Ultrasound-Guided Spinal Procedures for Pain

A Review

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KEYWORDS

• Epidural • Facet • Interventional spine • Interventional pain • Pain management • Sonography • Spine injections • Ultrasonography

KEY POINTS

- Ultrasound (US) has become a more common imaging modality for spinal interventions.
- US has some advantages and disadvantages compared with fluoroscopy and other imaging modalities.
- Most typical spinal pain procedures described under fluoroscopy have also been described with US guidance.
- Although there are multiple studies demonstrating the accuracy of US-guided spine procedures using cadaveric dissections as well as comparing their accuracy to procedures with CT or fluoroscopic guidance, there are no large studies comparing the safety or efficacy of US-guided spinal interventions to CT or fluoroscopic guidance.
- Some spinal interventions where the spinal vascular supply may be at risk may still benefit from fluoroscopic or CT-confirmed contrast-controlled verification.

INTRODUCTION

The aging population presents musculoskeletal clinicians with an increasing incidence of degenerative changes of the spine and associated pain. Although interventional spine procedures have been in use for decades, common imaging modalities have relied on ionizing radiation for guidance. US has more recently become used to image axial structures and guide procedures in this region.

Like other imaging modalities, US has certain advantages and disadvantages. US imaging is ideal for visualizing soft tissues, bony surfaces, and needle manipulation

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in real time. Significant nerves and blood vessels can readily be visualized by a well-trained sonographer. Unfortunately, the deeper the tissue, the more challenging sonographic visualization becomes. In addition, bone completely obstructs US visualization of deeper structures in the path of sound waves. As such, clinicians should consider US one of several options for image guidance for spine procedures.

ULTRASOUND-GUIDED CERVICAL SPINE PROCEDURES

Anatomy

The cervical spine is composed of 7 vertebral levels with the atlanto-occipital (C0-C1) and atlantoaxial (C1-C2) having unique anatomic features. This article's focus is on the middle and lower cervical joints. Potential pain generators at each level include the vertebral body, facets, nerve roots, and disks. Under US guidance, the cervical facets and medial branches are relatively accessible in most patients.[1] At the C2-C3 level, the facet may refer pain to the third occipital nerve (TON), which may also be blocked.[2]

Indications

The cervical facets can be prominent pain generators in patients with both occipital and posterior neck pain. This pain can be related to osteoarthritic and whiplash injuries.[3] Facetogenic pain may be present despite normal CT, bone scan, or MRI findings. In whiplash-induced neck pain, medial branch blocks of the cervical facets are often needed to confirm the correct pain generator. Common interventions for facetogenic pain in the cervical spine include facet injections, medial branch blocks, and radiofrequency ablation of the medial branches.[4]

Technique

Ultrasound-guided technique for identification of the correct cervical level for cervical facet injections

The patient is placed in the lateral decubitus position with the side of interest facing upward. Typically, a high-frequency (>10 MHz) linear-array transducer is used in the axial plane to scan the lateral neck starting caudally (**Fig. 1**). The posterior tubercle of the segmental foramen can be well visualized. The C7 foramen can be localized because there is no prominent anterior tubercle (**Fig. 2**). The other cervical foramina have prominent anterior tubercles. At the C6 foramen, the C5-C6 facet is visualized. The needle then is advanced in-plane using an anterior-to-posterior approach. A posterior approach using a low-frequency (<10 MHz) curvilinear-array transducer in the prone position has also been described.[5]

Ultrasound-guided technique for cervical medial branch blocks and third occipital nerve blocks

For a TON block, the patient is placed in the lateral decubitus position and the transducer is placed in the coronal plane with the cephalic end of the transducer on the mastoid process. Next the transducer is moved 5 mm to 8 mm posteriorly until the articular pillar of C2 is well visualized (**Fig. 3**). The transducer is then translated caudally until the C2-C3 articulation along with the TON is visualized (**Fig. 4**).[2] To visualize the more caudal medial branches, the transducer can be translated caudally while maintaining a coronal view. The hyperechoic peaks with a cleft are articular processes and joints, whereas the hyperechoic valleys are where the medial branches lie. In an out-of-plane approach, a short 25-gauge needle can be advanced from anterior to posterior, targeting the deepest point in the near-contiguous hyperechoic bony

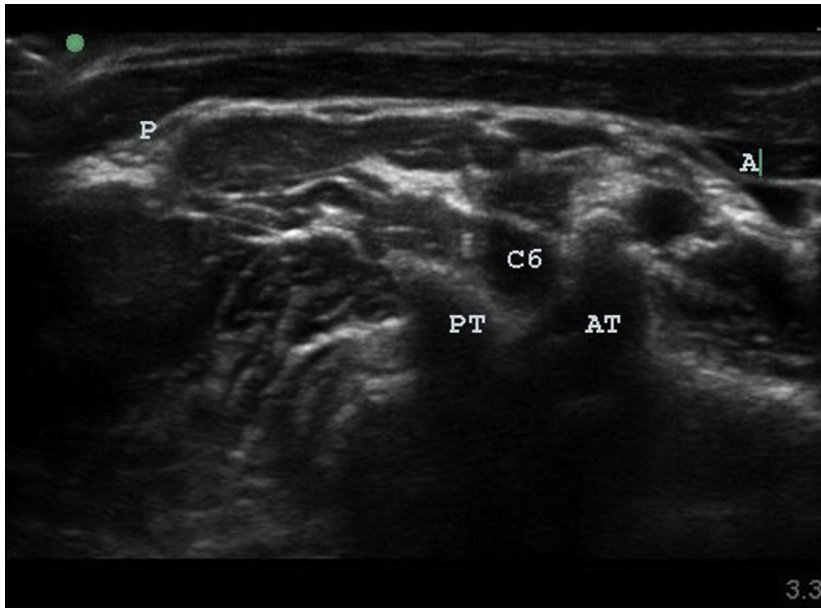

Fig. 1. Axial plane US image of the neck at the C6 level. Note that the vertebral artery is obscured by bone at this level. A, anterior; AT, anterior tubercle; C6, C6 nerve root; P, posterior; PT, posterior tubercle.

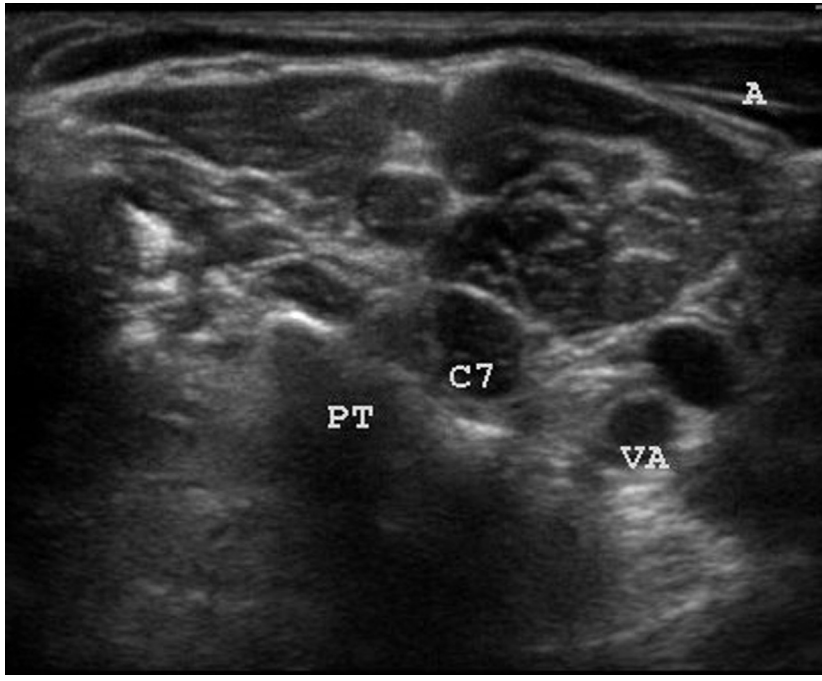

Fig. 2. Axial plane US image of the neck at the C7 level. Note that the vertebral artery is not obscured by bone at this level. A, anterior; C7, C7 nerve root; PT, posterior tubercle; VA, vertebral artery.

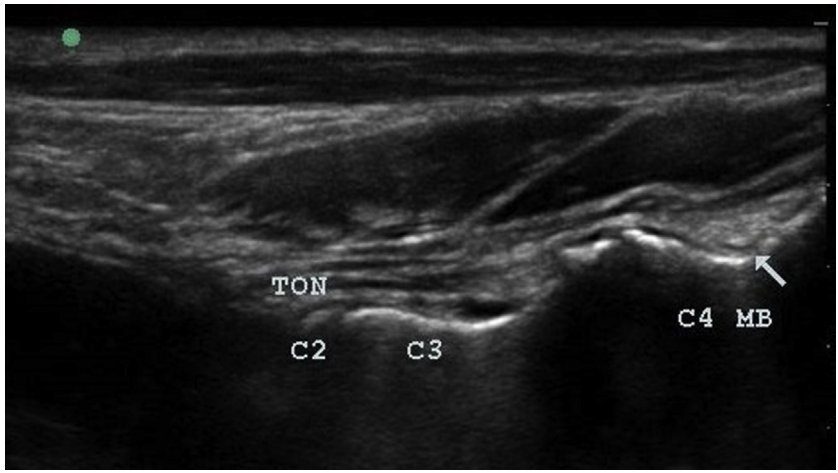

Fig. 3. Coronal plane US image of the TON. The nerve sits on the joint between C2 and C3. (*Arrow*) C4 medial branch (MB).

ridge.[6] Only 0.3 mL of a local anesthetic is needed under direct observation. The vertebral artery, radicular feeder arteries, nerve roots, and spinal cord are in close proximity to these structures, and clinicians should take appropriate precautions to carefully avoid them.

ULTRASOUND-GUIDED THORACIC PROCEDURES

Anatomy

The thoracic spine is composed of 12 vertebral levels. Thoracic back pain is not as common as lumbar or cervical pain; however, it is present in approximately 15% of

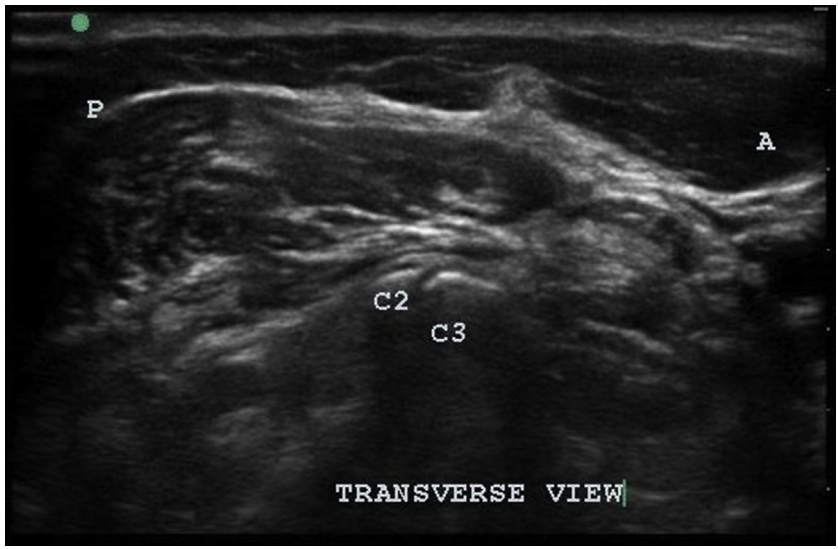

Fig. 4. Axial plane US image of the TON. A, anterior; C2, inferior articular process of C2; C3, SAP of C3; P, posterior.

adults. This pain can be chronic and severe.[7] Common pain generators include the disks, facets, and nerve roots. Additional sources of pain, however, include the costovertebral and costotransverse joints. With US imaging alone, the disks and costovertebral joints are not commonly injected due to poor visualization. US-guided facet and costotransverse joint injections, however, have been described.[8,9]

Indications

Thoracic joint injections are usually performed to treat inflamed, painful, arthritic facets and costotransverse joints. If conservative options fail, CT, bone scan, or MRI can be used to help localize the pain generator. Because of the close proximity of the disks and facet, costotransverse, and costovertebral joints to each other at each segment, it is frequently difficult to isolate the pain generator using physical examination alone.

Technique

Ultrasound-guided technique for thoracic facet injections

A key to completing successful thoracic facet injections is isolating the correct level. Caudal-to-cranial scanning is used to locate the 12th rib on the affected side. In the sagittal plane, the 12th rib is followed medially until the costotransverse joint is visualized. When translating the transducer slightly more medially, the hyperechoic lamina of the 12th vertebra becomes visible. The transducer is then moved in a cephalic direction while counting laminar levels until the level of choice has been located. At this point, while still in the sagittal plane, the transducer is tilted medially so the US beam is aiming slightly lateral (**Fig. 5**). The sawtooth pattern of the facets then comes into view. At this point, the skin is marked to delineate the transducer location and needle entry site caudally. The needle is subsequently advanced in a caudal-to-cephalic fashion into the joint.

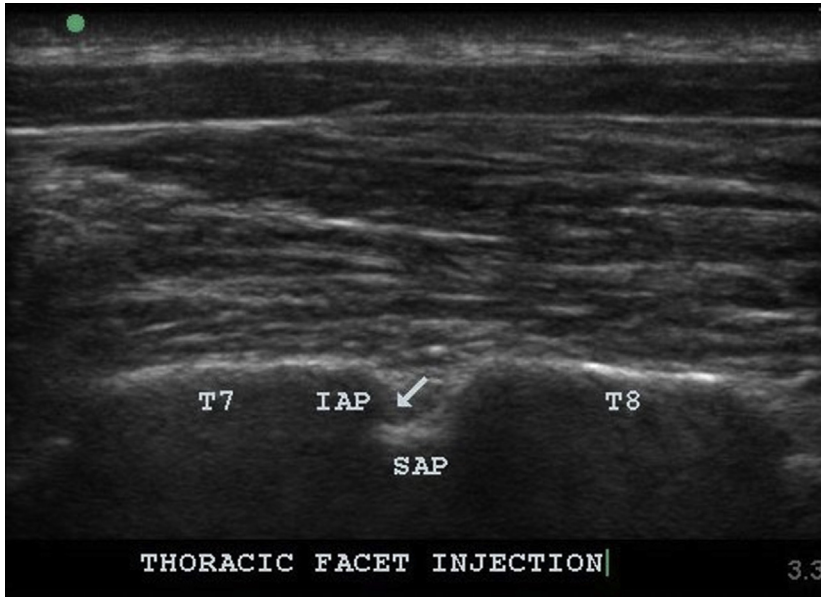

Fig. 5. Parasagittal plane US image of the T7-T8 facet. IAP, inferior articular process of T7; SAP, SAP of T8; *arrow*, joint space of the facet joint.

Ultrasound-guided technique for costotransverse joint injections

The patient is placed in the prone position. As described previously with the thoracic facets, caudal-to-cranial scanning in the sagittal plane is used to identify the 12th rib on the side of interest. The ribs can then be counted until the level of interest has been reached. The transducer is then rotated directly over until the rib and transducer are parallel. The rib is then followed medially until the costotransverse joint is visualized (Fig. 6). The skin is marked to verify the position of the transducer. After the skin is prepped in the usual sterile fashion, a 22-gauge spinal needle is advanced in-plane in a lateral-to-medial approach into the joint.

ULTRASOUND-GUIDED LUMBAR SPINE PROCEDURES

Lumbar pain and radicular leg pain are leading reasons people seek treatment with their primary care provider.[10,11] Typical treatment options include physical therapy, oral analgesic/anti-inflammatory medications, and injection therapies. Recently, image-guided interventions have become common among pain specialists.[12] Over the past decade, more evidence is building that US is a viable imaging modality for lumbar spinal procedures.[13,14]

Anatomy

The lumbar spine is composed of 5 vertebral levels separated by disks anteriorly. These disks can become a source of pain, or they can compress adjacent nerve roots causing neuropathic pain. Posteriorly, the lumbar facet joints are composed of the inferior articular process of the more cephalic level and the superior articular process (SAP) of the more caudal level. These facet joints are diarthrodial, containing hyaline cartilage and a synovial lining.

Indications

With arthritic changes or inflammation, the facets can be a significant pain generator.[15] Skeletal imaging, such as MRI, plain x-ray films, or CT scan, is needed to confirm the number of lumbar vertebrae prior to any US-guided lumbar intervention, because anatomic anomalies can affect procedural performance and safety.

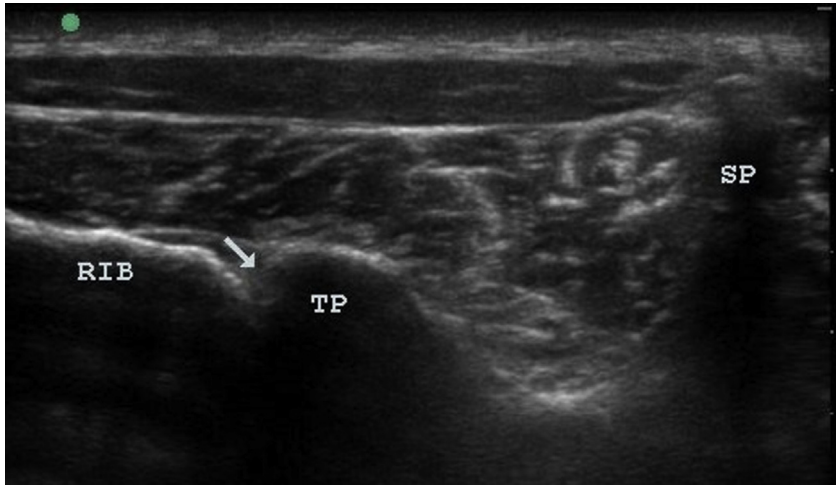

Fig. 6. Axial plane US image of (*arrow*) costotransverse process joint. RIB, thoracic rib; SP, spinous process.

Technique

Ultrasound-guided technique for identification of the correct lumbar level for lumbar facet injections and medial branch blocks

The patient is placed in the prone position with either 1 or 2 pillows under the lower abdomen to flex the lumbar spine for optimal visualization. Usually, a low-frequency (<10-MHz) curvilinear-array transducer is used to obtain sufficient sonographic penetration. The transducer is placed over the midline in a sagittal plane at the lumbosacral junction to visualize the lumbar spinous processes and the crest of S1. The lumbar spinous processes can be counted and labeled on the skin. The transducer can then be translated laterally, maintaining a strict sagittal view until a contiguous sawtooth pattern is observed (Fig. 7). This long-axis view of the spine shows a series of more superficial rounded hyperechoic facets in series (Fig. 8). Just lateral to the facets and parallel to the spine in a slightly deeper plane, the medial transverse processes (TPs) come into view (Fig. 9).

After identifying and marking lumbar levels in the longitudinal view, the transducer can be rotated 90° to view the spine in an axial plane (Fig. 10). At the level of the sacral crest, the S1 foramina and posterior superior iliac crest can be visualized. Maintaining an axial plane and translating the transducer cephalically, the interlaminar space and dura come into view medially. Laterally, the L5-S1 facet and sacral ala become visible. With the cephalic scan, the L4-L5 facets come into view. By translating the transducer laterally, the TP can be seen in the axial plane.

Technique for ultrasound-guided lumbar facet injections

The patient is placed in the prone position and the lumbar spine is scanned in the sagittal and axial planes (as outlined previously). Special attention is given to correctly mark the lumbar levels and the lumbosacral junction. The facet of interest can be identified by scanning in between the spinous processes of the target level in the axial plane and scanning slightly laterally to visualize the facet on the affected side. The transducer position is marked and the skin is then prepped and draped in the usual sterile fashion. After the skin is anesthetized, a 22-gauge spinal needle is advanced from lateral-to-medial into the joint.[16] The more cephalic lumbar facet joints typically have a more sagittal orientation than the more caudal joints.

Fig. 7. Parasagittal view of the lumbar spine where the lamina is seen in a sawtooth pattern. L3, L4, L5, the lamina of the respective lumbar vertebral levels.

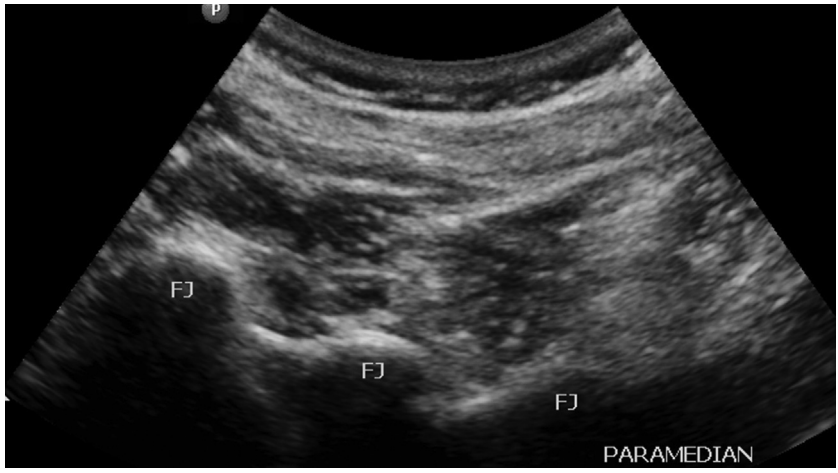

Fig. 8. Parasagittal plane US image of lumbar facet joints, lateral to lamina. FJ, lumbar facet joints in succession.

Technique for ultrasound-guided lumbar medial branch blocks

The patient is placed in the prone position and the lumbar spine is scanned in the sagittal and axial planes (as outlined previously). Once the spinous processes are correctly marked, the transducer is placed over the level of interest in the axial plane and is translated laterally until the SAP and the TPs are visualized. The transducer position is marked and the skin is the prepped and draped in the usual sterile fashion. The skin is properly anesthetized prior to advancing a 22-gauge spinal needle medially, targeting the angle between the SAP and TP. Once a bony endpoint has been established, the transducer is rotated 90° (parasagittal) to ensure the needle tip has a cephalic position on the TP.[14,17]

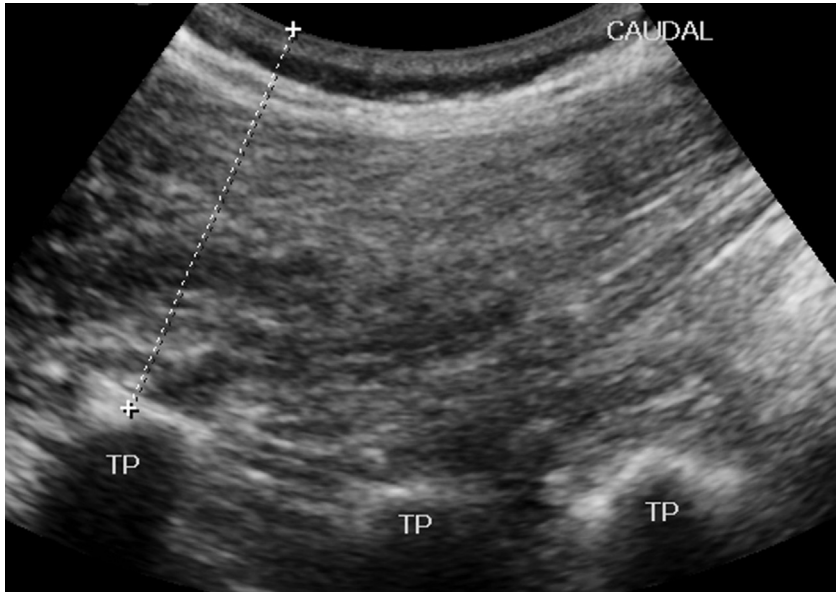

Fig. 9. Parasagittal plane US image of the lumbar TPs. TP, lumbar TPs in succession.

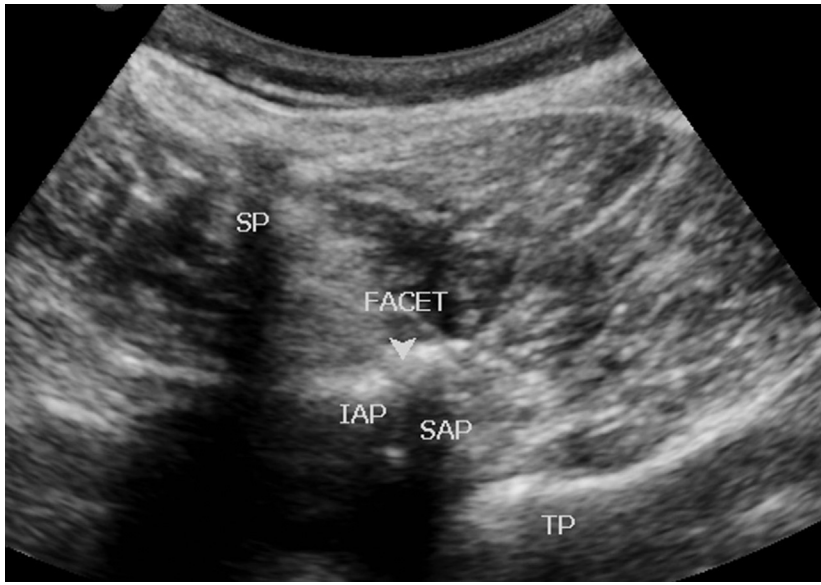

Fig. 10. Axial plane US image of the lumbar facets. IAP, inferior articular process; SP, spinous process; *arrowhead*, lumbar facet.

ULTRASOUND-GUIDED SACROILIAC JOINT INJECTIONS

Anatomy

The sacroiliac joint (SIJ) links the spine to the pelvis. Typically, the more caudal portion of the joint has true synovium, whereas the more proximal portion may contain only fibrocartilage.[18] The posterior SIJ is innervated by the dorsal S2-S4 nerve roots, whereas the anterior joint is innervated by the L2-S2 nerve roots.[19]

Indications

Typically, patients present with pain in the area of the rejoin of the SIJ. Provocative maneuvers and imaging studies do not provide highly reliable diagnostic information with regard to pain generation. Currently, a diagnostic injection of the SIJ can provide clinicians with more reliable data.[20]

US-guided SIJ blocks were described by Pekkafahli and colleagues[21] with CT confirmation. The investigators described a significant learning curve with a 60% success rate in the initial 30 injections and a 93.5% success rate in the subsequent 30 injections. A feasibility study using CT confirmation published in 2008 showed a higher success rate at the caudal pole SIJ injections in cadavers compared with a more cephalic approach.[22] In the same study using live patients (10 injections), the success rate was 100%.

Technique

The patient is placed the prone position and the area of interest is exposed. The posterior superior iliac spine (PSIS) can be palpated as the most prominent bony landmark slightly lateral to midline and just caudal to the lumbosacral junction. Once the transducer has been placed over the PSIS in the axial plane, the SIJ can be observed by slowly scanning caudally as the step-off between the sacrum and ilium becomes less pronounced. Eventually, the ilium is no longer visible once the transducer is over the

sciatic notch. At this point, the transducer's direction is changed, rescanning in the cephalic direction until the ilium is visualized. This scanning technique helps confirm the caudal pole SIJ injection (Fig. 11). Next, a 22-gauge spinal needle is advanced from the medial side of the transducer using an in-plane approach into the SIJ.

ULTRASOUND-GUIDED CAUDAL EPIDURAL INJECTIONS

Anatomy

Typically, the sacral hiatus can be located around the level of S4 and S5 along the midline of the posterior sacrum. The sacral cornua create the lateral borders of the hiatus whereas the posterior sacrum creates the floor. Distally, the hiatus is covered by the sacrococcygeal ligament. The epidural space extends all the way to the sacral hiatus whereas typically the dura only extends to the S2 level. The anterior component of the sacral epidural space tends to be the most vascular.[23]

Indications

Typically, caudal epidural injections are considered when patients have had multilevel posterior spinal fusion with poor epidural access. Patients also may be suffering from chronic and diffuse lumbosacral, leg, or pelvic pain.

Technique

US-guided caudal epidural injections have been described by Yoon and colleagues.[24] The patient is placed in the prone position. Typically, the sacral cornua can be palpated just lateral to midline along the distal sacrum. A high-frequency (>10-MHz) linear-array transducer is placed directly over the cornua so they can be visualized as 2 prominent hyperechoic osseous structures connected via a thinner hyperechoic sacrococcygeal ligament (Fig. 12). Next, the transducer is pivoted 90° while maintaining a midline view between the cornua (Fig. 13). A 22-gauge spinal needle is then advanced in-plane between the dorsal sacral plate and the anterior sacrum into the sacral canal. Unfortunately, there is no highly reliable method using US to verify the needle is accurately positioned in the epidural space and not in a vascular structure. This US-guided technique may be used when contrast is contraindicated or fluoroscopy alone proves challenging.

Fig. 11. Axial plane US image of the inferior pole of the SIJ (*arrow*). The lateral sacral crest is medial to the joint, whereas the iliac crest is lateral to the joint. Left, medial; right, lateral.

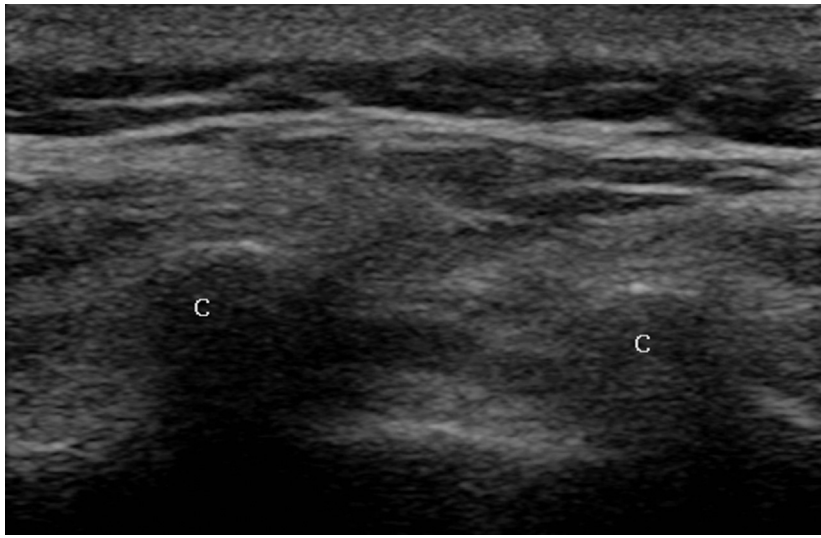

Fig. 12. Axial plane US image of the sacral cornua. The sacral cornua in short axis are depicted by the hyperechoic line above both letters, C. The hyperechoic line between the cornua represents the sacrococcygeal ligament just superficial to the sacral hiatus.

ULTRASOUND-GUIDED INTERLAMINAR EPIDURAL INJECTIONS

Anatomy

At the level of the thoracic spine, there are 12 interlaminar spaces posteriorly between T1 and L1. The spinous processes of the thoracic spine slope caudally covering a significant portion of the posterior interlaminar opening. In addition, the ligamentum flavum may be absent at the midline in the upper thoracic spine.[25] At the lumbosacral

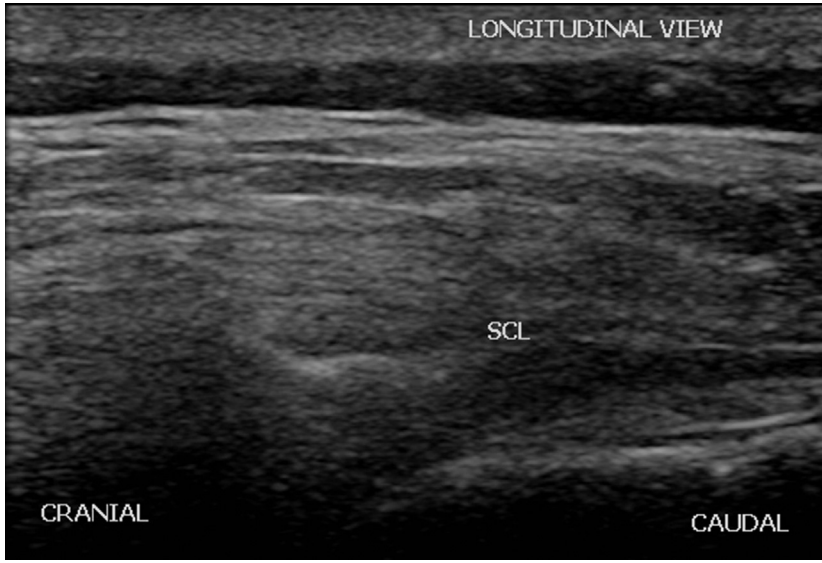

Fig. 13. Sagittal plane US image of the posterior sacrum in the position used for a caudal epidural injection. SCL, sacrococcygeal ligament.

level, there are 5 posterior openings between L1 and the sacrum. The largest opening is typically at the L5-S1 level. With age, the ligamentum flavum frequently becomes thicker.[26]

Indications

Epidural injections have been used in both the acute and chronic setting to control pain.[27,28] Typically, there is a radicular component to the pain in the chronic setting. Advanced imaging can show discrete neural compromise or inflammation that correlates with the location of the symptoms. In the lumbar spine, a provocative physical examination maneuver, such as a straight leg raise, can help confirm the diagnosis of radiculopathy.

Technique

Lumbar and thoracic epidural injections have been described by Grau and colleagues[29] in the literature.[30] The patient is placed in the prone position with the thoracolumbar spine flexed. For the thoracic spine, the ribs are counted to verify the correct level (as discussed previously). A view of the facets is obtained in the parasagittal plane. The transducer is then tilted so that the US beam is directed medially into the interlaminar space. The skin is then marked and prepped in the usual sterile fashion. After the administration of local anesthetic, a Tuohy spinal needle is advanced from the caudal to cephalic position. Once the needle is advanced past the lamina medially, a loss-of-resistance technique is used. A third hand is required to assist with either holding the transducer or advancing the needle.

For a lumbar epidural injection under US, a similar approach is used.[5] A view of the correct lumbar level is obtained (as outlined previously). Once a view of the facets is obtained in the parasagittal plane, an oblique angle is obtained so that the US beam is aimed medially (**Fig. 14**). The skin is then marked and prepped in a sterile

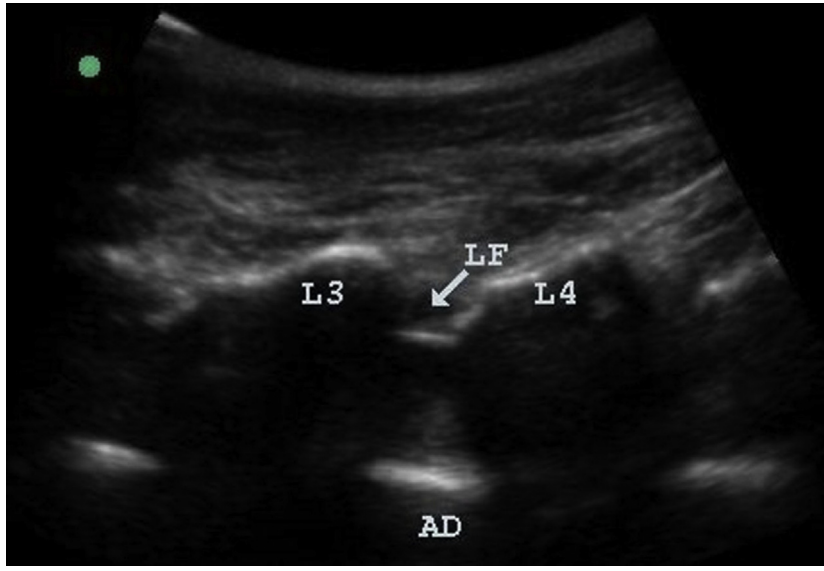

Fig. 14. Parasagittal oblique plane US image of the lumbar spine. AD, anterior dura; L3, lamina of L3; L4, lamina of L4; LF (*arrow*), ligamentum flavum; hyperechoic line deep to ligamentum flavum, posterior dura.

fashion. The skin at the needle entry site is anesthetized. A spinal needle is then advanced from caudal to cephalic directly under the transducer until the needle is imbedded into the denser tissue of the ligamentum flavum. At this point, a loss-of-resistance technique is used with an assistant.

SUMMARY

US has become increasingly common as an imaging modality for spinal interventions. It has advantages and disadvantages versus CT and fluoroscopic guidance and should be considered an option among the interventional spine clinician's repertoire. Large studies comparing the safety and efficacy of US-guided spinal interventions versus CT and fluoroscopy are needed to further define the role of these procedures.

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