Mini-Review

Protecting the spinal cord during thoracic endovascular aortic repair—who should place the spinal drain?

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Contributions: (I) Conception and design: ED Foley; (II) Administrative support: None; (III) Provision of study materials or patients: ED Foley; (IV) Collection and assembly of data: None; (V) Data analysis and interpretation: None; (VI) Manuscript writing: Both authors; (VII) Final approval of manuscript: Both authors.

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Abstract: A well-placed and functioning lumbar spinal drain, for spinal cord protection, is an important aspect of the perioperative care of patients undergoing thoracic endovascular aortic repair (TEVAR) procedures. Spinal cord injury (SCI) is a devastating complication of TEVAR procedures and is most often associated with Crawford type 2 repairs. Current evidence-based guidelines for the surgical management of patients with thoracic aortic disease include the role of lumbar spine catheter placement and drainage of cerebrospinal fluid (CSF) intraoperatively as part of a strategy to prevent spinal cord ischemia. More often than not, the procedure of lumbar spinal drain placement, using a standard blind technique, and subsequent drain management is the responsibility of the anesthesiologist. However, institutional protocols are inconsistent, and, failure to successfully place the lumbar spinal drain pre-operatively in the operating room, in clinical situations such as patients with poor anatomical landmarks or prior back surgery, presents a clinical dilemma and impacts spinal cord protection during TEVAR. Although a relatively safe procedure, potential complications of lumbar spine catheter placement range from a self-limiting headache to hemorrhage and permanent neurological injury. Spinal drain placement with image-guided fluoroscopy by interventional radiology should be considered in the preoperative assessment and planning and is an alternative to conventional, blind lumbar drain insertion.

Keywords: Lumbar spinal drain; paraparesis; paralysis; thoracic endovascular aortic repair (TEVAR)

Submitted Dec 22, 2022. Accepted for publication Apr 25, 2023. Published online May 30, 2023.
doi: 10.21037/jss-22-116
View this article at: https://dx.doi.org/10.21037/jss-22-116

Introduction

In the absence of a consistently reliable and successful method to prevent spinal cord ischemia during thoracic endovascular aortic repair (TEVAR), the value of lumbar spine catheter placement and drainage of cerebrospinal fluid (CSF) cannot be overstated. More often than not, the procedure of lumbar spinal drain placement and subsequent drain management is the responsibility of the anesthesiologist. However, there is no universally accepted evidence-based clinical approach and there are significant risks associated with the procedure. Current evidence-based guidelines for the management of patients with thoracic aortic disease, endorsed by many international societies, have been published in both North America and Europe, which include the role of lumbar spinal drainage of CSF. While the details of both sets of guidelines differ, they both promote lumbar drain placement for TEVAR among other methods to prevent spinal cord ischemia. Given how devastating a complication spinal cord ischemia is known to be, including the association with earlier mortality, a particular clinical dilemma arises when the drain is unable to be placed in the operating room prior to the procedure or when there is a significant clinical complication with placing the drain, such as drain migration out of the intrathecal space or drain blockage prior to the start of surgery.

The National Inpatient Sample data for the twelve-year period from 2000 through 2012 shows that the use of TEVAR for thoracic aortic aneurysms and dissections significantly increased, whereas in-patient mortality steadily decreased (1). The Food and Drug Administration (FDA) approved the TEVAR procedure in 2005. With a yearly average mortality of approximately 46,817 patients, it is known that the natural history of descending thoracic aneurysms/thoracoabdominal aortic aneurysms (DTA/TAAA) is devastating with 5-year survival rates ranging from 13–50%. The majority of patients are elderly and are unable to tolerate the significant physiological insult of open surgical repair (2). Historically, Crawford type 2 aneurysm repair patients have suffered most often from postoperative spinal cord injury (SCI) (3). However, in the last three decades, outcomes from open surgical procedures for DTA/TAAA repair have improved co-incidentally with the introduction of several neuroprotective adjuncts and possibly due to CSF drainage. The current benchmark for endovascular repair-associated SCI is approximately 2–6% for all types of Crawford aneurysms with Crawford type 2 repairs being the most extensive and posing the greatest risk of postoperative spinal cord deficit (4). SCI is debilitating for the patient, increases healthcare costs as well as early mortality and can become a significant socio-economic burden. The most recent US guidelines from the American Heart Association/American Heart Foundation (AHA/AHF) published in 2010 recommend CSF drainage for TAAA open and endovascular repairs (5). Additionally, a Position Statement from the European Association for Cardiothoracic Surgeons recommends that CSF drainage be considered in patients undergoing TEVAR for prevention of SCI, though with mostly expert opinion evidence, not randomized controlled trials (RCTs) (6). The evidence for lumbar drains in open repair to significantly reduce SCI is available and meta-analysis and retrospective analysis of studies has concluded that SCF drainage confers some advantage in reducing the risk of SCI in open TAAA repairs (7,8). However, similar high quality data is not available for TEVAR procedures.

Indications and protocols for CSF drain use during TEVAR vary widely between institutions across North America. While the placement of a spinal drain is not required in every patient undergoing TEVAR, patients considered for prophylactic CSF drain placement are those deemed at high risk for spinal cord ischemia. A study by Suarez-Pierre *et al.* of 1,292 propensity-matched pairs of patients (2,584 total patients) from the Vascular Quality Initiative TEVAR registry found that spinal drain placement was associated with a reduced risk of SCI [1.5% *vs.* 2.5%; risk-adjusted odds ratio (OR), 0.47; 95% confidence interval (CI): 0.24–0.89; P=0.02]. In this study, among patients undergoing thoracic and thoracoabdominal endovascular aortic repair, preoperative placement of a spinal drain, compared with no drain, was associated with reduced risk of SCI (9).

Given the paucity of reliable pharmacological interventions to protect the spinal cord, options are generally limited to CSF drainage and management of hemodynamics affecting blood pressure in particular. Therefore, a clinical dilemma for the perioperative team presents when we are unable to place the lumbar drain successfully. What is the best way to manage this problem—continue with the case without a lumbar drain in situ, refer the patient to interventional radiology emergently or postpone the case and reschedule the operation for another date? We recommend an urgent consultation with IR and to transport the patient under general anesthesia to interventional radiology for placement under fluoroscopic guidance.

There are some reasons why SCI may be less of a concern with TEVAR than with open repair considering TEVAR procedures avoid cross-clamping the aorta as well as reimplanting spinal arteries. In light of the recent research data, based on behavior, MRI, histopathological and metabolome comparisons, evidence suggests that the mechanisms of SCI from endovascular repair seem to be drastically different to those from open repair (10). Despite the surgical differences, the risk of SCI between endovascular repair and surgical repair is not significantly different with the most important factor being the extent of the aortic disease and the extent of the aortic repair. Prior distal abdominal aortic aneurysm (AAA) repair preceding endovascular repair increases this risk.

At our institution, we use standard American Society of Anesthesia (ASA) monitoring with bispectral index (BIS) depth of anesthesia monitoring, intraoperative transesophageal echocardiography (TEE), pre-induction arterial line placement for dynamic blood pressure monitoring, awake lumbar spinal drain placement in the sitting position (*Figure 1*) and somatosensory evoked potential/motor evoked potential (SSEP/MEP) neurophysiological monitoring.

Additionally, we usually decide upon central venous line (CVL) placement post induction of anesthesia depending on our peripheral intravenous access. SSEP are less sensitive to

Figure 1 Awake lumbar spinal drain placement, sitting position.

anesthetic drugs, less complex and limited to integrity of the lateral and posterior columns of the spinal cord. MEP are very sensitive to anesthetic medications as well as paralytics and are associated with the phenomenon of anesthetic fade. Recognition of this feature is important to avoid false-positive MEP interpretation.

Hypothermia is associated with decreased metabolic demand and reduced spinal cord oxygen consumption. Cellular protection by membrane stabilization and attenuating the inflammatory responses to ischemia during reperfusion are also beneficial. Based on this, regional spinal cord epidural cooling would seem to offer some benefit, however, contamination issues and the recognition that edema may occur on cessation of cooling are two of the reasons why we do not use this method. Delayed postoperative rewarming is part of the TEVAR protocol in some institutions however, there are no RCTs to support this approach. At our institution, we allow passive rewarming of patients in the post-operative period rather than active warming. Additionally, the use of free radical scavengers, barbiturates, steroids and intrathecal papaverine theoretically may confer some benefit, however they have failed to gain widespread acceptance and we do not use any of these pharmacological agents. Naloxone infusions up to 1 microgram/kilogram/hour in addition to bolus doses of mannitol and methylprednisolone have been associated with some spinal cord protection. However, these patients required greater quantities of opioid analgesics and experienced higher postoperative pain scores compared with patients not managed with naloxone. Glutamate inhibition could explain the neuroprotective effects of naloxone. Evidence suggests the role of kappa receptors in SCI, with minimal delta receptor involvement. Naloxone may also reduce proteolysis, neutrophil superoxidase release and fluctuations in calcium movement across membranes. The observation that similar reductions in SCI can be achieved by combining different therapies, seems to reflect the complexity of spinal cord blood supply and neuronal injury. Hyperbaric oxygen therapy has been described in several case reports as part of the multimodal treatment for spinal cord ischemia, including as adjunct rescue treatment for patients with SCI refractory to traditional medical management.

Traditional teaching is spinal cord perfusion pressure (SCPP) = mean arterial pressure (MAP) – CSF pressure. As in most centers, we target a perfusion pressure of 70 mmHg with MAP goal over 80 mmHg with or without norepinephrine (NE) infusion. Theoretically, it has been shown that aggressive use of hyperosmotic agents and hyperventilation may be as effective as spinal drainage in maintaining SCPP (11). At our institution, we recommend CSF drainage to keep CSF pressure 10–15 cmH_2O with up to 20 cc per hour fluid removal and to leave the catheter in situ for at least 72 hours post operatively.

Given the reliance on a functioning CSF drain, there is a dilemma for anesthesiologists in the event that we are unable to successfully place the catheter prior to TEVAR. Known factors associated with difficult neuraxial blockade (NAB) are quality of anatomical landmarks, patient positioning, anesthesiologist's experience, prior back surgery and the presence of lumbar spine hardware. We recommend a referral to interventional radiology in the event that lumbar drain placement is anticipated to be difficult on preoperative assessment, multiple failed prior attempts at NAB or for post-operative patients with a coagulopathy if the anesthesiologist is uncomfortable placing the drain blindly. A recent 2021 systematic review of RCTs with meta-analysis and trial sequential analysis sought to compare the efficacy, efficiency and the safety of pre-procedural ultrasound to landmark palpation in the non-obstetric adult population. Pre-procedural ultrasound increased the total time taken and subgroup analyses revealed no influence of the predicted difficulty of the neuraxial procedure on outcomes (12). Interventional radiologists (IR) catheterize the spinal canal with patients in the prone position which is associated with less CSF loss and better patient satisfaction scores when compared to the sitting position (13). Other advantages of IR placed drains are constant visualization of the spinal canal, position of the catheter tip can be verified and unlike anesthesiologists, the paramedian approach is used more often.

In summary, to prevent SCI there are many important factors for anesthesiologists to consider in patients undergoing TEVAR—appropriate selection of patients, early referral to IR for a perceived difficult spinal drain placement, anesthetic drugs affecting SSEP/MEP monitoring, blood pressure and spinal cord perfusion pressure goals, body temperature and rewarming in the immediate post-operative period. Despite many advances and improvements in our understanding of spinal cord perfusion, spinal cord ischemia and infarction causing postoperative injury remains an important and debilitating complication of TEVAR with the associated morbidity and mortality justifying the routine clinical application of techniques to prevent and treat SCI. It would be welcome to gain evidence by RCTs to eventually develop a widely acceptable evidence-based approach.

Acknowledgments

Funding: None.

Footnote

Peer Review File: Available at https://jss.amegroups.com/article/view/10.21037/jss-22-116/prf

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://jss.amegroups.com/article/view/10.21037/jss-22-116/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Foley ED, Kumar V. Protecting the spinal cord during thoracic endovascular aortic repair—who should place the spinal drain? J Spine Surg 2023;9(2):186-190. doi: 10.21037/jss-22-116