Subclavian Graft Thrombosis As an Alternative Cause for Delayed Spinal Cord Ischemia Following Hybrid Aortic Arch Repair

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SPINAL CORD ISCHEMIA is a potentially devastating complication following any repair of the descending thoracic aorta. The literature suggests that the risk with descending aortic surgery may be lower with endovascular compared with open intervention.[1,2] Current estimates for the incidence of spinal cord ischemia with endovascular repair is in the range of 3% to 7%.[1-3] Thoracic aortic aneurysmal disease involving the aortic arch conventionally has required open repair involving cardiopulmonary bypass (CPB) and deep hypothermic circulatory arrest. Despite technical advances in surgical technique and perioperative care, the risk of mortality or significant morbidity remains high.[4,5] Hybrid arch repair is an evolving surgical approach for diffuse aortomegaly. It involves 2 steps, which can be performed together during a single surgery or staged over time. The first step involves conventional open aortic branch revascularization, while thoracic endovascular aortic repair (TEVAR) completes the process. Various approaches to the hybrid arch repair exist, with a wide range of reported incidence of neurologic complications.[6-8] Several risk factors have been identified for spinal cord ischemia in patients undergoing TEVAR, including previous abdominal aortic repair, hypotension, coverage of the left subclavian artery, and extensive endograft coverage.[9-16] The authors present a case of left subclavian graft thrombosis as a possible new etiology for delayed paraplegia in a patient following hybrid arch repair.

CASE REPORT

A 68-year-old, right-handed female patient presented with a fusiform aneurysm of the ascending aorta, distal arch, and proximal descending thoracic aorta (Fig 1). Other comorbidities included medically controlled hypertension, lower extremity peripheral vascular disease, and a 40-pack-years history of smoking. Preoperative laboratory values (including coagulation parameters), coronary angiogram, and transthoracic echocardiograph all were normal. In addition to standard monitors, intraoperative monitoring included right radial and femoral arterial catheters, a pulmonary artery catheter, and cerebral oximetry. The authors elected not to place a lumbar cerebrospinal fluid (CSF) drain preoperatively. Following induction, the patient was maintained on sevoflurane at 0.7 to 1.2 minimum alveolar concentration during the case. Antifibrinolytic therapy consisted of a postinduction bolus of tranexamic acid (30 mg/kg) followed by an infusion for the duration of the procedure (10 mg/kg/h).

The surgery performed was a single-stage hybrid arch repair with full arch debranching, using a recently published technique.[17] Prior to sternotomy, the right axillary artery was exposed and a side graft was sewn on through a small incision in the chest. Following sternotomy, CPB was initiated via the right axillary artery side graft and a 2-staged venous return cannula in the right atrium. The patient was cooled to 28°C and CPB maintained via the axillary side graft throughout the procedure. The ascending aorta was cross-clamped proximal to the aneurysm, at the level of the sinotubular junction. The aneurysmal ascending aorta and arch then were resected, leaving behind a short section of diseased ascending aorta (Fig 2). Dissection of the 3 arch vessels ensued, with the left subclavian artery being particularly challenging as it was positioned posteriorly. A prefabricated Dacron4-limb graft (Vascutek; Terumo Cardiovascular Systems, Ann Arbor, MI) was sutured proximally at the sinotubular junction and then distally onto the short section of remaining ascending aorta. The 3 limbs of the graft then were anastomosed sequentially to the previously dissected arch vessels and the patient was weaned from CPB. Total CPB time was 224 minutes, with flow rates ranging from 2 to 2.5 L/min/m^2 and mean arterial pressure (MAP) maintained at 60 to 70 mmHg with a phenylephrine infusion. Full exclusion of the aneurysm then was completed by deploying 2 endovascular grafts in antegrade fashion through the fourth limb of the graft, with the proximal landing zone overlapping the distal section of the 4-limb graft (Fig 3). Total descending aorta coverage with endograft was less than 15 cm, ending at a T8 spinal level. Intraoperative angiography demonstrated patency of all limb grafts and no endograft leak. The patient had mild biventricular dysfunction postoperatively and was transported to the cardiovascular intensive care unit intubated with low-dose infusions of milrinone (0.125 μg/kg/min) and norepinephrine (0.1 μg/kg/min).

The patient was extubated without incident on the first postoperative day (POD 1) and remained neurologically intact as her pharmacologic support was weaned toward an MAP of 70 mmHg. On POD 2, the patient suffered acute isolated bilateral lower limb paralysis. At this time, her MAP was 65 mmHg, with a central venous pressure of 8 mmHg and a cardiac index of 3.3 L/min/m^2. The intensivist, cardiac anesthesiologist, and attending cardiac surgeon immediately were informed. The patient's MAP was increased to 90 to 100 mmHg with a 500 mL bolus of hydroxyethyl starch (130/0.4) 6% and an infusion of norepinephrine (see Table 1 for details). When only partial recovery was achieved, the MAP was increased to 100 to 110 mmHg, red blood cells were transfused to achieve a hemoglobin value of 10 g/dL, and an emergency lumbar CSF drain was inserted by the cardiac anesthesiologist. The initial spinal cord pressure was 14 mmHg, and 20 mL of CSF were drained immediately. The spinal cord pressure decreased to 8 mmHg and the drain was set to 10 cmH_2O. Over the next 4 hours, there was a gradual improvement, with a full recovery to baseline neurologic function achieved by 10 hours after onset of symptoms. The MAP was maintained at 90 to 100 mmHg until 24 hours after the onset of spinal cord ischemia, at which point norepinephrine was weaned. MAP was lowered sequentially to a goal of 80 to 85 mmHg over the next 48 hours while assessing neurologic status hourly. The lumbar drain was removed 48 hours after being placed (POD 4), and drained a total of 9 mL of CSF following the reversal of spinal cord ischemia. No further neurologic events occurred and the patient was discharged from the cardiovascular intensive care unit to the surgical ward on POD 6. Of note, at no point in the patient's treatment did she ever suffer appreciable weakness/pain, diminished pulses, decreased capillary refill, or temperature or color changes to the left arm.

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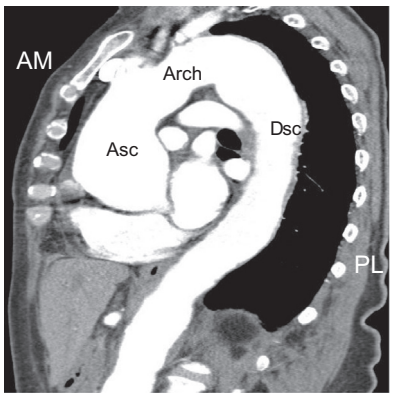

Fig 1. Preoperative computer tomographic angiography study, displayed in an oblique saggital plane (known as the aortic or candycane view). The anteromedial (AM) and posterolateral (PL) borders of the thorax are identified. A diffuse fusiform aneurysm is seen involving the ascending aorta (Asc), aortic arch (Arch), and proximal 2/3 of the descending aorta (Dsc).

The standard at the authors' institution is to perform a routine predischarge computed tomographic angiography scan to create baseline images for comparison to any future follow-up imaging. This scan was performed for the patient in the present study on POD 10 and unexpectedly revealed complete thrombosis of the left subclavian artery graft limb with left vertebral artery steal (Fig 4). Following this result, bilateral noninvasive blood pressures were acquired, with a value of 119/61 mmHg on the right and 100/57 mmHg on the left. Magnetic resonance imaging was performed, which showed no evidence of spinal cord ischemia or injury. The patient was now neurologically asymptomatic with a normal blood pressure and had acceptable collateral flow to the left arm. No further treatment was deemed necessary and the patient was discharged home in stable condition.

DISCUSSION

Spinal cord ischemia following TEVAR is a serious complication that carries considerable impact on patients' outcomes. The authors believe this case represents a previously undescribed etiology for delayed spinal cord ischemia following hybrid arch repair.

The spinal cord receives its primary blood supply from the anterior and posterior spinal arteries, which arise from the vertebral arteries and are supplemented by intercostal, hypogastric, and lumbar radicular arteries along the length of the aorta.[16,18] Placement of a thoracic endograft can disrupt the vertebral or intercostal arteries' blood supply by covering the left subclavian or descending thoracic aorta, respectively. Endograft occlusion of the origin of the left subclavian artery has been shown to increase the risk for spinal cord ischemia.[11-13] Similarly, extensive descending thoracic aorta coverage also is considered a risk.[14,15] More recently it has been suggested that the spinal cord can tolerate an interruption in blood supply from 1 of these sources, but that ischemic risk escalates substantially once both are disrupted.[16] It is important to note that although various factors have been shown to increase the risk of spinal cord ischemia, no patient undergoing TEVAR is completely risk-free.

A secondary source of blood supply comes from the collateral network, a mesh-like series of interconnected, small-caliber intraspinal and paraspinal arteries.[19] There is evidence that immediately after segmental artery disruption, only a small percentage of aortic pressure actually is transmitted to the collateral network.[20] In this study, the collateral network pressure increased from 27% of its initial baseline to 90% by the fifth POD. Another study underscored these findings by demonstrating that within the same 5-day period, the collateral network undergoes changes in the orientation and

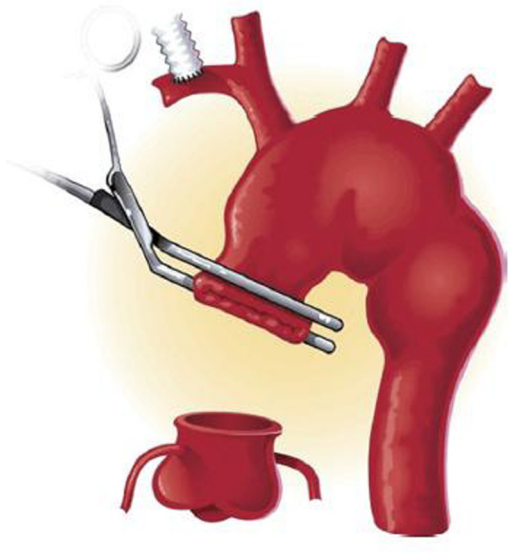

Fig 2. Illustration of the hybrid arch repair technique. The aneurysmal ascending aorta has been cross-clamped and resected, exposing the aortic root and valve. Also displayed is the side graft sewn to the right axillary artery, which was used to maintain full CPB (from Kent et al,[11] with permission). (Color version of figure is available online.)

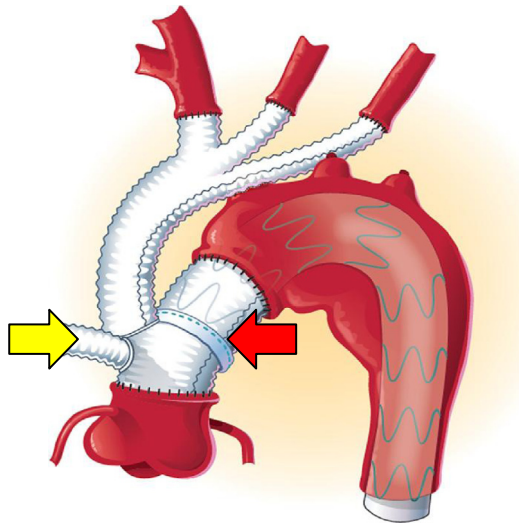

Fig 3. Illustration of the finished hybrid arch repair. Proximal and distal aortic anastomoses with full arch debranching have been completed. An endovascular stent graft has been deployed through the 4th limb (yellow arrow) of the Dacron 4-limb aortic graft. The endograft proximal landing zone is within the 4-limb graft (red arrow) (from Kent et al,[11] with permission).