REGIONAL ANESTHESIA AND ACUTE PAIN

BRIEF TECHNICAL REPORT

Real-Time Ultrasound-Assisted Thoracic Epidural Placement
A Feasibility Study of a Novel Technique

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Abstract: The placement of thoracic epidural catheters is complicated by the layering of the vertebral lamina. Therefore, traditional blind palpation techniques require insertion of an epidural needle with likely contact of lamina with redirections into the epidural space. We discuss a safe and consistent technique using true real-time ultrasound visualization of the needle with a paramedian sagittal oblique view to improve the consistency of placing an epidural in the thoracic spine for postoperative analgesia. Successful epidural placement was achieved in every patient. All catheters were found to be effective for use in the postoperative phase.

(*Reg Anesth Pain Med* 2018;43: 613–615)

Thoracic epidural analgesia provides reliable intraoperative and postoperative pain relief for patients undergoing abdominal and thoracic surgeries. Conventional methods for locating the epidural space are dependent on the use of surface anatomical landmarks and loss-of-resistance (LOR) techniques. However, relying on surface anatomy often leads to incorrect identification of the targeted thoracic interspace and can be difficult to distinguish.[1] This may cause increased procedural time, multiple needle placements, patient discomfort, inadequate neuraxial blockade, and dural penetration.[2]

Ultrasound (US) imaging can be a valuable tool to preview spine anatomy.[3–7] Preprocedural imaging, however, still requires blind advancement of the epidural needle and does not reduce the time or number of needle redirections required to place a thoracic epidural catheter.[8] Interest in using real-time US visualization during needle advancement to improve rates of catheter placement at the lumbar spine has recently developed.[9,10] However, this technique is difficult at the thoracic spine, given the narrow interlaminar space and steep angulation of the spinous processes, which provide poor US visibility.[11] There have been no published reports on successful real-time US-assisted thoracic epidural placements.

In this article, we describe the practice for thoracic epidural placement under real-time US visualization of the Tuohy needle utilizing a paramedian sagittal oblique view on patients undergoing abdominal or thoracic surgery at a single institution.[12] We review the results of our technique in the first 15 patients in a teaching institution regarding the feasibility of this technique and whether it may have advantages over the standard landmark-based technique.

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Accepted for publication November 20, 2017.
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The authors have no sources of funding to declare for this article.
This work was presented in part as an abstract at the American Society of Regional Anesthesia and Pain Medicine's 42nd Annual Regional Anesthesiology and Acute Pain Medicine Meeting; April 6 to 8, 2017; San Francisco, CA.
The authors declare no conflict of interest.

ISSN: 1098-7339
DOI: 10.1097/AAP.0000000000000761

METHODS

This retrospective review was approved via a waiver for informed consent by the Memorial Sloan Kettering Cancer Center internal review board and supported by Memorial Sloan Kettering Cancer Center support grant (P30 Core Grant) and the Department of Anesthesiology and Critical Care. Patients older than 18 years who presented in August 2016 for elective abdominal or thoracic surgery (American Society of Anesthesiologists physical status I–III) under general anesthesia and requesting thoracic epidural analgesia for postoperative pain control were included in this review. Patients provided informed consent as our standard of practice for abdominal and thoracic surgery, including perioperative pain control with an epidural. Patients were not eligible for a thoracic epidural if they had any contraindications for neuraxial anesthesia, history of spine surgery, known spinal deformity, coagulopathy, sepsis, or allergy to local anesthetic.

Epidural catheter placements were performed preoperatively. Intravenous access and routine monitoring (pulse oximetry, electrocardiogram, and noninvasive blood pressure) were established prior to placement. Patients were put in a sitting position, and midazolam (1–4 mg) was administered intravenously for premedication following positioning. The targeted interspace for epidural catheterization was determined by the surgical incision site. All preparation was completed with sterile technique. All placements were performed by a single postgraduate year 4 anesthesiology resident (D.J.P.) and attending anesthesiologist (A.G.) who oversaw the placement.

Technique

Ultrasound imaging was completed using a GE LOGIQe 9L linear probe, 8 to 10 MHz (GE Healthcare, Wauwatosa, Wisconsin). After determining the thoracic level using US technique of locating the 12th rib and tracking cephalad, the US probe was placed in the longitudinal plane on the midline of the patient's back (Fig. 1A) to visualize the thoracic spinous processes (Fig. 1B). As is our standard of care, the T8–T9 interspace was most commonly chosen for placement of a thoracic epidural, although discretion was allowed for variations in surgical incision site and technique. Once the appropriate interspace was localized, a paramedian sagittal transverse process view was obtained by moving the probe 2 cm lateral (on the operative side for thoracic operations) from the spinous process (Fig. 1C) to visualize the corresponding transverse processes, which appear as successive hyperechoic domes (Fig. 1D).

Maintaining the paramedian sagittal orientation, the probe was moved 1 cm medial for the articular process view (Fig. 1E), where the superior articular process of the inferior vertebrae could be seen (Fig. 1F). Then a paramedian sagittal oblique view was obtained by turning the cephalad end of the probe medially with a concurrent medial tilt (Fig. 1G) until the superior articular process of the targeted interlaminar space could no longer be visualized (Fig. 1H). Further tilting motions of the probe were made to optimize the gaps in between the laminae, which represent the corresponding interlaminar spaces. It is important to note that with our US probe and technique the

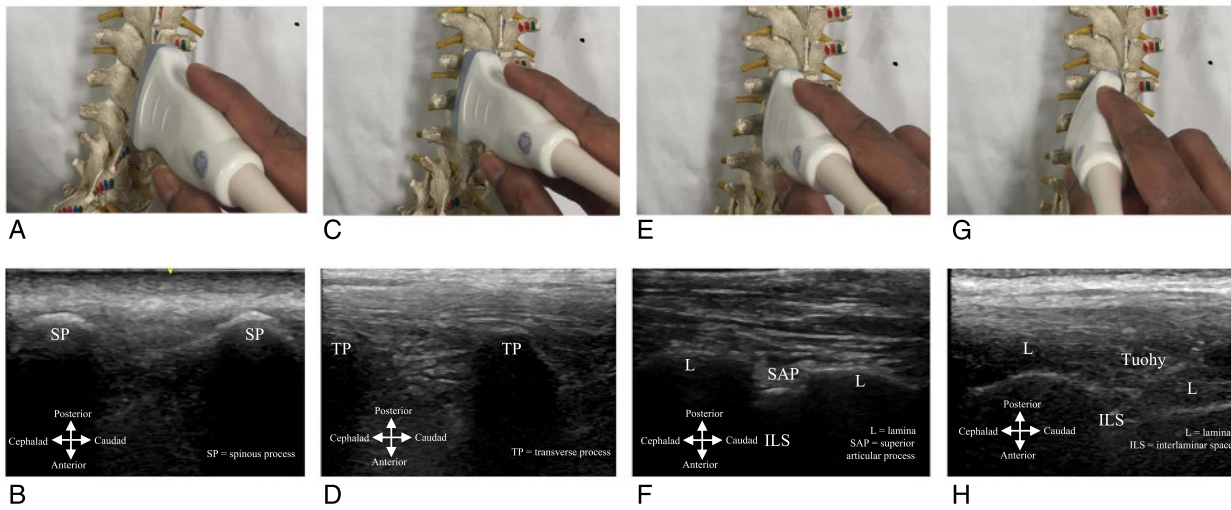

FIGURE 1. For the spinous process view of the thoracic spine, the US probe should be orientated longitudinally along the midline of the thoracic spine (A) so that successive spinous processes can be seen on US (B). For the paramedian sagittal transverse process view, the US probe is moved 2 to 3 cm lateral from the spinous process (C). Successive hyperechoic domes with fingerlike shadowing or "trident sign" represent the transverse processes (D). For the paramedian sagittal articular process view, the probe is moved 1 cm medially (E). The superior articular process of the inferior vertebra can be seen along with the corresponding laminae (F). The paramedian sagittal oblique view can be obtained by turning the cephalad end of the probe medially with a slight medial tilt (G) to optimize the view of the interlaminar space seen in (H), where the Tuohy needle is advanced under direct visualization.

epidural space was not visualized. This is a critical point, especially at a depth greater than 4 cm.

Once the targeted interlaminar space was identified, the intended needle entry site at the skin was infiltrated with 2% lidocaine. A 17-gauge Tuohy needle was inserted from the caudal end of the probe and advanced under real-time US assistance using an in-plane approach to the interlaminar space until the tip of the Tuohy was safely directed to the distance of the previously visualized superior articular process of the inferior lamina. No attempt was made to deliberately contact the lamina with the needle. Once the Tuohy was visually localized in the previously mentioned position, the needle was advanced until the epidural space was identified with LOR to air because the needle tip could not be visualized at all times under US at these depths.[9] The epidural catheter was advanced such that 4 cm remained in the epidural space.

Data points were collected by nursing staff as a part of the standard of care for epidural placement at our institution (including time of midazolam administration, lidocaine administration, and any redirections or reinsertions of the needle). After excluding for intravascular and intrathecal placement, a 2-mL test dose of 2% lidocaine was administered, and the catheter was secured. Following induction of general anesthesia in the operating room, intraoperative epidural analgesia was instituted with an infusion of 0.05% bupivacaine with hydromorphone 8 μg/mL at a rate of 6 mL/h with adjustments at the discretion of the attending anesthesiologist for hemodynamic changes. The infusion was continued postoperatively and discontinued at the discretion of the surgical and acute pain teams. As part of our institution's standard of care, if an epidural is not "working," another local test dose is attempted, and the epidural is discontinued if a patient does not exhibit signs of pain improvement or an appropriate "anesthetic level."

Outcomes

The primary outcome measure was the number of needle redirections required for successful epidural placement. This was to be in comparison to traditional landmark-based techniques that usually require contact with lamina with subsequent redirections. Secondary outcomes included the number of attempts as measured by needle reinsertions, procedure complications, procedure times, and catheter failures.

RESULTS

Sixteen patients received US-assisted epidurals during the retrospective review period. A single patient was excluded from data analysis because the primary and secondary outcome data were not recorded in the epidural procedure note. Median age was 62 ± 17.3 years, with 53.3% being male (Table 1). With regard to type of surgery, 40.0% of the patients underwent abdominal surgery, and 60.0% underwent thoracic surgery. The majority of the epidurals were placed at the T7–T8 (46.7%) and T8–T9 (46.7%) interspaces.

Median length of time from midazolam administration (given as a premedication to all patients) to subcutaneous lidocaine infiltration was 5 ± 4.4 minutes. This was due to preprocedural US scanning of the spine. The median length of time from lidocaine infiltration to local test dose administration was 10 ± 7.0 minutes. The median distance from skin to epidural space was 5.2 ± 1.1 cm. The number of postoperative days of epidural use was 2 ± 1.6 days. No procedure complications were noted for any of the patients, including dural puncture or intravascular catheter placement. There were no catheter failures postoperatively, and all patients reported adequate analgesia.

It is notable that 11 (73.3%) of 15 patients required a single needle insertion for successful catheterization, with only 3 patients (20.0%) requiring 2 insertions and 1 patient (6.7%) requiring 3 insertions. Thirteen (86.7%) of 15 patients did not require any needle redirections, with 2 patients (13.3%) requiring a single redirection. We avoided laminar contact (as would be done in a landmark-based technique) in those patients who required no redirections and reinsertions (10 [66.7%] of 15 patients). In patients in which

TABLE 1. Patient Characteristics

	US Epidural Patients (n = 15)
Age (range), y	62 ± 17.3 (25–84)
Sex	
Male	8 (53.3%)
Female	7 (46.7%)
Surgery	
Abdominal	6 (40.0%)
Thoracic	9 (60.0%)
Location	
T7–T8	7 (46.7%)
T8–T9	7 (46.7%)
T9–T10	1 (6.6%)
T10–T11	0
Midazolam to lidocaine infiltration time, min	5 ± 4.4 (1–19)
Lidocaine to test dose time, min	10 ± 7.0 (4–25)
Skin to epidural distance, cm	5.2 ± 1.1 (4–7.1)*
Epidural complications	0
Postoperative epidural use, d	2 ± 1.6 (1–6)

Values are shown as median ± SD or number and percentage.

*A parasagittal line was drawn from skin to the epidural space at the corresponding thoracic epidural level; these data were independently recorded and analyzed.

redirection or reinsertion occurred, contact with lamina or lateral border of the spinous process is assumed.

DISCUSSION

To the best of our knowledge, this is the first study to evaluate the efficacy of true real-time US-assisted thoracic epidural catheter placement. We were able to achieve this by visualizing advancement of the Tuohy needle in the plane of the paramedian sagittal oblique view, which circumvents the spinous processes and provides direct visualization of the interlaminar window.[5,12] It is noteworthy that the remaining 0.5 to 1 cm from the Tuohy needle at the laminar edge to the epidural space was completed with LOR and not solely guided under US because the needle tip could not be visualized at all times at these depths. While Salman et al[5] and Auyong et al[8] described preprocedural US techniques to facilitate thoracic epidural placements, there have been no studies examining a real-time technique at the thoracic spine.

Traditional paramedian approaches for thoracic epidural placement involve redirecting the needle off the superior laminar edge until the epidural space is encountered by LOR techniques. Patients often experience discomfort from periosteal contact, needle redirections, and multiple skin punctures.[5] In this study, successful US-assisted epidural placement was achieved in every patient, with 73.3% of the patients requiring only a single insertion site and 66.7% not requiring any bony contact to achieve LOR (as would be done in a landmark-based technique). Therefore, by directing the needle under real-time US visualization, procedural success can probably be optimized. Potential complications due to blind needle advancement, such as dural puncture, can also be reduced, although not completely removed because the epidural space is not visualized with our described technique.

In addition to facilitating real-time visualization of the Tuohy needle, US imaging of the thoracic spine enables one to precisely localize a targeted interspace. This is superior to traditional palpation techniques, where bony landmarks are used for localization and are often difficult to identify. This helps to achieve better coverage of the desired dermatomes to provide adequate analgesia.

There are limitations to our study. The small sample size and retrospective nature of the study prevented us from making robust comparisons between patients receiving US-assisted epidurals and those receiving epidurals under traditional landmark palpation techniques. A prospective, randomized study comparing the 2 techniques would be needed to confirm the potential benefits of our technique.

In addition, 1 physician performed all of the epidurals in this study, likely leading to similar efficiencies for all placements. Future studies should include multiple providers with varying degrees of experience to investigate the utility of US across all skill levels. Lastly, while US imaging was used to advance the Tuohy to the ligamentum flavum, the epidural space was still identified with traditional LOR because of difficulty of visualizing the needle tip at that depth. Acoustic shadowing from the lamina as the Tuohy needle approaches the interlaminar space can also contribute to poor visualization. Complete US guidance to the epidural space may be possible with laser-etched needles and improved US technology.

Our study demonstrates that these data points may be a feasible basis for a prospective study comparing US-assisted epidural placements to traditional landmark-based techniques. By potentially reducing the number of needle redirection, reinsertions, and periosteal contact, this technique may improve procedural success while reducing patient discomfort and complications.

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