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Ultrasound Guided Spine Injections: Advancement Over Fluoroscopic Guidance?

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Abstract This review article discusses the current role of ultrasound in interventional spine practice as both a diagnostic tool and as a modality for image guidance with procedures. Epidemiology of spine pain, the emergence of ultrasound, advantages and disadvantages of ultrasound in comparison to other image modalities are discussed. Recent selected published articles pertaining to the role of ultrasound in the guidance of spinal interventional procedures are reviewed. The potential for the use of ultrasound with spine procedures is discussed as well as further evaluation of its cost-effectiveness, accuracy, safety, and efficacy when compared to the current standards of practice.

Keywords Ultrasound · Sonography · Spine · Injections

Introduction

Spine pain is one of the most common medical problems in the adult population with a lifetime prevalence reported as high as 80 % [1–4]. Spine pain emanating from the cervical, thoracic, lumbar, and sacral levels is a leading factor in lost productivity, disability, and medical expenditures [5, 6]. There are multiple treatment options for spine pain including but not limited to physical therapy and functional rehabilitation, oral and topical analgesics, psychologic intervention, complementary care including acupuncture and chiropractic treatment, non-surgical interventional procedures and surgery. For patients with spine pain not responsive to conservative management, interventional spinal injections have been utilized for the past 50 years as both diagnostic tools and also as a less invasive, potentially safer, and more cost-effective therapeutic treatment intervention than surgery [5, 7].

While the literature on the long term effectiveness, appropriate medical necessity and specific indications for interventional spine procedures has been long debated, there has been a recent proliferation in the number of interventional spine procedure techniques available for use and marked increases in the use rates for many of these procedures [5]. A recent study demonstrated the growth in interventional spine procedures in the Medicare population from 1.5 million procedures in 2000 to 4.8 million procedures in 2011 [7].

The most commonly performed interventional spine procedures include epidural steroid injections (ESIs), facet or zygapophyseal joint-related procedures, and sacroiliac joint injections [3]. The standard of care for most of these procedures includes the use of imaging modalities to increase the precision of spinal injections and reduce the risk of neurovascular complications. These interventional spine procedures are most commonly performed under fluoroscopic guidance and less commonly under computed tomography (CT) or magnetic resonance imaging (MRI) [8••].

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Emergence of Ultrasound Guidance

Ultrasound (US) guidance began to emerge as an imaging technique in interventional spine pain management in 2001 as advances in US technology allowed significant improvements in resolution to image the spine and neuraxial structures [9]. With the clear evidence of the reliable role of US guidance in increasing the efficacy and safety of diagnostic and therapeutic peripheral nerve blocks and spinal anesthesia [9–12], there has been a growing interest in the use of US guidance with interventional spinal procedures. Although fluoroscopy remains the most frequently used imaging technique employed by interventional spine physicians [13, 14••], reports of the use of US guidance have begun to emerge [15–18]. Thus, it is timely to review the scientific and clinical value of US guidance in the most commonly utilized procedures of the spine.

Epidural Injections and Nerve Root Blocks

Epidural steroid injections (ESI) are one of the most widely used spinal pain interventions [19]. The use of corticosteroid injections to the epidural space has been used for decades for the treatment of pain secondary to lumbar, thoracic, and cervical pathologies [20, 21]. They are commonly used for the treatment of single and multilevel pathology, spondylolisthesis, spinal stenosis, or radiculopathy. The use of corticosteroids reduces the inflammation and irritation caused by chemical or mechanical etiologies such as neural compression from disc herniations, central and/or foraminal stenosis or annular tears. Traditionally, ESIs are performed under real-time fluoroscopic guidance with contrast media to enhance visualization of the injectate pathway and minimize intravascular injections. ESIs may be accomplished using either transforaminal (TFESI) or interlaminar (ILESI) or caudal approaches.

Previously, due to limited resolution at deep levels and the presence of bony artifacts that limit visualization, US was considered not as useful in neuraxial (epidural or intrathecal) blocks [22•]. Recently, several groups have demonstrated techniques that have successfully accessed the epidural space using real-time US guidance [23, 24].

Selective cervical nerve root blocks are widely performed to diagnose the specific spinal level of a cervical radiculopathy as well as to treat radicular pain. A selective nerve root block utilizes the same approach as a transforaminal epidural injection but focuses on the target nerve root instead of the epidural space. Although a standard procedure, the unintentional intravascular injection may cause fatal complications such as vertebral artery dissection or brain or spinal cord infarction [25]. As the primary advantage of US is direct visualization of soft tissue and neurovascular structures, US can be particularly advantageous in the cervical spine where there are many vital structures susceptible to injury if only fluoroscopy-guided injections are used [26]. However, the particular limitation of US guidance during epidural injection lies in the potential of vertebrae obscuring needle placement due to US's inability to penetrate bone. As per Couri et al. [27], US guidance is not highly recommended for any interlaminar injections and should never be used solely for a transforaminal epidural injection due to the inability to visualize vasculature within the spinal canal during an injection or gauge the depth of the needle once advanced past the bone. Thus, with US guidance in an interlaminar or transforminal epidural injection, there is no assurance that the injectate has not been placed intravascular or that a dural puncture has not occurred [27].

Ultrasound-Guided Cervical Epidural Injections and Nerve Root Blocks

In an experimental cadaver study, Galiano et al. [28] described the feasibility of US-guided peri-radicular injections in the middle and lower cervical spine as confirmed with CT scan. In the two part study, the team was able to identify the spinal nerve root at C3–C7 in 35 of the 40 attempts and was able to place all eight needle tips within 5 mm dorsal to the nerve and less than 5 mm away from the transverse process.

Yamauchi et al. [29] studied the accuracy and clinical effects of US-guided cervical nerve root block in a dual cadaver and clinical patient study. In the cadaver study, the authors confirmed with anatomic dissection around C5–C7 and the cervical plexus that US-guided injection of blue dye in 10 fresh cadavers was 100 % accurate at the exact spinal level and evaluated the spread surrounding the target cervical nerve root. In the clinical study, 12 patients diagnosed with monoradiculopathy between C5–C7 underwent US-guided nerve root block. Pre-procedure radicular pain scores (on a 0–100 pain scale) decreased from a median score of 65 to 25 at 24 h and 40 at 30 days following intervention. The study findings did suggest that injected solution by US-guidance mainly spreads to the extraforaminal direction compared with the conventional fluoroscopic technique. Yet despite the absence of intraforaminal epidural spread, the procedure still provided significant analgesic effect lasting for 1 month. The authors suggest the US-guided technique could provide a possibly safer selective peripheral nerve root block than the traditional cervical nerve root block under fluoroscopy.

Jee et al. [30] conducted a blinded, randomized control study evaluating US-guided selective nerve root block versus a fluoroscopy-guided block for the treatment of

cervical radicular pain in 120 subjects. The study found equal efficacy between groups in pain relief and functional improvement as assessed by the verbal numeric pain scale and neck disability index at time of procedure, at 2 and 12 weeks. Additionally, US identified 38 instances of critical vessels in unexpected locations relative to the intervertebral foramen in the subjects. The authors suggest that the US-guided method may facilitate identifying critical vessels and avoid injury to such vessels which is the leading cause of the reported complications from cervical injections utilizing a transforaminal approach [31].

Ultrasound-Guided Lumbar Epidural Injections

Galiano et al. [32] described a feasibility and accuracy study of US guidance in the lumbar spine using a transforaminal approach with subsequent CT imaging. Fifty US-guided approaches at five levels (L1–S1) were performed on five embalmed cadavers, and the Pearson correlation coefficient was 0.99 ($P < .001$) between sonography and CT. In the experimental study, all 10 needle tips were placed peri-radicular to the spinal nerves.

Gofeld et al. [33] performed a cadaveric study to evaluate the feasibility of US-guided lumbar transforaminal injections on multiple levels. Specifically, accuracy of the spinal segment identification, patterns of the radiopaque contrast spread, and visibility of the defined target were evaluated. The authors used a modified in-plane technique aiming at the vertebral body as a US landmark preventing further advancement into the neuraxial compartment. In the study, after US-guided injection occurred, fluoroscopy confirmation demonstrated the foraminal placement in all 46 injections (100 %) with the needle tip located at the ventral part of the intervertebral foramen on the lateral view and under the pedicle on the anteroposterior view and the correct spinal level was identified in all 46 cases (100 %). The contrast spread was intra-foraminal in 42 cases (91.3 %) and extra-foraminal (nerve root) in 4 cases. The authors suggest that US-guided transforminal injection may be an option when the dorsal vertebral body is visible at the foraminal level however the clinical correlation of the study was limited in its preclinical setting.

Ultrasound-Guided Caudal Epidural Injections

Injection of corticosteroids via the caudal route has been widely used by practitioners without image guidance. The caudal approach to the epidural space via the sacral hiatus is often preferred by non-interventionalists because it carries a lower risk of inadvertent thecal sac puncture and intrathecal injection [15] and greater ease of execution in patients with a history of spinal surgery [34].

The most common method to identify the caudal epidural space is through the palpation of the sacral hiatus and detecting the characteristic "give" or "pop" when the sacrococcygeal ligament is penetrated [35]. Yet even with experienced physicians, the failure rate of the placement of needles into the caudal epidural space has been reported as 25–38 % [15, 36]. Thus, US offers a useful tool for appropriate needle placement for caudal epidural injections [37].

Klocke et al. [15] were the first authors to describe the use of US to identify the sacral hiatus landmarks to facilitate real-time guidance of injections into the caudal epidural space in a small group of patients. However, the authors did note that inadvertent intravenous injection, which may occur in 5–9 % of caudal epidural procedures, is a major limitation that cannot be avoided with this particular technique. This is particularly important because aspiration or return of blood does not appear to be very sensitive or specific for intravenous positioning of the needle [15].

Chen et al. [38] performed a larger feasibility study in 70 patients with low back pain and radiculopathy utilizing soft tissue ultrasonography to locate the sacral hiatus. A 21-gauge spinal needle was inserted and guided by US to the sacral hiatus and into the caudal epidural space with proper needle placement confirmed by fluoroscopy. The authors found 100 % accuracy in identifying the sacral hiatus accurately by US, and the spinal needle was guided successfully to the sacral hiatus and into the caudal epidural space with 100 % accuracy as confirmed by contrast dye fluoroscopy.

Yoon et al. [20] studied the feasibility of using real-time high resolution US for guiding the spinal needle into the caudal epidural space as well as confirming epidural flow of medication with color Doppler US in 53 patients. Forty-seven of the 53 subjects had a positive flow spectrum and 50 of the 52 subjects with positive Doppler change, had fluoroscopic confirmation. The major limitation of the study was that even small movements of the needle could cause an artifactual color change and a false-positive sign could occur as seen by fluoroscopy in the patients with spread outside of the epidural space [39].

Sacroiliac Joint Injections

Sacroiliac (SI) joint arthrosis is a common cause of lower lumbosacral axial pain with a reported prevalence rate of 15–30 % [40–42]. The SI joint is a wedge-shaped diarthrodial joint composed of an inferior cartilaginous joint that contains a joint capsule, synovial lining, and synovial

fluid and an upper fibrous articulation [43]. SI joint pain may occur due to degenerative changes as well as non-degenerative conditions such as trauma, pregnancy, spondyloarthropathies, infection, and malignancy [41]. Treatment options for pain emanating from the SI joints include oral non-steroidal anti-inflammatory drugs and physical therapy. In painful cases refractory to conservative treatment, local treatment of the SI joint through intra-articular corticosteroid injection has provided diagnostic value and clinical improvement [16].

Because of its complex anatomical structure, the SI joint injection can be difficult to enter with a needle [44]. Using a blind palpation method, accuracy in SI injections has been reported to be as low as 22 % [45]. Thus, the need for image guidance for successful SI joint injections has become very important. Using fluoroscopic guidance, the success of SI joint injections has been reported with a high accuracy rate of 97 % [43]. However, measurements related to radiation exposure for a fluoroscopic guided SI joint injection has been reported as ranging from 12 to 30 mGy/min for skin and 0.1–0.6 mGy/min for gonads [46].

The feasibility of US guided injection of the SI joints has been demonstrated to have a high success rate of up to 90 % [40]. Chen et al. [44] describes the technique of maintaining the transducer in the transverse orientation and moving it in a cephalad direction until the second bony contour of the ileum is identified. The cleft between the bony contours of the sacrum and ileum represents the posterior aspect of the SI joint. By tilting the transducer in a caudal direction, the lower third of the SI joint is identified and because of its synovial component, this is the portion of the joint in which the injection should be performed.

Pekkafahli et al. [16] performed a feasibility and effectiveness study of US guided intra-articular SI joint injection with fluoroscopic validation in 34 patients with sacroiliitis, 26 patients with bilateral disease and 8 patients with unilateral disease. The synovial portion of 60 SI joints was injected under US guidance, resulting in 46 (76.7 %) successful injections and 14 (23.3 %) missed injections. The team noted that successful intra-articular injection rate was 60 % for the first 30 injections with improvement to 93.5 % in the last 30 injections. Procedure time averaged 9 min. Therapeutic efficacy and clinical outcomes were not evaluated in this study. The team concluded that with recent improvements in the technology and with user experience, US is a promising aide for SI joint injection but that further study of this modality was needed [40].

Facet Joint Injections

The zygapophysial joints, often referred to as facet joints, have long been recognized as a primary source of spine pain [47]. The facet joints, which form the posterolateral articulations connecting the vertebral arch of one vertebra to the adjacent vertebral arch, are densely innervated with nociceptors which fire when the joint capsule is stretched or subjected to local compressive forces which leads to cumulative microtrauma leading to inflammatory and degenerative changes [47–49].

The facet joints are well-documented sources of head, neck, and shoulder pain with an estimated prevalence of 36–50 % in patients with chronic pain in these areas [50–52]. In the thoracic spine, the facet joints have also been identified as sources of local and referred pain patterns in the upper back, mid back and chest wall with an estimated prevalence reported as 34–48 % [19]. In the lumbar spine, pain arising from the lumbar facet joints is common with an estimated prevalence of 15–45 % [19, 48, 49]. In addition to localized axial pain, facet joint pain may refer pain to the buttocks, flank, hip, thigh, groin, whereas pain distal to the knee rarely associated with facet pathology [7, 49, 53].

As each facet joint is innervated by the medial branches of the spinal nerves' dorsal rami at and above the level of interest, neural blockade of these medial branch nerves can provide diagnostic as well as potential therapeutic value. In patients who have facet joint-related pain, therapeutic interventional procedures can include intra-articular corticosteroid injections, medial branch nerve blocks and radiofrequency (RF) denervation or rhizotomy of the medial branch nerves. RF denervation of the medial branches is considered the gold standard for the treatment of facetogenic pain and is typically recommended only after a positive diagnostic nerve block as the technique involves using RF energy channeled through a small-diameter needle to create a controlled burn that severs the facet joint nerve supply [49, 54].

Because the facet joints are deeply located and cannot be accessed using anatomic landmarks, radiologic guidance under fluoroscopy or less commonly under CT has been routinely required for all facet injection procedures to maximize medication placement success and to avoid neurovascular complications [55–59]. Cohen et al. has reported a 7 % incidence of unintentional intravascular injection during fluoroscopy-guided cervical medial branch block. The standard technique for intra-articular facet injections requires intra-articular placement of the needle into the target joint under fluoroscopic control with minimal contrast medium injected to obtain an arthrogram and verify intra-articular placement. The traditional technique for a medial branch block involves the use of fluoroscopy with placement of the needle tip against the periosteum in the centroid of the articular pillar as determined by both anteroposterior and lateral radiographic views [60]. Use of a local anesthetic volume of 0.5 ml/block preceded by 0.3 ml contrast agent is performed to determine proper

distribution and rule out venous uptake, which occurs in 8 % of blocks and contributes to false-negative results [60, 61]. RF denervation uses a similar technique as medial branch blocks as the placement of the RF needle is identical but additional motor and sensory testing is utilized for confirmation of location prior to the ablation.

Ultrasound-Guided Cervical Facet Injections

Eichenberger et al. [62] reported a feasibility study of US guidance in blockade of the third occipital nerve (TON) in a 14 subject observational study. Twenty-eight needles were placed under US guidance and confirmed by fluoroscopy with the C2–C3 facet joint identified correctly by US in 27 out of 28 cases. Local anesthetic versus normal saline was injected in a randomized, double-blind manner in 11 subjects with accuracy of needle position confirmed by fluoroscopy in 82 % of insertions and 90 % success of nerve blockade indicated by sensory anesthesia. The major limitation to the study was that all subjects were healthy. It is unclear if the same accuracy with US guidance would apply to patients with degenerative and spondylitic changes.

Siegenthaler et al. [63] performed a study in 50 patients and was able to successfully identify cervical medial branch nerves ranging from 96 % of the TONs to 84 % of the medial branch nerves at C6 under US. However, the medial branch nerve at C7 was only visualized in 32 % of the subjects. In a follow-up study, Siegenthaler et al. [50] also evaluated the accuracy of US-guided cervical zygapophysial joint nerve blocks in 60 healthy volunteers to establish potential clinical usefulness. In this study, multiple levels from C2–C7 were tested with placement confirmed by fluoroscopic imaging. The results of the study found variation of accuracy dependent on the level with an overall simulated block success rate of 84 %. Simulated block success was 88 % at the TON, 94 % at C4, 88 % at C6, and 41 % at C7. The decreased accuracy at C7 was attributed to poor placement of the transducer due to the presence of the clavicle. Additionally, the study found an incidence of 3 % for aberrant foraminal spread of contrast dye and 12 % for spread over more than one segment with multilevel spread observed in most cases involving the TON.

Finlayson et al. [60] reported the feasibility of US-guided cervical medial branch nerve block utilizing a novel technique in a cohort of 53 patients and 163 injections in a two-phased imaging study. In Phase 1, the authors found the accuracy of needle tip position in twenty patients undergoing 46 cervical medial branch blocks between C3 and C6 to be 80.1 %. In phase 2, with 50 patients that underwent 163 level injections with local anesthetic and contrast with radiographic confirmation, the contrast was found to cover the appropriate level in 94.5 % with no reported complications. The study found the incidence of aberrant spread to adjacent levels to be 13.5 %, similar to Siegenthaler et al. [50]. One noted limitation is that the authors miscounted the cervical spine level in two patients—a problem that can be easily avoided using fluoroscopy. The authors point out that US should be as accurate as fluoroscopy in identifying the correct level and that a standardized protocol for US examination of the cervical spine is recommended for accuracy and reproducibility [64].

Ultrasound Guided Lumbar Facet Injections

Beginning in 2004, the reports of US guidance in facet procedures in the cervical [31, 47, 50, 65•, 66–69] and lumbar spine [18, 32, 70] were described in the literature. Comprehensive review of the literature shows a higher number of quality studies evaluating the role of US in lumbar facet-related procedures (Table 1). Greher et al. [70] described the first feasibility study of US-guidance in lumbar medial branch nerve blocks. Direct visualization of the facet nerve at a 5 cm depth using US guidance was unable to be performed but using their method based on a sonographic cross-axis and long-axis view, the authors were able to set the needle target point for a lumbar medial branch nerve block demonstrating that 25 of 28 US-guided needles in five patients were correctly positioned and that injection of 1 ml solution results in a remarkable spread around the needle tip as confirmed on fluoroscopy. In a follow-up study, Greher et al. [18] tested the accuracy of their US-guided technique for fifty bilateral lumbar medial branch nerve blocks with a CT imaging study. Using the target point of the groove at the cephalad margin of the transverse process adjacent to the superior articular process, the authors found 45 of the 50 needle tips at L1–L5 located at the exact target point and in 47 of 50 cases, the applied contrast dye reached the groove where the nerve is located, corresponding to a simulated block success rate of 94 %. Although seven of 50 cases showed paraforaminal spread, five of 50 showed epidural spread, and two of 50 showed intravascular spread, these approaches were deemed successful by the authors as indicated by contrast dye at the target point.

In a nonrandomized crossover trial, Shim et al. [71] evaluated the success rate and validity of the US-guided facet block method used by Greher et al. [70] using fluoroscopy controls in patients diagnosed with lumbar facet pain. Fluoroscopy-guided medial branch nerve blocks were performed in 20 patients and 1 month later, the same patients received another lumbar medial branch block with US guidance. Their findings indicated a precision of 95 %.

Table 1 Summary of the evidence for ultrasound in lumbar facet injections

References	Procedure	No. of subjects	Study design	Comparative technique	Outcome
Shim et al. [71]	Medial branch block	20 subjects (101 injections)	Nonrandomized crossover trial	Fluoroscopy	95 % (96/101) success in accuracy
Galiano et al. [69, 74•]	Medial branch block	40 subjects, 20 in each group	Randomized control trial	CT scan	85 % (17/20) success in accuracy
Jung et al. [72]	Medial branch block	50 subjects (95 injections)	Observational study	Fluoroscopy	91.6 % (87/95) success in accuracy
Yun et al. [8••]	Facet joint injection	57 subjects, 32 in FS group, 25 in US group	Randomized control trial	Fluoroscopy	No report on accuracy. Improvement in all scores of VAS, PaGA, PhyGA, MODI at 1 week, 1 and 3 months with no statistical difference between FS vs US groups

Narouze [22•] highlighted a major limitation to the aforementioned study as the mean weight and body mass index of the patients in the study were only 51 kg and 22.8 kg/m^2 and still, US could not detect intravascular injections in two patients in the study. As obesity is the major limiting factor in using US in lumbar spine injections, Narouze reported that US cannot be recommended to be the solo imaging technique while performing lumbar medial branch nerve blocks, especially in obese patients.

Jung et al. [72] performed a prospective observational study in 50 patients with chronic back pain by facet arthropathy utilizing a US-guided longitudinal facet view obtained by a curved array transducer. After the surface landmarks of the spinous process and iliac crest line were confirmed, longitudinal facet views were obtained. The spinous process and facet joint with transverse process were delineated by transverse sonograms at each level and the target point for the block was defined as lying on the upper edge of the transverse process. The needle was inserted toward the target point and after a contrast injection, the placement of the needle and contrast was checked by fluoroscopy with reported 91.6 % accuracy in successful needle placement by US.

Galiano et al. [73] reported the feasibility, accuracy, and minimal risk of an US-guided approach targeting the joint space of the lumbar joint articulations using an inline approach in which the spinal needles were advanced in parallel to the long axis of the transducer to keep them in the echo plane. The technique provided real-time monitoring of the inserted needle along its entire length into the space of each lumbar facet joint with needle tip placement verified by CT. The authors point out the major advantages of the US technique over fluoroscopy and CT to be the live guidance of the needle, less expensive equipment, and less patient and operator exposure to radiation. However, as the authors confounded the facet joints and mamillary process during their own study, the importance for a systematic protocol, knowledge in US imaging of the lumbar paravertebral region and practice in handling a transducer in combination with a needle was deemed essential for the success of US-guided facet injections.

Galiano et al. [74•] published the first prospective randomized clinical trial (RCT) study comparing US guided lumbar facet joint injections to a CT controlled procedure. The authors evaluated the feasibility (defined as percentage of patients with fully or partially visible facet joints), accuracy (calculated as CT verified exact needle placement), pain relief (using a visual analogue scale (VAS) 30 min after the injections and 6 weeks after the procedure), time-savings, and radiation doses in 40 adult patients with chronic low back pain who were randomized to either to intra-articular facet corticosteroid injections under US-guidance or CT-guidance. Sixteen of the 20 subjects in the US group had facet joints that were clearly visible and all 16 of the associated facet joint injections were performed correctly. Thus, the authors report accuracy of US-guided interventions as 100 % for patients with clearly visible facet joints and 94 % for all patients who were approachable with US. Both groups showed a statistically significant benefit of pain relief via VAS from facet joint injections with no significant differences between groups in VAS at 6 weeks post-injection. There was a definite statistically significant difference in duration of procedure with 14.3 ± 6.6 min under US and 22.3 ± 6.3 min under CT guidance, both times which are much longer than the widely used fluoroscopy technique. The radiation dose was 14.2 ± 11.7 mGy cm in the US group, and 364.4 ± 213.7 mGy cm in the CT group. This study highlights the advantages of the US approach to the facet joints as compared to CT guided facet injections with a significant reduction of procedure duration and radiation dose. However, limitations of US guidance for facet injections in obese patients was highlighted in the study as poor

resolution was obtained in two subjects with higher BMIs of 28.3 and 32.9 whose facet joint depth was more than 8 cm.

Gofeld et al. [33] published a recent preclinical cadaveric study further validating the feasibility and accuracy of US-guided lumbar facet injections with the use of fluoroscopy with contrast injection as a second imaging modality. In 44 of 50 (88 %) injections within five cadavers, the intra-articular spread of the contrast agent was clearly observed on the fluoroscopy image. In four of the six failed injections, the facet-joint opening was not sonographically visible which further confirmed that when the facet joint was undetectable, accurate injection is not possible. The authors also suggest from their study that intra-articular placement per se may not be important for attaining the appropriate spread of injectate. As fluoroscopy does not allow precise subcapsular placement because it relies on bony landmarks and radiologic confirmation of the intra-articular needle location, the authors suggest that US-guided injections of lumbar synovial facet joint recess may be an appropriate and effective alternative to fluoroscopy or CT-guided intra-articular injections.

Yun et al. [8••] recently conducted the only RCT comparing clinical efficacy beyond pain relief with fluoroscopy in lumbar facet injections. Fifty-seven subjects with facet syndrome of the L4–L5 and L5–S1 levels were randomized to receive intra-articular injections either under fluoroscopic guidance or US guidance. Treatment effectiveness was assessed using the VAS, physicians and patient's global assessment (PhyGA, PaGA), and the modified Oswestry Disability Index (MODI) pre-injection, at 1 week, 1, and 3 months after the injections. Both groups that received fluoroscopic and US guided injections showed significant improvement in pain control and return to activities of daily living at 1 week, 1, and 3 months with no significant differences between groups. The only statistically significant difference between groups was the reduction in procedure time utilizing fluoroscopy: 248.7 ± 6.5 s versus US: 263.4 ± 5.9 s when the level of injections were limited to both the L4–L5 and L5–S1 levels. The limitations of the study included a small patient group with a relatively low BMI (fluoroscopy: $24.2 + 2.2$, US: 23.8 ± 2.7) as compared to the usual BMI in lumbar facet patients given that obesity is the major limiting factor in US in lumbar spine injections. Moreover, this study was limited to injections only of the lower spine at the L4–L5 and L5–S1 levels. The authors highlight the fact that as the level of facet joint increased, the joints are harder to visualize on US.

Advantages of Ultrasound-Guided Spine Injections

Ultrasound (US) technology offers many inherent advantages in interventional spine guidance. US can identify soft tissues such as muscles, tendons, and ligaments as well as osseous surface landmarks. Importantly, vessels can be viewed on Doppler US and nerves can be identified offering direct visualization of structures that can be difficult to identify using other imaging modalities (Table 2). Unlike fluoroscopy and CT imaging, US does not expose patients and personnel to radiation. Although the radiation dose during each procedure by fluoroscopy or CT is not large, the accumulation of physician exposure can be significant over time [12]. Also, with this advantage, additional equipment for protection against radiation is not required. The advances in US machine technology has allowed for decreased costs for the equipment and increased portability allowing procedures to be conducted in various locations and within the clinic. This can also provide the convenience of performing same day evaluation and treatment for those with immediate needs. As with other imaging modalities, US allows imaging to be performed in real-time. The ability to identify nerves under US provides the unique opportunity to assure circumferential spread of the injected solution at the site of administration without the use of a contrast medium. Contralateral examination can also be easily performed with US and can evaluate for any anatomic aberrations including the unexpected presence of vessels or perineural edema. Contraindication for radiation exposure, such as in pregnancy, can also be avoided by utilizing US.

Disadvantages of Ultrasound-Guided Spine Injections

The main disadvantage of US-guided spinal injections is operator experience and the required long learning curve that is required for the physician to be well acquainted with

Table 2 Differences between the common image-guided modalities for spinal injections

	Ultrasound	Fluoroscopy	CT
Nerve visualization	Yes	No	Yes
Vessel visualization	Yes	No	Yes
Bone visualization	Yes	Yes	Yes
Visualization under bone	No	Yes	Yes
Visualization of medication	Yes	No	Yes
Visualization of intravascular injection	No	Yes (with contrast)	Yes (with contrast)
Radiation exposure	No	Yes	Yes
Portability	Yes	Limited	No
Affordability of equipment	Low/ middle/ high	High	High

As modified from [40]

the simultaneous manipulation of an US transducer, placement of needles, and the correct interpretation of musculoskeletal sonographic images [44]. The reproducibility among doctors is low [14••]. US offers only a narrow imaging window, which is extremely sensitive to the probe's position and direction potentially leading to misinterpretation of imagery due to anisotropy. Tissue interpretation errors can lead in inaccurate injections with possible short-term or permanent neurological deficits. Therefore, in-depth knowledge of applied anatomy and specific training are required to master these techniques. The acoustic impedance of bone is high, and thus it has significant limitations for imaging spinal structures when the target is obscured by bone tissue. This gives rise to increased risk for accidental dural punctures due to decreased visibility [39]. Given that a higher US image resolution allows for decreased tissue penetration, it will be more difficult to identify neurovascular structures in patients who are more obese. The quality of US imaging also varies from each machine and the diagnostic capabilities of portable machines that are more affordable may offer less resolution than higher cost stationary machines possibly increasing the difficulty level of image interpretation for the sonographer.

Conclusions

The use of US guidance for spinal injections has been increasing as US technology has continued to improve and become more accessible to practitioners. The advantages to utilizing US are many and revolve around its convenience, lack of radiation, and visibility of vital neurovascular structures. The disadvantages include its inability to penetrate osseous structures limiting the view of internal spinal structures, reliance on user experience for identification of structures, and resolution deficits with deeper structures. A review of the literature has demonstrated that US can be reliable and safe with certain injections.

The literature on US-guided injections has greatly expanded in recent years but most studies have been small feasibility studies that have focused primarily on the description of the techniques. As feasibility does not necessarily encompass meaningful use in clinical practice, there is a great need for validating US-guided injections with more clinical research. Of the interventional spine procedures reviewed for this article, US guidance offers more compelling evidence to support its use with SI joint injections, caudal epidural injections, and facet joint injections and medial branch nerve blocks. US guided cervical and lumbar transforaminal injections still remain controversial among interventional pain physicians with the belief that US may not guarantee needle placement, accurate spread of the injectate, and prevention of intravascular injection. Concomitant use of US with other standard imaging modalities, such as fluoroscopy, may provide additional usefulness especially in areas where a greater risk of intravascular injection is present. Until there is more quality data to provide an evidence-based background for the efficacy and safety of US-guided interventional spine procedures, fluoroscopic guidance will remain the standard of care.

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- •• Of major importance

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