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Catheter-Based Transepidural Approach to Cervical and Thoracic Posterior and Perineural Epidural Spaces: A Cadaveric Feasibility Study

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Abstract

BACKGROUND AND OBJECTIVES—Approaching the cervical and high thoracic level epidural space through transepidural route from lumbar region represents a method to lower the occurrence of complications associated with direct approach. The authors performed a cadaveric pilot project to determine the feasibility of various catheter-based manipulation and cephalad advancement using the transepidural route.

STUDY DESIGN AND METHODS—Two cadavers were used to determine the following: 1. Ability to place a guide sheath over a guidewire using a percutaneous approach within the posterior lumbar epidural space; 2. The highest vertebral level catheter can be advanced within the posterior epidural space; 3. Ability to cross midline within the posterior epidural space; and 4. Ability to catheterize the perineural epidural sheaths of the nerve roots exiting at cervical and thoracic vertebral levels.

RESULTS—We were able to advance the catheters up to the level of cervical vertebral level of C2 within the posterior epidural space under fluoroscopic guidance from a sheath inserted via oblique parasagittal approach at the lumbar L4–L5 intervertebral space. We were able to cross midline within the posterior epidural space and catheterize multiple perineural epidural sheaths of the nerve roots exiting at cervical vertebral level of C2, C3, and C4 on ipsilateral or contralateral sides. We also catheterized multiple epidural sheaths that surround the nerve roots exiting at the thoracic vertebral level on ipsilateral or contralateral sides.

CONCLUSIONS—We were able to advance a catheter or microcatheter up to the cervical vertebral level within the posterior epidural space and catheterize the perineural epidural sheath of the nerve root exiting at cervical and thoracic vertebral levels. Such observations support further exploration of percutaneous catheter based transepidural approach to cervical and thoracic dorsal epidural spaces for therapeutic interventions.

Keywords

Transepidural approach; epidural sheath; catheter; microcatheter; cervical vertebra; thoracic vertebra; lumbar vertebrae; nerve roots

INTRODUCTION

Accessing the cervical and high thoracic epidural spaces is desirable for the injection of therapeutic agents and currently requires direct entry through interlaminar or transforaminal epidural approaches [13,29]. The vertebral artery in proximity to the trajectory of epidural cervical approach [16,24] and direct injury can result in fatal and nonfatal vertebrobasilar or anterior spinal artery distribution ischemic strokes [18,36,40]. Headache, seizures [3], neck pain [10], cardiac arrest due to vasovagal stimulation [31,38], air embolism-related myelopathy [32], syrinx formation [26], and radicular artery perforation [43] have been reported with direct

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cervical epidural approach. Urinary retention and hypotension [4,45] spinal hematoma [28], dural perforation [33], cerebrospinal fluid cutaneous fistula [17], local bleeding [30], and radicular pain syndrome [37] have been reported with direct thoracic epidural access.

Approaching the cervical and high thoracic level epidural space through transepidural route from the lumbar region represents a method to lower the occurrence of the aforementioned complications. The epidural space is enclosed between the dura mater and the walls of the vertebral canal with intermittent attachment by displaceable connective tissue [22,34]. Between the dura mater and the vertebral canal is a thin layer of areolar tissue containing the internal vertebral venous plexus and a posterior deposit of fat which lies in a recess between the ligamenta flava [34]. The feasibility of advancing and manipulating catheters for diagnostic and therapeutic purposes has been supported by placement and advancement of 18-gauge epidural catheter to a depth of 2.5 to 5 cm in the epidural space [8,9,15,20,35] and lead delivery system into the epidural space from lumbar vertebra 4–5 levels up to thoracic vertebra 12 levels [27]. We performed this study to determine the feasibility of various catheter-based manipulation and cephalad advancement using the transepidural route within a cadaver model.

METHODS

The study protocol was reviewed and approved by the Anatomy Bequest Program at the University of Minnesota, Minneapolis, MN. Fresh human cadavers were placed in prone position. The image intensifier of angiographic unit was angled to optimally demonstrate the space between the spinous processes and laminae of L4 and L5 vertebra. The oblique parasagittal technique was performed by placing the needle on left side of the spinous process. The fluoroscopic beam was placed in caudal angulation. A 16-gauge Tuohy spinal needle was advanced cephalad at an angle of 10° and toward midline at an angle of 20°. Subsequently, the lateral plane was imaged using fluoroscopy and a 16-gauge Tuohy spinal needle was advanced into the interspace between the spinous processes and laminae of L4 and L5. The loss of resistance method with a plastic syringe was used to localize the epidural space while advancing the Tuohy needle [15]. A total of 1°cc of Gastrografin (Bracco Diagnostics Inc., Monroe Township, NJ) diluted with 2°cc of water, was injected to confirm the cephalad posterior epidural spread on the lateral view [44]. A floppy-tipped 0.035-inch guidewire was then advanced into the epidural space, followed by removal of the needle. A 5 or 6 Fr short catheter with 4–5 Fr inner dilator is placed over the existing wire, followed by removal of the dilator and wire.

In the first cadaver experiment, a 100-cm GLIDECATH® (5 Fr) angle tapered (Terumo Glide Technology, Somerset, NJ) hydrophilic coated distal tip (40 cm) was advanced cephalad within the posterior epidural space without a guidewire. In the second cadaver experiments, PROWLER® SELECT® Plus microcatheter 45 angle 2.8F/2.3F (Codman & Shurtleff, Inc. Raynham, MA) was used with intermittent use of Synchro2 TM guidewire (Boston Scientific, Natick MA) 0.014 inch 200 cm to facilitate advancement and navigation of microcatheter. The catheter/microcatheter was advanced within the posterior epidural space in the cephalad direction under fluoroscopic guidance until resistance was noted. At that point, catheter/microcatheter was manipulated with or without microwire assistance until a path could be identified for advancing the catheter/microcatheter. If this step was not successful, 1cc of Gastrografin diluted with 2cc of water was injected through the catheter/microcatheter to identify a patent cephalad epidural space based on posterior epidural spread on the antereoposterior view. The catheter/microcatheter was manipulated with or without microwire assistance to traverse the identified patent epidural channel. Attempts were made to place the catheter/microcatheter into the perineural epidural sheath of nerve roots exiting at cervical and thoracic vertebral levels. When the catheter/microcatheter was positioned under fluoroscopic guidance, 1cc of gastrografin diluted with 2cc of water was injected to confirm the position of catheter/microcatheter by opacification of the perineural epidural sheath. The arch of C-1 and the atlanto-occipital joint, the superior and inferior most ribs, [11] 10th rib line [25] (an imaginary line that joins the lowest points of the rib cage on the flanks) and first sacroiliac joint were used for the identification of the correct vertebral level.

The endpoints accessed in the study were as follows: 1. Ability to place a guide sheath over a guidewire using a percutaneous approach within the posterior epidural space; 2. The highest vertebral level catheter/microcatheter can be advanced within the posterior epidural space; 3. Ability to cross midline within the posterior epidural space; and 4. Ability to catheterized the perineural epidural sheath of the nerve roots exiting at level of cervical and thoracic vertebra.

RESULTS

We were able to place a guide sheath over a guidewire using a percutaneous approach within the posterior epi-

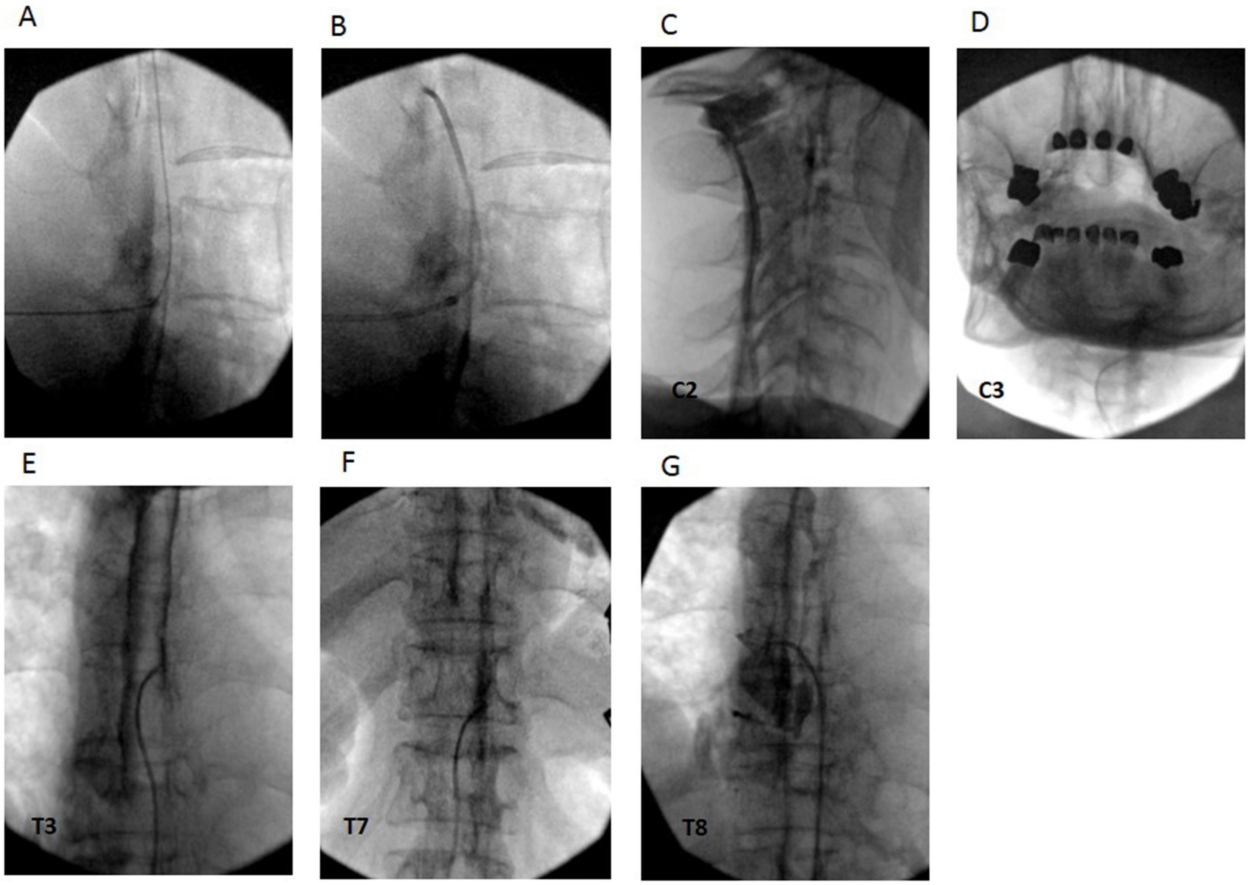

Figure 1. A–B. The 6F guide sheath introduced over a 0.035-inch short guide wire and GLIDECATH® (5 Fr) advanced into the posterior epidural space through the guide sheath. C. Epidural contrast injection from GLIDECATH® (5 Fr) at level of cervical vertebral level of C2 within the posterior epidural space. D–G. Catheterization the perineural epidural sheath of the nerve root exiting at cervical and thoracic vertebra.

dural space in both cadaveric experiments. In both experiments, we noticed an anterior bulge of the guide sheath at the entry point into the epidural space.

In the first cadaveric experiment, we were able to advance the GLIDECATH® (5 Fr) up to level of cervical vertebra C2 within the posterior epidural space. We were able to cross midline within the posterior epidural space. We catheterized the perineural epidural sheath of the nerve roots exiting at cervical vertebral level of C2 and C3 on contralateral side. We catheterized the perineural epidural sheath of the nerve roots exiting at thoracic vertebral level of T3 and T7 on contralateral side and thoracic vertebral level T8 on ispilateral side. (Fig.1). There was technical difficulty noticed in advancing the catheter into the perineural epidural sheaths presumably due to the size of catheter.

In the second cadaveric experiment, we were able to advance the PROWLER® SELECT® Plus microcatheter (Codman & Shurtleff, Inc. Raynham, MA) up to the level of cervical vertebra C2 within the posterior epidural space. We were able to cross midline within the posterior epidural space. The success of catheterizing the perineural epidural sheaths was higher with PROWLER® SELECT® Plus microcatheter. We catheterized the perineural epidural sheath of the nerve roots exiting at cervical vertebral levels of C3, C4, C5, and C6 on ipsilateral side. We catheterized the perineural epidural sheath of the nerve roots exiting at thoracic vertebral levels of T4 and of T5 and T6 on ipsilateral and contralateral sides, respectively. We catheterized the perineural epidural sheath of the nerve roots exiting at lumbar vertebral levels of L1 and L2 on ipsilateral and contralateral sides. (Fig. 2) There was greater technical ease noticed in advancing the microcatheter into the perineural epidural sheaths presumably due to smaller size of microcatheter.

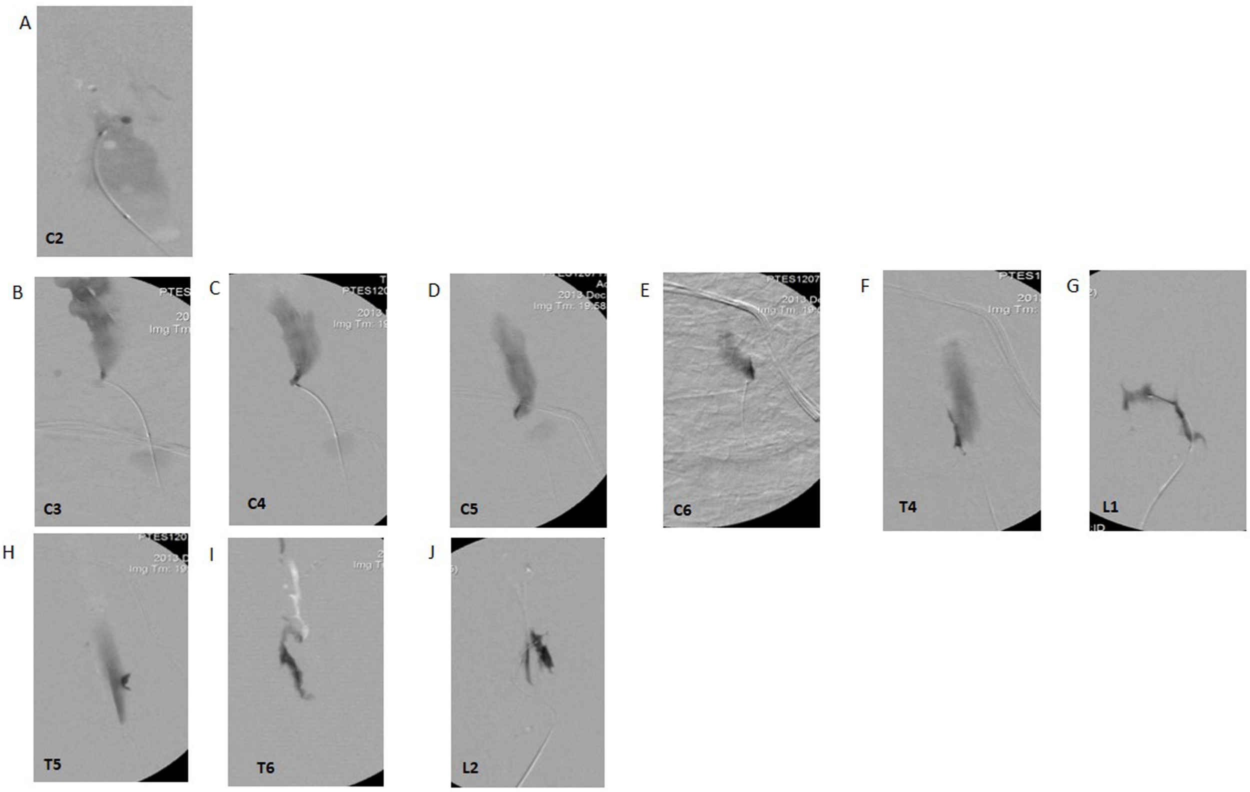

Figure 2. First row: A. Contrast injection from PROWLER® SELECT® Plus microcatheter at level of cervical vertebra C2 opacifying the posterior epidural space.
Second row: B–G, Catheterization the perineural epidural sheath of the nerve root exiting at cervical, thoracic, and lumbar vertebra on ipsilateral side.
Third row: H–J, Catheterization the perineural epidural sheath of the nerve root exiting at thoracic and lumbar vertebra on contralateral side.

DISCUSSION

In our experiments, we were able to place a guide sheath over a guidewire using a percutaneous approach within the posterior epidural space in the lower lumbar region and advance a catheter or microcatheter up to the cervical vertebral level and maneuver the catheter in both ipsilateral and contralateral direction under fluoroscopic guidance. We were ability to catheterize the perineural epidural sheath of the nerve roots exiting at cervical and thoracic vertebral levels. Amar et al. [2] reported the feasibility of advancing a 2.3-French microcatheter and a 0.018-inch steerable guidewire through a 18-gauge Tuohy needle into the lumbar epidural space and advancing the catheter to the cervical epidural space in 13 patients. The authors did not attempt manipulation of microcatheter along the transverse axis or direct catheterization into the epidural sheath surrounding the exiting nerve roots. Cephalad advancement of epidural catheters to the thoracic region via the caudal route has been shown to be feasible in neonates and small infants [21,42]. Gunter and Eng [21] advanced 24-G epidural catheter (20/24 microcatheter system) with stylet into the epidural space through a 20-G intravenous catheter inserted through the sacrococcygeal ligament, and advanced the catheter to lower thoracic segments in 20 children. However, Valairucha et al. [42] reported that cephalad advancement of epidural catheters without fluoroscopic guidance can result in inadequate placement in 32% of infants. Catheters were inadvertently introduced in high thoracic or cervical region or were coiled in the lumbosacral area. One catheter was found to be outside the epidural space in the presacral area. Blanco et al. [7] inserted and advanced a 19-G catheter into the epidural space at L4-5 level through an 18-G Tuohy needle with bevel directed cephalad. In the absence of fluoroscopic guidance, the catheter tip reached the target of thoracic vertebral levels of T10 to T12 in only 22% of the infants. The technical success of cephalad advancement of small catheters is limited in children over the age of 1 year without the ability to manipulate the catheter with real-time feedback by fluoroscopic imaging [6].

Our observations along with those of Amar et al. [2] support further exploration of percutaneous catheter based transepidural approach to cervical and thoracic dorsal epidural spaces. There is a range of microcatheters that are currently commercially available for the catheterization of tortuous arteries of the brain. The stainless steel or platinum-braided microcatheters with or without tapering have a degree of flexibility to traverse remote vascular locations and a degree of strength to advance the microcatheter with adequate propulsion. Our experiments suggest that off label use [1] of such microcatheters in the dorsal epidural space is possible using routinely available fluoroscopic units. Most portable angiographic C arm units have road-mapping capability which allows digitally acquired angiographic images to be superimposed at the same magnification and radiologic projection as the live fluoroscopic image onto the video monitor. The digital roadmap image provides immediate feedback to the interventional physician enabling them to direct the catheter/microcatheter into the appropriate direction within the posterior epidural space [41]. The next generation of angiographic units allows 3D dynamic roadmapping in deformable regions with live fluoroscopy to facilitate catheter manipulations and compensate for the apparent respiratory motion [5,19]. Therefore, the advances in both imaging and microcatheter technology are expected to increase the technical success of percutaneous catheter-based transepidural approaches. The range of transepidural approach-based procedures may include multilevel selective injection of anesthetics into epidural nerve root sheaths, selective delivery of antibiotics and chemotherapeutic agents in settings of epidural metastases or abscesses, and even delivery of implantable devices.

The limitations of transepidural space include the necessity of contiguous patency of posterior transepidural space in patients. Diminished epidural contents, discontinuous ligamentum flavum, and formation of compartments at the thoracic and cervical levels may provide restrictions on microcatheter manipulation and advancement [22]. As seen in another experiment [unpublished data], deformities in the vertebral bones prevent adequate manipulation of the microcatheter within the epidural space. Postsurgical adhesions within the epidural space can result in obliteration of the passage for cephalad passage of the microcatheter within transepidural space [14,23]. Takeshima et al. [39]characterized epidural adhesions using a video-guided catheter with an endoscope in patients with failed back syndrome.The epidural adhesions involved in epidural space alone, epidural space and nerve root sheath, and nerve sheath alone in 10, 9, and 9 patients, respectively [39]. Contrast injected in the epidural space can identify epidural fibrosis as filling defects [12] which may allow manipulation of the microcatheter between the adhesions. In elderly individuals, compression of the epidural space is not uncommon due to degenerative disc and joint changes [22]. However, complete obliteration of epidural space at any spinal level is uncommon with the aforementioned processes. The percutaneous introduction of a sheath in the epidural space through lumbar approach provides a stable platform for inward or outward movement of the microcatheter. Although technically feasible, the mechanical distortion of the epidural space at point of entry due to stiffness of the sheath and immediate and long-term consequences of such distortion require further investigation.

CONCLUSIONS

In our experiments, we were able to access and advance a catheter or microcatheter up to the cervical vertebral level within the posterior epidural space from the lower lumbar region. We were also able to catheterize the perineural epidural sheath of the nerve roots exiting at cervical and thoracic vertebral levels. Such observations support further exploration of percutaneous catheter-based transepidural approach to access cervical and thoracic dorsal epidural spaces for therapeutic interventions.

References

1. Abdihalim MM, Hassan AE, Qureshi AI. Off-label use of drugs and devices in the neuroendovascular suite. *AJNR Am J Neuroradiol* 2013;34:2054–2063.
2. Amar AP, Wang MY, Larsen DW, Teitelbaum GP. Microcatheterization of the cervical epidural space via lumbar puncture: technical note. *Neurosurgery* 2001;48:1183–1187.
3. Arora D, Mehta Y, Jain A, Trehan N. Headache and seizures after cervical epidural injection in a patient undergoing coronary artery bypass grafting. *Ann Card Anaesth* 2012;15:244–246.
4. Baidya DK, Khanna P, Maitra S. Analgesic efficacy and safety of thoracic paravertebral and epidural analgesia for thoracic surgery: a systematic review and meta-analysis. *Interact Cardiovasc Thorac Surg* 2014
5. Bender F, Groher M, Khamene A, Wein W, Heibel TH, Navab N. 3D dynamic roadmapping for abdominal catheterizations. *Med Image Comput Comput Assist Interv* 2008;11:668–675.
6. Blanco D, Llamazares J, Martinez-Mora J, Vidal F. Thoracic epidural anesthesia by the caudal route in pediatric anesthesia: Age is a limiting factor. *Rev Esp Anestesiol Reanim* 1994;41:214–216.
7. Blanco D, Llamazares J, Rincon R, Ortiz M, Vidal F. Thoracic epidural anesthesia via the lumbar approach in infants and children. *Anesthesiology* 1996;84:1312–1316.
8. Blomberg RG. Technical advantages of the paramedian approach

for lumbar epidural puncture and catheter introduction. A study using epiduroscopy in autopsy subjects. *Anaesthesia* 1988;43:837–843.

9. Blomberg RG, Jaanivald A, Walther S. Advantages of the paramedian approach for lumbar epidural analgesia with catheter technique. A clinical comparison between midline and paramedian approaches. *Anaesthesia* 1989;44:742–746.

10. Botwin KP, Castellanos R, Rao S, Hanna AF, Torres-Ramos FM, Gruber RD, Bouchlas CG, Fuoco GS. Complications of fluoroscopically guided interlaminar cervical epidural injections. *Arch Phys Med Rehabil* 2003;84:627–633.

11. Connor SE, Shah A, Latifoltojar H, Lung P. MRI-based anatomical landmarks for the identification of thoracic vertebral levels. *Clin Radiol* 2013;68:1260–1267.

12. Devulder J, Bogaert L, Castille F, Moerman A, Rolly G. Relevance of epidurography and epidural adhesiolysis in chronic failed back surgery patients. *Clin J Pain* 1995;11:147–150.

13. El Abd OH, Amadera JE, Pimentel DC, Pimentel TS. Intravascular flow detection during transforaminal epidural injections: A prospective assessment. *Pain Physician* 2014;17:21–27.

14. Epter RS, Helm S 2nd, Hayek SM, Benyamin RM, Smith HS, Abdi S. Systematic review of percutaneous adhesiolysis and management of chronic low back pain in post lumbar surgery syndrome. *Pain Physician* 2009;12:361–378.

15. Evron S, Sessler D, Sadan O, Boaz M, Glezerman M, Ezri T. Identification of the epidural space: loss of resistance with air, lidocaine, or the combination of air and lidocaine. *Anesth Analg* 2004;99:245–250.

16. Fitzgerald RT, Bartynski WS, Collins HR. Vertebral artery position in the setting of cervical degenerative disease: Implications for selective cervical transforaminal epidural injections. *Interv Neuroradiol* 2013;19:425–431.

17. Franklin AD, Hays SR. Successful management of a thoracic cerebrospinal fluid cutaneous fistula in a two year old child using a thoracic epidural blood patch. *J Clin Anesth* 2013;25:331–334.

18. Furman MB, Giovanniello MT, O'Brien EM. Incidence of intravascular penetration in transforaminal cervical epidural steroid injections. *Spine (Phila Pa 1976)* 2003;28:21–25.

19. Glockler M, Halbfabeta J, Koch A, Achenbach S, Dittrich S. Multimodality 3D-roadmap for cardiovascular interventions in congenital heart disease–A single-center, retrospective analysis of 78 cases. *Catheter Cardiovasc Interv* 2013;82:436–442.

20. Griffin RM, Scott RP. Forum. A comparison between the midline and paramedian approaches to the extradural space. *Anaesthesia* 1984;39:584–586.

21. Gunter JB, Eng C. Thoracic epidural anesthesia via the caudal approach in children. *Anesthesiology* 1992;76:935–938.

22. Hogan QH. Epidural anatomy examined by cryomicrotome section. Influence of age, vertebral level, and disease. *Reg Anesth* 1996;21:395–406.

23. Hsu E, Atanelov L, Plunkett AR, Chai N, Chen Y, Cohen SP. Epidural lysis of adhesions for failed back surgery and spinal stenosis: Factors associated with treatment outcome. *Anesth Analg* 2014;118:215–224.

24. Jee H, Lee JH, Kim J, Park KD, Lee WY, Park Y. Ultrasound-guided selective nerve root block versus fluoroscopy-guided transforaminal block for the treatment of radicular pain in the lower cervical spine: A randomized, blinded, controlled study. *Skeletal Radiol* 2013;42:69–78.

25. Jung CW, Bahk JH, Lee JH, Lim YJ. The tenth rib line as a new landmark of the lumbar vertebral level during spinal block. *Anaesthesia* 2004;59:359–363.

26. Khan S, Pioro EP. Cervical epidural injection complicated by syrinx formation: A case report. *Spine (Phila Pa 1976)* 2010;35:E614–E616.

27. Kinfe TM, Schu S, Quack FJ, Wille C, Vesper J. Percutaneous implanted paddle lead for spinal cord stimulation: Technical considerations and long-term follow-up. *Neuromodulation* 2012;15:402–407.

28. Ladha A, Alam A, Idestrup C, Sawyer J, Choi S. Spinal haematoma after removal of a thoracic epidural catheter in a patient with coagulopathy resulting from unexpected vitamin K deficiency. *Anaesthesia* 2013;68:856–860.

29. Manchikanti L, Cash KA, Pampati V, Malla Y. Two-year follow-up results of fluoroscopic cervical epidural injections in chronic axial or discogenic neck pain: A randomized, double-blind, controlled trial. *Int J Med Sci* 2014;11:309–320.

30. Manchikanti L, Malla Y, Wargo BW, Cash KA, Pampati V, Fellows B. Complications of fluoroscopically directed facet joint nerve blocks: A prospective evaluation of 7,500 episodes with 43,000 nerve blocks. *Pain Physician* 2012;15:E143–E150.

31. Markewich S, Wunnava M. Unclear mechanism of cardiopulmonary arrest following cervical epidural steroid injection. *Pain Physician* 2012;15:E539–E540.

32. Mehta S, Khalil AA, Alshekhlee A. Air myelopathy following a cervical epidural injection. *Pain Med* 2010;11:1678–1679.

33. Meyer-Bender A, Kern A, Pollwein B, Crispin A, Lang PM. Incidence and predictors of immediate complications following perioperative non-obstetric epidural punctures. *BMC Anesthesiol* 2012;12:31.

34. Parkin IG, Harrison GR. The topographical anatomy of the lumbar epidural space. *J Anat* 1985;141:211–217.

35. Podder S, Kumar N, Yaddanapudi LN, Chari P. Paramedian lumbar epidural catheter insertion with patients in the sitting position is equally successful in the flexed and unflexed spine. *Anesth Analg* 2004;99:1829–1832.

36. Scanlon GC, Moeller-Bertram T, Romanowsky SM, Wallace MS. Cervical transforaminal epidural steroid injections: More dangerous than we think? *Spine (Phila Pa 1976)* 2007;32:1249–1256.

37. Scherer R, Schmutzler M, Giebler R, Erhard J, Stocker L, Kox WJ. Complications related to thoracic epidural analgesia: A prospective study in 1071 surgical patients. *Acta Anaesthesiol Scand* 1993;37:370–374.

38. Stauber B, Ma L, Nazari R. Cardiopulmonary arrest following cervical epidural injection. *Pain Physician* 2012;15:147–152.

39. Takeshima N, Miyakawa H, Okuda K, Hattori S, Hagiwara S, Takatani J, Noguchi T. Evaluation of the therapeutic results of epiduroscopic adhesiolysis for failed back surgery syndrome. *Br J Anaesth* 2009;102:400–407.

40. Tiso RL, Cutler T, Catania JA, Whalen K. Adverse central nervous system sequelae after selective transforaminal block: The role of corticosteroids. *Spine J* 2004;4:468–474.

41. Tobis J, Johnston WD, Montelli S, Henderson E, Roeck W, Bauer B, Nalcioglu O, Henry W. Digital coronary roadmapping as an aid for performing coronary angioplasty. *Am J Cardiol* 1985;56:237–241.

42. Valairucha S, Seefelder C, Houck CS. Thoracic epidural catheters placed by the caudal route in infants: The importance of radiographic confirmation. *Paediatr Anaesth* 2002;12:424–428.

43. Verrills P, Nowesenitz G, Barnard A. Penetration of a cervical rad-

icular artery during a transforaminal epidural injection. *Pain Med* 2010;11:229–231.

44. Weil L, Frauwirth NH, Amirdelfan K, Grant D, Rosenberg JA. Fluoroscopic analysis of lumbar epidural contrast spread after lumbar interlaminar injection. *Arch Phys Med Rehabil* 2008;89:413–416.

45. Wuethrich PY, Kessler TM, Burkhard FC. The effects of thoracic epidurally administered drugs on urethral sphincter function in women: A pooled analysis. *Pain Med* 2013;14:1248–1253.