

Transesophageal Echocardiography

A Novel Technique for Guidance and Placement of an Epidural Catheter in Infants

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EPIDURAL block has been used extensively in pediatric patients.¹ Epidural block reduces the need for opioid usage, improves hemodynamic stability,² decreases the need for postoperative ventilator support,³ and lowers perioperative stress levels.⁴ Although cephalad advancement of epidural catheters from the caudal space to the thoracic region is commonly used, blind catheter advancement can be technically challenging, yielding a frequent failure rate in infants due to catheter curling and arrest at lumbar levels.⁵ Moreover, the inability to verify catheter tip placement at the targeted thoracic levels could lead to an inappropriately high spinal level of catheter placement.⁶

To overcome these issues, a number of confirmatory techniques have been described, including radiological fluoroscopy, epidural electrocardiography,⁷ and epidural electrical stimulation for muscle contraction.⁸ In terms of problems, these methods may require unnecessary exposure to ionizing radiation and contrast⁹ or exhibit limitations in confirming exact catheter tip placement^{7,10}.

Due to the growing popularity of surface ultrasound in regional anesthesia, use of this technique in epidural catheter placement has also been successfully explored yet may be limited by patient age.^{11,12} In contrast, transesophageal echocardiography (TEE) may potentially overcome this age limitation by obtaining images through the intervertebral disc. We present a series of 12 cases using TEE to visualize the structures within the spinal column as well as caudally placed thoracic epidural catheters. The real-time images generated by TEE allow for three-dimensional visual confirmation of the intraepidural spread of anesthetic, making

TEE advantageous to alternative confirmation methods. Our preliminary findings suggest that TEE can visualize thoracic epidural catheters and can evaluate injected anesthetic distribution in cardiac procedures.

CASE DESCRIPTIONS

Review of this retrospective series of cases was approved by the Institutional Review Board (Human Subjects Office, the University of Iowa, Iowa City, Iowa). Twelve cases using the caudal approach for thoracic epidural catheter placement under TEE guidance were identified. These included eight female and five male cardiac surgery patients aged between 16 days and 4 yr, weighing between 3.3 and 23.5 kg. The cases are listed in table 1 and included five ventricular septal defect repairs, four Glenn procedures and three miscellaneous cardiac cases.

After the induction of anesthesia and endotracheal intubation, a Mini-Multi TEE probe (Model T6207 (21381A), Philips, Bothell, WA) was placed at mid esophageal level. TEE is a standard monitor already used in cardiac surgery; we attempted to visualize an epidural catheter with TEE. Rotation of approximately 180 degrees until the descending aorta was identified, followed by an additional rotation of 10–20 degrees with an increased gain and depth decreased to 2–3 cm, allowed for appreciation of an image of the spinal cord, epidural space, dura mater, nerve roots, and anterior and posterior spinal arteries (fig. 1). Then, the patient was placed in lateral decubitus position for catheter insertion. After sterile preparation, an 18-gauge × 2-inch Tuohy needle (B. Braun Medical Inc., Bethlehem, PA) was inserted through the sacral hiatus and caudal space and was confirmed with loss of resistance technique. A 20-gauge Perifix multiorifice epidural catheter (B. Braun Medical Inc.) was threaded through the 18-gauge Tuohy needle into the epidural space under real-time TEE image. As soon as the catheter entered the image plane, it was fixed and a test dose of normal saline was manually injected at a rate of 1 ml/3 s to visually confirm expansion of the epidural space and catheter tip location (fig. 2).

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Table 1. Results

Case No.	Sex	Weight, kg	Surgical Procedure	Catheter Location	Haemodynamic Response to Incision
1	F	5.5	VSD repair	P	No
2	M	5.3	VSD repair	AL	Yes
3	F	5.0	Glenn procedure	A	No
4	F	3.5	VSD repair	PL	No
5	F	3.3	VSD repair	P	No
6	F	6.8	VSD repair	L	Yes
7	F	6.2	Glenn procedure	P	No
8	M	8.8	Glenn procedure	L	Yes
9	M	3.3	PDA ligation	P	No
10	F	15.3	Fontan procedure	A	No
11	F	6.7	Glenn procedure	P	No
12	M	23.5	Redo-MVR	L	Yes

AL = anterolateral; L = lateral; MVR = mitral valve repair; P = posterior; PDA = patent ductus arteriosus; VSD = ventricular septal defect.

Caudal and cephalad advancement of the TEE probe, one vertebral level above and below the injection site, distinctly verified the catheter tip. The catheter was visualized anteriorly in two patients, laterally in five patients, and posteriorly in five patients (fig. 3).

As shown in the video clip, Supplemental Digital Content 1, <http://links.lww.com/ALN/A887>, saline spread in the posterior epidural space is confirmed by real-time TEE image. Identifiable on the image is the spinal cord, epidural space, dura mater, nerve roots, and pulsating anterior and posterior spinal arteries. Surprisingly, when the test dose of saline was given, the spread of solution was not uniform within the epidural space as would be expected. Instead, saline localized around its injection point resulting in significant unilateral compression of the subarachnoid space for a period of minutes before dissipating. Then, all patients received bolus dosages of 0.2–0.4 ml/kg of 0.25% bupivacaine and 30 mcg/kg of preservative-free morphine

through the epidural catheter at least 15 min before surgical incision.

We retrospectively reviewed catheter position and patient hemodynamic records from the beginning of surgery using the following criteria from previous studies:¹² no change in heart rate or blood pressure or changes less than 20% from baseline and requiring no intravenous fentanyl were considered “no response” to surgical stimulation. Heart rate or blood pressure changes more than 20% from baseline and/or required intravenous fentanyl for hemodynamic control were considered “yes response” to surgical stimulation. Of note, each of the four patients that showed lateral catheter positioning on TEE exhibited hemodynamic response to surgical incision.

Discussion

The ability to successfully confirm thoracic epidural catheter placement in this series of 12 cases suggests TEE as a potential

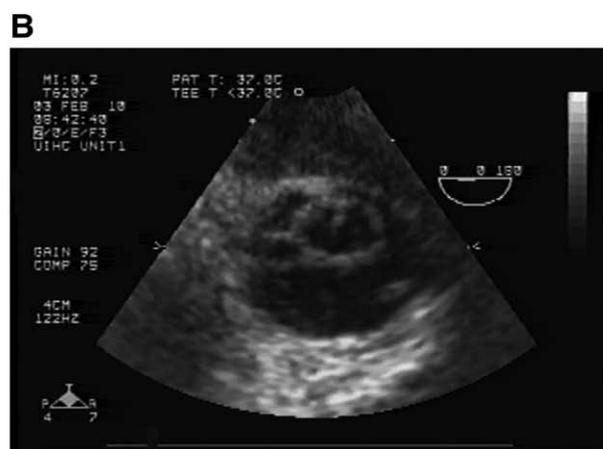
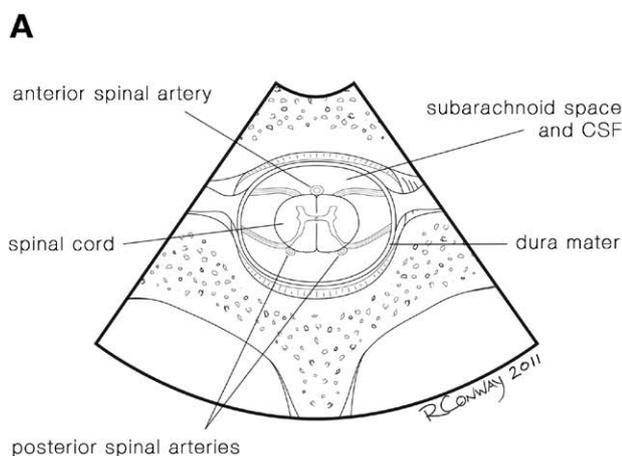


Fig. 1. A, Transesophageal echocardiogram illustration identifying the spinal cord, duramater, subarachnoid space, and CSF, and anterior and posterior spinal arteries. B, Transesophageal echocardiogram image identifying the spinal cord, dura mater, subarachnoid space, and CSF, and anterior and posterior spinal arteries. CSF = cerebral spinal fluid. Used with permission of the University of Iowa Hospital and Clinics, Iowa City, Iowa.

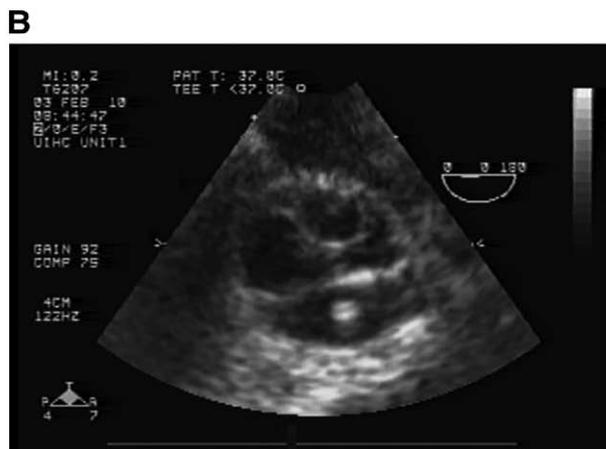
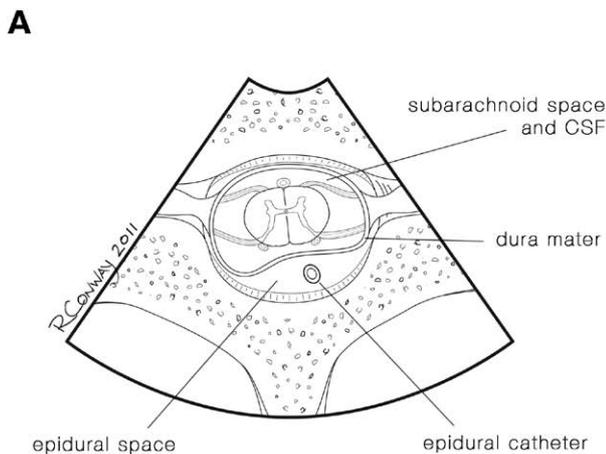


Fig. 2. A, Transesophageal echocardiogram illustration exhibiting white thoracic epidural catheter and expanded posterior epidural space due to localized saline spread. Also identifiable on the image is the spinal cord, dura mater, subarachnoid space, and CSF. B, Transesophageal echocardiogram image exhibiting white thoracic epidural catheter and expanded posterior epidural space due to localized saline spread. Also identifiable on the image is the spinal cord, dura mater, subarachnoid space, and CSF. CSF = cerebral spinal fluid. Used with permission of the University of Iowa Hospital and Clinics, Iowa City, Iowa.

alternative to radiological fluoroscopy, epidural electrocardiography, and epidural electrical stimulation. Further, the real-time imaging of anesthetic injected within the epidural space makes TEE a novel technique that provides better understanding of the mechanisms surrounding epidural drug distribution.

Although use of real-time surface ultrasound can provide epidural catheter location and show injected drug distribution, surface ultrasound fails to generate an image in patients older than 6 months of age due to ossified vertebrae interfering with the ultrasound beam.¹² In contrast, we show TEE was able to visualize an image of the spinal cord and epidural space in patients aged up to 4 yr. The TEE ultrasound beam likely generated an image through the intervertebral disc; therefore, a clear image was easily appreciated in these pediatric patients. Others report structures within the spinal canal can be seen

with TEE in some adult patients as well.^{13,14} Although we did not confirm the range of visible thoracic spinal levels in these case reports, the structures within the spinal canal at mid thoracic levels were all clearly identified in all cases reviewed.

Because two anatomical landmarks estimate thoracic spinal level *via* the TEE technique, the vertebral target level may be accurately determined. The level of the tracheal carina and esophageal–gastric junction correspond with the fifth/sixth and eleventh thoracic vertebrae, respectively.^{15,16} Further studies are warranted to determine whether there is an age limit for the visualization of spinal structures with TEE.

Because TEE is associated with minimal risk¹⁷ and is already routinely used in cardiac surgery, it serves as an ideal monitor for thoracic epidural catheter threading. Although TEE has been safely used in cardiac and noncardiac cases; it is still minimally invasive. This is especially so in neonates in whom esophageal injury, airway compression,¹⁸ or accidental endotracheal tube extubation¹⁹ can occur. Whether the use of TEE should be expanded to noncardiac cases, specifically for the purposes of anesthesia, requires further studies identifying the limits of TEE.

This case report provides insight into critical issues surrounding the efficacy of epidural block. The catheter tip could be located posterior, anterior, or laterally to the spinal cord on TEE image and intraepidural saline distribution varied depending on tip position. This observation correlates with previous studies that proposed that the uneven circumferential spread of anesthetic is due to the misplacement of the epidural catheter tip.²⁰ Further, our findings regarding lateral catheter positioning and subsequent hemodynamic response to surgical incision provide solid ground work for future studies using TEE to understand anesthetic spread and block success.

In summary, we presented successful confirmation of thoracic epidural catheter placement and tip location *via* caudal approach with TEE in 12 pediatric patients. TEE image of

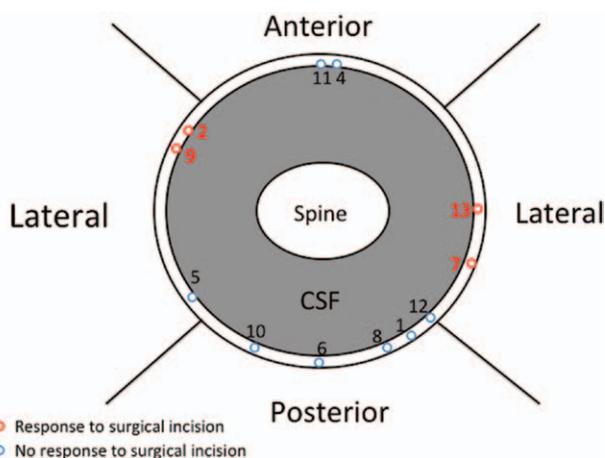


Fig. 3. Exhibits catheter tip location within the epidural space as anterior, posterior, or laterally to the spinal cord and response to surgical incision. These data correspond numerically to patient demographic data presented in table 1. CSF = cerebral spinal fluid.

lateral migration of the catheter tip followed by unilateral distribution of local anesthetic was associated with a response to surgical incision. The option to use TEE to visually assess the spread of anesthetic in both longitudinal and circumferential dimensions in the intraepidural space, make TEE potentially advantageous to other imaging methods currently in use. Further investigation is needed to assess whether TEE can be successfully used in older patients and with various levels of thoracic epidural catheterization.

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