannot visualize the real-time spread of the injectate in the epidural space under ultrasonography or rule out intravascular injection (contrary to the commonly used fluoroscopy in pain medicine practice), then it is a "partially blind technique." Nevertheless, US-assisted neuroaxial block may be more advantageous than the traditional "blind" surface-landmark approach that is used in regional and obstetric anesthesia.

The present article focuses on various US-guided axial (spine) interventional procedures in pain management excluding neuroaxial applications for the aforementioned reasons.

Cervical Selective Nerve Root (Transforaminal) Injection

Anatomy

The cervical spinal nerve occupies the lower part of the foramen with the epiradicular veins in the upper part. The radicular arteries arising from the vertebral, ascending cervical, and deep cervical arteries lie in close approximation to the spinal nerve.[2]

Huntoon[3] showed that the ascending and deep cervical arteries may contribute to the anterior spinal artery (not only the vertebral artery). In more than 20% of the foramina dissected

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(21/95), either the ascending or deep cervical artery or a large branch was found within 2 mm of the needle path for a cervical transforaminal procedure. One third of these vessels entered the foramen posteriorly, potentially forming a radicular or a segmental feeder vessel to the spinal cord, making it vulnerable to unintentional injury or injection even during correct needle placement. Variable anastomoses between the vertebral and cervical arteries were found; therefore, it is possible to introduce steroid particles into the vertebral circulation via the cervical arteries.[3]

Also, in a single cadaver dissection study, Hoeft et al[4] showed that radicular artery branches from the vertebral artery lie over the most anteromedial aspect of the foramen, whereas those that arise from the ascending or deep cervical arteries are of greatest clinical significance because they must course medially, transversing the entire extent of the foramen.

Cervical transforaminal injections have been performed traditionally with the use of fluoroscopy or CT. However, there have been reports of fatal complications as a result of vertebral artery injury[5,6] and/or infarction of the spinal cord and the brain stem.[7–11] The mechanism of injury was contended to be either vasospasm or unintentional arterial injection of the particulate steroid injectate and embolus formation in critical arteries.[12,13]

Currently, the guidelines for cervical transforaminal injection technique involve introducing the needle under fluoroscopic guidance into the posterior aspect of the intervertebral foramen just anterior to the superior articular process (SAP) in the oblique view to minimize the risk of injury to the vertebral artery or the nerve root.[2] Despite strict adherence to these guidelines, adverse outcomes have been reported.[7,8] A potential shortcoming of the described fluoroscopic-guided procedure is that the needle may puncture a critical feeder vessel to the anterior spinal artery in the posterior aspect of the intervertebral foramen.[3] Here, ultrasonography may have potential utility, as it allows for visualization of soft tissues, nerves, and vessels and the spread of the injectate around the nerve; thus, it may be advantageous to fluoroscopy. The fact that US allows real-time recognition of an artery before needle puncture is a distinct advantage over fluoroscopic guidance, wherein this complication can be recognized only after aberrant arterial flow is noted when contrast agent is injected.

Literature Review of US-Guided Cervical Nerve Root Block

Galiano et al[12] described the use of US-guided periradicular injections in the middle and lower cervical spine in cadavers that were later confirmed with CT. The needles were positioned within 5 mm dorsal to the spinal nerve, and 5 of the 40 positioning attempts could not depict the spinal nerve because of reduced imaging conditions. They were not able to comment on the relevant blood vessels in the vicinity of the vertebral foramen, and this raised some concerns about the safety of performing the procedure with US at that time.[13] With the introduction of high-resolution US transducers and gaining more experience, we were able to visualize small critical arteries with ultrasonography.

Narouze et al[14] reported a pilot study of 10 patients who received cervical nerve root injections using US as the primary imaging tool, with fluoroscopy as the control. The radiologic target point was the posterior aspect of the intervertebral foramen just anterior to the SAP in the oblique view, and at the midsagittal plane of the articular pillars in the anteroposterior (AP) view. The needle was exactly at the target point in 5 patients in the oblique view and in 3 patients in the AP views. The needle was within 3 mm in all patients in the lateral oblique view and in 8 patients in the AP view. In the other 2 patients, the needle was within 5 mm from the radiologic target. In 4 patients, they were able to identify vessels at the anterior aspect of the foramen, whereas 2 patients had critical vessels at the posterior aspect of the foramen, and in 1 patient, this artery continued medially into the foramen most likely forming a segmental feeder artery. In these 2 cases, such vessels could have been easily injured in the pathway of a correctly placed needle under fluoroscopy.

Sonoanatomy and US-Guided Technique for Cervical Selective Nerve Root Block

With the patient lying in the lateral decubitus position, a US examination of the cervical spine is performed using a high-resolution linear array transducer. The transducer is applied transversely to the lateral aspect of the neck to obtain a short-axis view of the cervical spine (Fig. 1). One can easily identify the cervical transverse process with the anterior and posterior tubercles as hyperechoic structures presenting "2-humped camel" sign and the hypoechoic round-to-oval nerve root in between[14] (Fig. 2). First, the cervical level is determined by identifying the transverse process of the seventh and sixth cervical vertebrae (C7 and C6).) The seventh cervical transverse process (C7) differs from the above levels as it usually has a rudimentary anterior tubercle and a prominent posterior tubercle.[15] Then, by moving the transducer cranially, the transverse process of the sixth cervical spine comes into the image with the characteristic sharp anterior tubercle (Fig. 3), and thereafter, the consecutive cervical spinal level can be easily identified. Another way to determine the cervical spinal level is by following the vertebral artery, which runs anteriorly at the C7 level before it enters the foramen of C6 transverse process in about 90% of cases. However, it enters at C5 or higher in the remaining cases[16] (Fig. 4).

Once the appropriate spinal level is identified, a 22-gauge blunt-tip needle can be introduced under real-time US guidance from posterior to anterior with an in-plane technique to target the corresponding cervical nerve root (from C3 to C8) at the

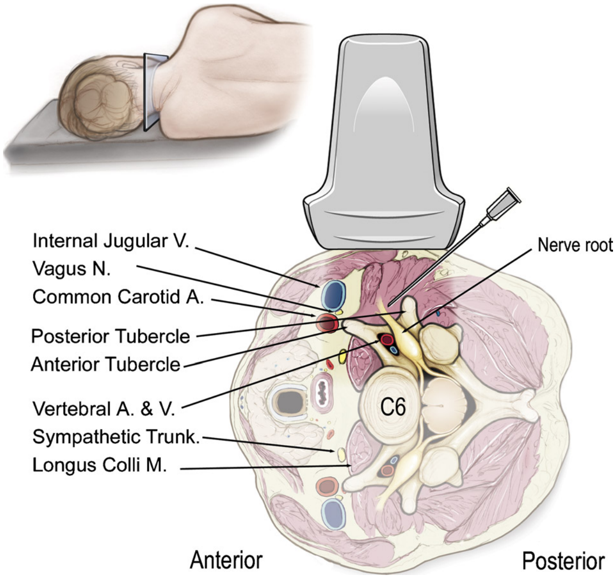

FIGURE 1. Illustration showing the relevant anatomy at C6 and the orientation of the US transducer to obtain a short-axis transverse US view. Reprinted with permission from Cleveland Clinic.

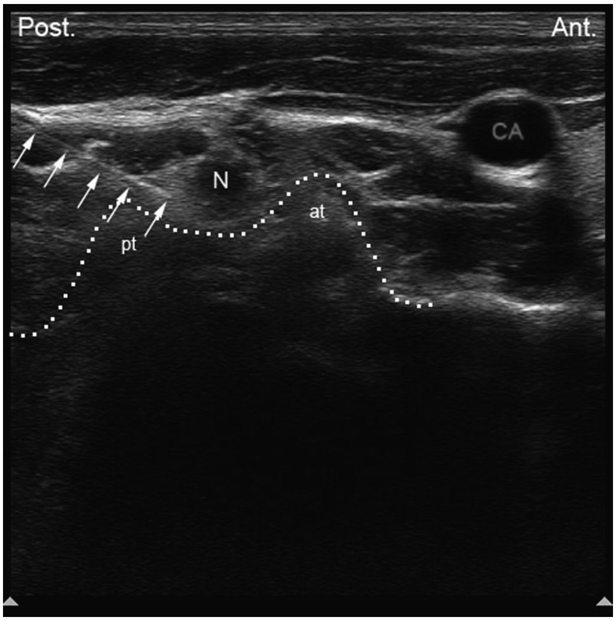

FIGURE 2. Short-axis transverse US images showing the anterior tubercle (at) and the posterior tubercle (pt) of the C5 transverse process as the ''2-humped camel'' sign. N indicates nerve root; CA, carotid artery. Solid arrows point to the needle in place at the posterior aspect of the intervertebral foramen. Reprinted with permission from Cleveland Clinic.

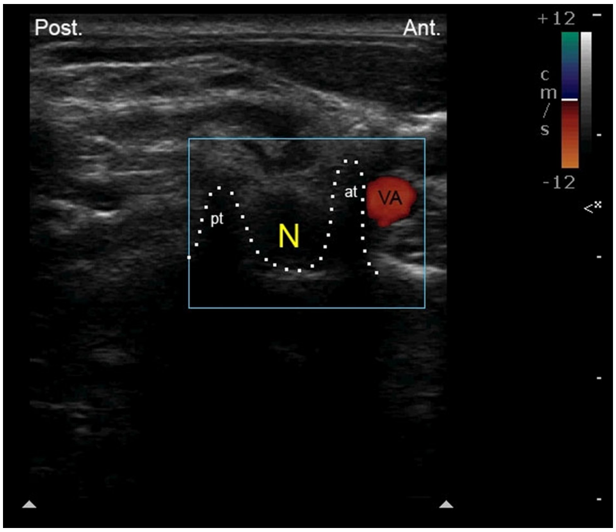

FIGURE 4. Short-axis transverse US image showing the sharp anterior tubercle (at) of the C6 transverse process, and the vertebral artery (VA) is anterior. N indicates nerve root; CA, carotid artery; at, anterior tubercle; pt, posterior tubercle. Reprinted with permission from Cleveland Clinic.

external foraminal opening between the anterior and posterior tubercles of the transverse process. One can successfully monitor the spread of the injectate around the cervical nerve with real-time ultrasonography, and the absence of such spread around the nerve root may suggest unsuspected or unintentional intravascular injection (Fig. 5). However, it is difficult to monitor the spread of the injectate through the foramen into the epidural space because of the bony dropout artifact of the transverse process. We therefore refer to this approach as a "cervical selective nerve root block" rather than cervical transforaminal epidural injection.

The authors believe that visualization of very small vessels (radicular arteries) may be very challenging especially in obese patients and requires special training and expertise. Real-time

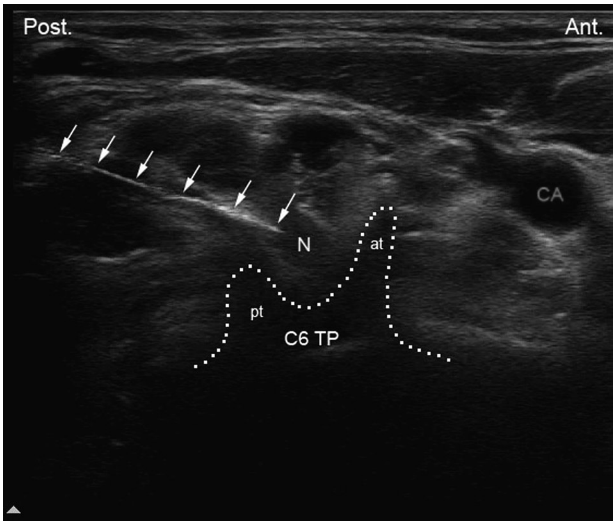

FIGURE 3. Short-axis transverse US image showing the sharp anterior tubercle (at) of the C6 transverse process (C6TP). N indicates nerve root; CA, carotid artery; at, anterior tubercle; pt, posterior tubercle. Solid arrows point to the needle in place at the posterior aspect of the intervertebral foramen. Reprinted with permission from Cleveland Clinic.

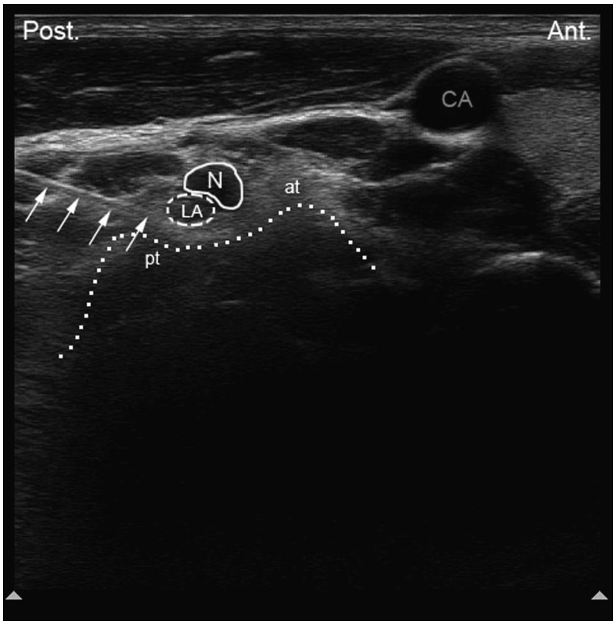

FIGURE 5. Short-axis transverse US image showing the spread of the local anesthetic (LA). N indicates nerve root; CA, carotid artery; at, anterior tubercle; pt, posterior tubercle. Reprinted with permission from Cleveland Clinic.

fluoroscopy with contrast injection and digital subtraction—when available—should remain the standard of care.

Cervical Medial-Branch and Facet Joint Injections

Anatomy

Cervical zygapophyseal (facet) joints are diarthrodial joints formed by the SAP of 1 cervical vertebra articulating with the inferior articular process of the vertebrae above at the level of the junction of the lamina and the pedicle. The angulation of the facet joint increases caudally, being about 45 degrees superior to the transverse plane at the upper cervical level to assume a more vertical position at the upper thoracic level. The SAP also faces more posteromedially at the upper cervical level, and this changes to more posterolaterally at the lower cervical level, with C6 being the most common transition level.[17,18]

The cervical zygapophyseal joints are innervated by articular branches derived from the medial branches of the cervical dorsal rami. The C4-C8 dorsal rami arise from their respective spinal nerves and pass dorsally over the root of their corresponding transverse process. The medial branches of the cervical dorsal rami curve medially, around the corresponding articular pillars, and have a constant relationship to the bone at the dorsolateral aspect of the articular pillar as they are bound to the periosteum by an investing fascia and held in place by the tendon of the semispinalis capitis muscle.[19]

This area is easily identified fluoroscopically where the medial branches are safely located away from the spinal nerve and the vertebral artery. The articular branches arise as the nerve approaches the posterior aspect of the articular pillar, one innervating the zygapophyseal joint above and the other innervating the joint below. Consequently, each typical cervical zygapophyseal joint has dual innervation, from the medial branch above and below its location.[20]

The medial branches of the C3 dorsal ramus differ in their anatomy. A deep medial branch passes around the waist of the C3 articular pillar similar to other typical medial branches and supplies the C3-C4 zygapophyseal joint. The superficial medial branch of C3 is large and known as the third occipital nerve (TON). It curves around the lateral and then the posterior aspect of the C2-C3 zygapophyseal joint giving articular branches to the joint. Articular branches may also arise from a communicating loop that crosses the back of the joint between the TON and the C2 dorsal ramus. Beyond the C2-C3 zygapophyseal joint, the TON becomes cutaneous over the suboccipital region. So pain derived from the C2-C3 zygapophyseal joint can be addressed by blocking the ipsilateral TON as it crosses the lateral aspect of the joint, and pain derived from joints below C2-C3 can be addressed by blocking the cervical medial branches as they pass around the waists of the articular pillars above and below the corresponding joint.[21]

Literature Review of US-Guided TON and Cervical Medial-Branch Block

Eichenberger et al[22] reported the use of US guidance in blockade of the TON in volunteers. The needles were placed under US guidance and then confirmed by fluoroscopy. The TON was visualized in all volunteers and showed a median diameter of 2.0 mm. The C2-C3 facet joint was identified correctly by US in 27 of 28 cases, and 23 needles were placed correctly into the target zone. They defined the radiologic target point arbitrarily as the intersection of a vertical line passing through the middle of the C2-C3 zygapophyseal joint and an oblique line passing directly over the joint line. They reported accuracy of needle position as confirmed by fluoroscopy in 82% of insertions and a 90% success of nerve blockade.

Although they reported the feasibility of identifying the medial branch of C3, there is no other feasibility studies regarding US-guided lower cervical medial-branch block. Nevertheless, the technique has been described.[23,24]

Literature Review of US-Guided Cervical Facet Intra-Articular Injections

Galiano et al[25] studied the feasibility of US as a guiding tool for simulated cervical facet joint intra-articular injections in cadavers using a lateral approach. They were able to accurately identify the facet joints from C2-3 to C6-7 in 36 of 40 attempts. All needle tips were located inside the joint space as verified by CT. Subsequently, they have studied and advocated the use of a US-guided CT-assisted navigation system as a teaching tool for performing facet injections.[20]

Sonoanatomy and US-Guided Technique for Cervical Facet Intra-Articular Injection

Lateral approach

The patient is placed in the lateral position, and the correct cervical level is identified as mentioned above. A high-frequency linear transducer is used, and a short-axis view is obtained; the superior articular and the inferior articular processes forming the facet joint appear as hyperechoic signals, and the joint space in between as anechoic gap. The needle is inserted just lateral to the transducer and advanced from posterior to anterior, in-plane, under real-time ultrasonography, to the target (joint space). The target was defined as the midpoint of the joint space on the lateral surface at the middle of the facet joint craniocaudal extension.[25]

Posterior approach

The authors prefer the posterior approach for several reasons. It is easier to identify the correct cervical level with the patient in the prone position. We start counting from cranial to caudal (C1 spine has no or only a rudimentary spinous process, and the first identified bifid spinous process belongs to C2). Another advantage of this approach is that the needle will be advanced in a caudal-to-cranial direction, and this is matching the caudal angulation of the cervical facet joint, making it easier for the needle to get into the joint space atraumatically. Also, bilateral injections can be performed without the need for position change.[26]

A linear or a curved transducer may be used, depending on the size of the patient. A longitudinal scan is obtained initially at the midline (spinous process), and then by scanning laterally, one can easily see the lamina, and further laterally, the facet column will appear in the image as the characteristic “saw sign” (Fig. 6). If in doubt, one can scan even more laterally until the facet joints are no longer in the image and then come back medially toward the facet joints. The inferior articular processes of the level above and the SAP of the level below appear as hyperechoic signals, and the joint space appears as anechoic gap in between. The needle is then inserted inferior to the caudal end of the transducer and advanced from caudad to cephalad—in-plane—to enter the inferior part of the joint under real-time ultrasonography (Fig. 6).

Sonoanatomy and US-Guided Technique for TON and Cervical Medial-Branch Block

Third Occipital Nerve

Eichenberger et al[22] described the technique in detail. The patient is placed in the lateral position, and a high-frequency linear transducer is applied, just caudal to the mastoid process

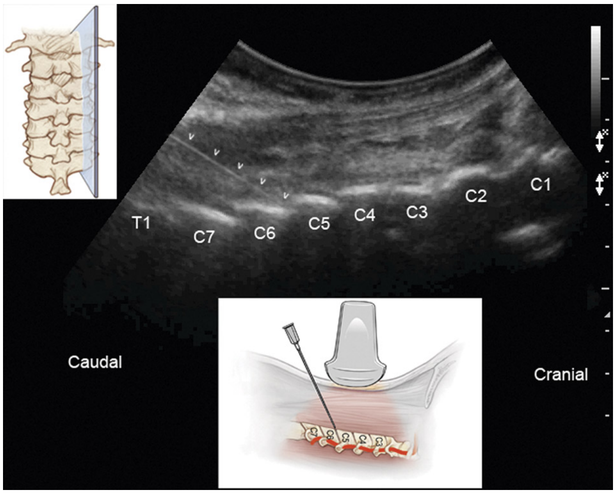

FIGURE 6. Sagittal (longitudinal) ultrasonographic view showing the hyperechoic articular processes of the facet joints as the ''saw sign'' and the anechoic facet joint space in between. Needle is introduced caudal to the transducer and advanced in-plane into the caudal part of the C5-C6 facet joint (arrowheads). Inset, Illustration showing the paramedian position of the US transducer to obtain a longitudinal scan through the facet column. Reprinted with permission from Cleveland Clinic.

exactly perpendicular to the lateral aspect of the neck in a transverse plane, to obtain a short-axis view.

Moving the transducer slowly caudally, the lateral mass of the axis and the transverse process of C1 are easily visible. Moving the transducer only 1 to 3 mm more caudally, the vertebral artery appears, and by following this artery caudally, the vertebral artery disappears in the transverse foramen of C2, and the C2-3 joint appears posteriorly. It presents as a convex density covered by the laminated densities of the overlying neck muscles. The apex of the convexity of the joint was identified and constituted the target point for the needle insertion.

The needle is introduced from immediately below the US probe and advanced perpendicular to the beam (out-of-plane) under US guidance toward the apex of the convexity of the joint, until bony resistance was encountered. Then, the transducer is rotated to the longitudinal plane because the nerve is best visualized in this view (Fig. 7). The TON is identified with the typical sonomorphologic appearance of a small peripheral nerve just lateral to the C2-3 joint, and the needle was adjusted as needed to lie closer to the nerve.

Cervical Medial-Branch Block

The patient is placed in the lateral position, and a high-frequency linear transducer is applied longitudinally with its upper end just below the mastoid process to obtain a longitudinal view of the cervical spine. Once the C2-3 joint is identified as above, the transducer is slowly moved in a caudal direction to view the lower facet joints until the desired level of the cervical facet joint is reached. The highest points in the bony reflex of the articular pillars represent the facet articulations, and the medial branches can be visualized at the deepest point over the articular pillars between the 2 articulations in contrast to the TON, which runs over the highest point of the articulation[24] (Fig. 7).

The needle can be introduced just caudal to the US transducer and advanced under real-time ultrasonography to the target nerve (in-plane). Alternatively, once the correct level is identified, the transducer is rotated to obtain a short-axis view, and the needle is advanced perpendicular to the beam (out-of-plane) under US guidance toward the articular pillar until bony resistance was encountered. Then, the transducer can be rotated to the longitudinal plane, as the nerve is better visualized in this view, and the needle is adjusted as needed to lie closer to the nerve in the same manner described above for TON block[22](Fig. 7).

The authors believe that visualizing such small nerves (cervical medial branches and TON) is usually very challenging especially in obese patients and requires special training and experience. Fluoroscopy may be superior in this application especially in radiofrequency ablation of the medial nerves as this requires precise needle placement along the targeted nerve.

Lumbar Medial-Branch and Facet Joint Injections

Anatomy

The facet joints of the lumbar spine are diarthrodial joints involving the hyaline cartilaginous surfaces of the articular processes of adjacent vertebrae. The joint space is small, with a volume of about 2 mL.[27] The capsule of the facet joint is innervated by the medial branches of the dorsal rami from the same vertebral level and from the superior vertebral level. For example, L3-4 facet joint receives the innervations from L2 and L3. The medial branches of the L1-L4 dorsal rami have a similar course.[28] Each medial branch crosses the root of the inferior transverse process and then runs in a groove formed by the junction of the corresponding transverse process and SAP. Here, it runs under the medial curve of the mammilloaccessory ligament before it innervates the multifidus muscle. This is especially important as the ligament holds the nerve in position, thereby affording minimal anatomic variability to the location of the nerve.[29]

After entering the multifidus muscle, the nerve gives superior and inferior articular branches to supply the facets above

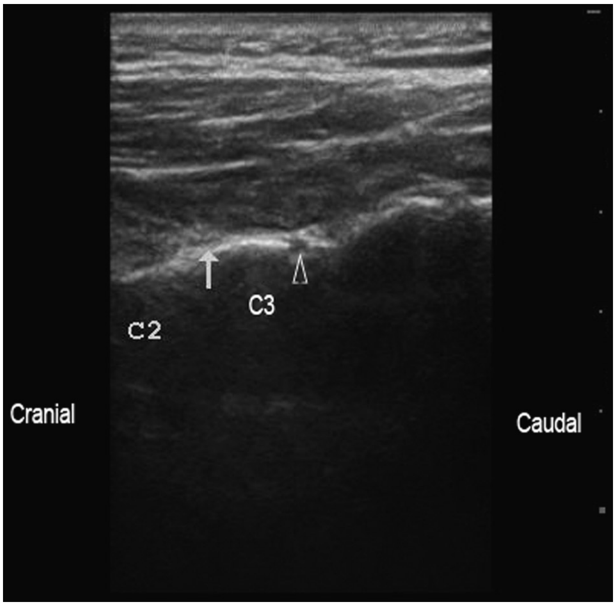

FIGURE 7. Sagittal (longitudinal) ultrasonographic view at C2-3 level showing the TON (solid arrow) crossing C2-3 joint and the C3 medial branch (arrowhead) as a hypoechoic oval structure at the deepest point (waist) of the articular pillar. Reprinted with permission from Cleveland Clinic.

and below at each level. This dual nerve supply explains the diffuse and poorly localized nature of the pain associated with degenerative facet disease.[30] Further, the L5 dorsal ramus differs in its anatomy from the other lumbar dorsal rami. It crosses the sacral alae and gives off the medial branch only as it reaches the caudal aspect of the L5-S1 zygapophyseal joint.[28]

Literature Review of US-Guided Lumbar Medial-Branch Block

Greher et al[31] described the US-guided approach for lumbar facet medial-branch block. They tried 4 different transducers and found that the 2- to 6-MHz curved transducer produced the best results. They conducted a clinical case series of 28 US-guided facet nerve injections in 5 patients under real-time US with fluoroscopic confirmation. Twenty-five of the 28 needle placements were accurate, and the remaining 3 were within 5 mm of the target point.

The same group also studied the accuracy of the US technique confirmed with CT in human cadavers.[32] They defined the target as the groove at the cephalad margin of the transverse process adjacent to the SAP. The needles were placed with US guidance, then 1-mL contrast dye was injected, followed by axial transverse CT to evaluate needle positions and spread of contrast medium. Forty-five of 50 needle tips were at the exact target point. The remaining 5 were within 5 mm of the target. In 47 of 50 cases, the applied contrast dye reached the target, corresponding to a simulated block success rate of 94%. Paraforaminal spread was observed in 7 injections and epidural spread in 5, with 2 showing intravascular spread.

Recently, Shim et al[33] evaluated the success rate and validity of this US method by using fluoroscopy controls in patients previously diagnosed with lumbar facet joint–mediated pain. They initially performed fluoroscopy-guided medial-branch blocks in 20 patients. One month later, the same patients received lumbar medial-branch blocks under US guidance, and the needle tip position was confirmed with fluoroscopy before injection. They were able to place the needles in correct position under US guidance 95% of the time. The mean time required for each needle placement was 5 (SD, 1) min. The visual analog scale scores of patients after US-guided lumbar medial-branch blocks also compared with those obtained in the same patients after fluoroscopy-guided blocks. However, the mean weight and body mass index of the patients in this study were only 51 kg and 22.8 kg/m^2, respectively.

Literature Review of US-Guided Lumbar Facet Intra-Articular Injections

Galiano et al[34] produced similar encouraging results in their cadaver study of feasibility of US-guided facet joint injections with a correlation coefficient of 0.86 between US- and CT-derived measurements. This led the same group to design the first prospective randomized clinical trial comparing US-guided versus CT-guided lumbar facet injections.[35] Forty adult patients with chronic back pain were consecutively enrolled and evenly assigned to either a US or CT group. In the US group, a 4- to 9-MHz curved array probe was used, and needle inserted under continuous imaging if the facet joints were visible by US. The needle was attempted to be placed within the facet joint or at least within 5 mm of the joint and verified by CT. In the CT group, the patients had an initial topogram, and then the needle was advanced under CT to the target. In the US group, 16 patients had facets joints well visualized with accurate needle placement. Ultrasound-guided needle placement was faster than with CT, with much less radiation, and there was no difference in benefit detected between the 2 groups.

Sonoanatomy and US-Guided Technique for Lumbar Medial-Branch Block

The patient is placed in the prone position, and a low-frequency curvilinear transducer is used. First, a longitudinal midline sonogram is obtained to identify the correct spinal level. The dorsal surface of the sacrum is easily identified, and the lumbar spinal processes can be counted from caudal to cephalad. By sliding the transducer laterally, a longitudinal paravertebral image is obtained, and the corresponding transverse processes can be easily seen. Once the appropriate level is identified, the transducer can be rotated transversely to obtain a short-axis view showing the transverse process and the corresponding SAP (Fig. 8). The target is the groove at the junction between the base of the SAP and the superior border of the transverse process. A 20-gauge needle is advanced in-plane with the US beam from lateral to medial under real-time ultrasonography aiming toward the target (Fig. 9). Once the bone is contacted, a longitudinal paravertebral image is obtained to make sure that the needle is at the cephalad margin of the corresponding transverse process. L5 dorsal ramus block is usually more difficult secondary to the US bony artifacts from the iliac bone.[32]

Sonoanatomy and US-Guided Technique for Lumbar Facet Intra-Articular Injection

The patient is placed in the prone position, and a low-frequency curvilinear transducer is used. Once the appropriate level is identified as above, the transducer can be rotated transversely to obtain a short-axis view showing the facet joint space between the inferior articular process and SAP (Fig. 10). The target is the midpoint of the joint space. A 20-gauge needle is advanced in-plane with the US beam from lateral to medial under real-time ultrasonography aiming toward the target.[34,35] Often it is difficult to see the entire needle shaft clearly while it is advanced because the needle angle is usually between 45 and 60 degrees.

As mentioned earlier, the major limitation of ultrasonography is the inability to obtain a high-resolution image at such depth needed for facet injections. That is why visualizing the

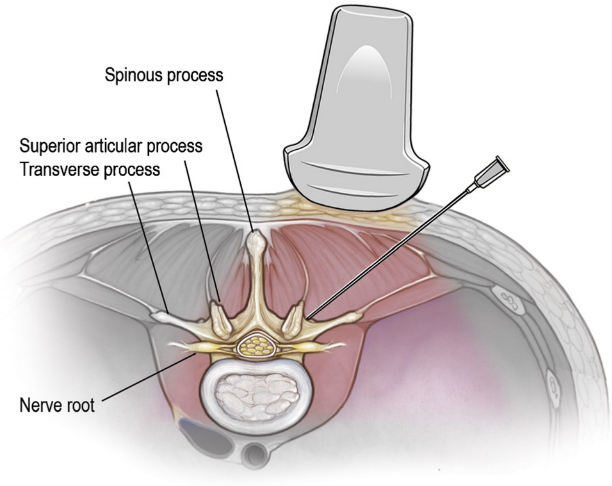

FIGURE 8. Illustration showing the orientation of the US transducer to obtain a short-axis transverse US view of the lumbar spine. The needle is placed for lumbar medial-branch block at the groove between the SAP and the transverse process. Reprinted with permission from Cleveland Clinic.

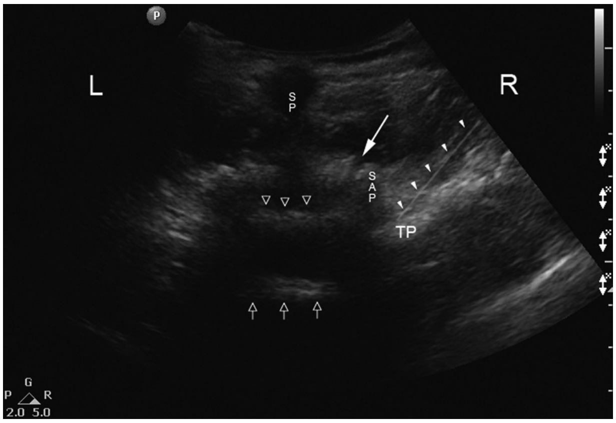

FIGURE 9. Short-axis transverse US image of the lumbar spine showing the in-plane needle (solid arrowheads) for lumbar medial-branch block at the groove between the SAP and the transverse process (TP). Long solid arrow points to the facet joint gap. Note the reflection of the posterior dura (hollow arrowheads) and the anterior dura/posterior longitudinal ligament (hollow arrows), which can be seen by insonating the US beam through the interspinous space (SP). Reprinted with permission from Cleveland Clinic.

needle and spread of injectate (to role out intravascular injections) may be suboptimal or very challenging especially in obese patients.

US-Guided Lumbar Nerve Root Injection

Contrary to the cervical area, lumbar nerve roots are usually not well seen with ultrasonography because the depth (compared with cervical) and the presence of bony structures of different contour in the lumbar spine obscure or prevent the visualization of the target structures in the neural foramen. Although the technique was described before as periradicular injections,[36] we believe that as long as we cannot accurately delineate the nerve root, it is more or less a paravertebral or psoas compartment block. Real-time fluoroscopy and contrast injection with digital subtraction—when available—should remain the standard of care.

Sacroiliac Joint Injection

Anatomy

The SIJ is a unique diarthrodial (synovial) joint, with the articular surfaces of the sacrum and ilium separated by a joint space enclosed in a fibrous capsule.[37] It also has been considered an amphiarthrosis, with its 2 hyaline cartilage surfaces joined by fibrocartilage. It bears characteristics of a synovial joint, especially in the superoanterior and inferior aspects of the joint. The superoposterior joint surface lacks a joint capsule and contains the interosseous ligament. The anterior joint capsule gives origin to the anterior sacroiliac ligament, whereas the posterior aspect contains the posterior sacroiliac, sacrotuberous, and sacrospinous ligaments that stabilize the joint.[38]

The muscular and fascial support of the SIJ is derived from the gluteus maximus and medius, the erector spinae, latissimus dorsi, thoracolumbar fascia, biceps femoris, piriformis, oblique muscles, and the transversus abdominis. The gluteus maximus, biceps, and piriformis attach to the sacrotuberous ligament, whereas the thoracodorsal fascia connects to the remaining muscle groups.[38–41] This extensive support provides for reduced mobility and enhanced stability of the SIJ.

The posterior SIJ is predominantly innervated by the lateral branches of the L4-S2 nerve roots with contributions from the superior gluteal nerve and S3. The anterior SIJ innervation is from the L2-S2 segments.[42,43] Moreover, the synovial capsule and ligaments contain free nerve endings as well as mechanoreceptors that transmit proprioceptive and pain sensation from the joint.[39]

Literature Review of US-Guided SIJ Injection

Musculoskeletal US has been used to diagnose and monitor many enthesopathies and inflammatory joint syndromes including sacroiliitis.[44,45] Although the use of musculoskeletal US in sacroiliitis has gained prominence over the past few years, there is a paucity of literature showing its effective use for SIJ injections. Pekkafahli et al[46] in 2003 had studied the feasibility of US-guided SIJ injections and reported a 76.7% overall success rate (N = 60), with a steep learning curve. The success rate improved from 60% with the first 30 injections to 93.5% in the next 30 injections. Although they advocated further use of this modality, the popularity of fluoroscopy-guided SIJ injections permitted minimal use of ultrasonographic guidance in performing these injections. With the recent improvement in US technology, its use in performing SIJ injections is being revived. Recently, Klauser et al[47] assessed the feasibility of US-guided SIJ injection in 10 human cadavers bilaterally at 2 different puncture sites. Upper level was defined at the level of the first posterior sacral foramen, and the lower level at the level of the second posterior sacral foramen. Then they attempted the injection in 10 patients with unilateral sacroiliitis. Computed tomography confirmed correct intra-articular needle placement in cadavers by showing the tip of the needle in the joint and intra-articular diffusion of contrast media in 16 (80%) of 20 SIJs (upper level, 7/10 [70%]; lower level, 9/10 [90%]). In patients, 100% of US-guided injections were successful (lower level, 8; upper level, 2), with a mean pain relief of 8.6 after 3 months.

Sonoanatomy and US-Guided Technique for SIJ Injection

The patient is placed in the prone position, and a low-frequency curvilinear transducer is used. The transducer is placed transversely over the lower sacrum (at the level of the

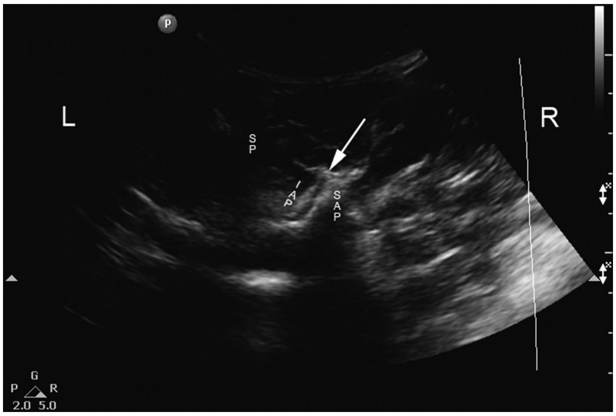

FIGURE 10. Short-axis transverse US image of the lumbar spine showing the anechoic facet joint space (solid arrow) between the hypoechoic inferior articular process (IAP) of the level above and the SAP of the level below. Reprinted with permission from Cleveland Clinic.

sacral hiatus), and as the lateral edge of the sacrum is identified, the transducer is moved laterally and cephalad until the bony contour of the ileum is identified (Fig. 11). The cleft between the ileum and the lateral sacral edge represents the SIJ, and the target is the most inferior part.[47,48] A 22-gauge needle is then inserted at the medial end of the transducer and advanced laterally under direct vision in-plane with the US beam until it enters the joint (Fig. 12).

The major limitation is the potential for periarticular rather than intra-articular injection compared with fluoroscopy, where one can reliably obtain an arthrogram with contrast agent injection in most cases. Also, US is not entirely reliable in detecting intravascular injection while performing SIJ injections secondary to the bony artifacts casted by the iliac bone.

Caudal Epidural Injections

Anatomy

The epidural space extends from the base of the skull cranially to the level of the sacral hiatus caudally. The sacral hiatus is present about 3 cm below the level of S2 where the dural sac terminates. Below this level, the epidural space continues as the caudal epidural space, which can be accessed via the sacral hiatus.[49,50]

The sacrum and coccyx are formed by the fusion of 8 vertebrae (5 sacral and 3 coccygeal vertebrae). As a result, there is a natural defect present from incomplete fusion of the lower portion of S4 and entire S5 in the posterior midline. This defect is termed the sacral hiatus and is covered by the sacrococcygeal ligament. The hiatus is bounded laterally by the sacral cornua, and the floor is composed of the posterior aspect of the sacrum.[51]

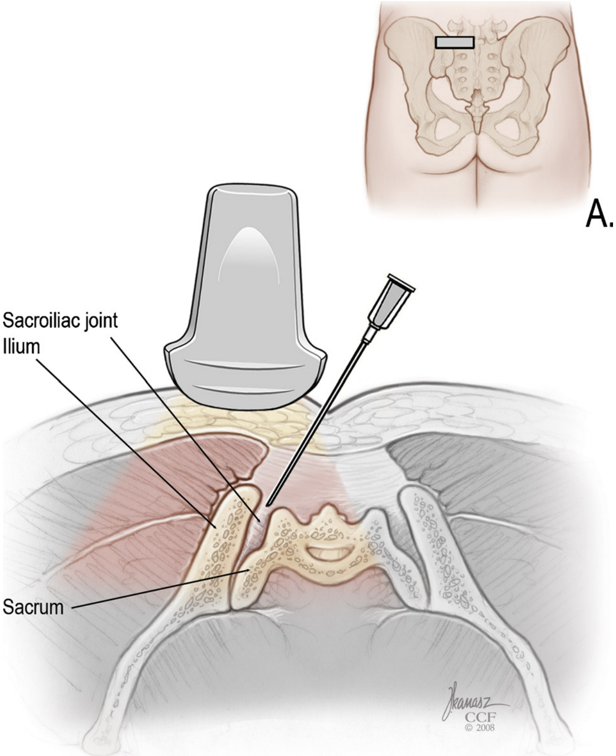

FIGURE 11. Illustration showing the orientation of the US transducer in the transverse plane over the SIJ. Reprinted with permission from Cleveland Clinic.

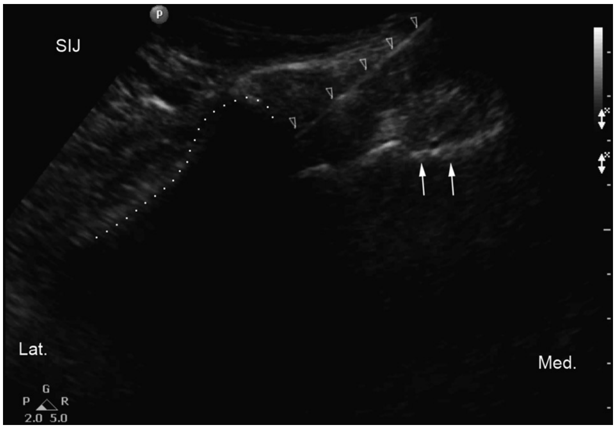

FIGURE 12. Short-axis US view showing the needle—in plane—inside the SIJ (arrowheads); the dotted line is delineating the ilium bony surface; solid arrows point to the dorsal sacral surface. Reprinted with permission from Cleveland Clinic.

Anatomic variations of the sacrum and the neurovasculature within the sacral canal pose a challenge during caudal epidural steroid injections. Variations in sacral anatomy have been reported to be as high as 10%,[52] and misplaced needles during caudal epidural injections without fluoroscopic guidance as high as 25.9%, even when the procedure was performed by experienced physicians.[53] The sacral canal contains the sacral nerves, fatty tissues, and the sacral venous plexus that lie anterior against the anterior wall of the canal.

Unintentional intravascular injection has been reported to range from 2.5 to 9%,[52–54] and negative needle aspiration for blood is neither sensitive nor specific for intravascular positioning of the needle.[54,55] Intravascular injection is more common in elderly patients as the epidural venous plexus, which usually ends at S4, may continue inferiorly in these patients.[56] This provides the rationale for the need of performing caudal epidural injections with real-time imaging study, to maximize the outcome and minimize the complications.[57]

Literature Review of US-Guided Caudal Epidural Injections

Klocke et al[58] described the use of US imaging in caudal epidural steroid injections. They found it particularly useful in moderately obese patients or patients with difficulty in positioning prone. They reported good visualization of landmarks but needed lower-frequency transducer (2–5 MHz) in obese patients to achieve adequate penetration. Subsequently Chen et al[59] conducted a feasibility study involving 70 patients with lumbosacral neuritis. They used a high-frequency transducer (5–12 MHz) to identify the sacral hiatus. They initially performed a transverse view of the sacral hiatus to identify their landmarks followed by a longitudinal view under which a 21-gauge Tuohy needle was advanced under vision into the caudal epidural space. The needle position was also confirmed by contrast fluoroscopy. They had a 100% success in needle placement but observed that the needle tip was no longer visualized after the needle was advanced into the sacral epidural space secondary to the bony artifacts. There was no means of identifying a dural tear or intravascular placement other than aspiration. This led Yoon et al[57] to evaluate the use of color Doppler ultrasonography for caudal injections to identify any intravascular injections. After accessing the epidural space, they injected 5 mL

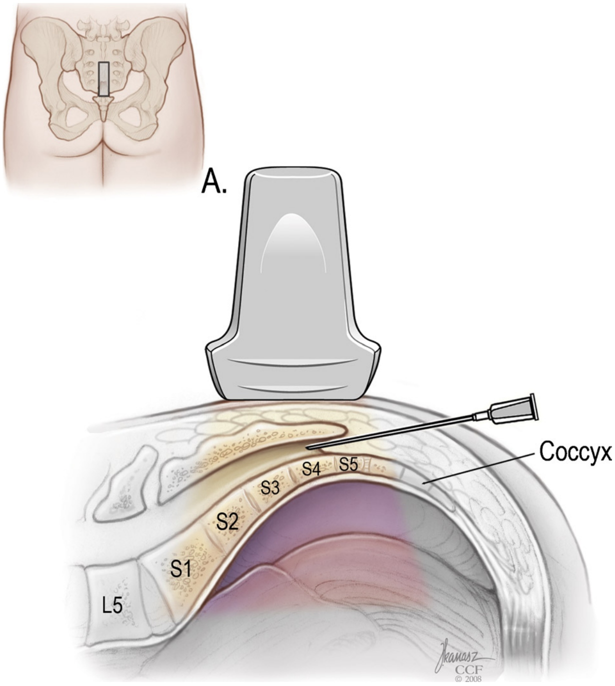

FIGURE 13. Illustration showing the orientation of the US transducer in the longitudinal plane over the sacral hiatus. Reprinted with permission from Cleveland Clinic.

of the solution while observing the flow spectrum using a high-resolution transducer (5–12 MHz) and color Doppler mode. They defined the injection as being successful if unidirectional flow (observed as 1 dominant color) of the solution was observed with color Doppler ultrasonography through the epidural space beneath the sacrococcygeal ligament, with no flows being observed in other directions (observed as multiple colors). The correct placement of the medication was then confirmed by contrast fluoroscopy. In 52 of the 53 subjects, the medications were successfully injected into the caudal epidural space with ultrasonography assistance. In fluoroscopy, of these 52 patients, 50 revealed correct placement of the medicine into the epidural space. However, 3 patients, including 1 patient with a negative Doppler spectrum and 2 with positive spectrums, showed contrast dye outside the epidural space. Recently, a retrospective observational study of caudal injections in 83 pediatric patients was conducted to compare the accuracy of caudal needle placement with the "swoosh" test, 2-dimensional transverse ultrasonographic evidence of turbulence within the caudal space, and color flow Doppler.[60] The authors concluded that ultrasonography is superior to the swoosh test as an objective confirmatory technique during caudal block placement in children. They found the presence or absence of turbulence during injection within the caudal space to be the best single indicator of block success.

Sonoanatomy and US-Guided Technique for Caudal Epidural Injection

With the patient in the prone position, the sacral hiatus is palpated, and a linear high-frequency transducer (curved low-frequency transducer in obese patients) is placed transversely at the midline to obtain a sonographic transverse view of the sacral hiatus.[58,59] The 2 bony prominences of sacral cornua appear as 2 hyperechoic reversed U-shaped structures. Between the 2 cornua, one can identify 2 hyperechoic band-like structures: the sacrococcygeal ligament on top and the dorsal bony surface of the sacrum at the bottom and the sacral hiatus as the hypoechoic area in between. A 22-gauge needle is then inserted between the 2 cornua into the sacral hiatus. A "pop" is usually felt as the sacrococcygeal ligament is penetrated. The transducer was then rotated 90 degrees to obtain a longitudinal view of the sacrum and sacral hiatus, and the needle is advanced into the sacral canal under real-time sonographic in the longitudinal view (Figs. 13 and 14). In adults, it is usually difficult to follow the needle once in the sacral canal secondary to the bony artifacts from the sacrum wall. After negative aspiration for cerebrospinal fluid and blood, injection is carried out under real-time sonography, where one can notice turbulence in the sacral canal and monitor the spread of the injectate cephalad, which is not an easy task in adults. Color Doppler mode may be used as discussed above[57]; however, it is very subjective and unreliable because turbulence from the injectate can be interpreted as flow in many directions with different colors and can be misinterpreted as intravascular injection. The best way to rule out unintentional intravascular or intrathecal injection is still by contrast fluoroscopy. Ultrasound can be used if fluoroscopy is not available or to guide needle placement into the sacral canal as an adjuvant to fluoroscopy.

Limitations of US in neuroaxial applications are discussed earlier, and the authors feel that neuroaxial (intrathecal and spinal) applications of US should be limited to regional anesthesia and obstetric anesthesia practice where fluoroscopy is not readily available. Until we have better technology, US should have no role in neuroaxial (intrathecal, epidural) blocks in chronic pain practice as fluoroscopy (which is superior) is readily available; hence, these applications will not be discussed in this review.

CONCLUSIONS

Ultrasound is a welcomed addition to other imaging techniques in interventional pain management. It is a valuable tool for imaging soft-tissue structures and bony surfaces, guiding needle advancement, and confirming the spread of injectate around the target, all without exposing health care providers and patients to the risks of radiation. There is a rapidly growing

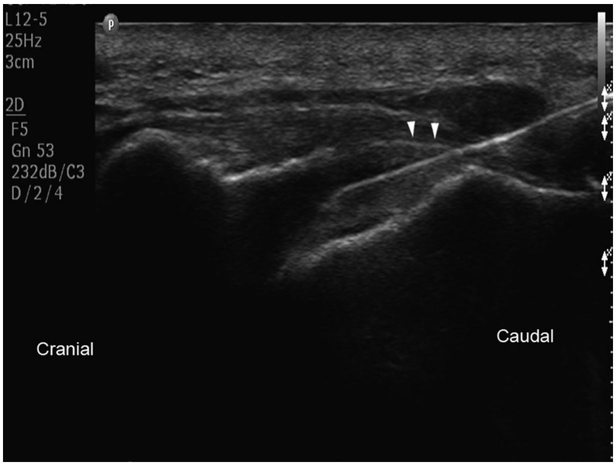

FIGURE 14. Longitudinal US view showing the needle-in plane-inside the caudal epidural space. Arrowheads point at the sacrococcygeal ligament covering the sacral hiatus. Reprinted with permission from Cleveland Clinic.

interest in USPM as evidenced by the surging number of publications in the last few years. The published reports suggest a useful role for US in soft-tissue injections, joint injections, and cervical spine injections; and only limited role in lumbar spine injections. More studies on the efficacy and safety of US-guided techniques are required.

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