Editorial

Spinal cord protection: lessons learned from open repair

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Introduction

Thoracoabdominal aortic aneurysm repair techniques and perioperative management have undergone many iterations and attempts to reduce complication rates. While respiratory and renal failure are some of the most common complications following aneurysm repair (1), lower extremity paresis/paraplegia is most feared. In an early, large series, the rate of spinal cord injury was as high as 16% (1). Multivariate analysis in this series demonstrated that extent of aneurysm resection and cross-clamp time were significant predictors of paraplegia or paraparesis, among these patients (1). Multiple adjuncts have been attempted in order to reduce or eliminate spinal cord ischemia, with early attempts focused on cardiopulmonary or atriofemoral bypass with systemic cooling, resulting in modest reductions in paraplegia/paraparesis rates (2).

The addition of cerebrospinal fluid drainage via intrathecal drain placement either alone, or in combination with intrathecal papaverine administration have shown significant promise in reducing paraplegia/paraparesis in this population and is a surgical adjunct we use at the Cleveland Clinic. Early studies on aortic cross-clamping in baboons demonstrated the combination of cerebrospinal fluid drainage and intrathecal papaverine administration eliminated paraplegia through a combination of dilation and increased blood flow to the lower anterior spinal artery (3). This technique was subsequently tested in a small randomized control trial in thirty-three patients with extent I and II thoracoabdominal aortic aneurysms (4). Only two of 17 patients who received cerebrospinal fluid drainage plus intrathecal papaverine developed spinal cord injury, while seven of 16 developed neurologic injury in the control group (4). Multivariate analysis revealed longer aortic cross-clamp time, failure to actively cool with bypass, and post-operative hypotension were associated with neurologic injury, while cerebrospinal fluid drainage plus intrathecal papaverine administration was protective (4).

Significant discussion and research has focused on the preservation of segmental blood supply to the spinal cord via re-implantation of intercostal and lumbar arteries at the time of thoracoabdominal aortic repair (2). Contemporary management of intercostal and lumbar arteries during aneurysm repair focuses on re-implantation of patent vessels, when technically feasible, below the sixth thoracic vertebra. Early analysis focusing on this problem found that rates of paraparesis/paraplegia increase if patent intercostals are oversewn, particularly between the levels of T7-L1 (2). However, which arteries to reimplant is debatable and has led some to perform pre-operative selective angiography to determine the key intercostals/lumbars supplying the spinal cord. While re-implantation of these vessels seems important, it comes at the cost of longer aortic cross-clamp times. Thus, surgeons must keep in mind a balance between maintaining blood supply to the spinal cord and ischemic time.

More recently there has been a novel approach to spinal cord protection for patients undergoing thoracoabdominal aortic aneurysm repair. The approach, spear-headed by Dr. Christian Etz of University Heart Center in Leipzig, Germany, focuses on the concept of minimally invasive segmental artery coil embolization to pre-condition the spinal cord prior to thoracoabdominal aortic aneurysm repair (5). The investigators are utilizing a technique termed minimally invasive staged segmental artery coil

embolization (MIS^{2}ACE) to induce arteriogenesis and collateral network formation as a robust alternative blood supply to the spinal cord (5). Their research began utilizing a large animal model to selectively embolize segmental arteries in Yorkshire pigs, followed by injecting the pigs with a resin at different timepoints after segmental embolization (5). The cast of the vasculature was then examined and demonstrated robust increases in collateralization and size of remaining vessels perfusing the spinal cord (5). This research eventually made it to the bedside and they reported a 57 patient case series utilizing this technique with none of the patients developing spinal cord ischemia during thirty-day follow-up (6); however, 55 of 57 patients underwent endovascular repair thus limiting the generalizability of their study to those undergoing open repair. Their work has resulted in the initiation of a multi-center randomized controlled trial investigating ischemic pre-conditioning of the spinal cord prior to aortic repair (7). Patients in the treatment arm undergo a minimally invasive procedure utilizing coils to selectively embolize segmental arteries and create a robust collateral network to the spinal cord. Then, several weeks-to-months later the patients will undergo their planned operation (either open or endovascular). The trial is aiming to enroll 500 patients across 33 international centers.

It is our practice at the Cleveland Clinic to perform these cases with a multi-faceted approach to spinal cord protection. Patients undergoing thoracoabdominal aneurysm repair receive a cerebrospinal fluid drainage catheter prior to anesthetic induction in the operating room (8). Ten minutes prior to aortic cross-clamping, 2 mL of CSF is withdrawn and 3 mL of warmed, preservative-free 1% papaverine solution is infused intrathecally over five minutes (8). The catheter is then flushed with 2 mL of cerebrospinal fluid and the catheter is allowed to drain freely by gravity during the duration of cross-clamping (8). Cerebrospinal fluid drainage is continuous in the post-operative period to maintain intrathecal pressure below 10 cmH_2O. Drainage is limited to 450 mL/day or 25 mL/h (8). We routinely perform left heart bypass with moderate hypothermia to 32 ℃ (8). These techniques have resulted in excellent outcomes in open thoracoabdominal aneurysm repair at our institution. A recent analysis demonstrated that in the era of endovascular repair, paraplegia and stroke rates and mortality were similar (9). While endovascular repair had less perioperative morbidity, open repair had better long term survival and less need for reintervention (9).

Conclusions

Despite the intensive research effort that has gone into understanding and preventing spinal cord ischemia during open thoracoabdominal aortic aneurysm repair, the ideal repertoire remains elusive. However, several crucial elements are evident. Minimizing aortic cross-clamp time, while reducing spinal cord metabolic demand with systemic cooling, plays a major role in reducing spinal cord ischemia. Optimizing spinal cord perfusion pressure with cerebrospinal fluid drainage and administration of intrathecal papaverine can significantly reduce the incidence of paraparesis/paraplegia. The results of the trial utilizing the MIS^{2}ACE technique may provide yet another weapon in the armamentarium of surgeons as they attempt to treat this difficult problem while minimizing neurologic complications.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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