

Real-Time Ultrasound-Guided Paramedian Epidural Access Using a Paramedian Transverse Oblique Scan: A Prospective Case Series

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ABSTRACT

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Background: Current methods for the real-time ultrasound (US)-guided epidural access face a challenge in clinical practice. In the study, we described a new US-guided technique for epidural access through a paramedian transverse scan at the level of articular process, with the needle in the plane of the US beam.

Methods: A total of 18 American Society of Anesthesiologists physical status I to III patients with body mass index of less than 28 kg/m² scheduled for lower extremity surgery received the US scout scan. And then the combined spinal and epidural anesthesia was performed in patients with successful US scout scan. We evaluated the feasibility of performing real-time US-guided epidural access using the technique described.

Results: The US scout scan was successful in 16 out of 18 (88.8%) patients, in whom the articular process, ligamentum flavum, posterior dura, intrathecal space and anterior dura were visualized. The epidural space was visualized in 14 out of 16 (87.5%) patients with successful scout scan. The US visibility of spinal and neuraxial structures in patients with successful scout scan was judged as good in 14 (14/16, 87.5%), and average in 2 (2/16, 12.5%) patients. After sterile preparation, the epidural space was successfully identified in all patients with successful scout scan in 1 attempt using real-time ultrasound guidance and loss of resistance technique. There was a failure to observe the phenomena of the efflux of cerebrospinal fluid from the spinal needle in 2 patients. There were no inadvertent dura punctures or complications directly related to the technique described. Satisfactory anesthesia developed in all patients and recovery from the spinal anesthesia was uneventful.

Conclusion: We have demonstrated the feasibility of a new in-plane, single-operated technique for real-time US-guided paramedian epidural access through paramedian transverse oblique scan in patients. (Funded by the Program for High Levels of Health Personnel in Beijing, China.)

Neuraxial block is widely used for surgical procedures in China. Common complications associated with epidural insertion include failed epidural and accidental dural puncture, with reported rates of 1.5% to 20% for failed epidural and 1% to 5% for accidental dural puncture (1). Although the loss-of-resistance (LOR) technique is the gold standard for locating the epidural space, one cannot predict technical difficulties or the accuracy of needle placement before skin puncture with any of the landmark-based techniques (2). Recently, there has been an increasing interest in the use of ultrasound (US) to guide or facilitate neuraxial, epidural or combined spinal-epidural (CSE), blocks (3-5). US imaging has been used, either to preview the neuraxial structures before needle puncture or to visualize the advancing needle in real time. A preview scan performed before needle puncture improves the success rate of epidural access on the first attempt, reduces the number of puncture attempts (6). Previous studies have reported that the real-time epidural access under paramedian sagittal US scanning in adults, using in-plane or out-of-plane technique (1, 7, 8). Despite these encouraging and innovative approaches, there are no published data describing real-time neuraxial blocks under paramedian transverse US scanning, with the needle in the plane of US beam. The aim of this pilot study was to evaluate the feasibility of performing real-time paramedian epidural access through a paramedian transverse oblique scan at the level of lumbar articular process, by a single operator.

Methods

After obtaining the approval of research Ethics Committee of Beijing Chaoyang Hospital, Capital Medical University and written informed consent from the subject, a total of 18 American Society of Anesthesiologists physical status (ASA) I–III patients scheduled for lower extremity surgery, in whom a CSE anesthesia was planned, were enrolled for this study. Patients were excluded if they had a body mass index (BMI) > 28 kg/m², clinically obvious or known spinal deformity, infection in the back, allergy to local anesthetic drugs, previous spine surgery, or coagulopathy.

The intravenous access was established and

the electrocardiography (ECG), heart rate, non-invasive or invasive arterial pressure, and arterial oxygen saturation were monitored after the patient arrived at the operating room. Then, the patients were positioned in the lateral decubitus position, with the affected side downward. Sufentanil (5 - 10 µg) was administered intravenously, immediately before the positioning, to those who complained of fracture-associated pain. The US scan was performed by an experienced anesthetist (Dr. Yun Wang), who is skilled in spine US imaging and familiar with spine-related interventional injections.

US Guidance

All US scans were performed using a Sonosite Turbo (Philips Healthcare, Andover, MA, USA) ultrasound system and a curved array transducer (C5-2, 5-2 MHz). Some US gel was applied to the skin over the lumbar region for adequate acoustic coupling. The target vertebral level (L2-L3-L4) for the neuraxial block was identified by locating the lumbosacral junction (L5-S1 gap) on a paramedian sagittal scan, and then counting cranially to locate the lamina and transverse processes of the L2, L3, and L4 vertebrae (9). The paramedian transverse scan through the articular process was then performed with the transducer positioned 3 - 5 cm lateral to the midline in the transverse orientation at the L2-L3 or L3-L4 intervertebral level (Figure 1). The transducer was also directed medially so that the US beam was insonated in a paramedian transverse oblique plane. This was performed to ensure that the incident US signal entered the spinal canal through the interlaminar space (Figure 2). The orientation marker of the ultrasound transducer was oriented laterally during the US scans in all patients. The US scout scan was recognized as successful if the articular process, ligamentum flavum, posterior dura, intrathecal space and anterior dura were visualized at the L2-L3 or L3-L4 intervertebral level. The patients with successful US scout scan underwent the following CSE procedure under US guidance.

Epidural Access

The transducer was finally positioned over the L2/L3 or L3/L4 intervertebral spaces after the important spinal and neuraxial structures were

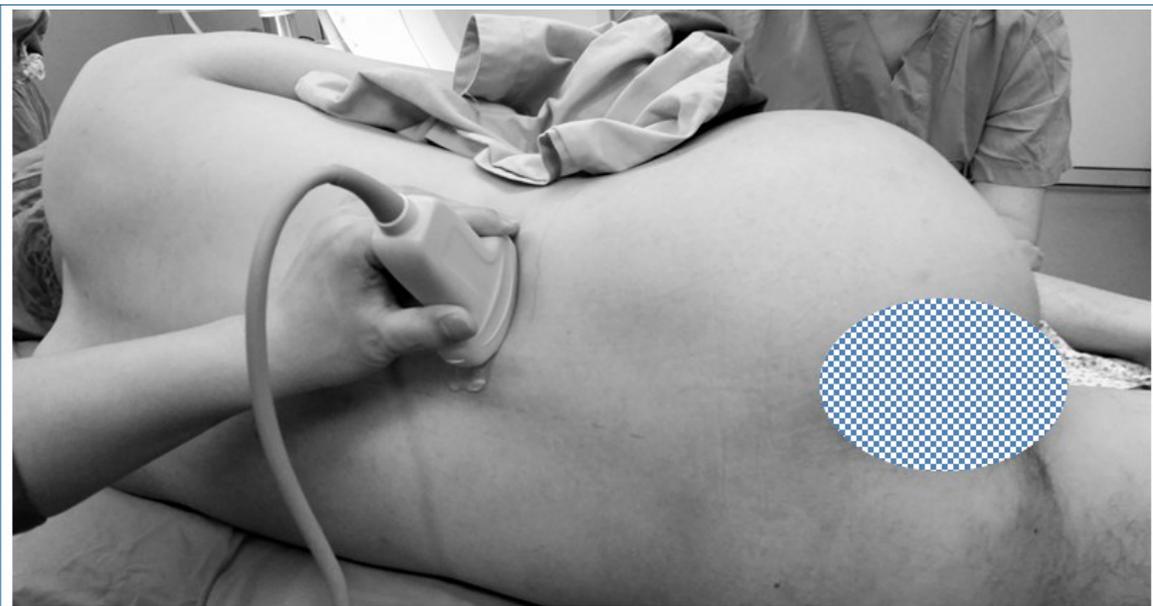


Figure 1. Figure Showing the Position of the Patient, Anesthesiologist, and How the Ultrasound Transducer Was Oriented During a Paramedian Transverse Oblique Scan.

visualized following the scout scans (Figure 3). The position of the transducer was marked on the patient's back using a skin marking pen to ensure that the transducer was returned to the same position after sterile preparations were made before the intervention. After sterile preparations, the CSE anesthesia was performed by Dr. Yun Wang (single operator technique). The US transducer with its cable was covered by a sterile plastic sleeve, with no air trapped between the footprint and plastic sleeve, after the transducer was prepared by applying a layer of US gel on its footprint. No US gel was applied directly to the skin over the area scanned, and Iodophor, which was applied using a sterile swab, was used as a substitute coupling agent. The transducer was held in the non-dominant hand of the operator. With the spinal and neuraxial structures such as ligamentum flavum, posterior dura or anterior dura in view on the US monitor, the operator used the dominant hand to infiltrate local anesthetic (lidocaine 1%, 2–3 ml) to the skin and underlying tissue, 1 cm lateral to the spinal midline at the US beam plane. The 18 G Tuohy needle (BD, Suzhou, China) was then inserted from the skin infiltration wheal, with its tip directed towards the interlam-

inar space (L2/L3 or L3/L4) on the US image.

This target interlaminar space was always viewed in the bottom-right of the US image (10). The trajectory for needle insertion was optimized while the needle was still in the erector spinal muscle. The Tuohy needle was gradually advanced to the interlaminar space, under real-time US guidance, until the tip was judged to have engaged in the ligamentum flavum (Figure 4). This was also confirmed by testing for 'resistance to air injection' through the Tuohy needle using the standard LOR syringe included in the kit. Since the Tuohy needle was inserted in the plane of the US beam, it was possible to follow the advancing needle in real time. The position of the needle tip could be inferred by observing tissue movement on the US scan. The needle-syringe assembly was then stabilized by the dominant hand holding it on the patient's back. The needle-syringe assembly was then gradually advanced, until the operator felt the sudden loss of resistance to pressure on the plunger. Then, the syringe and US probe were removed and a 27 G spinal needle was threaded into the Tuohy needle to perform the dural puncture. Once a free flow of cerebrospinal fluid (CSF) was seen, the spinal needle was fixed and 2.5 – 3 ml of hyper-

baric ropivacaine (0.5%, diluted in 10% glucose) was injected at a rate of 1 ml every 6 s. The spinal needle was removed and 3–4 cm of an epidural catheter was immediately inserted into the epidural space through the Tuohy needle and secured to the back. The patients were then returned to the supine position and no local anesthetic was injected through the epidural catheter unless the level of sensory block after the spinal injection was inadequate for surgery. Electrocardiography (ECG), oxygenation saturation and arterial pressure were monitored continuously for the duration of surgery. Hypotension (defined as < 20% decrease in systolic arterial pressure from the baseline) was treated using intravenous ephedrine (10 mg bolus). The level of sensory block was detected 10 min after the initial intrathecal injection. The oxygen (5 litre/min) was administered via a facemask to the patients.

Data Collection and Analysis

The following parameters were recorded during the study. The visibility of the six spinal and neuraxial structures (articular process, ligamentum flavum, epidural space, posterior dura, intrathecal space, and anterior dura) at the L2/L3 or L3/L4 lumbar interspace were scored during the scout scan, by Dr. Yun Wang who performed the US scan, using a four point numerical scale (0, not visible; 1, hardly visible; 2, well visible; 3, very well visible, maximum score possible = 18), and the total US visibility score (UVS) was determined for every patient (7,9). The scan was considered a success if both posterior and anterior dura were seen on the US imaging. The US visibility of the spine and neuraxial structures was judged to have been good, if the mean total UVS was > 12, average if the score was 6–12, and poor if the score was < 6 (7, 11). The number of attempts it took to access the epidural space was also recorded.

Complications directly related to the technique or inadequate block that required rescue epidural injection of local anesthetic during surgery was also recorded. The data were analyzed using SPSS for Windows (version 19, SPSS, Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to test the normality of the data recorded. The data are presented as mean (SD) when normally distributed and as median

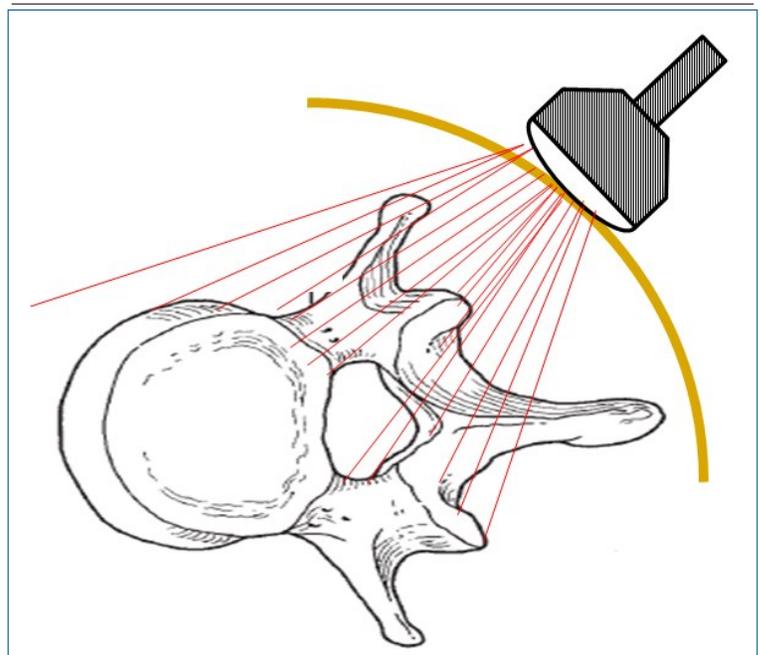


Figure 2. The Schematic Diagram Shows How the Incident US Signal Can Enter the Spinal Canal Through the Interlaminar Space During a Paramedian Transverse Oblique Scan at the Level of Articular Process.

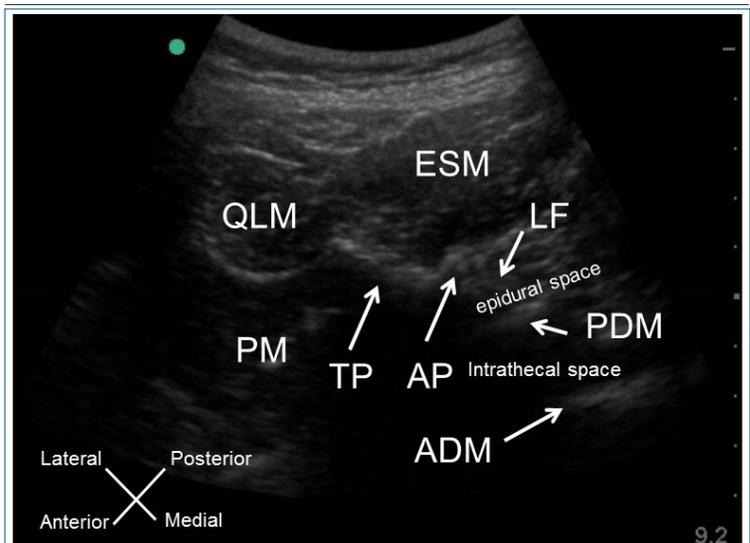


Figure 3. Transverse Sonogram of the Lumbar Spine as Seen During the Paramedian Transverse Scan at the Level of Articular Process Before the Combined Spinal and Epidural Procedure (Scout Scan).

Note the spinal and neuraxial structures such as transverse process (TP), articular process (AP), ligamentum flavum (LF), epidural space, posterior dura mater (PDM), intrathecal space, and anterior dura mater (ADM). ESM indicates erector spinal muscle; QLM, quadratus lumborum muscle; PM, psoas muscle.

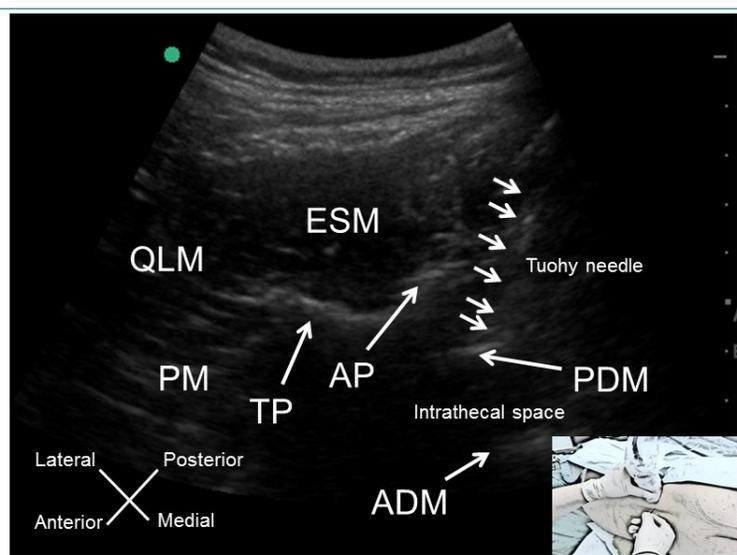


Figure 4. Transverse Sonogram of the Spine Showing the Trajectory of the Tuohy Needle During the Combined Spinal and Epidural Procedure.

ESM indicates erector spinae muscle; QLM, quadratus lumborum muscle; PM, psoas muscle; TP, transverse process; AP, articular process; PDM, posterior dura mater; ADM, anterior dura mater.

(range) when not normally distributed. The categorical variables are presented as n (%).

Results

The US scout scan was successful in 16 out of 18 (88.8%) patients, in whom the articular process, ligamentum flavum, posterior dura, intrathecal space and anterior dura were visualized. The real-time paramedian epidural access under the paramedian transverse oblique scan, in which the epidural needle was inserted in the plane of the US beam, was successfully performed in 16 adults with successful scout scans, by a single experienced operator.

There were nine men and seven women with a mean age of 60.9 (17.1) yr, weight 66.1 (6.5) kg, height 167.4 (5.4) cm, and BMI 23.5 (1.8) kg/m². In patients with successful US scan, the US visibility of the spinal and neuraxial structures was judged as good in 14 out of 16 (87.5%), and average in 2 out of 16 (12.5%) patients. The mean total UVS of the neuraxial structures in this cohort of patients was 13.5 (range 10 - 18).

Epidural space was only visualized in 14 out of 16 (87.5%) patients during the scout scan and the median of US visibility scores for epidural space was only 1 (0-3). The ligamentum flavum was hyperechoic, but less than the articular process, and often appeared as a thick band connected with the adjacent articular process (Figure 3). The posterior dura was the hyperechoic structure anterior to the ligamentum flavum and the epidural space was the hypoechoic area between the ligamentum flavum and the posterior dura (Figure 3). The thecal sac with the CSF was the anechoic space anterior to the posterior dura. The anterior dura was also hyperechoic.

The epidural space was successfully identified in all patients with successful scout scans in 1 attempt using real-time US guidance in combination with LOR to air. However, there was a failure in two patients (Patient 5 and 10) to obtain the efflux of CSF through the spinal needle using the technique described above. The procedure was successfully converted to a spinal anesthesia through the midline at the lower interspace. There were no inadvertent dura punctures during the epidural access or complications directly related to the technique described. Anesthesia adequate for surgery developed in all patients after the initial spinal injection, and there was no need for any intraoperative supplementation. Recovery from the spinal anesthesia was also uneventful.

Discussion

In our pilot study, we have shown the successful application of a real-time paramedian transverse oblique scan for paramedian epidural access in the lumbar region, with the epidural needle inserted in the plane of the US beam.

Although the spinal and neuraxial structure such as ligamentum flavum, posterior dura, anterior dura, and lamina is well visualized in the transverse or sagittal sonography in most patients, the real-time US guidance for epidural access is not used as popularly as US-guided peripheral nerve blocks (12, 13). The great challenge for real-time epidural access is how to establish a simple and single-operated approach. Grau and colleagues developed a two-operator technique of out-of-plane insertion of the epidu-

ral needle at the midline under a real-time paramedian sagittal scan during a CSE procedure (1, 8). Although this technique is effective, the need for a second operator proficient in spinal sonography to perform the US scan and the limited space available for the three or four hands that are required to perform the epidural access may be considered a disadvantage in clinical practice. Karmakar and colleagues described a real-time, in-plane, single-operator technique under a paramedian sagittal scan in adults, of the epidural needle insertion in the long axis of the US transducer from the caudal end with its tip directed towards the interlaminar space on the US image (7). However, using this technique, a right-dominant operator will hardly perform epidural needle insertion for patients positioned in their right sides. Additionally, the oblique trajectory of the needle from the puncture point at the skin to the posterior dura is much longer than the vertical distance (5.94 ± 0.71 versus 4.24 ± 0.48). It indicates that the commercially-provided epidural Tuohy needle for routine use in normal patients (80 mm long) is too short to use in some obese patients (14, 15).

In this study, we describe a novel technique of performing US-guided, in-plane, paramedian epidural access in the lumbar region through a real-time paramedian transverse scan. Since only a part of erector spinal muscle is visualized on US image through a paramedian transverse scan, the advancing needle can be visualized in real time after the epidural needle punctures into the erector spinal muscle for 1-2 cm distance. In the sonogram, we can identify that the epidural needle is engaged in the ligamentum flavum in real time during the procedure. The technique we described above has several advantages. First, we are able to circumvent the need for a second operator to perform the LOR. Second, since the traditional lateral approach (paramedian) combined with the short-axial, in-plane US technique is used for epidural needle insertion, the needle trajectory will be much shorter than that in the sagittal, in-plane technique. Third, the operator is free to perform the procedure without the limits of patient's position (right or left side), and dominant hand. Four, the operating space is comparatively favorable, since the epidural needle puncture site is 2-4 cm far from the

lower edge of US probe.

Epidural space was visualized on the US image in 14 out of 16 (87.5%) patients with successful scout scans. However, the median of US visibility scores for epidural space was 1. It may be attributed to the age-related changes in echogenicity because the majority of our patients were elderly. Therefore, the LOR technique was used to identify if the tip of the Tuohy needle was advanced into the epidural space. In the current study, we identified the epidural spaces in all patients using LOR technique without failure. However, we failed in the efflux of CSF from the spinal needle in two patients (Patient 5 and Patient 10). Inability to obtain CSF through a spinal needle during a needle-through-needle CSE may occur in 3-5% of cases (16), and various mechanisms have been proposed to explain this phenomenon, including the use of too short a spinal needle, lack of rigidity, and sharpness of the fine spinal needle to puncture the dura, pencil point spinal needles may not always pierce the dura even when properly inserted, lateral deviation of the spinal needle from the midline during insertion, a long fine-gauge spinal needle may enter the dura, and then be advanced to the anterior epidural space due to the delay in efflux of CSF, and blockage of the spinal needle (17). In other 14 patients, we saw the efflux of CSF from the spinal needle several seconds after the insertion of the spinal needle, which is different from the results reported by Karmakar et al. (7). A certain hydrostatic pressure has to be overcome before the CSF could emerge from the spinal needle, since the needle is inserted in the plane of the US beam from the non-dependent side and thus from a slightly higher level than the thecal sac. However, the hydrostatic pressure may not affect the efflux of CSF from the spinal needle, since the lumbar CSF pressure (0.78-1.76 kPa) in the normal person with a lateral position is much higher than the hydrostatic pressure.

The current study has several limitations. We only included the patients with BMI < 28 kg/m². Future studies should evaluate the utility of the technique we described above in the obese patients since epidural access can be challenging in these patients (18). Another limitation of our study is that it is descriptive and not a randomized trial. Larger randomized trials are required

to quantify the success and failure rates of the technique described.

In conclusion, we have described a new in-plane, single-operated, real-time technique for paramedian epidural access through paramedian transverse scan. Future research to establish its safety and efficacy compared with traditional

blind epidural access is warranted.

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The authors declare no other conflicts of competing interest for this work.

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