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Special Issue

Spinal cord protection in aortic endovascular surgery

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Abstract

A persistent neurological deficit, such as paraplegia or paraparesis, secondary to spinal cord injury remains one of the most feared complications of surgery on the descending thoracic or abdominal aorta. This is despite sophisticated advances in imaging and the use of less invasive endovascular procedures. Extensive fenestrated endovascular aortic graft prostheses still carry a risk of spinal cord injury of up to 10%; thus, this risk should be identified and strategies implemented to protect the spinal cord and maintain perfusion. The patients at highest risk are those undergoing extensive thoracic aortic stenting including thoracic, abdominal, and pelvic vessels. Although many techniques are available, lumbar cerebrospinal fluid drainage remains the most frequent intervention, along with maintenance of perfusion pressure and possibly staged procedures to allow collateral vessel stabilization. Many questions remain regarding other technical aspects, spinal cord monitoring and cooling, pharmacological protection, and the optimal duration of interventions into the postoperative period.

Key words: aortic aneurysm; cerebrospinal fluid; radiography; interventional; spinal cord injuries; vascular surgical procedures

Editor's key points

- Spinal cord injury occurs in 6.3% of patients undergoing repair of type II aortic aneuryms and 1–10% of patients undergoing endovascular repair of the thoracic aorta.
- The maintenance of an adequate blood pressure both during and after surgery is critical to maintaining spinal cord perfusion.
- Cerebrospinal fluid drainage to avoid pressures above 10 mm Hg is an effective strategy for preventing spinal cord injury but should be reserved for high-risk patients.

A persistent neurological deficit, such as paraplegia or paraparesis, secondary to spinal cord injury (SCI) remains one of the most feared complications of surgery on the descending thoracic or abdominal aorta. This is despite sophisticated advances in diagnostic and interventional strategies, including high-resolution three-dimensional imaging and a transition to less invasive endovascular procedures, including customized fenestrated endovascular aortic graft prostheses. The patients at highest risk are those undergoing extensive thoracic aortic repair for ruptured aneurysm or dissection. The broad class of aneurysm is often described by the Crawford classification, which relates to the origin and distal extent in the thoracoabdominal aorta, with type II being the most extensive (Table 1). In the past, estimates for the incidence of SCI were up to 31% of those undergoing open surgical repair of type II aneurysms, with rates even higher for those with aortic dissection.[1 2]

Specific strategies to protect the spinal cord focused on minimizing the cross-clamping time and the use of intercostal artery reimplantation. With a greater focus on spinal cord protection, including the use of cerebrospinal fluid (CSF) drainage and increased cardiopulmonary bypass, this rate has decreased to 6.3% for type II aneurysms in open surgery. Although arguably best practice, this figure is still significant, and it was hoped that endovascular techniques might provide some advantage by being less invasive. Ischaemic SCI with permanent dysfunction still occurs in 1–10% of patients in published series for thoracic endovascular aortic repair (TEVAR).[3] Endovascular aortic procedures are becoming increasingly common, replacing open surgical repair in the majority of instances involving aneurysm

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Table 1 Spinal cord ischaemia outcomes (percentage incidence) related to the Crawford classification of thoracoabdominal aneurysm extent for large series open procedures. *A Type V variant is also described (distal DTA to suprarenal). AA, abdominal aorta; DTA, descending thoracic aorta.

Crawford classification*	Aneurysm alone (Svensson and colleagues)[1] (*n*=1234)	Dissection with or without aneurysm (Svensson and colleagues)[1] (*n*=276)	Aneurysm (dissection not specified) (Coselli and colleagues)[2] (*n*=2286)
Type I (proximal DTA to suprarenal AA; %)	13	21	3.3
Type II (proximal DTA to infrarenal AA; %)	31	33	6.3
Type III (distal DTA to infrarenal AA; %)	6	13	2.6
Type IV (suprarenal AA to distal AA; %)	4	11	1.4

or dissection arising distal to the aortic arch. Paraplegia may also follow infrarenal abdominal aneurysm surgery, although for isolated open or endovascular aortic repair (EVAR) it is much less common (<0.25%).[4] Although surgery on the thoracoabdominal aorta is associated with a broad range of significant complications, this paper will focus on perioperative strategies for SCI prevention in TEVAR in particular, using a specific patient as an example.

Spinal cord protection

Spinal cord ischaemia is clearly the result of a compromise of perfusion, with neurological injury occurring primarily because of profound acute ischaemia or as a consequence of more prolonged insufficiency with or without reperfusion injury. Perfusion insufficiency may be secondary to restriction of segmental arterial inflow during and after surgery, increased tissue pressure attributable to oedema or elevated CSF pressure, or increased venous pressure limiting outflow. The extent of endograft coverage gives an indication of risk, and extensive covered stent placement from the thoracic aorta to the iliac arteries is a risk factor (Fig. 1).[5] Many strategies have been described either to maintain spinal cord perfusion during and after the procedure or to protect the spinal cord against ischaemic or reperfusion injury. Some methods apply to open repair only (e.g. selective intercostal reimplantation) and others are applicable to closed (endovascular) repair. Not all are consistently effective, and most rely on 'bridging' a period of ischaemic risk until adequate native perfusion can resume. Staged repairs have been reported to be of benefit in some retrospective series, presumably because this allows time for collateral blood vessels to develop and stabilize over smaller regions of the cord at risk of ischaemia.[3 6 7] For detailed recommendations that have recently been published, the reader is directed to a Position Statement by the European Association for Cardio-Thoracic Surgery after a wide review of the literature.[3] Identification of the at-risk patient is an inexact science because of variability in individual anatomy, the extent of endograft coverage, and the location and complexity of endograft placement,[5] in addition to the risk of compromise of spinal cord perfusion by blood pressure variability.

The following sections provide an overview of the various perioperative protective strategies, spinal cord anatomy and physiology. The risks of the individual protective strategies also need to be considered.

Minimizing the anatomical disruption of blood supply

It has become evident that the blood supply to the spinal cord is not simply dependent on a few key feeding vessels. Recent reviews and studies have emphasized that there is a rich anastomotic network of small vessels surrounding the cord that

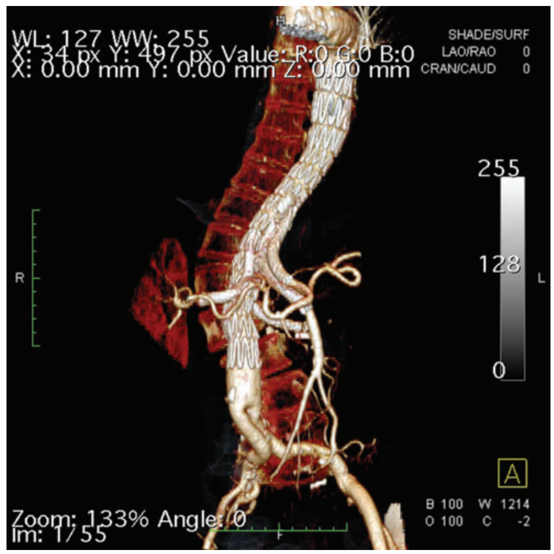

Fig 1 The postoperative computed tomography scan reconstruction of the thoracic endovascular aortic repair in the case study. Her initial woven Dacron infrarenal aorto-iliac graft can also be seen.

contributes to the usually single anterior and usually paired posterior spinal arteries.[8] The superior source vessels are branches from the left subclavian and vertebral arteries, which form the anterior and posterior spinal arteries. Throughout its length the anterior spinal arteries receive supply from the paired intercostal and lumbar segmental arteries and then caudally from branches of the inferior mesenteric, internal iliac, and sacral arteries. This rich network will be variably compromised by the anatomical disruption caused by the aortic pathology itself, by the operative ischaemic time, and by the persisting compromise after surgery. An additional concern is that reverse flow from spinal arteries may both contribute to extraprosthetic leaks after the placement of sealed or occlusive stent grafts (type II endoleaks) and 'shunt' blood from the spinal circulation by a low-resistance pathway. For these reasons, coiling of branch vessels is sometimes undertaken. Although this decreases the risk of an endoleak, the impact on SCI is less clear.

Preservation of vessels, selective re-anastomosis, or side-branch stenting of these larger supply vessels (including the artery of Adamkiewicz, an often large spinal artery in the lower thoracic to upper lumbar region) has controversial benefit.[3]