A direct aorta to segmental artery bypass for prevention of spinal cord ischemia after endovascular aortic repair

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ABSTRACT

Spinal cord ischemia remains a persistent challenge after endovascular aortic aneurysm repair. We present a novel direct aorta to segmental artery bypass before aneurysm repair in a 64-year-old woman presenting with an enlarging aneurysm following dissection. Through an eighth intercostal incision, a polyester graft was sewn into the aorta using pledgeted sutures. An entry needle was used to directly access the previously treated aortic segment, and the opening was stented and angioplasty was performed to create inflow. Anastomoses were performed to a prominent left T10 segmental artery with a harvested saphenous vein. The patient remained neurologically intact postoperatively and the 1-month follow-up angiography demonstrated bypass patency. (J Vasc Surg Cases Innov Tech 2024;10:101446.)

Keywords: Aortic aneurysm repair; Bypass technique; Segmental artery; Spinal cord ischemia

Spinal cord ischemia (SCI) is a long-standing complication after treatment of thoracoabdominal aortic aneurysms (TAAAs). Endovascular techniques, using thoracic endovascular aortic repair (TEVAR), have improved outcomes and mostly replaced open surgical repair.[1] Nonetheless, aortic coverage of the major segmental arteries of the spinal cord during these procedures can lead to SCI.[2,3] Preventing neurologic injury postoperatively in this patient population is a major and persistent challenge.

Recently, a novel prophylactic bypass technique has been described to create a direct extra-anatomic revascularization before fenestrated endovascular repair (FEVAR) of an aortic aneurysm.[4] Specifically, a bypass was created from the profunda femoris to a polytetrafluoroethylene graft, to a saphenous vein graft, and anastomosed to the left L1 radicular artery. They described this technique as revascularization prior to FEVAR, otherwise known as RpFEVAR.[4]

We present a modification of the reported RpFEVAR technique by creating an inflow directly from the aorta to a prominent left posterior intercostal (ie, segmental) artery at T10, producing a shorter and potentially more durable bypass.

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CASE REPORT

The patient was counseled and provided written informed consent for both the procedure and the report of her case details and imaging studies, including pre- and postoperative imaging studies, an intraoperative microsurgical video of the bypass procedure (Supplementary Video), and her medical history. Protected health information or identifiable information was not used in this study. The institutional review board approved the study.

A 64-year-old active woman with a history of multiple endovascular treatments for aortic degeneration, including aortic arch repair down to T10 and aorto-bi-iliac repair, presented for treatment of a growing abdominal aortic aneurysm. Subsequent imaging unfortunately demonstrated aneurysmal aortic degeneration between the untreated segment between T10 and L2, an area thought to be at high risk of SCI with further treatment. Aneurysmal dilation increased from 4.7 cm to 5.8 cm in diameter within a span of 1 year, prompting planning for endovascular stenting of this final remaining segment of the diseased aorta. The patient remained neurologically intact with full strength in her extremities.

Computed tomography angiography (CTA) was performed and demonstrated a prominent left T10 segmental artery, measuring approximately 6 mm in diameter (Fig 1). A discussion was held between vascular surgery and neurosurgery regarding the patient's case and the use of a prophylactic bypass to the segmental artery to provide adequate perfusion to the spinal cord postoperatively. A staged treatment was planned, using segmental artery bypass (RpFEVAR) followed by FEVAR of the paravisceral aorta.

RpFEVAR technique. The patient was counseled, provided written informed consent, and was brought to the operating room. The left saphenous vein was harvested. The patient was then placed in the right lateral decubitus position with the left side up. A left-sided posterior mini-thoracotomy was performed through an eighth intercostal incision. The left lung was

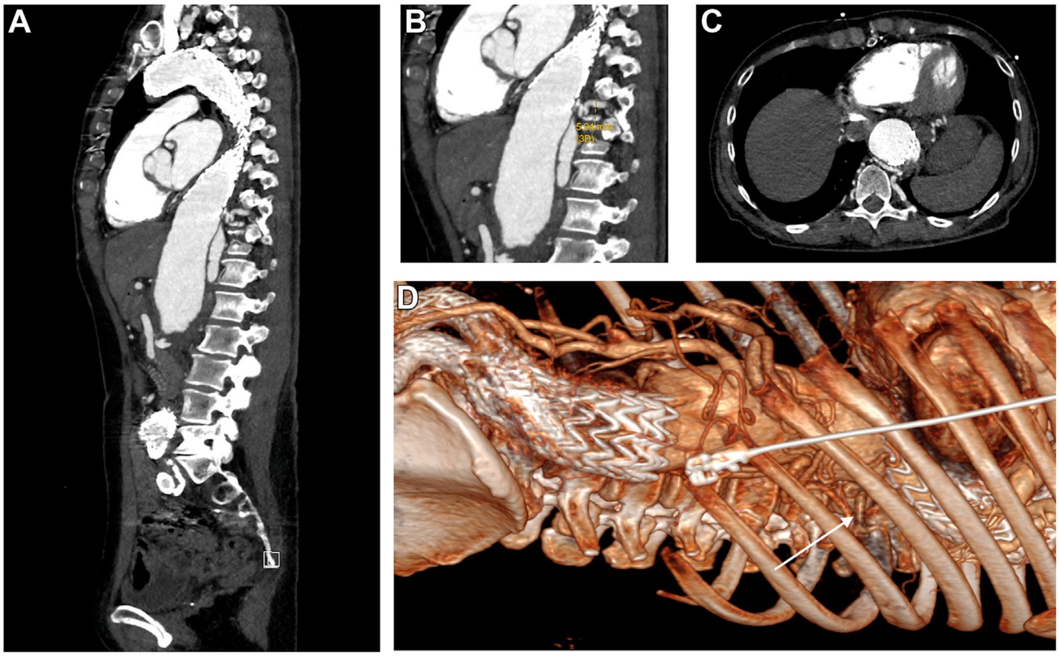

Fig 1. Preoperative computed tomography angiography (CTA) images demonstrating a prominent left T10 segmental artery: sagittal view (**A**), zoomed sagittal view demonstrating an artery diameter of 5.94 mm (**B**), axial view (**C**), and three-dimensional reconstructed lateral view demonstrating the artery (**D**; *white arrow*).

deflated, and the inferior left lobe was retracted to expose the lateral aspect of the T10 body.

The left T10 segmental artery was identified and circumferentially dissected from the thick investing connective tissue, which was aided significantly through microscopic illumination and magnification. Proximal and distal clips were placed, and an arteriotomy was performed using a sharp opening and aortic punch. Microsurgical anastomosis from a harvested saphenous vein graft with end-to-side technique was performed using 8-0 interrupted and running Nurolon sutures (Ethicon). Removal of the inflow and outflow clips confirmed hemostatic arterial anastomosis, and a clamp was applied to the proximal aspect of the saphenous vein graft. Attention was then turned to the aorta.

An 8-mm polyester (Dacron; DuPont) graft was sewn to the surface of the previously stented segment of the mid-thoracic aorta using interrupted pledgeted 4-0 sutures, with each bite taken on the adventitia only and creating a clampless aortic—prosthetic end-to-side anastomosis. Next, under fluoroscopic guidance, an entry needle was used to directly access the thoracic aorta through the open end of the side graft, and a stiff 0.35-in. wire was used to access the thoracic aorta. An 8F sheath was then pushed over the wire into the thoracic aorta. With the open end of the graft occluded over the shaft of the sheath, the sheath was pulled back into the side graft, and two 8-mm balloon expandable covered stents (iCast Atrium Medical Corp) were deployed over the wire to create aortic inflow into the Dacron graft. Proximal control was achieved, and the sheath was removed. An end-to-end anastomosis between the Dacron graft and saphenous vein graft was performed using running 6-0 Prolene suture (Ethicon).

The clips were removed, and excellent inflow was confirmed from the aorta through the bypass and into the left T10 segmental artery. A 10-mm Sugita aneurysm clip (Mizuho Medical) was kept on the proximal aspect of the left T10 segmental artery to ensure demand on the bypass and prevent retrograde endoleak back into the aneurysm sac. Patency was confirmed by Doppler ultrasound and microsurgical examination using video indocyanine green angiography. The thoracic cavity was irrigated, a chest tube was placed, and the wound was closed. No somatosensory- or motor-evoked potential changes were observed throughout the course of the procedure, and the wound was closed. A microsurgical video was obtained during the microanastamosis and during final indocyanine green angiography confirmation of flow (Supplementary Video). An illustration of the bypass is demonstrated in Fig 2.

FEVAR technique. Two days later, the patient was brought back to the operating room for FEVAR. A lumbar drain was placed before the operation. A transfemoral fenestrated endograft was delivered into the paravisceral aorta, and all branches were successfully stented. Angiography confirmed a good seal with no endoleak. Intraoperative angiography was performed, which demonstrated a patent aortic—T10 segmental artery bypass (Fig 3). All aortic branches were widely patent with no endoleak.

Postoperative course. The patient tolerated the procedure well, and she was extubated and monitored in the intensive care unit. Her postoperative neurologic examination demonstrated full strength in her upper and lower extremities, with sensation intact throughout. She resumed single-agent aspirin

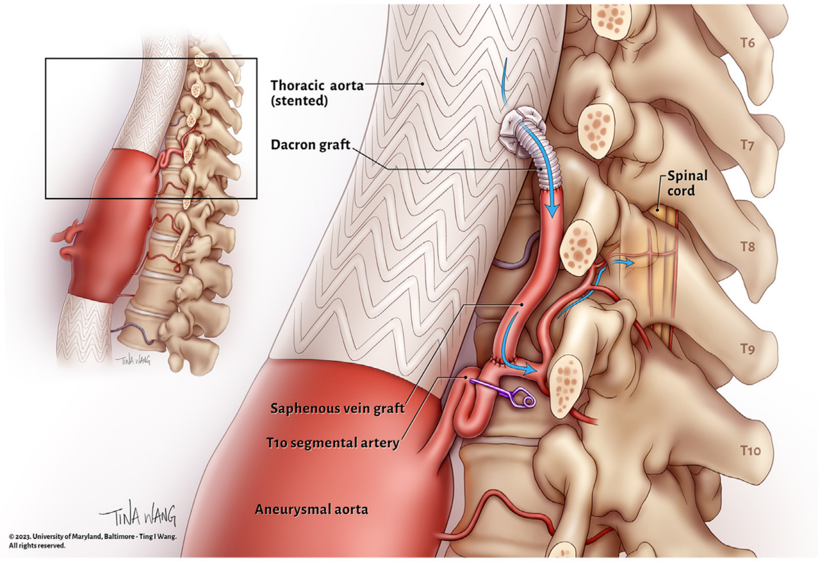

Fig 2. Illustration isolating the final bypass from the previously stented aorta to the left T10 segmental artery. *Left,* The zoomed image shows the vascular anatomy before bypass.

81 mg after the procedure. Lumbar drainage was performed according to our institutional guideline for patients with aortic repairs: if the intrathecal pressure is >12 mm Hg, the drain is opened to gravity until the pressure has decreased to <12 mm Hg. A total of 225 mL of cerebrospinal fluid (CSF) was drained in the first day after surgery, followed by 280 mL of CSF in the second day. In addition, 1.5 L of Plasma-Lyte (Baxter International Inc) was administered in this period. No vasopressor agents were used. Her lumbar drain and chest tube were removed on postoperative day 2.

Postoperative imaging and clinic follow-up. At 1 month of follow-up, the patient was recovering well with no postprandial pain, weakness, numbness, or pain in her lower extremities. She demonstrated equal and full strength in all her extremities, with intact sensation. At 2 months, her surgical wounds were healed, and she continued to have full strength in her extremities. She underwent CTA of her chest and abdomen, which demonstrated a small type II endoleak, likely from the segmental artery with good exclusion of the sac. Her bypass appeared intact and demonstrated patency from the aorta to the segmental artery (Fig 4). She will continue to be followed up clinically and radiographically with office visits and CTA studies at 6-month intervals for the first 2 years and annually thereafter.

DISCUSSION

The incidence of SCI in the perioperative period after endovascular management of TAAAs ranges anywhere from 6% up to even 31% in some cases, depending on the methods used to promote spinal cord perfusion.[5-8] These methods derive from the concept of spinal cord perfusion pressure, which is defined by the mean arterial pressure subtracted by the intrathecal pressure.

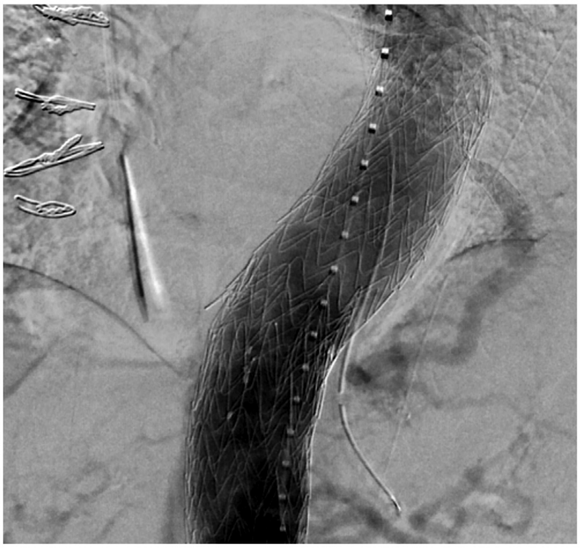

Fig 3. Intraoperative angiogram demonstrating filling of the bypass.

Therefore, augmenting systemic blood flow and/or diverting CSF will promote perfusion to the spinal cord.

The results from a randomized trial in 2002 suggested CSF drainage reduces the risk of SCI.[9] Since then, lumbar drains have been routinely used in patients undergoing open or endovascular TAAA repair, with some success.[10] However, CSF drainage carries risks in itself, including symptoms such as headaches and more severe complications such as intracranial hypotension or hemorrhage, intraspinal hematoma formation, and/or neurologic injury to nerve roots.[11]

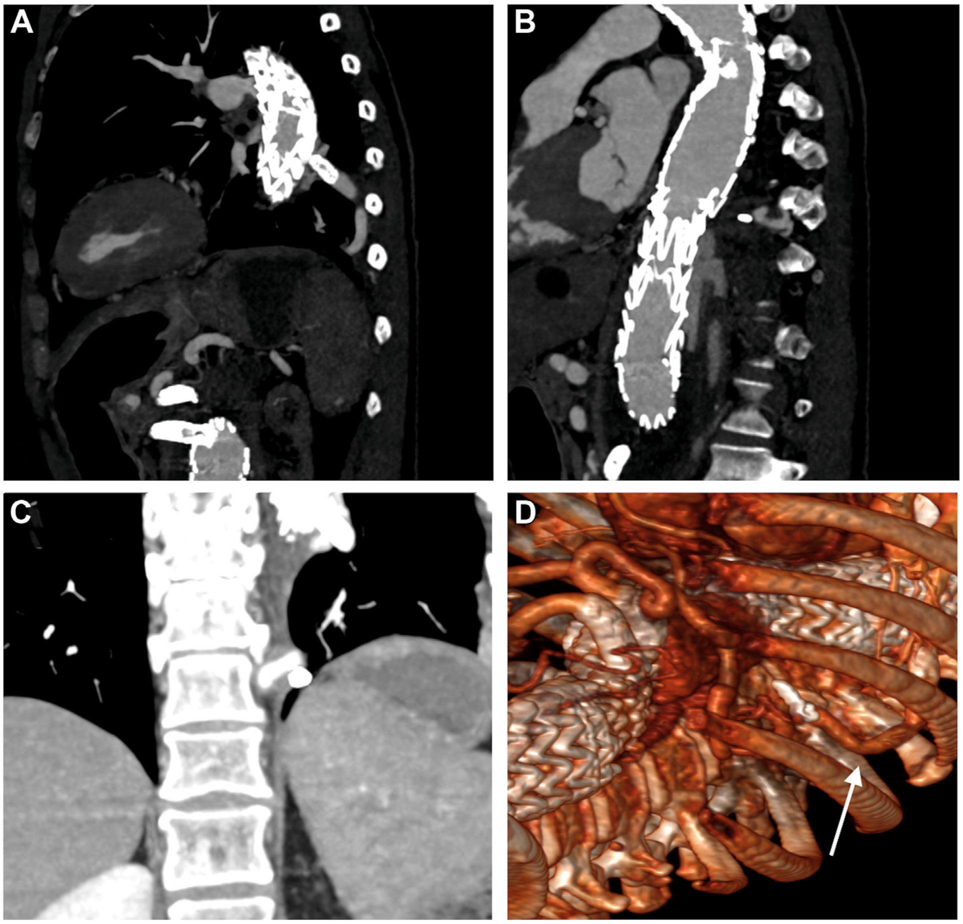

Fig 4. Postoperative computed tomography angiography (CTA) demonstrating patency of the bypass. **A,** Sagittal view of the proximal aspect of the bypass. **B,** Sagittal view of the distal aspect. **C,** Coronal view showing filling of the segmental artery. **D,** Three-dimensional reconstructed view demonstrating the patent bypass (*white arrow*).

In addition to perioperative measures to reduce the risk of SCI, surgical techniques and concepts have evolved over time to promote spinal cord perfusion. A persistent problem with endovascular grafts is that they are generally unable protect segmental arteries of the spinal cord that are responsible for the blood supply of the middle and lower thoracic spinal cord.[3] These fenestrated grafts are typically prepared with branches to major aortic branches, such as the celiac trunk, superior mesenteric artery and renal arteries but are difficult to align with the segmental arteries of the spine either due to the smaller size or acute originating angles off the aorta.[12] A recent study, however, demonstrated branch or fenestrated preservation of segmental arteries with relatively safe and effective outcomes, suggesting that in a select group of patients with optimal anatomy, these segmental arteries could be endovascularly preserved.[13]

Many surgeons also take advantage of the spinal cord's ability to develop collateral flow. This concept relies on the presence of networks of small arteries in the spinal column that are able to compensate for one another in the event of ischemia to one section of the spinal cord.[14] After aortic repair, evidence has also shown collateral network formation in some patients.[15,16] In clinical practice, this has given rise to techniques of preconditioning and staged repair. Preconditioning involves segmental artery embolization before TAAA treatment to promote the formation of spinal cord collateral networks. This was first performed using a pig model before attempts were made in human patients.[17,18] Although clinically feasible, the efficacy for this procedure is unclear at this time.

A more commonly adopted technique is the concept of staged repair. Patients with extensive aneurysmal disease of the thoracic aorta face a difficult problem. Repair of their entire pathology often occludes many levels of spinal segmental arteries, increasing the risk of SCI. The concept of staged repair involves repairing segments of diseased aorta with time between repairs to promote the formation of collateral blood flow to the spine.[19]

The rates of neurologic injury after staged repair ranged between 0% and 11%, suggesting a potential protective effect of this technique.[20-22]

We present a modified RpFEVAR following the technique reported by Atai et al[4] (Fig 4). We believe this is a technically feasible and safe method that can be used as an adjunct to already accepted techniques to promote spinal cord perfusion, such as staged repair and CSF drainage. In select patients with optimal anatomy, such as a prominent segmental artery, and in otherwise good health to undergo an additional operation, this technique could present an opportunity to allow for advancing bypass techniques to prevent SCI in patients undergoing TAAA repair.

CONCLUSIONS

Despite the current methods available to prevent SCI after endovascular repair of TAAAs, patients continue to experience neurologic deficits after these procedures. There is an opportunity to introduce bypass techniques that could provide durable, long-term solutions to promoting spinal cord perfusion in these patients. We present a case demonstrating a direct aorta to segmental artery bypass performed before endovascular aortic repair that demonstrated radiographic patency and clinical benefit to the patient. In select patients with optimal vascular anatomy, this could add to the surgeon's armamentarium in treating patients with TAAAs.

DISCLOSURES

None.

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