Endovascular Techniques for Treating Ascending Aortic Pathology

A review of the published data available to date for endovascular therapy in the unique anatomy of the ascending aorta.

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Lesions of the ascending thoracic aorta, especially in patients with a history of open surgical aortic repair, multiple comorbidities, or advanced age, represent extremely challenging cases with high associated mortality and morbidity. Type A dissection alone, for example, carries a 30% overall mortality rate. Morality increases to 60% in higher-risk patients with type A dissections,[1,2] and up to 30% of these patients are considered unfit for open surgery.[1]

In order to improve outcomes in high-risk patients presenting with ascending aortic pathology, selective endovascular therapy has been used. The ascending aorta is difficult to treat with endovascular techniques, however, mainly due to anatomic and hemodynamic limitations. Despite the absence of widely established endovascular approaches for treating ascending aortic disease, improvements in endograft technology have lead to shorter and larger-diameter endografts with shorter tips and more flexible delivery systems, such that half of patients undergoing open repair of type A dissections could now potentially benefit from an endovascular approach.[3]

PUBLISHED WORLD EXPERIENCE

In 2000, the first case of ascending aortic dissection treated with a customized endograft was reported.[4] Since then, several groups have published their experiences, and 101 total cases have been reported in 38 peer-reviewed articles.[4-17] A wide range of indications, techniques, materials, and results has been described (Table 1). At our institution, one case of ascending aortic pseudoaneurysm has been treated with initial success (Figures 1 through 4).

Aortic arch pathology treated with combined distal ascending aortic and arch endografts with concomitant use of chimneys in the supra-aortic trunks, cases utilizing total arch debranching, and cases of branched endografting have been not included in this review, as they relate to uniquely different pathologies and associated treatments.

Patient Selection

The most common indication for endovascular repair of the ascending aorta, as reported in the literature, is type A aortic dissection, representing 45% of all published cases.[11] Endovascular treatment of ascending aortic aneurysms,[13] pseudoaneurysms,[5] penetrating aortic ulcers,[7] and other pathologies (eg, intramural hematoma, floating thrombus, or iatrogenic coarctation) has also been reported.

In nearly all published cases, endovascular repair was performed due to the prohibitive risk of open surgery in patients with previous open aortic operations or severe comorbidities, such as heart failure or chronic pulmonary obstructive disease.

Anatomical Considerations

The anatomy of the ascending aorta presents unique challenges for endovascular repair. Accurate measurement of thoracic and abdominal aortic diameters and lengths and a thorough evaluation of associated aortic branch anatomy and pathology should be performed with preoperative CT angiography, anatomic reconstructions, and centerline measurements. Adequate iliac and femoral access anatomy must be confirmed before initiating endovascular aortic repair. Intraoperative aortography can also be useful to corroborate preoperative measurements. Transesophageal echocardiography should be used routinely to evaluate intraoperative cardiac function and rule out the presence of pericardial effusion, aortic regurgitation, and retrograde dissection. Selective preoperative heart catheterization can also be performed.

Although several groups have described individual cases of endovascular repair of ascending aortic pathology without specific anatomic details, several authors recommend the following for endovascular repair:[9,11]

- Entry tear present in the ascending aorta

TABLE 1. DETAILS OF 101 ASCENDING AORTIC ENDOGRAFT PROCEDURES PUBLISHED IN 38 ARTICLES IN IMPACT FACTOR JOURNALS

	N	%
Age	65 y (median)	22–89 y (range)
Indication for surgery		
Type A aortic dissection	46	45.5%
Aneurysm	25	24.8%
Pseudoaneurysm	19	18.8%
Penetrating aortic ulcer	7	6.9%
Intramural hematoma	2	2%
Floating thrombus	1	1%
Iatrogenic coarctation	1	1%
Endograft type		
Not specified or imprecise	26	25.7%
Cook devices (Zenith, Zenith cuffs, TX2, Pro-Form, and ascending dissection device)	34	33.7%
Excluder devices (TAG, Conformable TAG, and Excluder cuffs)	25	24.8%
Medtronic devices (Talent, Valiant)	7	6.9%
Custom made	7	6.9%
Jotec	1	1%
Relay	1	1%
Endograft size		
Diameter	39 mm	28–46 mm
Length	79 mm	30–200 mm
Access		
Not specified or imprecise	10	9.9%
Femoral	75	74.3%
Iliac	3	3%
Left common carotid artery	5	5%
Axillary (right or left)	3	3%
Transapical	4	4%
Ascending aorta	1	1%

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TABLE 1. DETAILS OF 101 ASCENDING AORTIC ENDOGRAFT PROCEDURES PUBLISHED IN 38 ARTICLES IN IMPACT FACTOR JOURNALS (Continued)	N	%
Additional intraoperative procedures		
Open SAV debranching (bypass) 3 CCb, 2 SCb+CCb, 2 ascending aorta-SAV bypass, 1 femoral-carotid bypass	8	7.9%
Endovascular SAV debranching (chimneys) 15 IAc, 2 IAc + CCb, 1 IAc and left carotid artery chimney	18	17.8%
Other 1 banding of the ascending aorta, 1 coronary stenting (not related)	2	2%
Initial success	97	96%
Early complications		
Intraoperative open conversion	3	3%
30-day mortality	8	7.9%
Access bleeding or complications	4	4%
Follow-up	15 mo (median)	0–55 mo (range)
Reinterventions* 4 open reinterventions (3 distal disease, 1 aortic valve repair), 4 endovascular reinterventions (3 endoleak embolization, 1 distal endograft)	8	11%

**Reinterventions during follow-up are calculated over series with more than 6-month follow-up (73 patients).*
Abbreviations: CCb, left carotid-right carotid bypass; IAc, innominate artery chimney; SAV, supra-aortic vessels; SCb, left subclavian-left carotid bypass.

- ≥ 2 cm distance between the sinotubular junction and the entry tear
- ≥ 0.5 cm distance between entry tear and brachiocephalic trunk (≥ 2 cm for some groups)[9]
- No signs of cardiac tamponade, severe aortic regurgitation, or ischemia of the aortic branches
- No previous cardiac revascularization originating from the ascending aorta

Other possible contraindications include inadequate arterial access (small or diseased femoral or iliac arteries, or tortuosity/narrowing of the descending aorta when transfemoral access is planned), evidence of acute myocardial infarction, history of life-threatening ventricular arrhythmia, or past medical history of connective tissue disorders. A history of mechanical aortic valve replacement increases the difficulty of accurate stent graft deployment and represents a relative contraindication to endovascular repair of the ascending aorta.

Overcoming common anatomical limitations usually requires lengthening the distal landing zone by placing stents in the innominate or left common carotid artery as chimney grafts,[5,7,17] performing total or partial aortic arch debranching,[6,7] or performing retrograde arch debranching (femoral to supra-aortic trunk bypass).[8] Banding of the ascending aorta to decrease aortic diameter has also been described.[6]

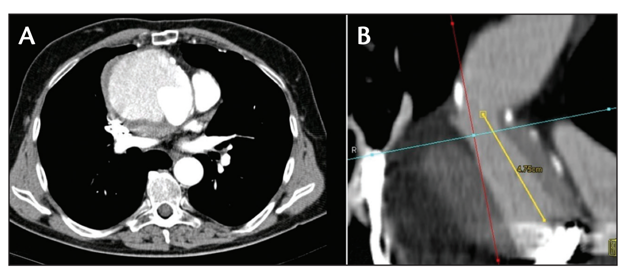

Figure 1. CT angiogram showing a pseudoaneurysm of the ascending aorta after a previous Bentall surgery (A, axial; B, coronal exams), which was treated at our institution.

Devices

The most commonly used endografts in the treatment of ascending aortic pathology are from Cook Medical (Zenith thoracic devices, TX2 and TX2 with Pro-Form, and ascending dissection devices or abdominal cuffs), followed by Gore & Associates (TAG, Conformable TAG, and

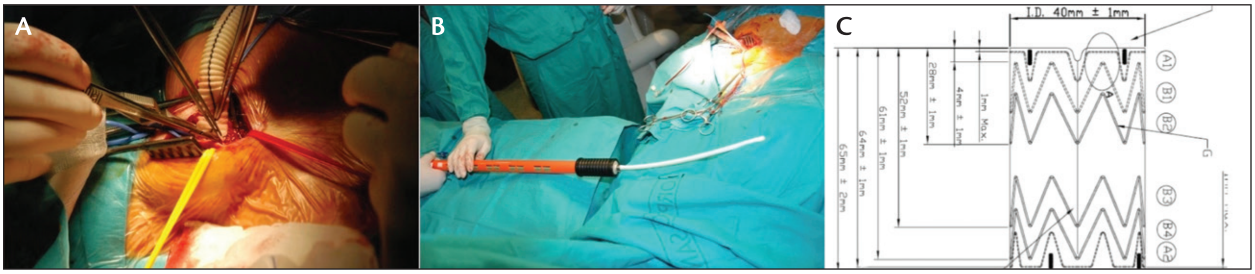

Figure 2. In the same case as Figure 1, left subclavian artery conduit (A) was used to introduce the endograft, a custom-made Relay graft (B, C).

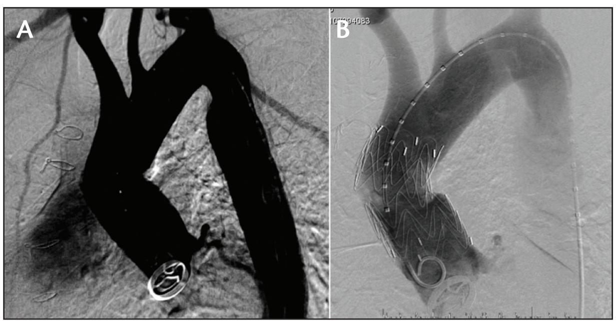

Figure 3. Intraoperative angiogram before (A) and after (B) placement of the ascending endograft to treat a pseudoaneurysm. No endoleaks or other complications were detected.

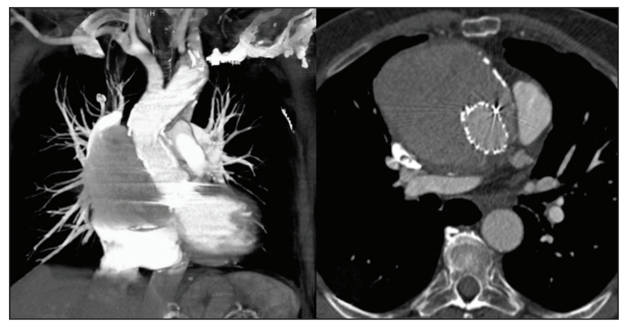

Figure 4. A 1-year control CT angiogram of the same patient showing no endoleaks or graft complications.

Excluder cuffs), Medtronic, Inc. (Talent and Valiant grafts), Jotec GmbH (Jotec stent graft system), Bolton Medical (Relay thoracic stent graft), and some physician-modified grafts. However, data regarding specific devices are absent or imprecise in up to 26% of cases.

Stent graft oversizing is not described in most articles, although 10% to 15% oversizing is commonly assumed. In cases of acute aortic dissection, stent graft sizing is usually based on the aortic diameter measured at the level of the dissection entry tear. At least 10% oversizing with respect to the true lumen, without exceeding the original aortic diameter, is common. In cases with previous ascending aortic grafts, 20% oversizing with respect to the original graft diameter is usually planned.[11]

In published cases, endograft diameters range from 28 to 46 mm (median, 39 mm), and endograft lengths range from 30 to 200 mm (median, 79 mm, depending on planned coverage of the aortic arch). Back-table endograft modification to include innominate fenestration and subsequent distal landing zone extension into the aortic arch, or reduce the endograft length, has been described.[13]

Deployment Techniques

Most groups use the femoral arteries for endovascular device access (74% of published cases);[9] however, other access routes have been used, including the iliac arteries via surgical conduit, and the axillary[5] or left common carotid arteries via direct cannulation.[13] Transapical or transascending aortic approaches have also been described.[10,14]

In most cases, after general anesthesia and systemic anticoagulation have been established, routine aortography of the ascending aorta from the sinus of Valsalva allows the identification of the coronary ostia and brachiocephalic aortic branches.[9] An extra-stiff guidewire is introduced through the ascending aorta and into the left ventricle, and the endograft delivery system is then advanced over the guidewire and into the ascending aorta. To ensure accurate deployment while using endografts with long, tapered delivery systems (eg, the Medtronic or Cook Medical devices),[7,9] the respective system's proximal nose cone must be passed carefully through the aortic valve and into the left ventricle.

In order to reduce cardiac output and systemic blood pressure during endograft deployment, controlled hypotension (systolic pressure ≤ 80 mm Hg),[12] rapid ventricular pacing,[9] adenosine[5] or nitroprusside[7] administration, and vena caval occlusion have been used. However, if the delivery system nose cone contacts the left ventricle wall, ventricular tachycardia and significant hypotension may occur, resulting directly in significant hypotension. In these cases, the endograft is deployed, and the delivery system is rapidly withdrawn from the ventricle. Ventricular tachycardia or fibrillation usually resolves within seconds. Nevertheless, chemical or electrical cardioversion should be immediately available.[9]

Balloon dilatation of the ascending endograft is rarely performed[5] but is occasionally implemented in a "kissing" fashion when a concomitant chimney graft is deployed in the innominate artery. Completion angiography is usually performed to confirm exclusion of the lesion, competency of the aortic valve, patency of the coronary arteries, patency of the supra-aortic vessels, and also to evaluate distal aortic anatomy.

Some reports describe the use of pre- and postoperative antiplatelet therapy (acetylsalicylic acid),[13] but most investigators do not regard this as essential. In cases with severe aortic arch calcification or intraluminal thrombus, clamping of the carotid arteries before wire and catheter introduction has been performed with concurrent extracorporeal bypass from the right groin to both carotid arteries to reduce the risk of cerebral embolization.[13]

Results and Follow-Up

Despite a relative lack of follow-up in reported cases, the limited results of ascending aortic endografting are promising, with an initial success rate of approximately 96% and a relatively low intraoperative and 30-day mortality rate of 8%. Stroke resulting from embolization during instrumentation of a diseased aortic arch or from iatrogenically induced progression of a dissection into the supra-aortic vessels is a potentially severe complication. Ventricular trauma from guidewire or device misplacement may also occur, emphasizing the need for accurate wire control and the use of devices with short nose cones. Aortic valve insufficiency may result from the inaccurate proximal deployment of an endograft[7]—this potentially catastrophic complication may be avoided intraoperatively with balloon-mediated distal pullback of the endograft.[13,15]

Long-term data after endovascular repair of the ascending aorta are sparse. Published reports with available follow-up data ranging from 0 to 55 months demonstrate sustained exclusion of aortic disease and maintenance of endograft patency without major complications. Although follow-up data are somewhat inconsistent, the reported need for reoperation is rare, with approximately 12% of all published cases with more than 6 months follow-up necessitating operative reintervention. The vast majority of these cases are performed for endoleaks and require proximal or distal stent graft extension, with or without additional debranching or coiling.[13] Late endograft removal and conversion to open surgery secondary to aortic root enlargement and severe aortic insufficiency has also been described.[16]

CONCLUSION

More than 100 cases of endovascular treatment of ascending aortic diseases have been published to date utilizing a wide range of techniques and promising short- to midterm results. The introduction of specific endovascular devices for the ascending aorta, their combination with percutaneous aortic valve techniques, and the use of fenestrated grafts for arch vessels may all combine to improved results of and broaden the indications for endovascular repair of the ascending aorta in the future. ■

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1. Hagan PG, Nienaber CA, Isselbacher EM, et al. The International Registry of Acute Aortic Dissection (IRAD): new insights into an old disease. JAMA. 2000;283:897-903.
2. Trimarchi S, Eagle KA, Nienaber CA, et al. Role of age in acute type A aortic dissection outcome: report from the International Registry of Acute Aortic Dissection (IRAD). J Thorac Cardiovasc Surg. 2010;140:784-789.
3. Sobocinski J, O'Brien N, Maurel B, et al. Endovascular approaches to acute aortic type A dissection: a CT-based feasibility study. Eur J Vasc Endovasc Surg. 2011;42:442-447.
4. Dorros G, Dorros AM, Planton S, et al. Transseptal guidewire stabilization facilitates stent-graft deployment for persistent proximal ascending aortic dissection. J Endovasc Ther. 2000;7:506-512.
5. Preventza O, Henry MJ, Cheong BYC, Coselli JS. Endovascular repair of the ascending aorta: when and how to implement the current technology. Ann Thorac Surg. 2014;97:1555-1560.
6. Uchida N, Katayama K, Takahashi S, Sueda T. Total arch repair using supra-aortic debranching technique with banding of the ascending aorta for endovascular stent graft fixation. Ann Vasc Surg. 2013;27:354.e5-8.
7. Bernardes RC, Navarro TP, Reis FR, et al. Early experience with off-the-shelf endografts using a zone 0 proximal landing site to treat the ascending aorta and arch. J Thorac Cardiovasc Surg. 2014;148:105-112.
8. Gomibuchi T, Kono T, Takahashi K, et al. Hybrid thoracic endovascular aortic repair of ascending aortic pseudoaneurysm. J Vasc Surg. 2014;59:1695-1697.
9. Lu Q, Feng J, Zhou J, et al. Endovascular repair of ascending aortic dissection: a novel treatment option for patients judged unfit for direct surgical repair. J Am Coll Cardiol. 2013;61:1917-1924.
10. Roselli EE, Brozzi N, Albacker T, Lytle BW. Transapical endovascular ascending repair for inoperable acute type a dissection. JACC Cardiovasc Interv. 2013;6:425-426.
11. Ronchey S, Serrao E, Alberti V, et al. Endovascular stenting of the ascending aorta for type A aortic dissections in patients at high risk for open surgery. Eur J Vasc Endovasc Surg. 2013;45:475-480.
12. Ye C, Chang G, Li S, et al. Endovascular stent-graft treatment for Stanford type A aortic dissection. Eur J Vasc Endovasc Surg. 2011;42:787-794.
13. Kolvenbach RR, Karmeli R, Pinter LS, et al. Endovascular management of ascending aortic pathology. J Vasc Surg. 2011;53:1431-1437.
14. Feezor RJ, Beaver TM. Antegrade deployment of a thoracic endograft using a minithoracotomy. Ann Thorac Surg. 2014;98:713-715.
15. Palma JH, Gaia DF, Guilhen JS, Buffolo E. Endovascular treatment of chronic type A dissection. Interact Cardiovasc Thorac Surg. 2008;7:164-166.
16. Zhang H, Li M, Jin W, Wang Z. Endoluminal and surgical treatment for the management of Stanford type A aortic dissection. Eur J Cardiothorac Surg. 2004;26:857-859.
17. Shirakawa Y, Kuratani T, Shimamura K, et al. The efficacy and short-term results of hybrid thoracic endovascular repair into the ascending aorta for aortic arch pathologies. Eur J Cardiothorac Surg. 2014;45:298-304.