REVIEW ARTICLE

Ultrasonography in Pain Medicine: A Critical Review

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■ **Abstract:** Recently, ultrasonography has been increasingly used in the field of regional anesthesia to assure reliable blockade of peripheral nerves and to visualize neuroaxial structures. As its popularity is steadily increasing, it may become a standard of care for both intraoperative analgesia and postoperative pain control. The application of ultrasound in chronic pain management, however, remains underutilized. Multiple reasons can be suggested to explain this situation. Nonetheless, numerous articles have been published and some interventionalists have gained experience and started to spread their knowledge through hands-on workshops and medical meetings.

It, therefore, seems timely to describe the techniques of ultrasound-guided injections for chronic pain, to review accumulated experience in this field, to reappraise the scientific and clinical value of this method, and to outline potential future developments. ■

Key Words: ultrasound, ultrasound-guided, chronic pain, pain medicine, evidence

In the past 5 years ultrasonography (US) has been increasingly used in the field of regional anesthesia, helping to achieve reliable blockade of peripheral nerves and to visualize neuroaxial structures. It can be expected to gain worldwide popularity and may become a standard of care for both intraoperative analgesia and postoperative pain control. Regional anesthesia journals have received an avalanche of new submissions describing the advantages of US-guided nerve blocks and comparing this method with nerve-stimulating techniques. However, the application of US in chronic pain management remains in an embryonic state. A number of reasons can be suggested to explain this situation.

First, image quality was poor, which made interpretation extremely difficult. Second, because of the technical requirements, relatively few experts have had the skills needed to use this tool, although recent improvements in resolution and processing have made it possible for most operators to distinguish small anatomic parts, including nerves. Third, diagnostic soft-tissue US has been generally abandoned in favor of magnetic resonance imaging (MRI). Obviously, the latter has greater capability for soft-tissue imaging, but performing injections under MRI guidance requires time, special equipment, and expertise in interventional rather than diagnostic radiology; it would also be exceptionally and unjustifiably expensive. Therefore, MRI will never rival US in routine clinical practice. Fourth, there is a deeply rooted acceptance of fluoroscopy and computed tomography (CT) as the gold standards of imaging in pain medicine. As such, pain societies and their members promote education and expertise in these methods (particularly fluoroscopy), but it could be that their knowledge of US is simply too limited to recognize its value. Fifth, advanced pain practitioners are still struggling to convince the wider medical community, as well as

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Submitted: April 9, 2008; Accepted: April 25, 2008
DOI. 10.1111/j.1533-2500.2008.00215.x

payers and patients, that only image-guided procedures should be performed and that the custom of office-based "nerve blockade" should be discouraged. Sixth, the quality control of US-guided injections is questionable, and there is a constant danger of "technological hijacking" whereby unvalidated and potentially harmful injections of all types are folded into the curricula for "image-guided procedures."

Nonetheless, some interventionalists have gained experience in US-guided injections and have started to spread their knowledge through hands-on workshops, medical meetings, and research publications. It therefore seems timely to describe the techniques of US-guided injections for chronic pain, to review accumulated experience in this field, to reappraise the scientific and clinical value of this method, and to outline potential future developments.

A MEDLINE database search with the key words "ultrasound," "nerve," "block," "epidural," and "caudal" yielded 28 articles relevant to the subject of chronic pain and another 19 articles related to ultrasound-guided celiac block. Review of articles describing musculoskeletal injections under US guidance was omitted, simply because it seemed obvious that injections of joints, muscles, and bursae are implemented routinely and do not require further elaboration.

A previous review[1] covered the literature published up to 2004 and described the authors' personal experience. The current review reiterates to some extent that previous knowledge but brings new insights to the analysis. We assessed levels of evidence using a modified version of the scale proposed by Manchikanti et al.[2] (Table 1).

Table 1. Levels of Evidence for Ultrasound-Guided Interventional Pain Techniques

Level I	Conclusive: research-based evidence with multiple studies using ex-vivo modeling and validation by standard imaging (fluoroscopy, CT, MRI)
Level II	Strong: research-based evidence from at least one properly designed trial with ex-vivo modeling and validation by standard imaging (fluoroscopy, CT, MRI)
Level III	Limited: ex-vivo or clinical feasibility study
Level IV	Indeterminate: case report, expert opinion, personal experience

CT, computed tomography; MRI, magnetic resonance imaging.

EQUIPMENT

US-guided procedures typically require high-resolution, multiple-beam imaging to allow visualization of small nerves and the interface between soft tissue and bone. (Figure 1). Color Doppler is a standard feature that helps to identify neighboring blood vessels. The choice of transducer is primarily related to the anticipated target depth and size. As a rule of thumb, a broad-band, low-frequency, curved-array probe is used for deep structures (eg, lumbar spine), whereas a broad-band high-frequency linear transducer is used for superficial targets. Use of a biopsy navigating tool has limited value because it is often necessary to rotate the transducer to verify needle position before the injection is performed. Needle choice depends on both target depth and operator preference. For instance, one may favor B-beveled stimulating needle while others would feel comfortable using Quincke-type spinal needle. A variety of needle types with improved US visibility are now available.

GENERAL CONSIDERATIONS

Four possible needle positions are possible (Figure 2). Typically, short-axis, in-plane or short-axis, out-of-plane positioning is used to access nerve and bone targets. Visualization of the needle from the entry point to the target area effectively prevents misplacement of the needle and adverse outcome. Once the needle has been positioned, the transducer can be rotated 90° (for example, from the short to the long axis) for further confirmation that the placement is correct. Localizing the needle tip is imperative. Stimulation of the target nerve may be performed at this time. If a needle is positioned in the vicinity of blood vessels, color Doppler helps to identify those structures and avoid intravascu-

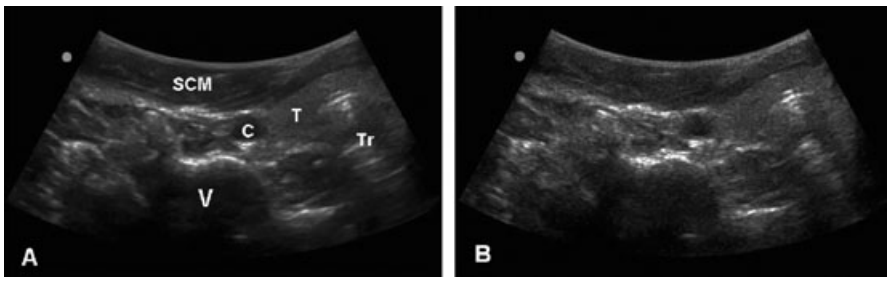

Figure 1. Ultrasonography of neck: (A) Multiple-beam mode enabled. (B) Multiple-beam mode disabled. V, vertebra; SCM, sternocleidomastoid muscle; C, carotid artery; T, thyroid; Tr, trachea.

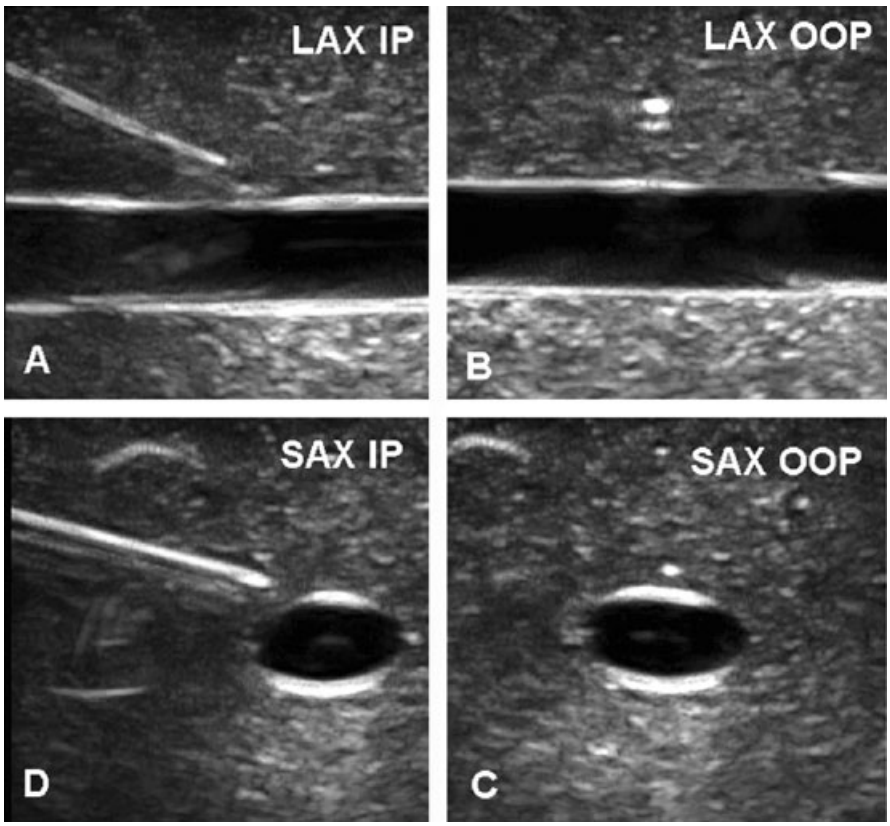

Figure 2. Needle position relative to target nerve (axis) and ultrasound beam (plane): (A) Long-axis, in-plane position (LAX IP). (B) Long-axis, out-of-plane position (LAX OOP). (C) Short-axis, out-of-plane position (SAX OOP). (D) Short-axis, in-plane position (SAX IP). Adapted from Gray AT. Ultrasound-guided regional anesthesia: current state of the art. *Anesthesiology.* 2006;104:368–373. Figure prepared using the Branched Vessel Ultrasound Phantom (Blue Phantom, Kirkland, WA, USA).

lar injection. A small amount of saline injected at this point during the procedure will appear as a hypoechoic area spreading from the needle tip. Failure to observe this phenomenon should alert the operator to possible intravascular placement.

Although fluoroscopy and CT should remain the standard image guidance tools for patients whose anatomic features pose particular challenges (eg, obesity, severe degenerative changes, malformation), US can be implemented in the office-based practice for diagnostic and therapeutic injections.

Using US for diagnostic comparative nerve blocks may have additional value in terms of the timing of the diagnosis and treatment. Because this procedure does not require a special setting (eg, imaging suite) or additional personnel, it can be performed at the time of initial assessment. If the result is positive, the confirmatory injection can be scheduled for a subsequent date and the physician may choose US or fluoroscopy guidance to exclude a false-positive response. However, if the result is negative, the physician must distinguish between true- and false-negative findings. A false-negative result may be attributable to technical imperfection, because of limited ability to recognize the target with US; however, even this result provides some information, indicating the lack of a placebo response. Confirmatory fluoroscopy-guided block should clarify the situation, since the results of this procedure can be considered "true."

US-GUIDED SPINAL INTERVENTIONS

Interlaminar Epidural Injection of Corticosteroid (Level IV evidence)

Although US has proven useful in regional and labor-related anesthesia,[3] no studies of interlaminar epidural steroid injection under US guidance have appeared in the literature. In fact, this application should be discouraged, because the technical ability to identify the correct level for injection does not necessarily imply proper deposition of injectate into the ventral epidural space and/or adjacent to the dorsal root ganglion. Because the energy of sound is completely absorbed by bone tissue, the injected solution cannot be seen within the epidural space. One might argue that, compared with "blind" injection, US at least offers accurate localization of the epidural space; nevertheless, it seems imprudent to recommend an incorrect approach merely because it is less

harmful than an incorrect approach that is known to be harmful.

Caudal Epidural Injection of Corticosteroid (Level IV Evidence)

Two clinical studies[4,5] have reported the usefulness of US imaging in caudal injections of corticosteroid. One of them[5] even described Doppler US as a tool for verifying deposition of injectate into the sacral canal. Notwithstanding the success of proper needle positioning, this method has the same flaws as other US-assisted neuroaxial injections, ie, the inability to track spread of the injected solution beyond the injection site. Therefore, this technique can be recommended only for remote facilities without access to a radiology suite. Its main advantage is in the confirmation of correct needle placement.

Transforaminal Lumbar (Periradicular) Injection (Level III Evidence)

In a feasibility study of US-guided lumbar (periradicular) injection, Galiano et al.[6] used CT to verify needle position within the intervertebral foramen. Although the experimental study confirmed that all 10 needle tips had been placed within the dorsal third of the intervertebral foramen in the periradicular area, there are two major drawbacks to this technique, which limit its use for clinical practice. The first is inability to confirm flow of the contrast agent into the ventral epidural space, which may not occur even with precise positioning of the needle tip (eg, in the presence of foraminal stenosis); the second is the potential risk of intravascular (intraarterial) injection of a particulate steroid. An injected fluid is usually seen with US, and intravascular injection can thus be prevented in certain situations. However, this problem is extremely difficult to visualize if it occurs deep in the tissues of the low back, and injection of even a minuscule amount of particulate drug into the radicular artery can be detrimental to the patient.

Nonetheless, the technique may be an attractive alternative to fluoroscopy if the patient is allergic to iodine or fluoroscopy is unavailable. In this case, a water-soluble corticosteroid (specifically, dexamethasone) must be used.

Transforaminal Cervical (Periradicular) Injection (Level III Evidence)

The evidence for transforaminal cervical injection is limited to one feasibility study using cadavers.[7] The transverse process was identified in all specimens, but depiction of the spinal nerves was not always possible. In each case, the needle tip was placed within 5 mm of and dorsal to the spinal nerve and less than 5 mm from the posterior tubercle of the transverse process, as verified by CT. The method drew criticism[8] because of the possible risk of spinal cord injury and intraarterial injection. Indeed, with ventrodorsal oblique insertion, the needle aligns with the transverse process and there is a danger that it will be placed too deep within the foramen. If this occurs, radicular damage is not the only concern. In addition, because of the location of the vertebral artery ventral to the exiting nerve root, the artery may be traversed by the needle, leading to a risk of arterial damage or intraarterial injection.

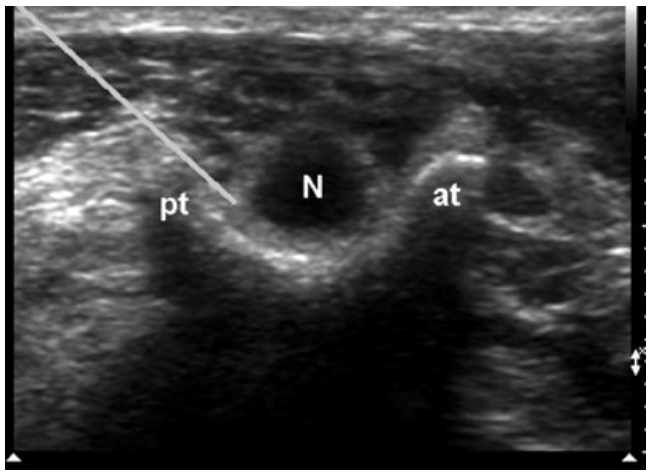

Figure 3. Needle pathway (white line) for blockade of a cervical nerve root: N, nerve root; pt, posterior tubercle of transverse process; at, anterior tubercle of transverse process.

This approach may be modified by changing the direction of needle insertion to oblique dorsoventral (Figure 3). The dorsoventral trajectory allows placement of the needle at the ventral aspect of the posterior tubercle of the transverse process, which diminishes the possibility of contact with any vascular elements. This angle also prevents inadvertent deep foraminal placement of the needle.

The anatomy of the cervical vertebrae can be easily identified by a combination of surface landmarks and sonoanatomy. The Chassaignac tubercle of the C6 transverse process can usually be palpated, and a US probe placed on this structure reveals the typical appearance of the transverse process of the vertebra, with its anterior and posterior tubercles and exiting nerve root (Figure 4). Scanning caudally and slightly dorsally will bring the C7 transverse process into view. It differs from

the C6 process by the presence of only one tubercle, the posterior one (Figure 5). The C7 nerve root is situated just anterior to this tubercle. It is worth mentioning that the vertebral artery may lie adjacent and parallel to the C7 nerve root. The nerve roots of C3 to C5 have the same sonoanatomy as the C6 nerve root and can be found by cephalad scanning.

Cervical injection is performed by in-plane needle placement. A stimulating needle can be used as an additional tool to confirm correct placement. For therapeutic purposes, a water-soluble corticosteroid should be used; for diagnostic or prognostic purposes, 0.5 to 1 mL of local anesthetic may be injected.

Radiofrequency ablation can be performed using the same imaging technique. Given that the cannula is positioned extraforaminally, cervical root neurotomy is feasible, but dorsal root ganglion is not accessible. The method should probably be reserved for the treatment of cancer pain associated with anterolateral Pancoast tumor that has spread into the brachial plexus and soft tissue, for which fluoroscopy-guided oblique ventrodorsal access is undesirable (Figure 6).

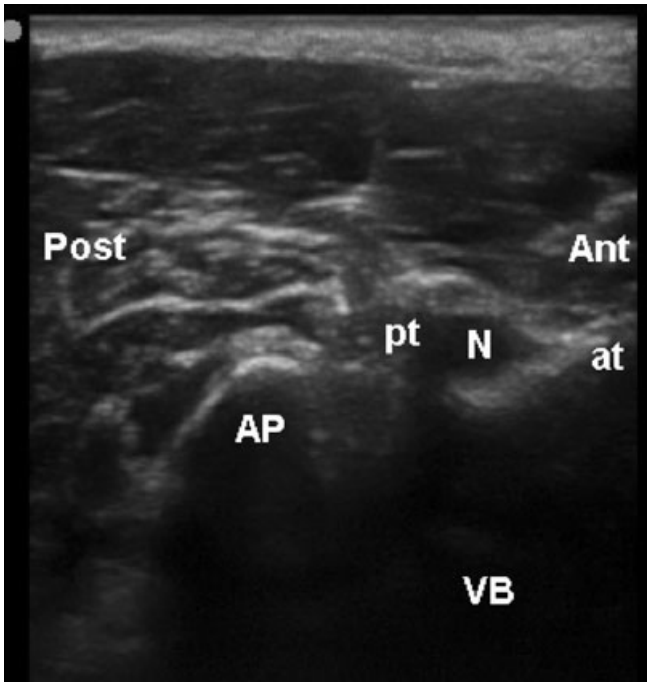

Figure 4. Sonoanatomy of the C6 cervical nerve root: N, C6 nerve root; at, anterior tubercle of C6 transverse process; pt, posterior tubercle of C6 transverse process; VB, C6 vertebral body; AP, articular pillar.

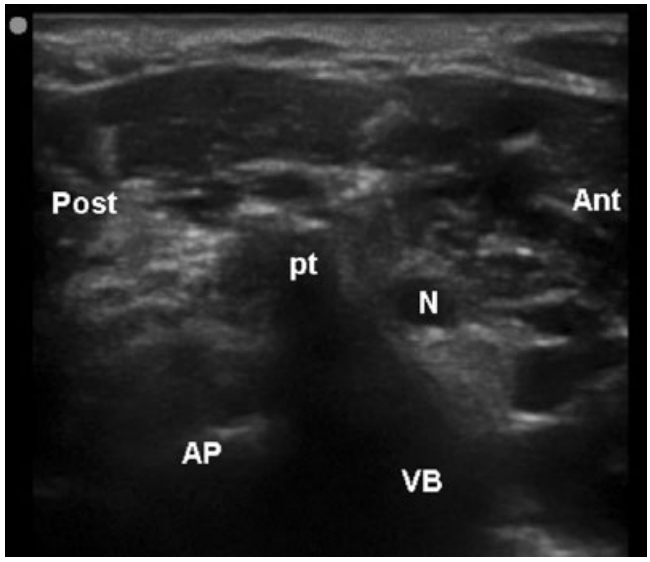

Figure 5. Sonoanatomy of the C7 cervical nerve root: N, C7 nerve root; pt, posterior tubercle of C7 transverse process; VB, C7 vertebral body; AP, articular pillar.

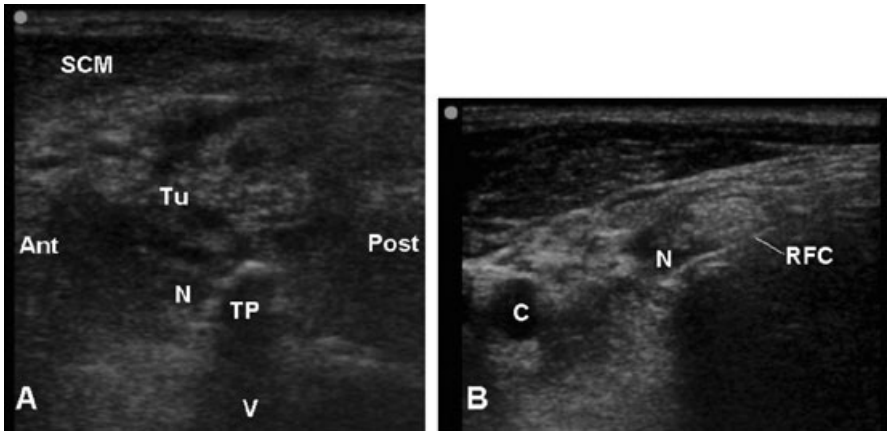

Figure 6. Radiofrequency ablation of the C7 nerve root in a patient with pancoast tumor. (A) Sonoanatomy of the C7 nerve root: N, nerve root; TP, transverse process of C7 vertebra; V, vertebra; Tu, tumor; SCM, sternocleidomastoid muscle. (B) Radiofrequency cannula (RFC) positioned adjacent to the C7 nerve root (N); C, carotid artery.

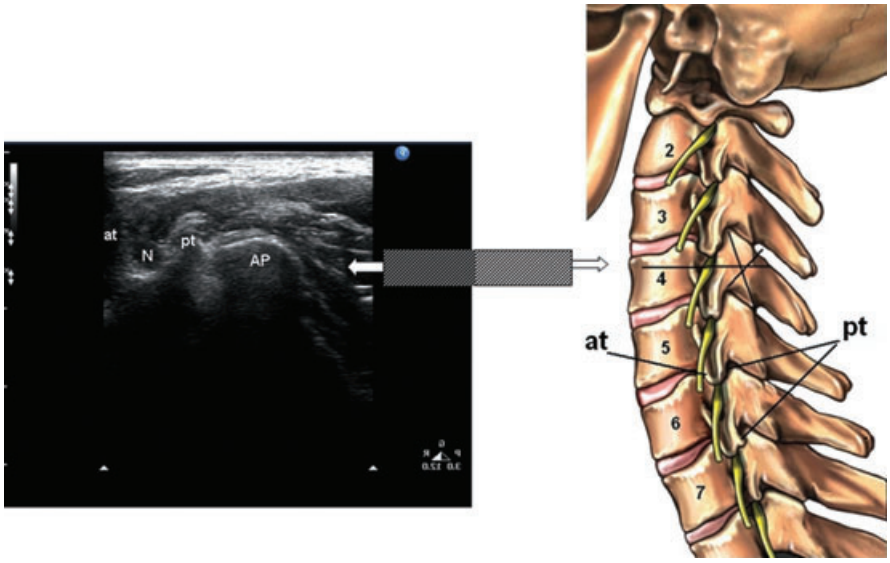

Figure 7. Sonoanatomy of cervical medial branch block. A line drawn dorsally from the transverse process crosses the middle of the pillar, the recommended site for blockade of the corresponding medial branch of a cervical nerve (right). Corresponding drawing of the axial sonoanatomy of the cervical vertebra (left). N, nerve root; at, anterior tubercle; pt, posterior tubercle; AP, articular pillar.

Third Occipital Nerve Block (Level II Evidence) and Cervical Medial Branch Block (Level IV Evidence)

The technique for achieving third occipital nerve block under US guidance has been described in detail elsewhere,[9] with validation against fluoroscopy using healthy volunteers. The radiographic accuracy for 23 of 28 needle placements and the clinical success in 9 of 10 blocks, strongly suggested that this type of block can be accurately performed under US guidance. Nonetheless, fluoroscopy, with a 100% technical success rate, remains the method of choice.

Diagnostic blockade of other zygapophysial joint nerves in the lower cervical spine has not been tested in either ex-vivo or clinical studies. However, a relatively simple technique can be used for C3–C7 medial branch blockade, based on the observed correlation between the axial position of the transverse process and the articular pillar. When the US transducer is positioned on the short axis of the cervical vertebra, both the transverse process and the articular pillar come into view. A line drawn dorsally from the transverse process will pass through the middle of the pillar, the recommended site for blockade of the corresponding medial branch (Figure 7). The needle is inserted in-plane dorsoventrally until it contacts the articular pillar posterior to the transverse process (Figure 8). This method has not been rigorously validated. However, of a series of 10 patients with negative outcomes on US-guided blockade who subsequently underwent confirmatory fluoroscopy-guided injection (unpublished data), only one reported pain reduction of more that 70% after the fluoroscopy-guided injection (ie, a 10% false-negative rate). Lack of tissue expansion while initiating the injection suggests intravascular uptake; if this occurs, the needle must be repositioned (usually withdrawn slightly, while maintaining contact with bone). A 0.5-mL volume of local anesthetic is typically used.

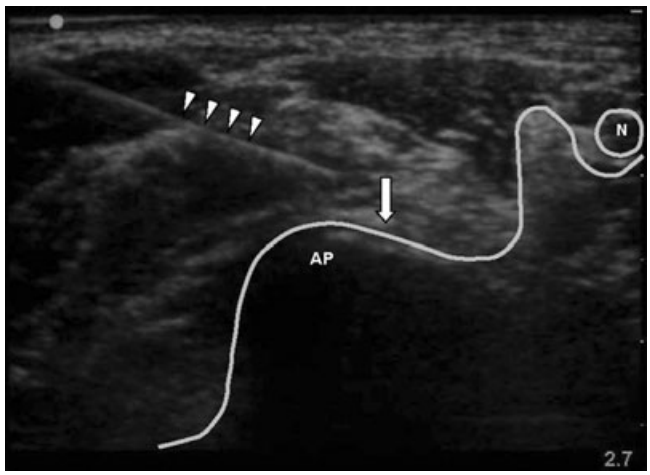

Figure 8. Posterolateral needle placement (arrowheads) for medial branch block. N, nerve root; AP, articular pillar; block arrow, bone surface target.

Cervical Zygapophysial Joint Injection (Level III Evidence)

A CT-controlled feasibility study showed that accurate US-guided injection in the middle to lower cervical spine is possible.[10] However, the technique has not been adopted in the clinical setting, probably because of the limited usefulness of injections to the cervical zygapophysial joint, regardless of the type of imaging assis-

tance.[11] Only one properly conducted study has been published, and it showed only a short-term benefit.[12]

Lumbar Zygapophysial Joint Injection (Level I Evidence)

Periarticular injection of lumbar zygapophysial joints was probably the first application of US guidance for spinal injections to be described,[13] and the method was recently validated against CT-guided injection in a randomized controlled study.[14] As for any lumbar spine injections, a broad-band, curved-array transducer operated at low frequency is used. Usually the cleft of the zygapophysial joint is readily apparent on the transverse view of the lumbar vertebra. However, obesity and severe degenerative changes may make visualization virtually impossible.

Lumbar Medial Branch and Dorsal Ramus Block (Level I Evidence)

Lumbar zygapophysial joint pain is routinely diagnosed by comparative blockade of the sensory nerves. Probably, this is the most common diagnostic procedure in the management of spinal pain. US guidance of such injections has been studied with healthy volunteers[15] and validated against CT.[16] In a recently published clinical study with fluoroscopic control,[17] all 101 needles were placed in the correct lumbar segment, and 96 (95%) of the needles were in the correct position. Two of the needles were associated with intravascular spread of the contrast dye. The mean pain score on a visual analog scale was reduced from 52 before to 16 after blockade.[17] The study had several limitations, in particular the relatively low body mass index (BMI) of the study patients, which might have allowed good visualization of the spine and ultimately high technical success. However, in the earlier study by Greher et al.,[15] US imaging was of adequate quality in a patient with a BMI of 36 kg/m^2, so BMI is not necessarily a limiting factor. It is also worth mentioning that patients with pain related to the lumbosacral zygapophysial joint were excluded from the study,[17] and L5 dorsal ramus block has therefore not been evaluated.

The procedure should start with longitudinal scanning of the midline, starting from the sacrum. A broad-band, low-frequency, curved-array probe is used. The most superficial bone shadows are the spinous processes (Figure 9). The transducer is rotated perpendicular to the long axis at the desired level, and a three-step shadow of the lumbar vertebra will become evident: the most superficial bone structure is the spinous process,

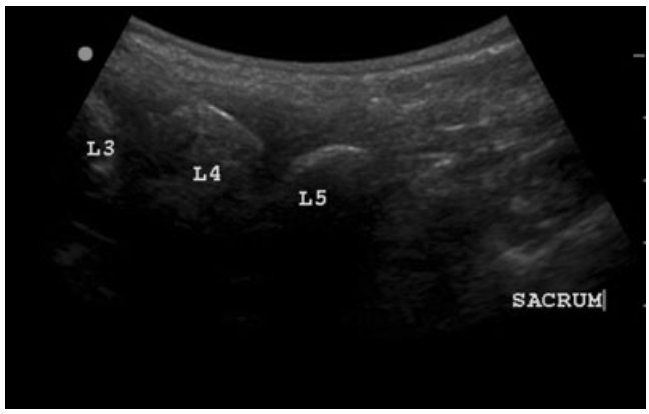

Figure 9. Sonographic long-axis view of the lumbar spine showing the spinous processes of the L3, L4, and L5 vertebrae and the sacrum. (Courtesy of Dr. Peter Chan.)

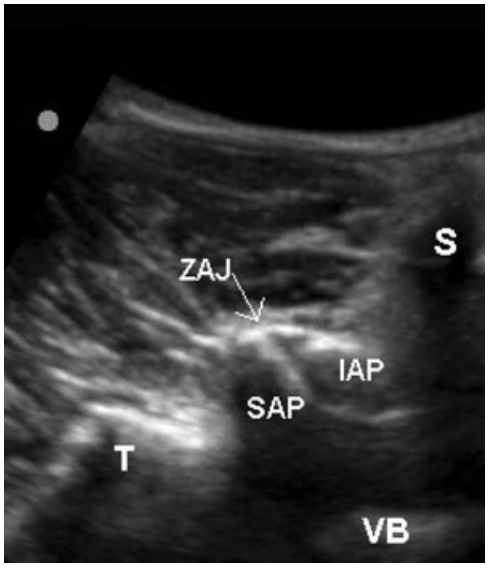

Figure 10. Sonographic short-axis view of a lumbar vertebra. S, spinous process; SAP, superior articular process; IAP, inferior articular process; ZAJ, zygapophysial joint; T, transverse process; VB, vertebral body.

with the zygapophysial joint positioned just inferiorly and lateral to it and the transverse process located further inferiorly and laterally (Figure 10). A block needle (22-gauge Quincke spinal needle or stimulating 3-inch block needle) is inserted in-plane and advanced until it contacts bone at the root of the corresponding transverse process or the sacral ala at the L5–S1 level. L5 dorsal ramus blockade can be technically challenging because of the iliac crest (Figure 11). Once bone contact has been made, the transducer is again rotated to obtain the longitudinal view, but the probe should then be

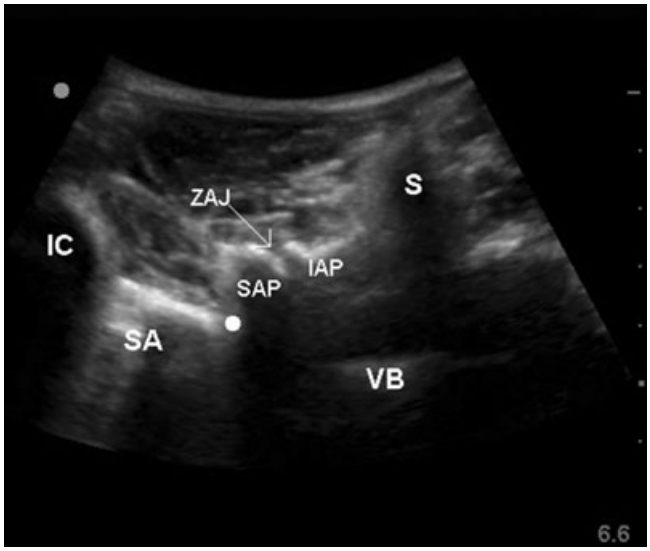

Figure 11. Sonoanatomy of L5 dorsal ramus block (axial view of the L5–S1 segment). S, spinous process of L5 vertebra; SAP, superior articular process of S1 vertebra; SA, sacral ala; IS, iliac spine; white dot, target point for the L5 dorsal ramus block.

positioned paravertebrally to seek the shadows of the transverse processes or the sacral ala. Agitation of the needle by careful jiggling will help to identify its position in this out-of-plane sonographic view. The needle tip must be seen on the upper part of the transverse process or the sacral ala. If the needle does not contact bone at a predetermined depth, the longitudinal view should clarify the position of the needle tip relative to the transverse process. Usually, the needle tip will be seen somewhat below or above the bone shadow. Failure to recognize the position of the tip may result in inadvertent transforaminal advancement of the needle and injury to an exiting nerve root. Once visualized, the needle is gently repositioned and redirected to the desired position. The operator must be able to visualize the needle tip at the time of injection. Failure to observe tissue movement around the needle tip should be interpreted as a sign of intravascular injection and the need for additional fine-tuning of the needle. After verification of needle position, 0.5 mL of local anesthetic is injected.

NONSPINAL PROCEDURES

Virtually all peripheral nerve blocks performed in regional anesthesia, as well as intraarticular, synovial, and soft-tissue injections, can be used in the treatment of pain. This section covers several unique applications with importance in pain medicine.

Only some of these procedures have been assessed against other imaging techniques. For example, celiac plexus block has been extensively investigated and reported, and although no ex-vivo data are available, the evidence can be considered conclusive (level I). Blockade of the cervical sympathetic chain should be classified as having limited evidence (level III), and the level of evidence for suprascapular nerve block (SSN) is as yet undetermined (level IV). It is difficult to define the level of evidence for blockade of other peripheral nerves. Ex-vivo feasibility studies may be valuable in confirming the precision of US-guided injection. However, the ability to localize a nerve is obviously greater with US guidance than with use of a nerve stimulator and surface landmarks.

Stellate Ganglion Block (Level III Evidence)

Kapral et al.[18] described a technique for US-guided stellate ganglion block in 1995. Direct visualization of the target, all nearby structures, the needle, and the spread of local anesthetic indicated that the method was safe and effective. The volume of local anesthetic required (5 mL) was significantly lower in the experimental group, compared with the blind-puncture group. Moreover, the onset of sympathetic blockade was hastened by US guidance. None of the patients in the US group experienced hematoma, but this problem occurred in 3 of the 12 patients in the blind-approach group.[18] Recently, two additional articles have been published. One was a case report addressing the feasibility of US-guided stellate ganglion block with avoidance of esophageal penetration, which might occur with blind injection.[19] The second study considered where the local anesthetic should be injected in relation to the longus colli muscle, either subfascially or suprafascially.[20] The authors speculated that subfascial injection might improve the spread of local anesthetic and decrease the incidence of recurrent laryngeal nerve palsy. Notwithstanding the technical success achieved, it should be emphasized that neither technique reliably delivers local anesthetic to the stellate (cervico-thoracic) ganglion. MRI has shown that the stellate ganglion is at the same level as or somewhat caudad to the head of the first rib. This position is more caudad than is commonly reported from dissections, which indicates that displacement may occur during handling of anatomic material. Axial images obtained at the level of the first thoracic vertebra show that the ganglion is consistently lateral and posterior to the lateral edge of the longus colli muscle. The ganglion also lies immediately posterior or medial to the

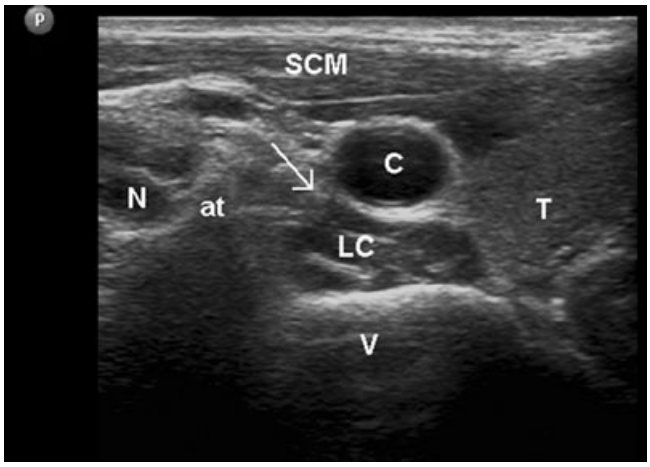

Figure 12. Sonoanatomy of the sympathetic chain at the level of the C6 vertebra. N, C6 nerve root; at, anterior tubercle; SCM, sternocleidomastoid muscle; V, vertebra; LC, longus colli muscle; T, thyroid; C, carotid artery; arrow, sympathetic chain.

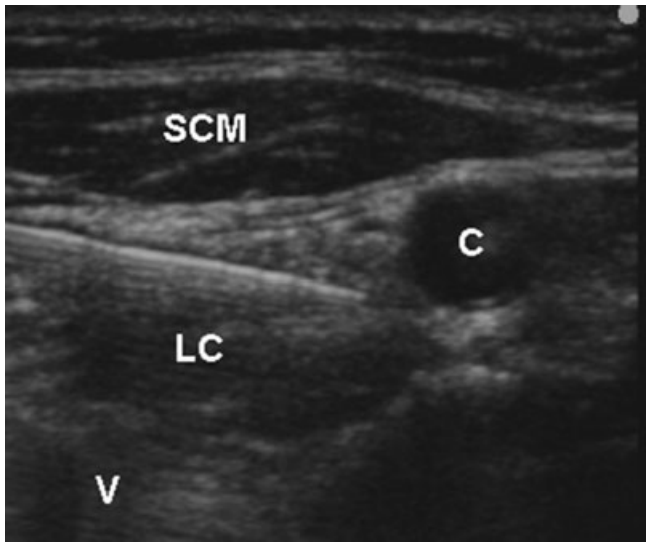

Figure 13. Cervical sympathetic trunk block: the needle is positioned adjacent and anterior to the longus colli muscle. SCM, sternocleidomastoid muscle; V, vertebra; LC, longus colli muscle; C, carotid artery.

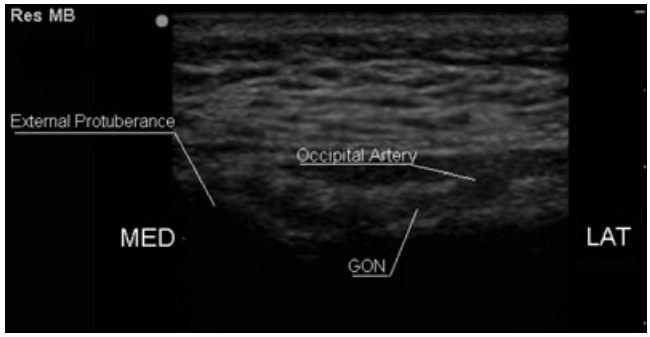

Figure 14. Sonoanatomy of greater occipital nerve block. GON, greater occipital nerve.

vertebral artery.[21] Therefore, the effect of an injection at the C6 or even C7 level on upper extremity sympathetic blockade resides in contact between the local anesthetic and the sympathetic postganglionic fibers, not the stellate ganglion.[22] The middle and intermediate cervical sympathetic ganglia can be readily blocked with needle placement at the C6 level, which represents indirect confirmation of the cephalad rather than the caudad spread of the anesthetic. Deliberate sympathetic blockade of the middle cervical ganglion may be indicated for the diagnosis and treatment of sympathetically maintained pain of the face, such as some atypical forms of facial pain and postherpetic neuralgia.

All of the articles describing stellate ganglion blockade mention concerns about anterior passage of the needle through the thyroid gland and in the vicinity of the inferior thyroid arteries. Therefore, a posterolateral approach is recommended, whereby the longus colli muscle is identified at the level of the C6 or C7 vertebrae on a lateral (short-axis to transverse process) US image (Figure 12). During subsequent anterolateral scanning of the neck tissues, the longus colli muscle is maintained in the center of the image. The typical "window" is identified, where the sympathetic chain can be accessed through the anterior scalene muscle, leaving the brachial plexus laterally and the carotid artery medially to the needle pathway (Figure 13). The needle is inserted subfascially at the anterolateral aspect of the longus colli muscle. For this procedure, it is helpful to use extension tubing with two syringes attached via a three-way stopcock: one syringe containing normal saline and the other containing a local anesthetic (eg, 5 mL of bupivacaine 0.25%). Once the needle is positioned, 1–2 mL of the normal saline is injected. This should cause expansion of the tissue and separation of the muscle tissue from the fascia, which confirms correct needle placement. The local anesthetic is then injected.

Greater Occipital Nerve Block (Level IV Evidence)

No data outlining occipital nerve block under US guidance has been published, but the greater occipital nerve can be easily localized immediately medial to the occipital artery (Figure 14). Only 1–2 mL of local anesthetic is required to perform the block, and vascular puncture is readily avoided. Typically, a small, linear, high-frequency "hockey-stick" probe is used for this procedure.

SSN Block (Level IV Evidence)

The first case report of US-guided SSN has only recently appeared,[23] and though no comparative studies with other imaging modalities have been published, the technique has been known for a long time. In the author's practice, this method is routinely used for diagnostic SSN blockade, and others report similar implementation (M. Greher, personal communication).

The technique is straightforward. A linear broadband, high-frequency transducer is placed parallel to the scapular spine on the medial part of the acromion. Medial scanning will reveal a "window" in the supraspinous fossa and a U-shaped suprascapular notch (Figure 15). The supraspinatus muscle is situated immediately above the notch, and the trapezius muscle lies superficially. The suprascapular artery is usually seen at the medial part of the notch, and occasionally the SSN can be visualized lateral to the artery. A 3-inch stimulating or spinal needle is inserted with an in-plane approach from the medial to lateral direction and is positioned below the suprascapular ligament. Mesiad direction of the injection may be associated with an increased risk of pneumothorax. A 3- to 5-mL volume of local anesthetic is required to complete the block.

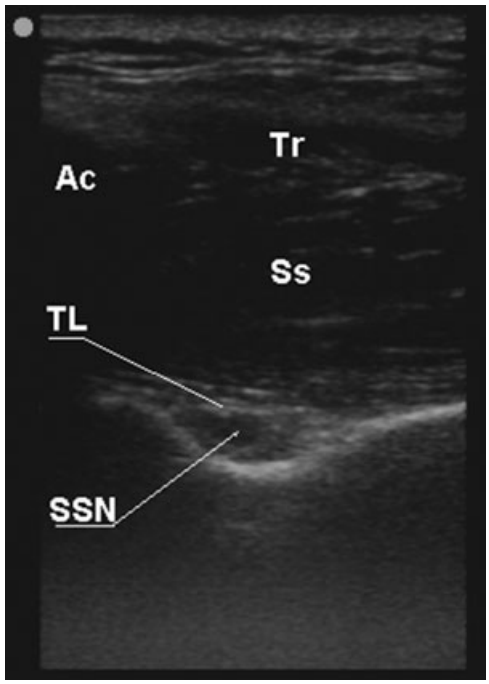

Figure 15. Sonoanatomy of suprascapular nerve block. Ac, acromion; TL, transverse ligament; SSN, suprascapular nerve; Ss, supraspinatus muscle; Tr, trapezius muscle.

Intercostal Nerve Block (Level IV Evidence)

Eichenberger et al.[1] described a technique for US-guided intercostal nerve block in their 2004 review. Using US, the nerves are rarely seen because they lie close to or are covered by the caudal edge of the rib. However, the pleura can be clearly visualized, and pneumothorax can therefore be reliably avoided. Usually, 2 mL of local anesthetic is sufficient to fill the intercostal space, which allows blockade of several intercostal nerves with minimal risk of toxic effects.

A small case series confirmed the feasibility and technical advantages of US-guided cryoablation of the intercostal nerves in four patients with postthoracotomy pain syndrome.[24] Although visualization of the pleura helped to avoid pneumothorax, pain relief lasted only 1 month.

Celiac Plexus Block (Level I Evidence)

A 1983 report of celiac plexus block was probably the first published application of US in pain medicine.[25] Since then, numerous reports of this technique have appeared, and 19 original research articles were identified in the MEDLINE search performed for this review. Both the anterior percutaneous approach and endoscopic US-guided celiac plexus block have been described for malignant and benign chronic upper abdominal pain. Although no ex-vivo study has appeared, multiple clinical studies, including a comparative CT trial,[26] provide a conclusive level of evidence.

The anterior percutaneous approach is simple, inexpensive, and (in contrast to the endoscopic method) does not require special equipment or formal training in gastroenterology.

The celiac trunk and abdominal aorta can be located with color Doppler imaging (Figure 16). The distance from the skin entry site, 2 cm below the xiphoid process, to the celiac trunk and the optimal angle of needle entry and depth are then determined. A 3-inch, 22-gauge spinal needle is advanced to the pre-aortic zone just above of the celiac trunk. Once the needle has been positioned correctly and aspiration has confirmed a nonvascular location, local anesthetic or alcohol can be injected. A 10-mL volume of local anesthetic is sufficient if the needle is placed properly, and 20–30 mL of 50–100% alcohol is recommended for neurolytic celiac plexus block. The spread of local anesthetic or neurolytic agent is visualized by real-time US. When alcohol is used, the pre-aortic zone becomes highly hyperechoic.

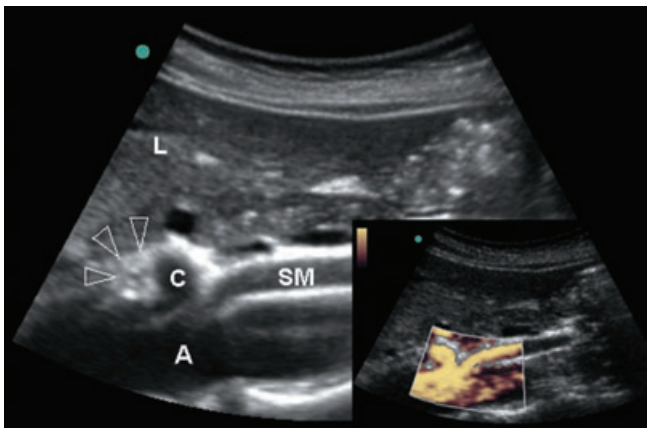

Figure 16. Sonoanatomy of celiac plexus block (long axis to blood vessels). A, aorta; C, celiac trunk; L, liver; arrowhead, celiac plexus. In inset—color Doppler.

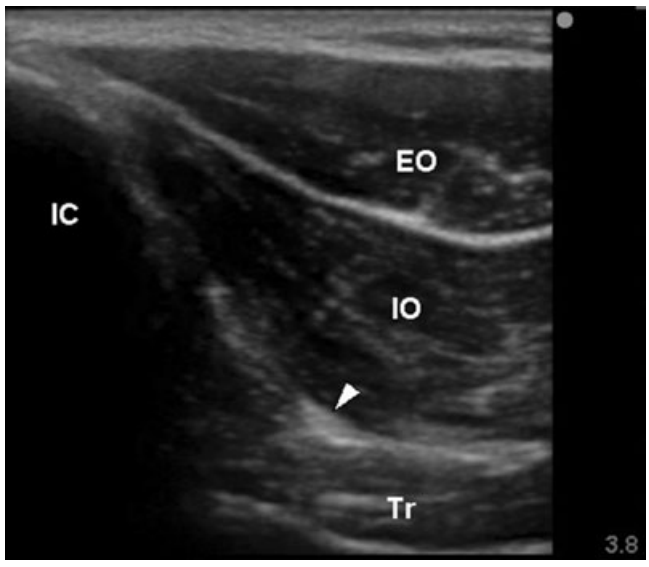

Figure 17. Sonoanatomy of ilioinguinal nerve block. IC, iliac crest; EO, external oblique muscle; IO, internal oblique muscle; Tr, transverse muscle; white arrowhead, ilioinguinal nerve.

Ilioinguinal and Iliohypogastric Nerve Block (Level II Evidence)

Ilioinguinal and iliohypogastric nerve block may be useful in the diagnosis of chronic pain in the ilioinguinal area and scrotum, which may occur after lower abdominal surgery. This form of pain occurs most often after repair of the ilioinguinal hernia, but cesarean section, tubal ligation, laparoscopy, and other procedures may also cause nerve damage in this area. If prognostic blockade relieves the pain, cryoablation of the corresponding nerve is considered a feasible option.

The nerves can be located by two methods. The first was described by Eichenberger et al.[27] and was validated by anatomic dissection. If a linear broad-band transducer is placed perpendicular to abdominal muscles, one or both nerves can be visualized just above the iliac crest (Figure 17). The nerves are usually seen between the internal and transverse muscles and can be blocked using an in-plane or out-of-plane technique. Because the distance between the target and the abdominal viscera is typically just 1.0 to 1.5 cm at that point, caution is required. Usually, short-axis, out-of-plane method of needle placement is required for performance of block, which makes it technically demanding. A different approach was recently described,[28] whereby the injection is performed medially to the anterior superior iliac spine, at the line connecting this landmark with the umbilicus. The advantage of this method is that it allows short-axis, in-plane placement of block needle. The nerves usually lie either between the exterior and interior muscles, or between interior and transverse muscles. Thus, the nerve pathway is less predictable in this area because the anatomic level of emergence from a deep to a more superficial location is variable, and it may make it difficult to identify the nerves. Execution of this method is aided by finding the ascending branch of the deep circumflex iliac artery. The nerves are typically situated adjacent to it, the ilioinguinal nerve laterally and the iliohypogastric nerve medially (Figure 18). A volume of 2–3 mL of local anesthetic effectively blocks the nerve.

Pudendal Nerve Block (Level III Evidence)

Kovacs et al.[29] first described a US-guided technique for localization of the pudendal nerve in healthy volunteers. However, these authors merely described the sonoanatomy; their study did not involve US-guided needle placement for nerve block. In a recently published clinical feasibility study,[30] the pudendal nerve was successfully blocked in all 17 patients. The nerve can be usually localized with a low-frequency, curved-array US probe positioned at the level of the ischial spine in the plane between the sacrospinous and sacrotuberous ligaments (Figure 19).

It is still unclear if the ability to localize and anesthetize the pudendal nerve has any clinical value. Corticosteroid supplementation may result in only a slightly longer duration of pain relief than local anesthetic alone, and the mechanism for such augmentation is unknown. The ramifications of pudendal nerve ablation for nonmalignant pain remain to be elucidated.

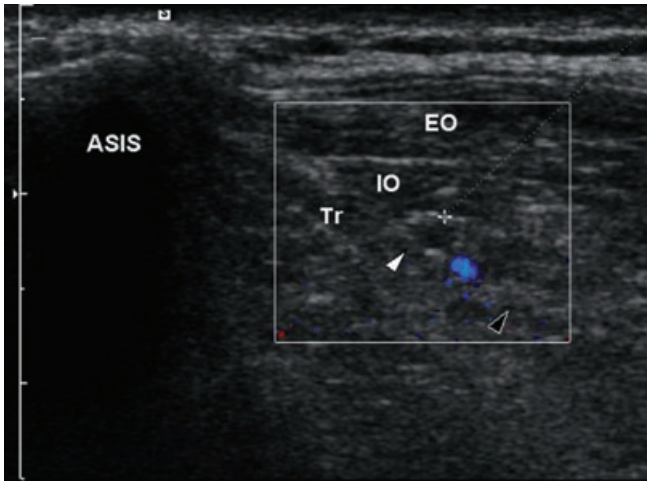

Figure 18. Sonoanatomy of ilioinguinal and iliohypogastric nerve block. ASIS, anterior superior iliac spine; EO, external oblique muscle; IO, internal oblique muscle; Tr, transverse muscle; blue color, branch of the deep circumflex artery; white arrowhead, ilioinguinal nerve; black arrowhead, iliohypogastric nerve.

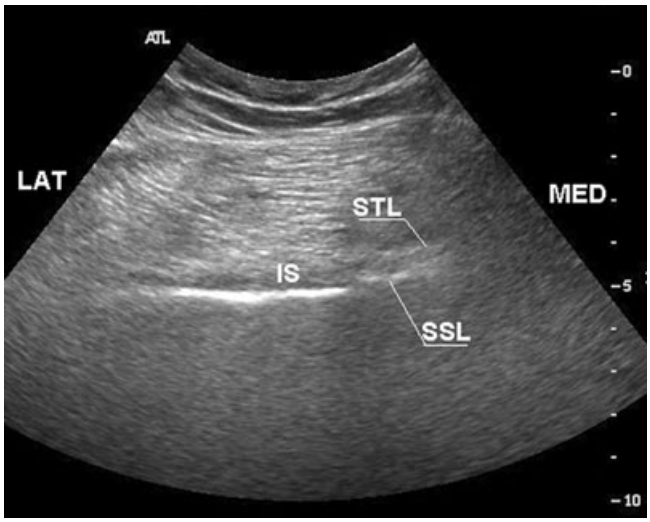

Figure 19. Sonoanatomy of pudendal nerve block. IS, ischial spine; SSL, sacrospinous ligament; STL, sacrotuberous ligament. (Courtesy of Dr. Philip Peng.)

Anesthetic Blockade and Ablation of Pure Sensory Nerves (Level IV Evidence)

Small sensory nerves can potentially be ablated with chemical agents, cryoprobe, or a radiofrequency current. Destruction of larger nerve trunks may result in loss of function and deafferentation sequela. Therefore, this procedure is warranted only for patients with limited life expectancy.

The prospect of visualizing a pure sensory nerve, which might be a pain mediator, and then performing precise diagnostic block with subsequent neurolysis is very attractive. Potential targets for this approach include the lateral femoral cutaneous nerve, the saphenous nerve and its infrapatellar branch, etc.

The lateral femoral cutaneous nerve can be located at its emergence just below the ilioinguinal ligament above the fascia lata.[31] The saphenous nerve can be readily identified lying between the femoral vessels and the vastus medialis muscle. Scanning the distal part of the nerve reveals the infrapatellar branch.[32] Blockade of this branch can be used in the diagnostic workup for postoperative or posttraumatic knee pain; ablation by cryoanalgesia or radiofrequency can be used to obtain lasting pain relief.

Anesthetic Blockade and Ablation of Painful Neuroma (Level IV Evidence)

Peripheral nerve neuroma is visualized as a globular nonhomogeneous hypoechoic structure, and the corresponding peripheral nerve can be localized proximally (Figure 20).

Local anesthetic blockade may not only help in establishing the diagnosis of neuroma pain, but may also predict the outcome of percutaneous destruction (by cryoablation, radiofrequency ablation, or chemical treatment) or surgical removal. Inability to alleviate spontaneous pain, whereby abolition of the presumed peripheral source does not resolve the pain, is strongly suggestive of a central sensitization, and local treatment would likely be ineffective.

In a large case series involving 101 patients, Morton neuroma was ablated by injection of alcohol.[33] Partial or total resolution of symptoms was reported by 94% of the patients, and 84% became totally pain free. Two other articles have suggested the usefulness of corticosteroid[34] and phenol[35] injections for neuroma pain of amputation stumps.

DISCUSSION

Renewed interest in US as an imaging tool in pain medicine, and its potential to at least partially replace fluoroscopy and CT in this area, has led to dissemination of mostly anecdotal evidence in the literature and has prompted pain physicians to seek continuing medical education programs on this topic. The analogy with US guidance in regional anesthesia is evident: initial attempts to facilitate nerve block with US three decades

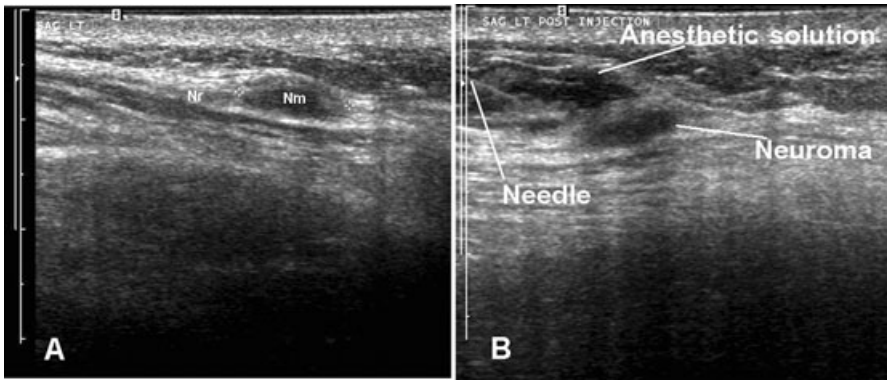

Figure 20. (A) Amputation neuroma (Nm), a globular nonhomogeneous hypoechoic structure connected to the proximal nerve (Nr). (B) Local anesthetic injected for diagnostic prognostic blockade.

ago[36] led to the development of a new branch of regional anesthesia, publication of numerous high-quality studies, and the establishment of US as a new standard of care in neural blockade. We are now witnessing the "childhood" of US in the diagnosis and treatment of pain. As such, it is important to establish standards by which to assess new applications of this modality. This article has used previously published recommendations for the evaluation of evidence[2] as the basis for assessing the evidence for US guidance in pain management, with adaptations suitable for comparisons of different imaging modalities. This appraisal of the evidence takes into account the various study designs that have been used. Thus, the existence of multiple studies comparing US with other imaging through both ex-vivo modeling and clinical validation represents the highest level of evidence, whereas case reports and expert experience represent an indeterminate level of evidence. Critical assessment of this type may prevent "delivery difficulties" in experimental and clinical applications of US imaging in pain medicine and facilitate evidence-based research and practice.

Currently available data, though limited, suggest that US can be viewed as an emerging technology in the interventional management of pain. US allows visualization of soft tissues, vessels, and nerves. In contrast to fluoroscopy, it does not require X-ray-compatible suite and protective gear, and there are no overhead costs for maintenance of equipment. Patients and medical personnel are not exposed to radiation, and the waiting time for a procedure can be significantly reduced.

This technology does have limitations. US offers only a narrow imaging window, which is extremely sensitive to the probe's position and direction. Tissue artifacts may lead to interpretation errors, whereby other tissues, such as tendon, vessel, connective tissue, or lymph nodes, are interpreted as nerves. Therefore, in-depth knowledge of applied anatomy and specific training are required to master these techniques. US cannot penetrate bone and therefore should not be used when the target is obscured by bone tissue. Finally, anatomic abnormalities such as obesity or severe degenerative changes may diminish the effectiveness of US.

Clinical trials are needed to investigate the efficacy and safety of US-guided pain procedures. Until firm evidence is available, US cannot replace radiology-based methods in routine clinical practice, especially for neuroaxial and cranial injections.

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