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

Adnan I. Qureshi, MD, Mushtaq H. Qureshi, MD, Ahmed A. Malik, MD, Asif A. Khan, MD, Amna Sohail, MD, Aveen Saed, MD, and Vikram Jadhav, MD, PhD
Zeenat Qureshi Stroke Institute, St. Cloud, MN, USA

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 transfornaminal 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 vertebrobasil 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...
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 1cc of Gastrografin (Bracco Diagnostics Inc., Monroe Township, NJ) diluted with 2cc of water was injected through the catheter/microcatheter to identify a patent cephalad epidural space; 2. The highest vertebral level 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 anteroposterior 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-
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 levels of C2 and C3 on contralateral side. We catheterized the perineural epidural sheath of the nerve roots exiting at thoracic vertebral levels of T3 and T7 on contralateral side and thoracic vertebral level T8 on ipsilateral 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 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.

Qureshi et al. 45

Journal of Vascular and Interventional Neurology, Vol. 8
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 lumbar vertebral on ipsilateral side. Amari 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
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 transendural space [14,23]. Takeshima et al. [39] characterized epidural adhesions using a video-guided catheter with an endoscope in patients with failed back syndrome.

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

8. Blomberg RG. Technical advantages of the paramedian approach


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