Endovascular Treatment of the Ascending Aorta: is this the Last Frontier in Aortic Surgery?

Eduardo Keller Saadi¹,², MD, PhD ; Ana Paula Tagliari², MD, MSc; Rui M. S. Almeida³, MD, PhD

Abstract
Regardless the successful treatment of the descending aorta with endovascular prosthesis, for the ascending aorta segment, because of several anatomic and physiologic issues, this technique has been considered an alternative only for high-risk or inoperable patients. Despite restricted indications, hundreds of treatments have been performed worldwide, demonstrating its safety and reproducibility if it is done in high-quality centers. Therefore, understanding patients' selection criteria and technique limitations are critical to its application.

Keywords: Ascending Aorta, Cardiac Surgery. Endovascular Procedures. Endovascular Surgery. Thoracic Endovascular Repair.

INTRODUCTION
The concept of treating the ascending thoracic aorta with endoprosthesis emerged after the first-in-man successful case described by Dorros et al.¹ in 2000. Since then, several studies have reported the safety and effectiveness of the ascending aorta endovascular repair.

Despite this, contrasting with the descending aorta, where thoracic aorta endovascular repair (TEVAR) is well established²,³; for proximal aortic disease, open surgery is considered the gold standard for treatment, although less invasive procedures are achieving an important role, especially in high-risk or inoperable patients.

The need for an alternative treatment becomes even more relevant when considering that more than 20% of the patients with type A aortic dissection (TAAD) are deemed inoperable⁴. In this context, ascending TEVAR could have potential advantages, such as absence of thoracotomy incision and need for partial or total extracorporeal circulatory support, as well as lower hospital morbidity rates and shorter length of hospital stay when compared to open surgery⁵,⁶. This was already well established on our initial experience⁷ (Figures 1 and 2).

Indications and Planning
According to the 2014 European Society of Cardiology (ESC) Guidelines on diagnosis and treatment of aortic diseases, the use of TEVAR should be decided on an individual basis, according to the anatomy, pathology, comorbidity, and anticipated durability criteria, using a multidisciplinary approach (Class I, Level C)⁸.

Planning the procedure, this guideline reinforces that it is mandatory to perform preoperative imaging and engineering analysis, with contrast-enhanced computed tomography (CT) representing the imaging modality of choice⁸.
these procedures should be done in a hybrid room, with cardiopulmonary bypass available, as well as transesophageal echocardiogram and transvenous pacemaker, and by a surgical team well trained on both procedures (conventional and endovascular)[11].

Regarding anatomical suitability criteria, a landing zone of at least 2 cm, an aortic diameter < 40 mm[8-11], an absence of grade 3/4 regurgitation, and iliofemoral vessels with a diameter > 7 mm and an angulation < 90° (for 24-French delivery system) have been required. Besides this, in cases of TAAD, a distance from the entry tear to the coronary ostia > 20 mm is also mandatory[12-14].

As mentioned by Muetterties et al.[15], these criteria are critical because the proximity between the endoprosthesis proximal landing zone and the aortic valve or the coronary ostia could result in aortic insufficiency or myocardial infarction if the stent graft (SG) is accidentally deployed in a proximal position. Likewise, distal stent migration could lead to brachiocephalic artery occlusion, resulting in stroke. Therefore, the ideal candidates for an ascending TEVAR procedure are patients with focal aortic defects, including pseudoaneurysms and ascending aortic dissections with focal entry tears in the middle third of the ascending aorta.

Conformability of the device to fit the aorta curvature and to provide a better seal along entry tears is also an important characteristic. Thus, for chronic disease, it is recommended an oversizing by about 20%, instead of the typical 10% recommended for acute dissections[16].

According to Moon et al.[17], for patients with TAAD evaluated by CT, other endograft suitability criteria are an adequate proximal landing zone (sinotubular junction [STJ] ≤ 38 mm), CT planning is indispensable because the ascending aorta has some particular characteristics different from the other segments, like its size, shape, hemodynamic forces, and proximity to other anatomic structures (Figure 3). Moreover, more complex anatomy and pathologies are frequently detected in the ascending segment[9].

Surgical Technique

As ascending aorta endovascular treatment involves several challenges and potential catastrophic complications[10],

CT planning is indispensable because the ascending aorta has some particular characteristics different from the other segments, like its size, shape, hemodynamic forces, and proximity to other anatomic structures (Figure 3). Moreover, more complex anatomy and pathologies are frequently detected in the ascending segment[9].

Surgical Technique

As ascending aorta endovascular treatment involves several challenges and potential catastrophic complications[10],
The most important complications in ascending TEVAR are cardiac tamponade, stroke, endoleak, stent distal migration, residual dissection, aneurysm, left ventricle perforation, injury and dissection of the aortic root, and occlusion of the coronary arteries[22].

Some of the advantages in this procedure concern the few cases of endoleak, as stated by Khoynezhad et al. [22], who highlighted that the absence of side branches in the ascending aorta makes type II endoleak not possible. The same applies to type III endoleak, in cases where just one graft is deployed, this complication is inexistent. Therefore, endoleaks observed in ascending aorta TEVAR are mainly type Ia and Ib.

Available Outcomes

In terms of clinical results, in 2015, Roselli EE et al.[9] published their own experience with 22 patients enrolled from 2006 to 2014 at the Cleveland Clinic. Cases of acute TAAD, intramural hematoma, pseudoaneurysm, chronic dissection, or aorta-cardiac fistula have undergone supracoronary ascending TEVAR procedure. Acceptable hospital mortality (13.6%) and an actual survival rate at 30 days, one year, and five years of 86%, 80%, and 75%, respectively, were demonstrated.

The same authors, in 2018, published a new article proposing a modification in the landing zone classification based on the evaluation of 39 patients, 36 of them managed with TEVAR. CT imaging analysis was performed, and the extent of aortic pathology was designated by the segmental proximity to the left ventricle, by diving the zone zero into three segments: a) zone 0A constitutes fenestration distal to STJ, minimum distance between intimal fenestration and STJ ≥ 10 mm, and absence of coronary bypass grafts originating from the ascending aorta.

Moreover, based on findings of the Global Registry for Endovascular Aortic Treatment (GREAT), Piffareti et al.[18] demonstrated that the most adequate SG size was selected using a three-dimensional centerline reconstruction workstation. For aortic dissection and pseudoaneurysm, an SG diameter equal to the wall-to-wall diameter without oversizing was used. For aortic aneurysms, the SG was oversized 20% based on the larger of two measurements performed at the STJ or at the distal ascending aorta. The authors also described that the SG should be ideally deployed under temporary overdrive cardiac pacing, generally, 190 beats/min.

The most common access sites are the transfemoral, transapical, or axillary arteries, being the last two a potential alternative when the anatomy is unfit for a standard retrograde approach[19].

Available Devices

TEVAR in the ascending aorta segment can be performed with dedicated ascending aortic SG (Zenith Ascend TAA Endovascular Graft, William Cook Europe, Bjaeverskov, Denmark), a standardized device or a surgeon-modified thoracic SG[20] (Figures 4 and 5).

Limitations to use standard thoracic SG in TAAD are the location of the intimal tear, presence of higher-grade aortic valve insufficiency, and an aortic diameter > 38 mm[21].

A concerning point is that the majority of the SGs currently available on the market are too long for ascending aorta deployment or have a too long nose cone, which could interfere with the native aortic valve during the deployment, leading to a necessity of customization or intraoperative modification of the devices[17] (Figure 4). Some devices also have a delivery system length that does not reach ascending aorta in big patients or patients with angulated aortas.

Available Devices

TEVAR in the ascending aorta segment can be performed with dedicated ascending aortic SG (Zenith Ascend TAA Endovascular Graft, William Cook Europe, Bjaeverskov, Denmark), a standardized device or a surgeon-modified thoracic SG[20] (Figures 4 and 5).

Limitations to use standard thoracic SG in TAAD are the location of the intimal tear, presence of higher-grade aortic valve insufficiency, and an aortic diameter > 38 mm[21].

A concerning point is that the majority of the SGs currently available on the market are too long for ascending aorta deployment or have a too long nose cone, which could interfere with the native aortic valve during the deployment, leading to a necessity of customization or intraoperative modification of the devices[17] (Figure 4). Some devices also have a delivery system length that does not reach ascending aorta in big patients or patients with angulated aortas.
In terms of national experiences, in 2011, Saadi et al.\textsuperscript{[27]} reported two successful lifesaving cases of patients with ascending aorta pseudoaneurysm managed with implantation of SG together with percutaneous coronary intervention secondary to ischemic disease, proving the feasibility of the combined method\textsuperscript{[23]} (Figure 6).

CONCLUSION

Ascending aorta TEVAR represents the final frontier of endovascular therapy and it is well proven to be a lifesaving procedure in selected patients, using customized or off-the-shelf endoprosthesis. There are still several anatomical, physiological, and technical challenges, such as the short distance between coronary arteries and BCT, aortic valve regurgitation and obstruction, high hemodynamic forces, angulation, coronary arteries, and cerebral perfusion. Potential serious complications like aortic dissection, rupture, coronary and BCT obstruction, and aortic valve damage require a well-trained multidisciplinary team in a hybrid room environment. Therefore, understanding patients’ selection criteria, limitations of the technology, and development of dedicated devices are critical to its application. Trials are needed to provide evidence-based data.
References

1. Dorros G, Dorros AM, Planton S, O’Hair D, Zayed M. Transeptal guidewire stabilization facilitates stent-graft deployment for persistent proximal ascending aortic dissection. J Endovasc Ther. 2000;7(6):506-12. doi:10.1177/152660280000700612.

2. Cheng D, Martin J, Shennib H, Dunning J, Muneretto C, Schueler G, et al. Endovascular aortic repair versus open surgical repair for descending thoracic aortic disease: A systematic review and meta-analysis of comparative studies. J Am Coll Cardiol. 2010;55(10):986-1001. doi:10.1016/j.jacc.2009.11.047.

3. Nienaber CA, Kische S, Rousseau H, Eggebrecht H, Rehders TC, Kudnt G, et al. Endovascular repair of type B aortic dissection: Long-term results of the randomized investigation of stent grafts in aortic dissection trial. Circ Cardiovasc Interv. 2013;6(4):407-16. doi:10.1161/circinterventions.113.000463.

4. Trimbarchi S, Nienaber CA, Rampoldi V. Contemporary results of surgery in acute type A aortic dissection: The International Registry of Acute Aortic Dissection experience. J Thorac Cardiovasc Surg. 2005;129:112-22. doi:10.1016/j.jtcvs.2005.04.039.

5. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr, et al. 2010 ACCF/AHA/ACS/ACR/ASAX/SCAI/SIR/STS/SVM Guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Vascular Surgery, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation. 2010;121(13):e266-369. doi:10.1161/CIR.0b013e3181d4739e.

6. Baioussis NG, Antonopoulos CN, Papakonstantinou NA, Argiriou M, Gerooulakos G. Endovascular stent grafting for ascending aortic diseases. J Vasc Surg. 2017 Nov;66(5):1587-601. doi:10.1016/j.jvs.2017.07.064.

7. Saadi EK, Almeida RMSA. Endovascular Treatment of The Ascending Aorta: Is This the Last Frontier in Aortic Surgery? Braz J Cardiovasc Surg 2019;34(6):759-64.

8. Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, et al. ESC Committee for Practice Guidelines. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J. 2014;35(41):2873-926. doi:10.1093/eurheartj/ehu281.

9. Roselli EE, Idrees J, Greenberg RK, Johnston DR, Lytle BW. Endovascular stent grafting for ascending aorta repair in high-risk patients. J Thorac Cardiovasc Surg. 2015;149(1):144-51. doi:10.1016/j.jtcvs.2014.07.109.

10. Plichta RR, Hughes GC. Thoracic endovascular aortic repair for the ascending aorta: experience and pitfalls. J Vis Surg. 2018 May 9;4(5):92. doi:10.21037/jovs.2018.03.01.

11. Almeida RMSA. Endovascular therapy of the ascending aorta as an interventionist. Rev Bras Cir Cardiovasc. 2009;24(2 Suppl):35s-37s. doi:10.1590/S0102-76382009000900005.

12. Lu Q, Feng J, Zhou J, Zhao Z, Bao J, Feng R, 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(18):1917-24. doi:10.1016/j.jacc.2012.08.994.

13. 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(5):1555-60. doi:10.1016/j.athoracsur.2013.11.066.

14. Ronchey S, Serrao E, Alberti V, Fazzini S, Trimbarchi S, Tolenaar JL, 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(5):475-80. doi:10.1016/j.ejvs.2013.01.033.

15. Muettetters CE, Menon R, Wheatley GH 3rd. A systematic review of primary endovascular repair of the ascending aorta. J Vasc Surg. 2018;67(1):332-42. doi:10.1016/j.jvs.2017.06.099.

16. Sobocinski J, O’Brien N, Maurel B, Bartoli M, Goueffic Y, Sassard T, et al. Endovascular approaches to acute type A dissection: a CT-based feasibility study. Eur J Vasc Endovasc Surg. 2011;42(4):442-7. doi:10.1016/j.ejvs.2011.04.037.

17. Moon MC, Greenberg RK, Morales JP, Martin Z, Lu Q, Dowdall JF, et al. Computed tomography-based anatomic characterization of proximal aortic dissection with consideration for endovascular candidacy. J Vasc Surg. 2011;53(4):942-9. doi:10.1016/j.jvs.2010.10.067.

18. Piffaretti G, Grassi V, Lomazzi C, Brinkman WT, Navarro TP, Jenkins MP, et al. GREAT participants. Thoracic endovascular stent graft repair for ascending aortic diseases. J Vasc Surg. 2019;70(1):141-9. doi:10.1016/j.jvs.2019.01.075.

19. Murakami T, Ninomiya S, Hosono M, Nakamura Y, Sohgawa E, Sakai Y, et al. Transapical endovascular repair of thoracic aortic aneurysm. Ann Thorac Surg. 2017;103(6):1468-74. doi:10.1016/j.athoracsur.2015.12.027.

20. Jaussaud N, Chitsaz S, Meadows A, Wintermark M, Cambrerono N, Azadani AN, et al. Acute type A aortic dissection intimal tears by 64-slice computed tomography: A role for endovascular stent-grafting? J Cardiovasc Surg (Torino). 2013.54(3):373-81.

21. Khoynezhad A, Donayre CE, Walot I, Koopmann MC, Kopchok GE, White KA, et al. Transapical endovascular repair of thoracic aortic pathology. Ann Thorac Surg. 2016 Jun;63(6):1483-95. doi:10.1016/j.jvts.2015.12.029.

22. Jaussaud N, Chitsaz S, Meadows A, Wintermark M, Cambrerono N, Azadani AN, et al. Acute type A aortic dissection intimal tears by 64-slice computed tomography: A role for endovascular stent-grafting? J Cardiovasc Surg (Torino). 2013.54(3):373-81.

23. Roselli EE, Idrees J, Greenberg RK, Johnston DR, Lytle BW. Endovascular stent grafting for ascending aorta repair in high-risk patients. J Thorac Cardiovasc Surg. 2015;149(1):144-51. doi:10.1016/j.jtcvs.2014.07.109.

24. Plichta RR, Hughes GC. Thoracic endovascular aortic repair for the ascending aorta: experience and pitfalls. J Vis Surg. 2018 May 9;4(5):92. doi:10.21037/jovs.2018.03.01.
Saadi EK, et al. - Endovascular Treatment of The Ascending Aorta: Is This the Last Frontier in Aortic Surgery?

26. Rylski B, Szeto WY, Bavaria JE, Branchetti E, Moser W, Milewski RK. Development of a single endovascular device for aortic valve replacement and ascending aortic repair. J Card Surg. 2014;29(3):371-6. doi:10.1111/jocs.12348.

27. Saadi EK, Moura LD, Zago A, Zago A. Endovascular repair of ascending aorta and coronary stent implantation. Rev Bras Cir Cardiovasc. 2011;26(3):477-80. doi:10.5935/1678-9741.20110025.

This is an open-access article distributed under the terms of the Creative Commons Attribution License.