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A Case Series of a Hybrid Approach to Aortic Arch Disease

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ABSTRACT

Objective: Debranching of the aortic arch and endovascular stent placement as a combination therapy for complex aortic arch pathology has emerged over the past few years as an alternative to traditional repair. This hybrid approach is a viable option for patients who would not tolerate conventional arch replacement, as well as for patients with a failed stent graft of the descending aorta and a subsequent type I endoleak.

Methods: We retrospectively reviewed the preoperative characteristics and postoperative outcomes of 5 patients who underwent debranching of the aortic arch and implantation of an endovascular stent across the aortic arch between 2008 and 2011. Data were analyzed with the Student t test and the Kaplan-Meyer method.

Results: The mean age was 70.6 ± 18 years; 4 men and 1 woman were evaluated. One patient had previous aortic surgery for dissection. The preoperative morbidities included arrhythmia (1 patient), chronic obstructive pulmonary disease (2 patients), cerebrovascular accident (1 patient), diabetes mellitus (2 patients), coronary artery disease (2 patients), and active angina (1 patient). One patient had a myocardial infarction 3 weeks before surgery. The primary technical-success rate was 100%, and none of the patients died in the perioperative phase. The mean follow-up time was 22 ± 18.4 months, and the median follow-up time was 13.8 months (range, 7.13-50.7 months). Two patients died during follow-up. The pathology of the aorta in the patients who died was arch aneurysm; the 3 remaining patients are alive and regularly followed at our institution.

Conclusion: The combination of surgery and simultaneous endovascular stenting in the operating room is an alternative approach for patients who are poor candidates for traditional arch repair under circulatory arrest.

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INTRODUCTION

Isolated and nonisolated aortic arch disease (Figure 1) can be repaired through a conventional approach such as the elephant trunk or frozen elephant trunk, but some patients with multiple morbidities may not tolerate a conventional approach that includes circulatory arrest [Czerny 2004; Brueck 2006; Schwartz 2008; Yilik 2012]. The endovascular approaches may also be difficult when there are inadequate proximal landing zones in the aortic arch [Vallejo 2012]. Such cases may require coverage of one or more aortic arch vessels [Cires 2011]. A hybrid approach combining open surgical and endovascular procedures has shown acceptable results in aortic arch repair, which have extended the indications for use of endovascular stents in the management of aortic arch pathology [Bavaria 2010]. The widespread use of endovascular techniques has necessitated extensive long-term follow-up for monitoring the potential risk of endoleakage. Consequently, the demand for hybrid repair of unsuccessful endovascular procedures will likely increase in the future. This approach can be performed safely with fewer complications and higher success rates and can be completed within the same session [Younes 2010; Cires 2011; Vallejo 2012; Yilik 2012].

Furthermore, stent placement in the descending aorta may preclude elephant trunk and frozen elephant trunk methods in patients with type I endoleakage from the proximal stent. Patients with a significant type I endoleak may require debranching and further stenting as the only option. In this report, we describe our initial experience with planned debranching of the aortic arch using rerouting techniques with bypass to create a landing area in zones 0 and 1 of the aortic arch, followed by endovascular stenting.

METHODS

We retrospectively reviewed the characteristics and outcomes of 5 patients, who underwent hybrid repair of aortic arch pathology between 2008 and 2011 at our institution. All patients were poor surgical candidates for standard repair under circulatory arrest, owing to preoperative comorbidities and/or low physiological reserves. All operations were performed via a standard approach with a median sternotomy. A spinal drain was used in all patients and was left in place until

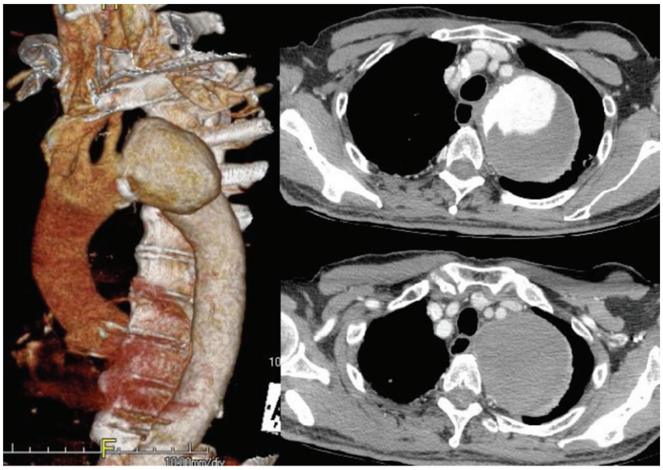

Figure 1. Complex aortic pathology. The aneurysm is a sac 11 × 8.7 × 8.4 cm and originates just downstream of the left subclavian artery.

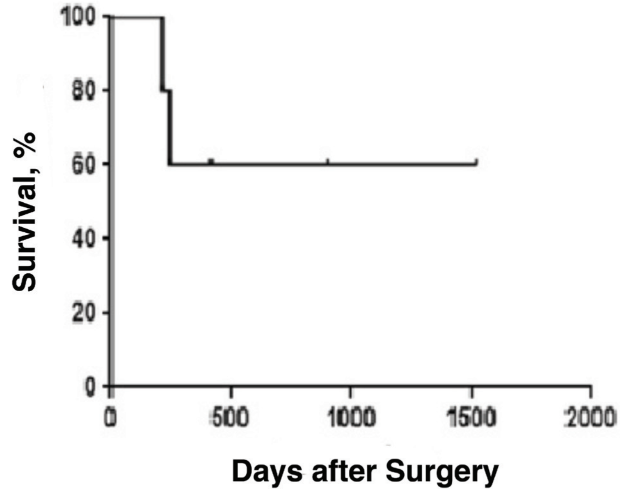

Figure 2. Kaplan-Meier survival curve. Two patients died, and the remaining 3 patients are doing well and are followed on a regular basis.

postoperative day 2. Total arch debranching and endovascular stent implantation (TAG Thoracic Endoprosthesis, W. L. Gore, Flagstaff, AZ, USA; or Talent stent graft, Medtronic, Minneapolis, MN, USA) were performed in the same session.

Statistical Analysis

Data on patient demographics, risk factors, and postoperative outcomes were collected. Hospital mortality was defined as death for any reason occurring within 30 days after the operation or at any time during the same hospitalization, regardless of the length of stay (LOS). Survival curves were generated with the Kaplan-Meier method. Continuous variables were calculated with the Student t test. This retrospective study was approved by the institutional review board at Montefiore Medical Center. GraphPad Prism (GraphPad Software, La Jolla, CA, USA) was used to analyze the data.

RESULTS

The mean age was 70.6 ± 18 years; 4 men and 1 woman were evaluated. The preoperative morbidities included arrhythmia (1 patient), chronic obstructive pulmonary disease (2 patients), cerebrovascular accident (1 patient), diabetes mellitus (3 patients), coronary artery disease (2 patients), and chest pain due to expanding aneurysm or pseudoaneurysm (2 patients). One patient had experienced a myocardial infarction 3 weeks before surgery. The 5 patients had the following characteristics: mean (±SD) ejection fraction, 53% ± 15%; New York Heart Association class, 1.6 ± 0.89; body mass index, 23.4 ± 0.64 kg/m2; body surface area, 1.78 ± 0.10 m2. The aortic pathologies included aneurysm in 4 patients and chronic dissection with expanding pseudoaneurysm in 1 patient. Below we review the cases of these 5 patients and describe their respective indications and hospital courses.

Three patients underwent their operations off cardiopulmonary bypass (CPB), and 2 patients had CPB support but without cardiac arrest and with only partial cross-clamping. The primary technical-success rate was 100%, and none of the patients died in the perioperative phase. Three patients received blood intraoperatively, and 2 patients required platelets. Postoperative complications included new-onset atrial fibrillation (1 patient), acute renal failure requiring renal replacement therapy (1 patient), and stroke (1 patient). Two patients required postoperative blood products, including red blood cells, platelets, and cryoprecipitate. The mean postoperative ventilation time was 18.8 ± 0.93 hours, and the mean LOS in the critical care unit was 50.8 ± 10.7 hours. We observed no respiratory failure (ventilation longer than 48 hours) in any of our patients, not did we observe spinal cord ischemia in any of the patients. The median hospital LOS was 19 days (range, 6-54 days). The mean LOS was prolonged because of 2 patients with multiple morbidities, who stayed in the hospital for 54 days and 34 days. Both patients died in skilled-nursing facilities during the follow-up period, one 2 days after discharge and the second 7 months after discharge. Two patients were discharged home, and 3 patients were discharged to extended-care facilities. The mean follow-up time was 22 ± 18.4 months, and the median follow-up time was 13.8 months (range, 7.13-50.7 months). The other 3 patients are still alive and have been regularly followed at our institution (Figure 2).

Presentation of Cases

Patient 1 was an 83-year-old man with diabetes mellitus, severe chronic obstructive pulmonary disease, and a compromised left ventricular ejection fraction. He was very frail and not a surgical candidate for CPB and circulatory arrest to repair the aneurysm of the descending aorta, which extended into the arch. This patient underwent his operation without cardiopulmonary bypass and with cross-clamping and a beating heart technique. A side-clamp was placed on the aorta to perform the anastomosis on the ascending aorta. The patient had a prolonged LOS in the hospital (54 days) and experienced a stroke

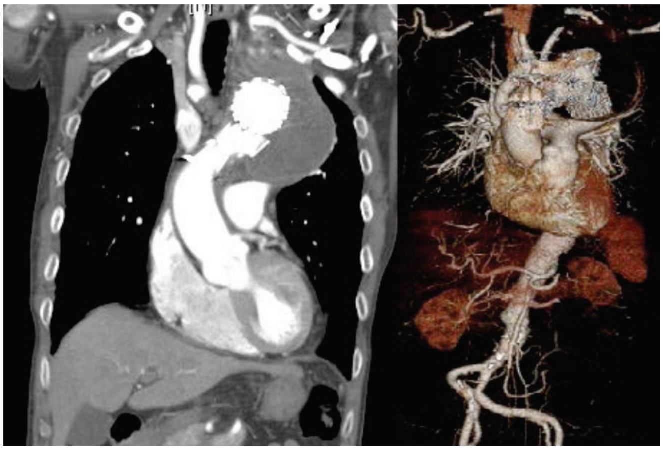

Figure 3. Bypass of the left carotid artery to the left subclavian artery.

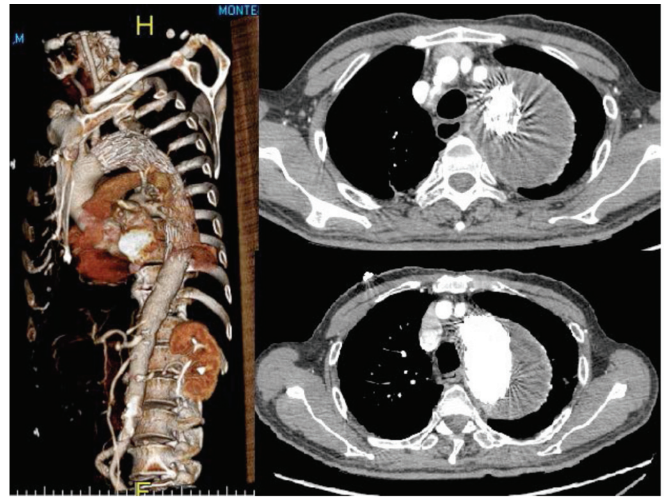

Figure 4. Resolution of the type I endoleak (left) and the decreased size of the aneurysm (right).

postoperatively. He died 2 days after he was discharged from the hospital. An autopsy was not performed, and the exact cause of death remains unknown.

Patient 2 is a 39-year-old deconditioned patient who had experienced an aortic dissection a few months earlier. The patient had undergone replacement of the ascending aorta, but her postoperative course was complicated by heparin-induced thrombocytopenia and compartment syndrome of a lower extremity that required fasciotomy and a prolonged hospital stay. The patient returned with an expanding aneurysm of the distal anastomosis involving the aortic arch. Given her condition and postoperative complications following her last surgery, the patient was reluctant to undergo further surgery. She was informed about the option of a hybrid approach, which she found less invasive and opted for a limited approach without cardiopulmonary bypass. Postoperatively, the patient did well without any serious complications. She is still alive and receives regular follow-up.

Patient 3 was a 76-year-old man with a type A dissecting aneurysm extending into the arch. His comorbidities included congestive heart failure, nonischemic cardiomyopathy (35%), placement of an automatic implantable cardioverter-defibrillator for his ventricular arrhythmias secondary to his cardiomyopathy, atrial fibrillation, left bundle branch block, a biventricular permanent pacemaker, hypertension, multiple-infarct dementia, and obstructive sleep apnea treated at home with continuous positive airway pressure. The patient was at very high risk for circulatory arrest and extensive surgery. The operation was performed with CPB and a beating heart technique, but without cross-clamping. His postoperative course was complicated by his multiple preexisting morbidities, and he stayed in the hospital for 34 days. He was discharged to an extended-care facility on postoperative day 34 and died 7 months after his discharge. No autopsy was performed, and the cause of death remains unknown.

Patient 4 is an 82-year-old man with a history of coronary artery disease, hypertension, hyperthyroidism, prostatic hypertrophy, gastric ulcer, and severe peripheral vascular disease. He had an aneurysm of the descending aorta distal that was very close to the left subclavian artery (LSA), without an adequate landing zone for a stent. He underwent transposition of the LSA to the left carotid artery (LCA) (Figure 3), followed by stent placement in the descending aorta that covered the LSA (Figure 4). The patient eventually returned a year later with complaints of persistent chest pain, cardiac arrhythmias, and lethargy. A computed tomography angiography examination revealed stent migration, a type I endoleak, and an expanding pseudoaneurysm (11 8 cm) at the proximal end of the stent in the distal aortic arch (Figure 5). A restenting was impossible owing to the absence of an adequate landing neck proximally and the extreme angulation of the previous stent. The patient underwent off-pump debranching of the aortic arch and endovascular stent placement during the same session (Figure 6). The endoleak was successfully eliminated, and the patient was discharged home on postoperative day 7. A follow-up computed tomography angiogram demonstrated patent grafts.

Patient 5 is a 74-year-old man with a history of hypertension, severe diabetes mellitus, and diabetic neuropathy. He presented to the emergency department complaining of chest pain. A computed tomography angiogram revealed a bovine arch and a penetrating ulcer in the aorta near the LSA (Figure 7) that was not accessible with an endovascular approach and stent placement. Furthermore, the LCA was attached to the innominate artery (IA) (bovine arch). Considering the patient's general condition, he seemed to be a poor candidate for a complete surgical repair, such as elephant trunk, under circulatory arrest. The patient underwent a hybrid approach. When considering the bovine arch, we entertained the idea of bypassing only the bovine arch; however, because of the proximity of the origin of the LCA to the orifice of the bovine arch, a ligation of the IA at its origin would have obstructed the LCA.

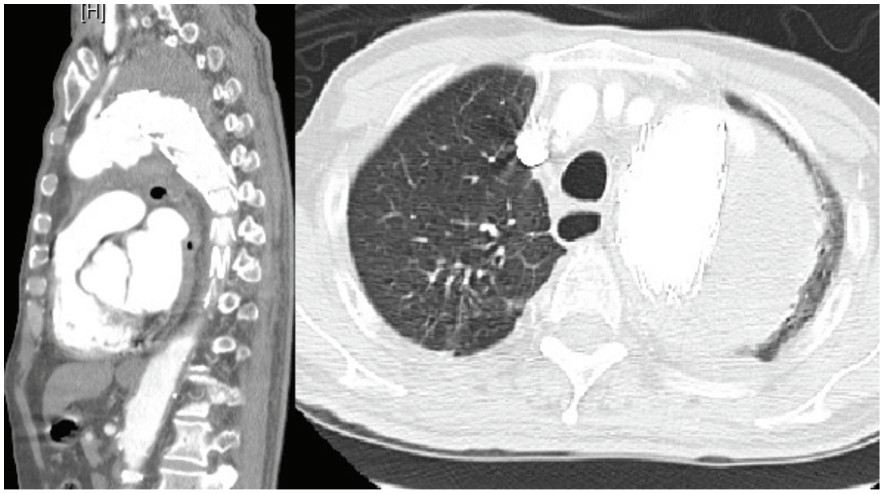

Figure 5. Type I endoleak and stent migration, with a 10-cm saccular aneurysm of the transverse aorta.

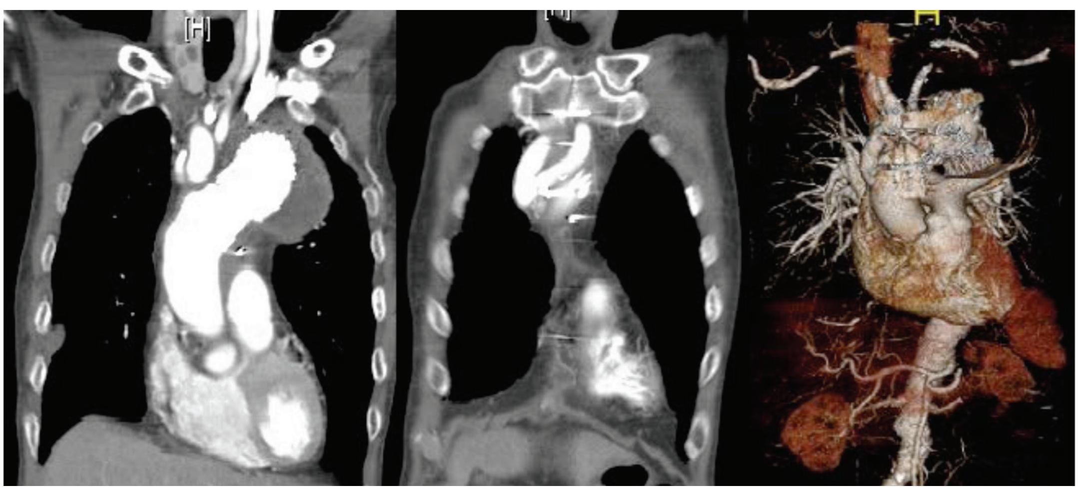

Figure 6. Six weeks after surgery with the hybrid approach, no evidence of endoleakage was apparent. Shown (left to right) are the excluded aneurysm sac, patent bypasses to the innominate artery and the left carotid artery, and a patent bypass of the left carotid artery to the left subclavian artery.

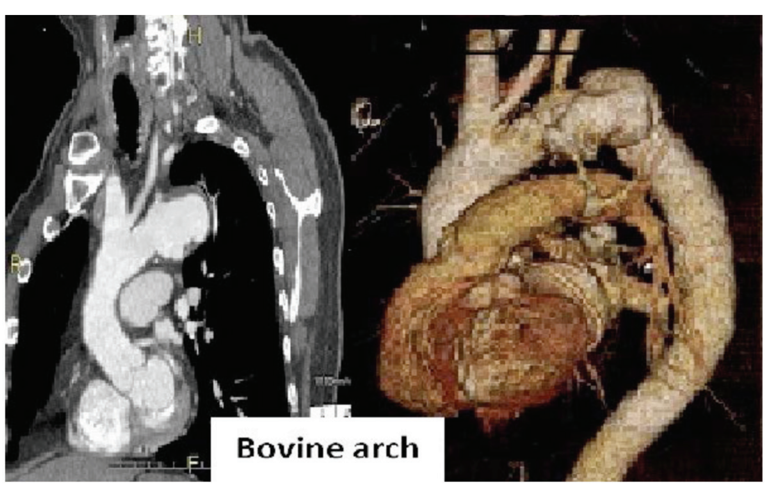

Figure 7. A computed tomography scan (left) with a reconstruction demonstrating the bovine arch and the location of the penetrating ulcer (right).

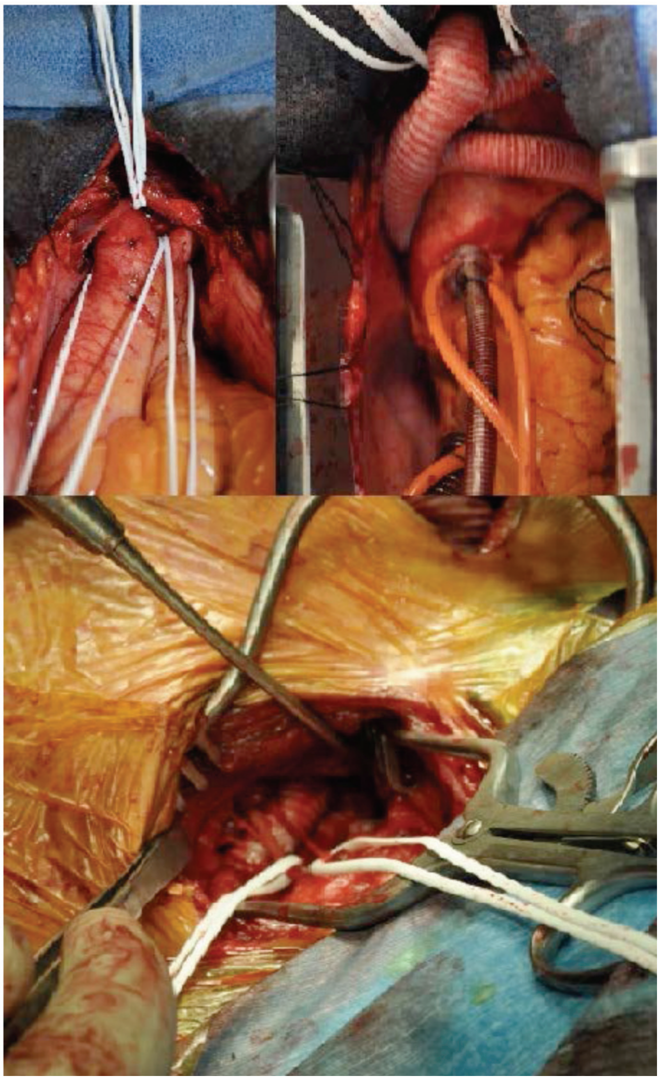

Figure 8. Isolation of arch vessels (top left), the supraclavicular approach for the left subclavian artery anastomosis (top right), and the completed debranching (bottom).

Technical Aspects

After a median sternotomy, the arch, the IA, and the LCA are dissected and isolated (Figure 8, top left). If the patient needs hemodynamic support, standard cannulation and CPB are performed. In hemodynamically stable patients, the debranching of arch vessels is performed without CPB. The arch vessels are dissected and isolated, and a trifurcated Hemashield graft (Maquet, San Jose, CA, USA) is tailored to the proper length and used to bypass and revascularize the arch vessels. A side-bite clamp is placed in the LCA and the IA; 8-mm and 12-mm grafts, respectively, are anastomosed in a side-to-end fashion. The proximal end of the graft is tailored to the appropriate length and then anastomosed to the ascending aorta by using a side-bite clamp on the ascending aorta. After completion of the anastomoses, the arch vessels are ligated at their origin with umbilical tape. The third limb of the graft is tied and left in place for LSA anastomosis. After completion of the intrathoracic anastomoses, a supraclavicular incision is made (Figure 8, top right), and the third limb of the graft is anastomosed to the LSA, followed by ligation of the LSA at its origin (Figure 8, bottom). Then, the right femoral artery is exposed and cannulated with a 7F sheath. After a standard endovascular approach, another angiography evaluation is performed to delineate the anatomy. The entire affected area is covered with a stent graft (Zenith TX2 stent graft; Cook Medical, Bloomington, IN, USA), which can extend as far as the ascending aorta. Another angiography evaluation is performed to document the final results. If the patient is on CPB, the patient can now be weaned from bypass. The chest is closed in a standard fashion. Follow-up angiography examinations before discharge and a few weeks postoperatively are recommended.

DISCUSSION

Some patients with aortic arch or descending thoracic aorta pathologies are not suited for open repair because of morbidities that would increase their risk of procedural complications and death [Vallejo 2012]. Furthermore, thoracic endovascular aortic repair (TEVAR) can be limited by inadequate proximal and distal landing zones. Debranching or hybrid TEVAR has emerged as a viable modality for the expansion of landing zones [Younes 2010], which allows extension of the thoracic endograft over arch vessels. This combined vascular and endovascular approach for the treatment of multisegmental thoracic aortic pathology has been welcomed by many surgeons in recent years [Czerny 2004; Gottardi 2008; Bavaria 2010]. Short-term results indicate the technical feasibility of this approach, but the long-term outcomes remain to be defined [Cires 2011]. The other indication for a hybrid approach is a type I endoleak following thoracic stent placement, which may not be amenable to restenting because of inadequate landing zones or a complex anatomy [Brueck 2006]. The quality and length of the landing zones are crucial for endovascular repair of a type I endoleak.

Czerny et al [2004] used a different debranching technique in 5 patients with aortic arch aneurysms involving the origin of the LCA. A sequential transposition of the LCA into the IA and transposition of the LSA into the already transposed LCA was followed by endovascular stent graft placement into the aortic arch. At the 10-month follow-up, computed tomography scans demonstrated patent arch vessels in all patients [Czerny 2004]. Bavaria et al [2010] reported on a series of 27 patients who underwent hybrid arch repair for distal aortic arch disease. The complications included stroke in 3 patients (11%), permanent paralysis in 2 patients (7%), and perioperative death in 3 patients (11%) [Bavaria 2010]. Ferrero et al [2012] reported a perioperative mortality rate of 11% for a series of 27 patients who underwent debranching and TEVAR for arch pathology. The rate of endoleakage was 3.7% (1/27), and endoleakage was due to stent graft migration. The authors endorsed a hybrid approach for arch pathology in high-risk patients on the basis of their promising early results, but they suggested a longer-term follow-up with a larger series was needed to confirm its safety and to achieve an acceptable outcome [Ferrero 2012].

Koullias et al [2010] performed a meta-analysis of hybrid aortic arch procedures. A total of 15 studies with 463 patients were included. With an overall 30-day mortality rate of 8.3%, the endoleakage rate was 9.2%, the stroke rate was 4.4%, and the rate of paraplegia was 3.9%. Treatment with an on-pump or off-pump technique did not affect the outcome [Koullias 2010]. Recently, Bavaria et al [2013] reported the single-center experience for a series of hybrid repairs of aortic arch pathology. The mean age was 71 years, and 14% of the cases involved a redo sternotomy. The authors performed their hybrid approach with CPB, cross-clamping, and circulatory arrest, which eliminate the advantages of a hybrid approach for patients who are not candidates for an extended but definite surgical repair. The authors reported a paraplegia rate of 5.5% (2 patients) and a stroke rate of 8% (3 patients). The in-hospital mortality rate was 8% (3 patients). At a median follow-up of 30 months, they reported favorable rates of freedom from all-cause mortality: 71%, 60%, and 48% at 1, 3, and 5 years, respectively. The authors recommended that a hybrid approach to an aortic arch aneurysm involving a zone 0 stent graft landing could be safely adopted. They achieved good midterm results in a cohort of elderly patients with significant comorbidities [Bavaria 2013]. It is questionable, however, whether their method can be referred to as a hybrid approach when they used cross-clamping, cardiac arrest, and circulatory arrest.

The rate of persistent endoleakage following TEVAR ranges from 5% to 11% [Czerny 2004; Gottardi 2008; Bavaria 2010; Torsello 2010; Riambau 2011], which underscores the need for close follow-up to achieve satisfactory long-term results following stent placement. Although type II endoleaks may be embolized, type I endoleaks mandate definite management. Surgical repair of a pseudoaneurysm in the distal landing zone following TEVAR has also been reported [Neragi-Miandoab 2006]. The indications for a surgical/hybrid correction of a failed TEVAR include retrograde type A aortic dissection; type I endoleak (if there is no adequate landing zone); false-aneurysm rupture due to distal stent migration, stent collapse, perforation, or fracture; and anatomic difficulties (severe angulation) [Czerny 2004; Gottardi 2008; Bavaria 2010; Torsello 2010; Riambau 2011]. Yilik et al [2012] reported that only 1 of 38 patients in their series required endovascular reintervention for type I endoleakage following debranching. No mortality or neurologic pathology was observed during the long-term postoperative follow-up [Yilik 2012]. The postoperative complications of debranching that have been reported include the need for hemodialysis postoperatively (7.9%), prolonged mechanical ventilation for respiratory insufficiency (47.4%), paraplegia (2.7%), and cerebrovascular accidents (13.1%). The results of others vary. For example, Vallejo et al [2012] reported an endoleakage rate of 11% and an overall 30-day mortality rate of 24% [Vallejo 2012], whereas Cires et al [2011] reported no endoleakage up to 25 months postoperatively, with all debranched vessels being patent. Younes et al [2010] observed a low mortality rate of 5%, with 43% of patients being staged for subsequent stent implantation a few days following surgical debranching. The authors did not observe reduced mortality with staging. Our results are in line with the published data and provide additional support for the feasibility and safety of the hybrid approach for management of arch pathology or a type I endoleak in the proximal landing zone of patients with multiple morbidities.

Coverage of the LSA ostium during TEVAR has been controversial. Tiesenhausen et al [2003] reported stenting of type B dissection or descending aneurysm in 10 patients with stent graft coverage of the LSA ostium. The authors did not observe a neurologic adverse event or left arm ischemia in the immediate postoperative period, whereas during follow-up (median, 18 months), 3 patients required surgical intervention for subclavian steal syndrome, left arm ischemia, or continuing perfusion of the dissected false aortic channel [Tiesenhausen 2003]. Therefore, close follow-up is necessary after intentional occlusion of the LSA ostium. We recommend that the LSA revascularization be individualized to each patient's specific condition and unique anatomy.

SUMMARY

Combined surgical and endovascular approaches for treating multisegmental thoracic aortic disease in patients with morbidities may reduce the burden of intervention, avoid hypothermic circulatory arrest and cardiac arrest, reduce total cross-clamp times, and reduce the extracorporeal perfusion time. Given the medical and anatomic complexity of aortic arch disease, the current results obtained with the hybrid approach are quite encouraging.

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