Real-time ultrasound-guided mid-thoracic epidural access using a novel paramedian cross (PX) view and drip infusion technique: a brief technical report

T Sivashanmugam, Areti Archana, P Nandhini, P Rani

ABSTRACT
Background Real-time ultrasound guidance (USG) has been applied for lower thoracic epidural access, but the more challenging mid-thoracic epidural (MTE) access remains underexplored. This report presents a technique of real-time US guidance with a novel paramedian cross view, termed “the PX view,” for securing MTE catheters, along with an outcome analysis from a retrospective case series.

Methods Medical records of patients who underwent USG-MTE catheter placement with the PX view and drip infusion technique from January to December 2022 were reviewed. All catheters were placed with patients in the prone position under mild to moderate procedural sedation. The process of acquiring the PX view, in-plane needling technique, and the use of drip infusion to identify loss of resistance were detailed. The incidence of successful PX view attainment, the number of attempts, redirections, failures, and any technique-related complications were recorded.

Results Fifty-one patients underwent USG-MTE catheter attempts (42 with median sternotomy, 3 fractured ribs, 3 upper abdominal laparotomies, 2 modified radical mastectomies, and 1 thoracotomy). A satisfactory PX view was obtained in all patients, and the epidural space was identified during the first needle entry in 49 cases, resulting in a 96% first-attempt success rate. Seven patients required needle redirections, while two patients needed a second needle entry. No technique-related complications were documented.

Conclusion The combination of the PX view and the drip infusion method proved effective for real-time ultrasound-guided MTE catheter placement.

BACKGROUND
Thoracic epidural analgesia sets the benchmark for any regional analgesia strategy for open heart, thoracic and upper abdominal procedures with proven benefits and better cardiac outcomes. However, securing a mid-thoracic epidural (MTE) catheter (T4–T8), which is congruent to the nociception is most challenging due to the overriding laminae resulting in tight interlaminar gaps, and sharply angulated spinous processes leaving a very narrow bony tunnel for midline approaches. A landmark or ultrasound-assisted approach may need multiple redirections, making the technique painful and risky, especially in the background of anticoagulation during cardiac surgery. Even though real-time ultrasound guidance (USG) has proven to improve performance and reduced complications for lumbar and lower thoracic epidural access, USG-guided MTE access has not been described. In this technical report, we describe the steps to access the MTE space, under real-time US guidance using a novel paramedian cross (PX) view and drip infusion method to identify the loss of resistance (LOR) of the epidural space.

Methods
We reviewed all the case records of patients over the age of 18 years who were attempted an USG-MTE catheter placement through the described technique from January to December 2022. Records with incomplete data were excluded. The anesthesia procedural notes were reviewed to identify the number of attempts, the number of redirections and failures. The epidural congruency and any technique-related complications such as epidural hematoma or prolonged neurological deficit were also noted.

Technique description
Patient positioning
All the USG-MTE catheters were performed inside the operating theater under standard American Society of Anesthesiology (ASA) monitors (pulse oximetry, non-invasive blood pressure, and ECG). Patients undergoing cardiac surgery received additional invasive lines as deemed necessary under local anesthesia prior to the central neuraxial procedure. All patients received continuous oxygen supplementation via Hudson mask at 6 L/min with Intra-venous midazolam 1–3 mg and fentanyl 1–2 µg/kg in titrated doses as a part of the procedural sedation protocol of the department. The patients were carefully positioned prone, with the head comfortably turned to one side, and both arms abducted above the head with elbows flexed, with sufficient care taken not to entangle the lines. To accentuate the natural thoracic kyphosis, a soft cushion was placed below the chest.

Equipment setting and ergonomics
All MTE catheters were secured under USG using a curved array transducer (C60x, 1–5 MHz; SonoSite) of X-Porte ultrasound system (SonoSite, Bothwell, Washington, USA) with tissue harmonic imaging capability. A musculoskeletal preset, a dynamic range of −3, and penetration mode were set on the US machine. All the epidural catheters were introduced by one consultant (ST) with over 15 years of experience in cardiac anesthesia and over 500 US-guided...
Brief technical report

<table>
<thead>
<tr>
<th>USG VIEW</th>
<th>PROBE POSITION</th>
<th>SONOANATOMY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Paramedian Sagittal Costal View</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Paramedian Sagittal Costotransverse joint View</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Paramedian Sagittal Transverse Process View</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Paramedian Sagittal Laminar View</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Paramedian Cross View “PX View”</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1  Showing the systematic scanning technique with probe position and corresponding sonoanatomy to be identified. *yellow star - represents the superior articular process of the T5 lamina. CTJ, costotransverse joint; SAP, superior articular process; SP, spinous process; TP, transverse process; USG, ultrasound guidance.

central neuraxial interventions. The performer stood on the left side of the patient with the US machine placed opposite to achieve appropriate ergonomics.

**Systematic scanning technique**

For ease of description, MTE catheter insertion through T4–5 space has been explained. Under aseptic preparation, using paramedian sagittal view with the probe marker cephalad, the T4–T5 intervertebral level was identified by counting cephalad from 12th rib to the 5th rib as described before.5 6 The M-mode curser was used as the center line. The probe was positioned to visualize the fourth, fifth, and sixth ribs from cephalad to caudal (figure 1A), with the fifth rib positioned at the center.

The probe was then slid from lateral to medial, to sequentially identify the costotransverse junction (figure 1B), the transverse process (figure 1C), and the interlaminar view where the superior articular process of fifth thoracic vertebra was seen to articulate with T4 lamina (figure 1D). Then a PX view was obtained by keeping the center of the probe steady at the T5 articular process and the probe was rotated 20°–30° clockwise without any tilt (figure 1E). During this rotational maneuver (figure 2A), the clinician observed the transition of T6 lamina into its transverse process at the caudal end of the US image. As T6 transverse process appears on the caudal end, the superior articular process of T5 disappears under the post acoustic shadow of the base of T4 spinous process at the cephalad end of the US image.
Brief technical report

At this sonoanatomy endpoint, where three different parts of three consecutive thoracic vertebrae (base of the T4 spinous process, lamina of the T5 and transverse process of T6) align from cephalad to caudal in the US image, the epidural needle was introduced in plane from caudal to cephalad direction (figure 2C).

Needling technique

An 18-gage Tuohy needle (Portex epidural mini pack system 1) with stylet in place was introduced in-plane and steadily navigated under real-time USG to the space cephalad to the T5 lamina (T4–5 interlaminar space). After crossing the upper end of the T5 lamina, the needle tip disappeared behind the postacoustic shadow of the base of T4 spinous process (figure 3). From this point till the ligamentum flavum (LF) was engaged, the needle travel inside the interlaminar space blind and guided by tactile feel on the performer’s hand. In case, bone was encountered; it was assumed to be the superior articular process of T5 lamina (figure 2C), and the needle was redirected medially to reach the LF. However, if bone is encountered prior to entering the interlaminar space, then it could be the base of T4 lamina or spinous process, or the medial border of the T5 lamina, in which case the needle would need to be redirected caudad or cephalad, respectively. Once the LF is engaged, the stylet was removed, and an adult intravenous drip set, primed with 0.9% normal saline was connected to the hub of the epidural needle. The other end of the drip set was connected to a 1 L saline bottle, which was hung 60 cm above the level of the operating table and placed beside the US screen. The intravenous set flow control was kept by the assistance who was helping the procedure. The lack of flow in the intravenous chamber indicated the needle tip was still within the tissue plane possibly LF. As the needle was carefully advanced further, the performer shifted gaze from the US image to the fluid chamber all the while keeping awareness on the tactile sense of resistance offered by the LF to the advancing needle. The LOR at the epidural space was identified by both the “give away feel” at the performer’s hand and the free flow of saline in the drip chamber. The saline flow was immediately halted by the assistant and the drip set disconnected from the Tuohy needle. As an additional confirmation, 2–3 mL of saline was injected through the Tuohy needle using a conventional LOR syringe, after negative aspiration, following which 5 cm of 20-gage epidural catheter was threaded into the epidural space and fixed at the skin with sterile transparent occlusive dressing.

Figure 2  Image showing the probe position (A) and sonoanatomy (B) of the Paramedian Cross view along with a simulated needle track with the view (C). *The superior articular processes of T4 and T5 vertebrae. SAP, superior articular process; SP, spinous process; TP, transverse process.
Study parameters recorded
The attainment of the PX view, the number of attempts, needle redirections, failures and any complications related to the procedure were reviewed from the anesthesia procedural notes or acute pain service record of the individual patients.

RESULTS
Fifty-one patients (42 median sternotomy, 3 fracture ribs, 3 upper abdominal laparotomies, 2 modified radical mastectomies, and 1 thoracotomy) were attempted USG-MTE catheter as described in the methodology during the study period. The medical records of all those patients were reviewed for the study parameters. There were 33 males and 18 females with a mean age of 52±8 years (mean±SD) and body mass index (BMI) of 22±4 kg/m² (mean±SD). A satisfactory PX view could be achieved in all patients and the epidural space was identified in the first needle entry in 49 patients (first attempt success rate 96%), where 42 patients had first pass success (82%) and 7 patients required 2 redirections and only 2 patients required a second needle entry to access the epidural space. The catheter insertion was successful in all patients. The sensory conduction blockade was confirmed before the induction of general anesthesia or handing over to APS team, the dermatomal coverage following 6 mL of 2% lignocaine with epinephrine ranged from minimum of T2 to 4 and maximum of T2–T12. The average needle length inserted, from skin to epidural space was 6.5±1 cm (mean±SD). The 1 L saline bottle hung at 60 cm height from the operating table exerted a mean pressure head of 40±8 mm Hg (n=5) at the epidural needle tip. All patients received satisfactory intermittent epidural top-ups in the postoperative period according to the acute pain services protocol except two patients who underwent off-pump cardiopulmonary bypass, were deferred local anesthetic administration due to episodes of hypotension on the first postoperative day and received injection morphine 50 μg/kg through the epidural catheter instead. All catheters were removed at the end of intended therapy. The median (range) catheter day was 3 (2–8). No technique-related complications, including dural puncture, intravascular catheter placement, bleeding, hematomas, or neurological symptoms, were registered.

DISCUSSION
We described a novel US window ‘The PX view’ for real-time USG-MTE access and demonstrated high first pass success rate just lateral to the midline and cephalad one-third of the probe only crosses the median plane (figures 2A and 3). The technique described is unique in two ways from the existing reports. First, the PX view aligned three different parts of three consecutive thoracic vertebra in a narrow US window that offers optimal access and demonstrated high first pass success rate in individuals with normal BMI. We term this view ‘Paramedian Cross’ as the US probe pivots over the superior articular process on March 8, 2024 by guest. Protected by copyright. http://rapm.bmj.com/ Reg Anesth Pain Med: first published as 10.1136/rapm-2023-105071 on 21 February 2024. Downloaded from http://rapm.bmj.com/ on March 8, 2024 by guest. Protected by copyright.
Although the paramedian scanning principles of thoracic spine have been well described before, the final probe position and endpoint sonoanatomy obtained in PX view are distinct from all previous reports. The PX view brings in three different components of three consecutive thoracic vertebra in a single line at a narrow US window where a slightest moment or tilting of the probe might miss the summit of the transverse process of the lower vertebra at the caudal end and post aquatic shadow of the spinous process of above vertebra at the cephalad end of the US image. In authors’ experience, this alignment is very crucial for setting up the perfect paramedian needle trajectory toward the midpoint of the thoracic epidural space. The oblique tilt of the probe in the traditional paramedian sagittal oblique view (PSOV) makes the needle alignment more challenging with the oblique ultrasound beam. Furthermore, handling the probe, needle, LOR syringe in a lateral or sitting position adds more complexity the procedure. Whereas in PX view, the endpoint sonoanatomy is obtained without any probe tilt and the prone position not only improved ergonomics for probe handling and needle maneuvering but also facilitated the effective administration of procedural sedation without the need of additional personnel to support the patient, as is required for lateral or sitting positions.

The drip infusion method was initially described by Baraka in 1972 for lumbar epidural access and later adapted for landmark-based MTE access in 2001. Traditionally during real-time ultrasound-guided thoracic epidural approaches, clinicians need to drop the probe or have an assistant to manually pressurize the air or saline-filled syringe to identify the LOR. In our approach, the drip infusion method not only relieved the performer’s dominant hand for needle advancement but also provided dual confirmation of the LOR through tactile feedback and visual observation of saline flow in the drip chamber while the needle penetrating the LF and entering the epidural space. Furthermore, the lack of retrolaminar fluid distention (plane between lamina and the erector spinae muscle) confirms that the saline is not flowing into one of the the most common false passage.

Following LOR identification, we observed variations in the drip rate among patients, possibly due to differences in epidural space compliance. This drip rate variation was reported by other authors as well. Although it is possible to reduce this variation by applying 50 mm Hg more pressure through a pressure bag, the present opening pressure of 40±8 mm Hg exerted by 1 L saline had not led to any false passage or dural puncture in our case series which is in alignment with published report. Despite the lack of evidence regarding the optimal pressure that is associated with least false positives, it is noteworthy that 40 mm Hg exerted by the 1 L saline is far less than the opening pressure of 250–300 mm Hg exerted during manual LOR technique.

We considered the use of the self-recoiling spring-loaded Episure syringe for real-time ultrasound-guided lumbar epidurals; however, concerns regarding cost and uncontrolled delivery pressure into the epidural space at the mid-thoracic level led us to favor the drip infusion method. However, the need for additional setup and aseptic preparation is needless to emphasize.

While we achieved successful epidural catheterization in three patients with a BMI of 30 kg/m² and four patients aged over 70 years within our study cohort, the majority of the patients had a normal BMI. Consequently, the current outcome data cannot be generalized to a population with challenging sonoanatomy and for novice performers. However, the narrow ultrasonic window of the PX view and the non-oblique tilt of the probe position are likely to minimize scanning errors and improve the needle visualization which is an added advantage in these difficult situations. Therefore, we conclude that the novel PX view with drip infusion method enabled effective real-time ultrasound-guided MTE catheter placement in normal built individuals, however, future randomized controlled trials should explore these advantages, especially in populations with difficult sonoanatomy.