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Saccular Aneurysms of the Transverse Aortic Arch

Treatment Options Available in the Endovascular Era

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Abstract

Saccular aneurysms of the aortic arch, whether single or multiple, are uncommon. The choice of repair technique is influenced by patients' comorbidities and age. Repairing saccular aneurysms with traditional open techniques can be technically demanding; therefore, endovascular technology and a variety of hybrid approaches have been developed to facilitate such repairs and, potentially, to improve clinical outcomes, especially in high-risk patients. There have been no large, randomized studies to compare the outcomes of these different treatment options in patients with single or multiple saccular aneurysms of the arch. In this review, we outline the etiology and common locations of these aneurysms, the different open, completely endovascular, and hybrid techniques used to treat them, and the treatment selection process.

Key Words:

Saccular aneurysms • Aortic arch • Chimney and snorkel technique • Hybrid technique

Introduction

Saccular aneurysm of the transverse aortic arch is an uncommon clinical entity whose natural history is poorly understood. Saccular aneurysms in general, including those of the transverse aortic arch, have been characterized as having a higher risk of rupture than fusiform aneurysms. Addressing a similar entity in the abdominal aorta, the Joint Council of the Society of Vascular Surgery and North American Chapter of the International Society of Cardiovascular Surgery has recommended the repair of all saccular aneurysms of the abdominal aorta, regardless of their size or symptomatology [1]. As new technology has emerged for treating aortic pathology, new paradigms for aneurysm therapy have been developed, including a variety of open, hybrid, and completely endovascular, catheter-based techniques. To date, however, there have been no large randomized trials to compare the outcomes of these different interventions. Reports of meta-analyses have been published but must be interpreted carefully because of the heterogeneity among patients and studies [2]. We outline the different methods for treating single or multiple saccular aneurysms of the aortic arch, and we explain our preference for certain techniques.

Etiology, Location, and Natural Course of Saccular Aneurysms

Fusiform aortic aneurysms are primarily due to connective tissue disorders, which are frequently associated with genetic conditions. In contrast, saccular aneurysms of the aorta have a wide variety of causes, including both active and remote infection [3, 4], inflammatory diseases such as tuberculosis and syphilis [5-7], degeneration and progression of a penetrating aortic ulcer, prior trauma or aortic surgery [3, 8], Behcet disease, and Takayasu arteritis. In a series recently reported by Shang et al. [9] at the University of

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Pennsylvania, the majority of saccular aneurysms arose as a consequence of atherosclerotic disease. Although the true natural history of saccular aneurysms remains unknown, their perceived malignancy has driven cardiovascular surgeons to use a lower diameter-based threshold for repairing saccular aneurysms than they use for repairing fusiform aneurysms.

The location of aortic saccular aneurysms is variable. Common locations include the inner curvature of the transverse aortic arch and close to the celiac axis, projecting posteriorly [10]. In the recent report by Shang et al. [9], among 322 saccular aneurysms, 68.1% were located in the descending aorta, 24.2% in the abdominal aorta, 7.1% in the arch, and 0.6% in the ascending aorta.

Repair Techniques for Saccular Aneurysms of the Aortic Arch

Open Repair

Most studies of the surgical management of transverse aortic arch pathology have focused on fusiform aneurysms. Recent series have produced very promising results, particularly in high-volume centers of excellence in aortic surgery. Leshnower and colleagues [11] reported a mortality of 9.7%, an overall incidence of stroke of 2.8%, and a temporary neurologic deficit rate of 5.6% among 145 patients who underwent total arch replacement. Among 721 patients who underwent arch replacement over a 17-year period at the University of Michigan, 30-day mortality was 5%, the incidence of stroke was 4.7%, and the 10-year survival rate was 65% [12]. Promising results were also reported by Thomas et al. [13] regarding 209 patients who underwent open arch replacement operations. Of the 65 patients who underwent total arch replacement, postoperative mortality rates were 5.5% for elective and 10% for emergency procedures, and stroke rates were 5.5% for elective and 10% for emergency procedures.

Various cerebral protection strategies were used in the abovementioned series: moderate hypothermia, deep hypothermia, antegrade cerebral perfusion, and retrograde cerebral perfusion. Endovascular and hybrid techniques were introduced in an attempt to avoid circulatory arrest and cardiopulmonary bypass in high-risk patients, thereby reducing mortality and stroke risk. In 1991, Ukrainian surgeon Nikolay Volodos and his colleagues [14] performed the first hybrid aortic arch operation, combining open surgery with debranching of the aortic arch and stent grafting. This patient was reportedly still alive with a stable endoprosthesis in February 2013 [15]. Since then, several techniques have been used to treat fusiform or saccular aneurysms of the arch: classic aortic arch debranching with endovascular exclusion of the arch, combinations of branch-artery stent placement and endovascular repair, stent graft fenestration, and branched stent grafting. These alternatives are not mutually exclusive, because surgical bypass of the head vessels at the neck can facilitate fenestrated and branched endografts.

Branched Stent Grafts

Custom-made branched stent grafts have been used for both fusiform and saccular arch aneurysm repair, but experience with these devices remains limited and investigational, and the different grafts and the techniques for using them are at various stages of development. Also, custom-manufacturing these devices necessarily delays treatment. In addition, there is only anecdotal evidence in the United States to support the use of these devices [16, 17]. As Chuter et al. [16] noted, these grafts allow endovascular bypass to the branches of the aorta through branches of the stent graft. These authors deployed a stent graft in the innominate artery to maintain flow, and a second stent graft in the aortic arch to exclude a saccular aneurysm on the inner curve. However, if the disease was at the orifice of the stented branch artery, the use of this technique resulted in endoleak. More extensive experience has been reported by Yokoi and colleagues [18], who examined results from 35 Japanese centers at which 383 patients were treated with a precurved fenestrated endograft. Among these patients, 141 were treated for lesions in zones 0 and 1. The other 242 patients were treated for zone 2 and 3 lesions. The endografts in this series were fabricated according to preoperative 3-dimensional computed tomographic images. Nineteen types of 3D curved stent skeletons and 8 types of graft fenestrations for arch vessels were used. Their endograft designs were based on data from 1000 clinical cases of arch endografting with a custom-made device. The tip of their devices was short and soft in order to facilitate safe access in the ascending aorta.

Using branched stent grafts also necessitates manipulating the arch and arch vessels. This poses a risk to patients with atherosclerosis of these vessels; a University of Pennsylvania study showed that the combination of aortic arch atheroma and intraoperative instrumentation of the aorta is associated with stroke in patients undergoing thoracic endovascular aortic repair [17]. Yokoi et al [18], in their series, had a low rate of cerebrovascular accidents. They attributed this finding to the precurved shape of their endograft and the orientation of the fenestration toward the supra-aortic arch vessels, which reduced the amount of wire and catheter manipulation that was necessary in the arch. Long-term data are not yet available due to the early stage of this study, and durability will be the key for widespread use of this technology.

Double-Barrel, Chimney, and Snorkel Grafting Technique

Double-barrel, chimney, and snorkel grafting are essentially different terms for the same technique that uses commercially available stent grafts. This technique was described as a rescue procedure to be used when a head vessel (left common carotid or innominate artery) is inadvertently covered, but it has also been described in different sequence for other situations. Wire and sheath access is gained from the branch vessel into the ascending aorta, alongside the undeployed stent graft with which the arch will be covered [19]. Baldwin et al. [19] reported using this technique to treat 4 saccular aneurysms and 1 penetrating ulcer in 7 patients who each previously had a stroke. The authors raised concerns about mechanical interaction between the branch stent and the aortic stent, as well as the possibility that hemodynamic forces within the aortic arch could cause stent fracture or vessel injury. In a review of 18 reports by Moulakakis et al. [20], among 124 patients (26% with degenerative aneurysms) 136 chimney grafts were used (25 in the innominate artery, 50 in the left common carotid artery, and 51 in the left subclavian artery). The stroke rate was 4%, and early mortality was 4.8%. The main disadvantage of this technique was the potential for endoleak (which occurred in 18.5% of cases) due to large "gutters" along the main graft. In addition, it was evident that in cases in which the innominate and the left common carotid artery were stented, complication rates were significantly elevated (44% and 22%, respectively). For the chimney technique, there is no consensus regarding which type of branch stent (covered vs. bare, self-expanding vs. balloon-expandable) [19-21] best promotes the technical success and long-term durability of the repair. This technique also requires manipulating and instrumenting the arch vessels, so the risk of stroke could be especially high in patients with multiple saccular aneurysms, in which atherosclerosis can be substantial [9]. In addition, if it is necessary to land the endograft in zone 0, extra-anatomic bypass is required [22].

Supra-aortic Arch Debranching, Hybrid Repair

This repair can be achieved via median sternotomy with the use of a prefabricated, trifurcated, bifurcated, or inverted Y graft. Alternatively, the reconstruction can be performed via extra-anatomic bypasses. Through a median sternotomy, a partial occluding clamp is applied to the ascending aorta, and the proximal anastomosis is performed with the main trunk of the Y graft. The individual distal anastomoses are performed first to the left subclavian artery, then to the left common carotid artery, and finally to the innominate artery. If the left subclavian artery is not easily reached, a left carotid–to–subclavian artery bypass is performed. This bypass is followed by the endovascular exclusion of the arch via antegrade or retrograde delivery of the stent graft. Compared to the previously mentioned endovascular techniques, this technique has the advantage of rerouting blood flow before stent graft delivery, potentially reducing neurologic sequelae. In addition, the endovascular part of the procedure is relatively simple, and the surgical part does not necessarily require exposing the aneurysm.

The morbidity associated with surgical debranching depends on the surgical accessibility of the branch. We have used this technique in high-risk patients with multiple saccular aneurysms of the arch for whom we considered open repair to be contraindicated by their substantial comorbidity [23] (Figure 1). Contemporary series of hybrid arch procedures with zone 0 (ascending aorta) as the proximal landing zone in high-risk patients have reported mortality rates of 0 to 29.6% and stroke rates of 0 to 11% [22, 24-27].

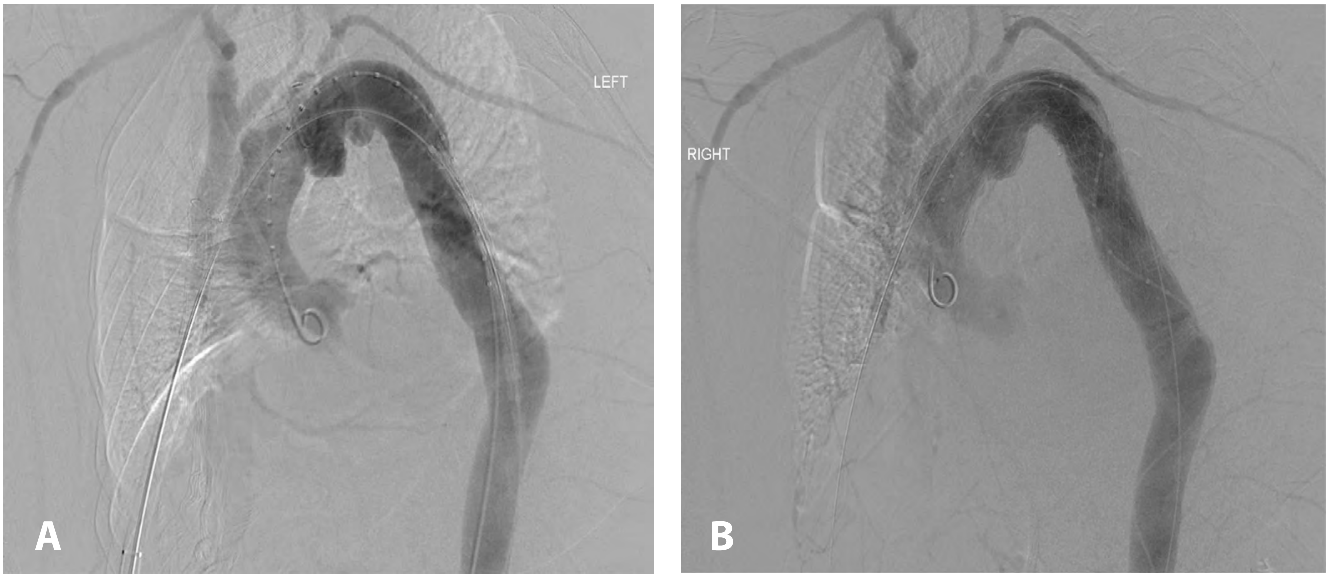

Figure 1. Intraoperative angiograms showing aortic arch debranching of all head vessels. (A) Aorto-innominate bypass, aorto–left common carotid artery (LCCA) bypass, and aorto–left subclavian artery (LSCA) bypass are performed, and multiple saccular aneurysms of the arch are visible. (B) Debranching is complete, and all saccular aneurysms have been excluded with two endovascular stent-grafts. (From Preventza O, Aftab M, Coselli JS. Hybrid techniques for complex aortic arch surgery. Tex Heart Inst J. 2013;40:568-571. Reproduced with permission.)

Paraplegia has been reported also (0-7%) [22, 24-27] and is associated with more extensive coverage of the descending thoracic aorta. Careful review of the literature is required because hybrid repair of the aortic arch in different series does not refer only to Zone 0 but includes also zones 1, 2, and 3. It is well documented that zone 0 landings are more strongly associated with various risks, including the risk of stroke, than are landings in the other zones, so it is important to make appropriate comparisons among similar patient populations [22, 24-27]. In addition, landings in the native zone 0 pose a risk of retrograde ascending aortic dissection, as previously reported [25]; this is not the case when the ascending aorta has been replaced with a Dacron graft.

Discussion

Meaningful comparison among the abovementioned hybrid techniques is complicated by the heterogeneity of both the studies and the patients. The techniques were not specifically developed to treat saccular aneurysms of the arch, and outcomes were not reported specifically for patients with these aneurysms. Patients also differed with regard to their comorbidities and characteristics and the selection biases of their treating physicians. For patients whose comorbidities would make open repair prohibitively risky, our preferred first-line therapy has been aortic arch debranching via median sternotomy, which is performed off-pump, followed by endovascular stent grafting to exclude the transverse aortic arch. Many saccular aneurysms of the transverse aortic arch are thin-walled and prone to rupture, as well as subject to severe, superimposed atherosclerosis and thrombosis, placing patients at risk for stroke. The concept of rerouting the blood to the brachial cephalic vessels before stent graft deployment and endovascular manipulation holds the promise of reduced risk of rupture and stroke secondary to atheroma.

Although useful in concept, the technique remains an off-label use of the currently available devices. The branched stent techniques currently under development are still experimental, and the graft devices must be custom-made to suit individual patients and their pathologies. Because many patients with single or multiple saccular aneurysms of the transverse aortic arch present with a variety of disease processes, many of which necessitate urgent intervention, significant delay is not optimal. In such cases, the double-barrel or chimney technique can be used in conjunction with extra-anatomic bypass, but concerns about the durability of the side-branch stents and the manipulation of wires and catheters in the arch have been already addressed. Consequently, the ultimate goal should be to develop effective techniques that use off-the-shelf, readily available devices.

In the absence of comparative randomized clinical trials, it is difficult to compare the abovementioned hybrid and total endovascular techniques. In addition, any comparison of the open technique with the hybrid or total endovascular technique is unfair because the patient populations treated with these techniques are fundamentally different, and because an individualized approach can offer the best results.

Conclusion

In patients who present with single or multiple saccular aneurysms of the arch and for whom open repair is not contraindicated, we believe that traditional surgical repair should remain the standard therapy. In high-risk patients, hybrid repair with aortic arch debranching via median sternotomy and antegrade or retrograde stent delivery for arch exclusion is our preferred approach.

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Conflict of Interest

W. L. Gore & Associates and Cook Medical, Inc have provided travel expenses for Dr. Preventza in the past. Dr. Preventza serves as a consultant for Medtronic, Inc. Dr. Coselli was provided program support by and has given lectures for W. L. Gore & Associates, and he serves as principal investigator for clinical trials conducted by W.L. Gore & Associates, Medtronic, Inc., and Cook Medical. In addition, Dr. Coselli serves as a consultant to and receives royalties from Vascutek Ltd., a subsidiary of Terumo Corporation.

Comment on this Article or Ask a Question

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