Lumbar Spinal Drains for Thoracoabdominal Aortic Surgery

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KEY POINTS

- Lumbar cerebrospinal fluid (CSF) drains are used in some institutions that perform thoracoabdominal aortic surgery to minimise the risk of spinal cord ischaemia.
- The rationale for inserting a spinal drain is that it reduces CSF pressure, thereby optimising spinal cord perfusion pressure.
- Patients most at risk of ischaemic spinal cord injury are those of advanced age, those who present as an emergency, patients with more extensive aortic disease including previous aortic intervention, and patients with certain comorbidities, such as diabetes and chronic kidney disease.
- There needs to be careful monitoring of the spinal drain both intraoperatively and postoperatively in order to prevent complications, including headache, intracranial haemorrhage, CSF leak, neuraxial haematoma, and meningitis.

INTRODUCTION

Ischaemic spinal cord injury (SCI) remains a significant complication of thoracoabdominal aortic surgery. Neurological deficit usually presents immediately after surgery; however, it can be delayed for several days. The impact of paraplegia on both the patient and society is substantial, and this complication increases patient mortality.[1]

Lumbar cerebrospinal fluid (CSF) drainage has been shown to reduce the risk of ischaemic SCI following aortic surgery. However, spinal drains are associated with significant complications in their own right. As such, an understanding of safe practice surrounding their insertion and management is paramount.

This article will discuss the rationale for lumbar CSF drainage in thoracoabdominal aortic surgery, the risk factors associated with developing SCI following these operations, the indications and contraindications for CSF drains, the technique for insertion and perioperative management, as well as the associated complications.

RATIONALE FOR CSF DRAINAGE

Incidence of SCI

Repair of thoracoabdominal aneurysm (TAAA) has become more common as surveillance has increased in conjunction with improved surgical and anaesthetic techniques.[2] The incidence of SCI—defined as a persistent paraparesis or paraplegia—following this surgery varies with the presence of certain risk factors. While the risk of SCI has declined over time, it remains

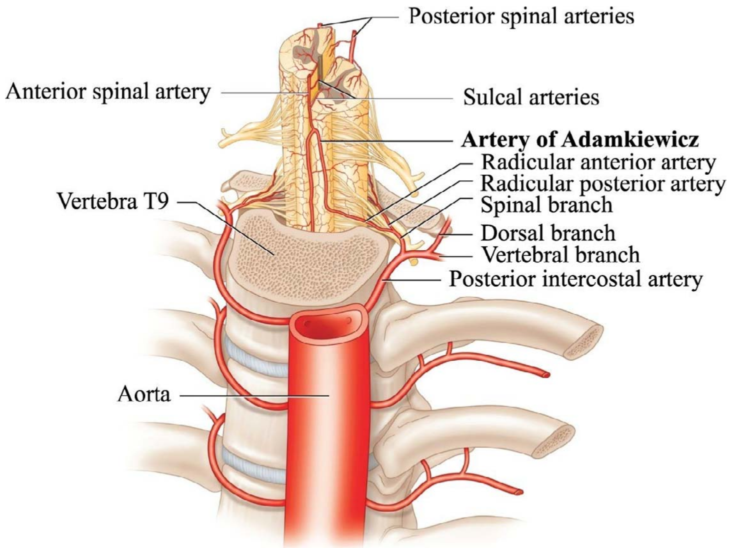

Figure 1. Image of arterial supply to spinal cord. (Permission for use under the Common Creative Attribution. https://doi.org/10.1590/1677-5449.0004)

significant, and may be as high as 24% for extensive open TAAA repairs.[3] The reported risk following thoracic endovascular aortic repair (TEVAR) is generally lower, approximately 4% on average, ranging from 0% to 10.3%.[4] A more recent systematic review of studies between 2016 and 2018 presented a rate of persistent SCI of 1% to 2% following TEVAR.[5] SCI following descending thoracic aneurysm repair is less common, but is often pooled with TAAA in the literature, giving the impression of lower average rates of SCI following TAAA repair.

Aetiology of SCI

Blood supply to the spinal cord is from (1) longitudinal arteries: the single anterior spinal artery and paired posterior spinal arteries, which arise from the vertebral arteries and (2) segmental arteries, which contribute to a complex anastomotic network involving the longitudinal vessels (see Figure 1). Segmental arteries include branches of the intercostal, lumbar, inferior mesenteric, internal iliac, and sacral arteries. The artery of Adamkiewicz is a major contributor to the anterior spinal artery supply to the thoracolumbar spinal cord and arises from a segmental artery at T9-12 vertebral level in most people.

Spinal cord perfusion pressure is analogous to cerebral perfusion pressure. It is the difference between the mean arterial pressure (MAP) and the greater of central venous pressure and spinal CSF pressure. Therefore, maintaining sufficient MAP, while limiting central venous pressure and spinal CSF pressure enables preservation of spinal cord perfusion pressure (SCPP), and reduces the risk of ischaemic insult to the spinal cord.

The aetiology of SCI following aortic surgery is multifactorial. During open TAAA repair, clamping of the aorta disrupts collateral blood supply to the spinal cord and increases blood pressure in the head and neck, resulting in increased CSF production and intracranial pressure and increased central venous pressure, and may lead to systemic administration of hypotensive agents. These factors result in a reduction in SCPP. Furthermore, SCPP may be compromised postoperatively due to spinal cord oedema caused by intraoperative ischaemia and reperfusion injury.[3]

While the impact of cross-clamping is avoided during TEVAR, occlusion of branches of the aorta by the endograft—particularly the left subclavian artery but also segmental branches—is thought to be the main cause of reduced blood flow to the spinal cord with this technique. Spinal cord perfusion may also be compromised by embolism of atherosclerotic plaques from the thoracic aorta and by a period of hypotension required for deployment of the endograft.[3]

Presentation of SCI may be immediate or delayed up to 48 hours after surgery. Delayed-onset symptoms are more common following TEVAR than open repair and tend to be associated with episodes of hypotension.[6,7]

Evidence for CSF Drainage

CSF drainage was first proposed for the prevention of SCI by McCullough et al[8] in 1988 and has since become a popular technique employed in TAAA repair. By monitoring CSF pressure and maintaining it below 10 mm Hg, spinal drains preserve SCPP. The evidence for CSF drainage provides differing results. The positive impact of CSF drainage in open TAAA surgery in preventing SCI is supported by 2 randomised controlled trials[9,10] and there are also a number of prospective

	Open aneurysm repair	Endovascular repair	Both
Surgical factors	Long aortic clamping time Extent of aortic graft replacement Emergency surgery	Extent of endograft coverage • Length > 20 cm • Placement over origin of artery of Adamciewicz (T9-12) • *Placement over subclavian artery without revascularisation** • Placement over internal iliacs and compromise of hypogastric artery flow • *Placement of 3 or more stents*	Crawford classification I & II aneurysms Increased blood loss
Patient factors		*Previous aortic surgery (if hypogastric artery compromised)* Atheromatous aorta	Comorbidities: *chronic kidney disease,* diabetes mellitus, hypertension, COPD Acute aortic dissection Anaemia Advancing age Female gender
Anaesthetic factors			*Perioperative hypotension (MAP < 70 mm Hg)* CSF drainage complications

Table 1. Risk Factors Associated With Spinal Cord Injury Following Thoracoabdominal Aortic Surgery. SCI indicates spinal cord injury; COPD, chronic obstructive pulmonary disease; MAP, mean arterial pressure. *Italics indicate major risk factors for SCI following thoracic endovascular aortic repair.[3,4,7]

nonrandomised studies and retrospective studies supporting the use of lumbar drains in TEVAR.[11] However, a systematic review of 3 randomised controlled trials found limited evidence in favour of CSF drainage.[12] Furthermore, Yoshitani et al[13] found an increase in motor deficit at discharge among patients who had spinal drains in a retrospective review of practice in Japan.[13]

In spite of equivocal evidence, CSF drainage is, nonetheless, recommended by the European Association of Cardiothoracic Surgery, the European Society of Cardiology, the American College of Cardiology Foundation, and the American Heart Association for high-risk thoracoabdominal aortic surgery.[3,14,15]

Other Techniques for Preventing SCI

Given the potentially devastating consequences of SCI, its prevention has been a key focus of research within aortic surgery. Methods that have been used include surgical revascularisation, for example revascularisation of the subclavian artery when an endograft occludes its origin; monitoring of spinal cord function using motor and somatosensory evoked potentials or near infrared spectroscopy; protection against ischaemic injury with methods such as hypothermia; and drugs, such as intrathecal papaverine.

RISK FACTORS FOR SCI

The incidence of SCI varies depending on a number of surgical, patient, and anaesthetic factors (see Table 1). Length and extent of surgery, previous surgery, chronic kidney disease (an indicator of the extent of atherosclerosis), and hypotension are factors that are commonly reported in the literature.

INDICATIONS

The decision to insert a spinal drain preoperatively depends on a balance of risks and benefits, which should be considered by the operating consultant surgeon and consultant anaesthetist. Preemptive insertion of a lumbar drain and maintenance of CSF pressure below 10 mm Hg is recommended by the European Association for Cardio-thoracic Surgery and the European Society of Cardiology for all open TAAA repair and high-risk TEVAR (see risk factors in italics in Table 1).[3,14] The American College of Cardiology Foundation/American Heart Association guidelines recommend CSF drainage for high-risk open and endovascular thoracic aortic repair.[15] Prolonged postoperative ventilation is an indication for CSF drainage since detection of neurological deficit is hindered in these cases. Spinal drains may also be placed postoperatively as an emergency treatment for patients showing signs of SCI.

CONTRAINDICATIONS

The only absolute contraindication to insertion of a lumbar drain for aortic surgery is patient refusal. Relative contraindications should be weighed against an individual's risk of SCI. Abnormal coagulation may increase the risk of neuraxial haematoma and intracranial haemorrhage. Guidance from national bodies such as The American Society of Regional Anaesthesia and Association of Anaesthetists of Great Britain and Ireland should be referred to and point-of-care coagulation testing may be useful to aid decision making in some cases.[16,17]

Drainage of CSF in those with raised intracranial pressure may lead to uncal herniation and tearing of the subdural veins, leading to subdural haematoma. Active infection, either local or systemic, increases the risk of central nervous infection and epidural abscess. Other relative contraindications include previous spinal surgery, physiological instability, and trauma.[18]

INSERTION AND SET-UP

CSF drainage systems consist of an intrathecal catheter connected to a transducer and reservoir. Insertion of the intrathecal catheter should be performed by a consultant anaesthetist or a senior trainee under their supervision. Alternatively, they may be inserted by a neuroradiologist under fluoroscopy guidance. While they are usually inserted immediately preoperatively, some institutions recommend spinal drain insertion the day before elective surgery to provide a longer delay before intraoperative heparinisation. However, this may require the patient to spend an extra night in a high-dependency setting.

Equipment

A standard epidural pack is required for insertion of the intrathecal catheter. A 16G Tuohy needle with a 19G catheter or a 14G Tuohy needle with a 16G catheter may be used. While there is a lower risk of drain failure with wider-bore catheters, there is a greater risk of complications, such as postdural puncture headache, neuraxial haematoma, and intracranial haemorrhage.[19] The catheter may be a standard, fenestrated, clear epidural catheter or a silicone catheter.

There are various forms of external drainage systems, most of which have the following common components: clear tubing, a 3-way tap with branches leading to a flushless transducer, and a drip chamber, which drains into a collection bag. Specific drainage kits include the Codman® EDS 3C™ External Drainage System (Johnson & Johnson Medical Ltd. Pinewood Campus, Nine Mile Ride, Wokingham, United Kingdom).

Technique

The procedure can be performed with the patient seated or in the lateral decubitus position. Insertion may be less technically difficult in the seated position; however, it may result in drainage of a greater initial volume of CSF, owing to the higher lumbar CSF pressure in this position. The lateral decubitus position may be used for insertion in the anaesthetised or sedated patient. Approach should be at the L3/4 or L4/5 vertebral level, below the termination of the spinal cord.

There should be meticulous attention to asepsis, including 'scrubbing up', draping the back and using chlorhexidine spray, which should be allowed to dry before needle insertion. The insertion technique is similar to insertion of an epidural, using loss of resistance to saline to locate the epidural space. Once in the epidural space, the loss-of-resistance syringe should be removed and the Tuohy needle advanced slowly, until the dura is penetrated and CSF flows freely. If a bloody tap occurs, resite at a different vertebral level and ensure heparinisation is delayed for at least 60 minutes. If 2 bloody taps occur, consider postponing surgery. The catheter is then threaded intrathecally and 6 to 9 cm is left in the space; if there is persistent paraesthesia, then the catheter should be withdrawn until this resolves. A filter should not be used as it may obstruct CSF flow. The catheter should be secured to the patient's back with a clear dressing, avoiding the surgical field. Aspiration of CSF should be confirmed after securing the catheter and after positioning of the patient on the operating table.

Setting Up the CSF Drainage System

The system should contain a flushless transducer and 3-way taps should be clearly labelled to prevent inadvertent intrathecal administration of fluid or drugs. Strict aseptic technique should be used, avoiding chlorhexidine. There is no recommendation by the National Patient Safety Agency for the use of a colour-coded drainage system; however, this may help avoid confusion with other transducers.[18]

The transducer should be positioned at a consistent height—for example, at the level of drain insertion, the right atrium, or the tragus—and the pressure wave should be labelled as ICP (intracranial pressure) on the monitor. The drip chamber is positioned around 15 cm below the transducer. The 3-way tap controls whether the CSF pressure is monitored (tap off to drain) or CSF is drained (tap off to transducer). Figure 2 depicts the CSF drainage system set-up.

Figure 2. Example of cerebrospinal fluid drainage system set-up. The system is open to drainage in this example and displayed on a table for clarity. (Image provided by Dr Emma James, Consultant Anaesthetist, St Mary's Hospital, and used with permission.)

INTRAOPERATIVE MANAGEMENT

The goal of CSF drainage is to maintain SCPP above 70 mm Hg. A CSF pressure of less than 10 mm Hg and a MAP between 80 and 100 mm Hg should therefore be targeted.[3] Continuous CSF drainage risks tearing of the subdural veins and intracranial haemorrhage. Instead, when CSF pressure approaches or exceeds 10 mm Hg, CSF should be drained in 5 to 10 mL increments until the pressure returns below 10 mm Hg. If CSF pressure continues to rise despite drainage, MAP should be increased until SCPP is greater than 70 mm Hg. Under normal circumstances, the rate of drainage should not exceed 15 mL/h. It is useful to bear in mind the normal physiological turnover of CSF, which is approximately 10 to 20 mL/h, to prevent excessive drainage.

POSTOPERATIVE MANAGEMENT

Patients with lumbar CSF drains should be managed postoperatively in a high-dependency or intensive care setting where clinicians are trained to manage CSF drains. The following variables should be monitored in the postoperative period: CSF pressure, MAP, Glasgow coma scale, pupil diameter and reactivity, lower limb power and sensation, and CSF colour and volume drained. The catheter site should be inspected regularly for signs of infection and CSF leakage. If the patient is invasively ventilated, sedation should be held regularly to allow neurological assessment.

If CSF pressure exceeds an agreed threshold, for example 10 mm Hg, then incremental drainage should be performed as above. Drainage should occur with the patient semirecumbent at 30° or less. If CSF pressure is persistently raised, a higher MAP should be targeted.

If a patient develops a lower limb neurological deficit, CSF should be drained freely with the patient lying flat until CSF pressure is less than 5 mm Hg. MAP should be increased above 90 mm Hg and haemoglobin maintained above 100 g/dL. Spinal cord imaging should be considered if symptoms persist as paraplegia may occur secondary to neuraxial haematoma, a complication of spinal drain insertion.

Complication	Incidence (%)	Notes
Headache	2.1-3.9	
Intracranial haemorrhage	0.3-1.5	If Glasgow coma scale score falls or pupils become abnormal, CSF drainage should stop and urgent brain imaging should be performed. If CSF becomes blood-stained, this may indicate intracranial haemorrhage as a result of overdrainage; therefore drainage should stop.
CSF leak	0.9-1.1	
Epidural haematoma	0.4-0.8	
Neurological deficit	0.1-0.6	Ideally, magnetic resonance imaging should be used for investigation of postoperative leg weakness, but this may not possible if metallic components are present in an endograft.
Death	0.3	
Drain fracture	0.1	
Insertion site infection	0.1	
Meningitis	0.1	Signs may include severe headache, meningism, turbid or cloudy CSF, signs of infection at insertion site, fever, and raised inflammatory markers.

Table 2. Complications Associated With Lumbar Cerebrospinal Fluid (CSF) Drainage for Thoracoabdominal Aortic Surgery.[5,20]

Anticoagulation

The American Society of Regional Anesthesia recommends a delay of 60 minutes between neuraxial technique and systemic heparinisation and most institutions support this.[16] Venous thromboembolism prophylaxis can be administered postoperatively with the drain in situ; however, there should be sufficient time between heparin administration on either side of catheter removal, according to local guidelines.

Catheter Removal

CSF drainage should continue for at least 48 hours postoperatively since the risk of developing SCI is highest in the first 2 days. In the event of lower limb neurological abnormality, then the drain may remain in situ for up to 5 days. Beyond 5 days, the risk of infection increases considerably. Prior to removal, some institutions advocate clamping the drain for a period of time, allowing CSF pressure to normalise while assessing lower limb neurology.

COMPLICATIONS

The overall rate of complications associated with lumbar CSF drainage is 6.5%.[20] The presence of the following factors is associated with a higher risk of complications: the use of a wider-bore catheter and Tuohy needle, difficult insertion, and blood-tinged CSF.[19] Table 2 shows the incidence of complications related to lumbar CSF drainage.

SUMMARY

Lumbar CSF drainage is an established strategy for reducing the risk of SCI following thoracoabdominal aortic surgery through optimisation of SCPP. There are several serious complications associated with the technique; therefore clinicians involved in the care of patients with spinal drains should be familiar with their perioperative management, including local protocols.

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