Revista da
SOCESP
Sociedade de Cardiologia do Estado de São Paulo

EVOLUTION AND TREATMENT OF THORACIC AORTIC ANEURYSMS

EVOLUÇÃO NO TRATAMENTO DOS ANEURISMAS DA AORTA TORÁCICA

Enio Buffolo[1]
José Honório de Almeida Palma da Fonseca[2,3]

1. Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, SP, Brazil.
2. Escola Paulista de Medicina - UNIFESP, São Paulo, SP, Brazil.
3. INCOR Zerbini Foundation, São Paulo, SP, Brazil.

Correspondence:
Rua Borges Lagoa, 1080 – 7º andar, Vila Clementino, São Paulo, SP, Brazil. CEP 04038-002.
enio.buffolo@terra.com.br

Received on 11/17/2017,
Accepted on 02/16/2018

ABSTRACT

The authors performed a didactic review of aortic diseases, focusing on the historical aspects, the development of treatment, and aspects of the current approach using the latest technology of hybrid surgical rooms. In recent years, thanks to the development of endovascular techniques, there has been a real treatment revolution, especially for diseases of the descending aorta, with the application of efficient procedures, resulting in a significant reduction in morbidity and mortality. The use of hybrid technology rooms and computer 3-D reconstruction technology, enabling customized endoprostheses, are significant advances to be used in the coming years, and that will change the paradigms of a sub-specialty.

Keywords: Thoracic aortic aneurysms; Aorta, thoracic; Endovascular procedures.

RESUMO

Os autores realizam uma revisão, de característica didática, das aortopatias, focalizando o histórico, o desenvolvimento do tratamento e os aspectos atuais de abordagem, utilizando a alta tecnologia das salas híbridas. Nos últimos anos, graças ao desenvolvimento das técnicas endovasculares, ocorreu uma verdadeira revolução no tratamento, especialmente para as patologias da aorta descendente, em que procedimentos eficientes foram aplicados com acentuada redução da morbimortalidade. A utilização de salas híbridas e tecnologia de moldes 3D, permitindo endoprótese customizadas, constituem-se em avanços significativos a serem utilizados nos próximos anos e que mudarão os paradigmas de uma subespecialidade.

Descritores: *Aneurismas da aorta torácica; Aorta torácica; Procedimentos endovasculares.*

INTRODUCTION

An aortic aneurysm is a dilatation of one or more segments of the aorta that involves all layers, i.e., the intima, media, and adventitia. In practice, an aneurysm is defined as the diameter of the aorta being twice its normal size.

One must differentiate aneurysms from aortic ectasias in which the vessel is evenly dilated, assuming an elongated and fusiform aspect characterizing dolico-mega aortas. These have a more favorable prognosis and do not require the same surgical management as aneurysms.

Aneurysms of the thoracic aorta have an annual incidence of 6-8/100,000, with 50% in the ascending aorta, 10% in the aortic arch, and the remaining 40% in the descending aorta.[1] There are no national reference data, but the detection of cases has been increasing due to the improvement of diagnostic methods as well as an increasingly elderly population.

Patients with untreated aneurysms follow a natural course that invariably terminates in rupture unless they die because of associated comorbidities such as coronary disease, stroke, or kidney disease.

The surgical and endovascular therapeutic resources that have been used in recent decades, with better results and lower risk, have considerably changed the outcomes of aneurysms and enabled a higher and better life expectancy.

For didactic purposes, we shall arbitrarily divide the thoracic aorta into three segments: ascending, aortic arch, and descending owing to distinct characteristics regarding the approach, anatomy, and selection of surgical procedures for these segments.

ASCENDING AORTA

This portion of the aorta begins at the aortic root, where the leaflets of the aortic valve and aortic sinuses are fixed, and extends for about 5 cm up to the origin of the brachiocephalic trunk, being totally intrapericardial. The sinotubular junction delimits the aortic sinuses of the ascending aorta.

In addition to acting as a conduit for blood circulation, the elastic properties of the aorta allow it to store the kinetic energy produced by the ventricle during systole in the form of elastic potential energy, which is again converted into kinetic energy during diastole, maintaining antegrade flow in the vessel. The loss of elasticity of the aortic wall *per se* leads to hemodynamic changes with an increase in differential pressure and can affect the long-term course.

Additionally, the aorta has an indirect role in regulation of blood pressure and heart rate due to baroreceptors located in the adventitia that send afferent signals to vasomotor centers in the brainstem via the vagus nerve.

This physiology is altered when the ascending aorta is surgically removed and replaced by a polyester tube (Dacron) and the patient is deprived of adaptive mechanisms in the postoperative period; orthostatic hypotension is more noticeable, but is attenuated with time.

One should differentiate two basic conditions in aneurysms of the ascending aorta: annuloaortic ectasia and an aneurysm of the ascending aorta alone, with preservation of the sinotubular junction.

In the first situation, the aorta is dilated from its root and extends to the sinotubular junction and the sinuses of Valsalva, often leading to aortic insufficiency of varying degrees owing to dilatation of the annulus. (Figure 1)

Aneurysms that preserve the diameter of the sinotubular junction can be found alone or accompanied by aortic valve stenosis and a bicuspid aortic valve.

In dilatation of an ascending aorta with a bicuspid aortic valve, combined structural alteration of the valve and aortic wall of congenital origin is apparent, and early surgery is indicated because of the risk of aortic dissection.

Surgical treatment of pathology of the ascending aorta and aortic valve became widely accepted after the description of implantation of a valved tube by Bentall and De Bonno in 1968,[2] which demonstrated excellent long-term results.[3-4] The technique was originally described using a mechanical valve prosthesis (Starr-Edwards) and was validated with a central flow mechanical prosthesis that seems to the best option, in our opinion.

More recently, a "biological Bentall," i.e., the implantation of a valved tube with biological prostheses has been primarily used because of anticipated use of a "valve-in-valve" in the future when the biological tissue fails, along with the use of anticoagulants.

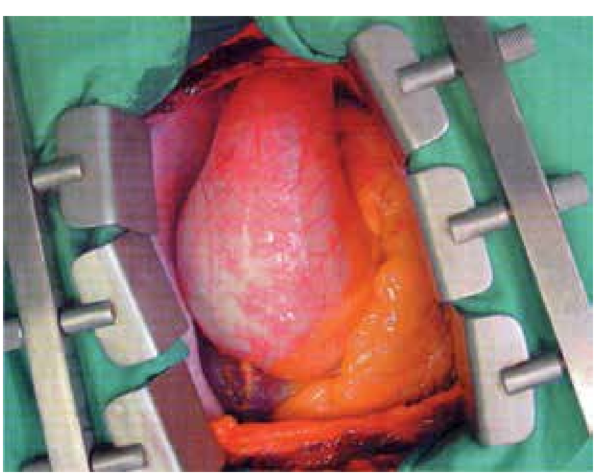

Figure 1. Surgical photo of annuloaortic ectasia, with deformation of the sinotubular junction.

In parallel to the Bentall-De Bonno procedure, other techniques that conserve the native aortic valve have been enthusiastically employed such as the reimplantation technique of Tirone,[5] Yacoub remodeling,[6] or variants thereof, such as the Van Son procedure.[7]

These techniques have attractive results in the long term, but they are operator-dependent and should only be performed to ensure reproducible results by groups with extensive experience. Meanwhile, the classic Bentall-De Bono operation is excellent and is less prone to failure.

With time, variations of the Bentall operation were introduced for some patients when reoperation or greater complexity required special reimplantation of the coronary ostia.[8,9]

Currently, the treatment of illnesses of the ascending aorta and its roots are well managed with the Bentall procedure and its variants, with low surgical risk and good long-term results.

However, some questions remain about the long-term results in patients with Marfan syndrome, with the undefined advantage of using a valvular tube with a "sinus of Valsalva" shaped in the tube itself, and whether the late results of valved tubes with biological prostheses will repeat the excellent results of the classic Bentall procedure.

At present, the use of less-invasive endovascular procedures in ascending aortic pathology is not yet clear, except for sporadic cases of catheter treatment for localized dissection or a pseudoaneurysm in patients with no other options. Recently, endovascular treatment has been proposed in patients with ascending aortic dysfunction who are inoperable for clinical reasons, using short endovascular prostheses when the dissection anatomy allows the prosthesis to be released without the risk of occluding the coronary ostia.[10,11]

AORTIC ARCH

Isolated dilatation of the aortic arch is less frequent than aortic dilatation of the ascending aorta extending to the aortic arch.

The surgical treatment in these situations is more complex as the exit of the cervical brachiocephalic, left carotid, and left subclavian arteries are affected.

The possibility of correction of this entity was successfully described for the first time by DeBakey,[12] using an extra-anatomical bypass, but with time, the use of extracorporeal circulation, deep hypothermia, and total circulatory arrest was validated for the treatment of the aortic arch.

With the temperature at 18ºC, extracorporeal circulation is interrupted and we have 30 minutes to correct the aortic arch with a Dacron tube, reimplanting the cervical vessels one by one or en bloc.

If the procedure exceeds the expected 30 minutes, we must establish the perfusion of the cervical vessels. After enthusiastic initial use, attempts at retrograde cerebral perfusion via the venous system were practically abandoned because of cerebral edema and inadequate protection of the brain.

Technical alternatives to correct aneurysms of the aortic arch have been used in an attempt to reduce the invasiveness of conventional treatment, and include hybrid procedures, use of endovascular stents in the aortic arch and descending aorta, and use of extra-anatomic bypass of the ascending aorta to the cervical vessels with thoracotomy (Figure 2).[13-15] The use of hybrid rooms, necessary for these combined interventions, allows one to foresee a promising future for hybrid treatment.

More recently, endovascular treatment of the aortic arch with branched grafts or even with the “chimney” technique has been performed, initially in patients at high surgical risk.

These procedures require hybrid rooms, with suitable material, highly experienced operators, and detailed preoperative planning, which sometimes exceeds the time used in the surgical room (Figure 3).

The immediate results are promising, with significant reduction of morbidity, but concerns over the long term regarding the patency of the cervical vessels as well as residual leaks.

It will take more years of observation for this to be the first option for the treatment of aortic arch disorders.

One trend that is increasingly accepted is to complement the treatment of the aortic arch with the implantation of a stent in the descending aorta. Thus, the entire thoracic aorta would be treated to diminish the need for future interventions, thereby enshrining the principle of the elephant trunk described by Borst, used by Palma in dissections, and proposed as a good option by Lus et al., with good late results.[16,17]

Currently, Dacron tube implants in the descending aorta, under direct vision as a complement to aortic arch surgeries, have been replaced by the implantation of self-expanding stents, with this technique being recognized as a “frozen elephant trunk,” and proving efficient in the long term.[18,19]

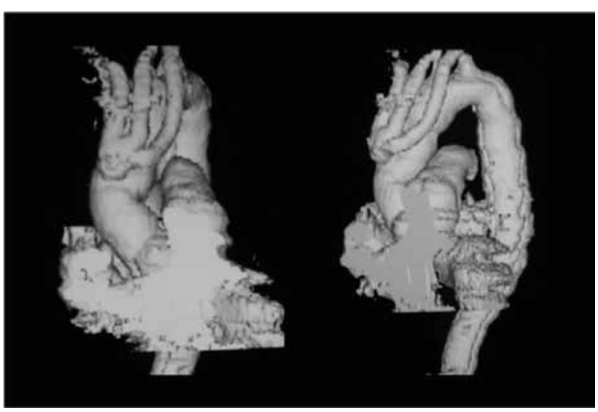

Figure 2. Controlled study of extra-anatomical derivation of the ascending aorta with branches to the brachiocephalic, left carotid, and left subclavian arteries.

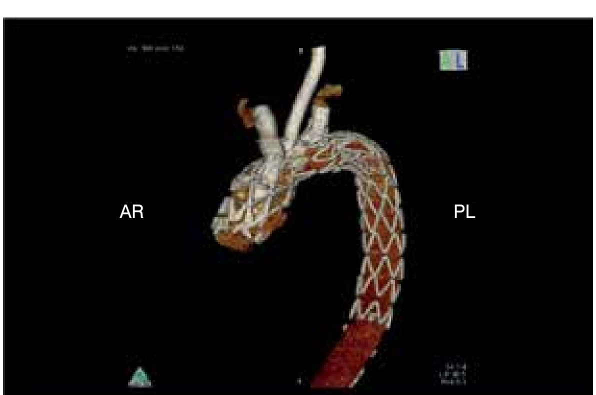

Figure 3. Total endovascular treatment of aortic arch with branched grafts.

DESCENDING AORTA

The anatomy and histology of the descending aorta have special anatomical and histological features, which provide this segment of the thoracic aorta with its own aspects of pathology and surgical treatment.

By definition, the descending aorta is the segment that goes from the left subclavian to the diaphragmatic reflection; beyond this caudal limit, we characterize thoracoabdominal aneurysms. With a variable and straight extension of 15 to 20 cm, important visceral vessels do not leave this segment, except for the intercostal pairs that perfuse the thoracic wall and connect with the anterior spinal artery to perfuse the anterior horns of the spinal cord. This anatomical feature is essential to understand the risk of paraplegia when sacrificing the intercostal branches in surgery or even in aortic dissection.

From a histological point of view, the descending aorta is closer to most of the abdominal aorta than the ascending portion and aortic arch.

The pathologies that affect this segment of the aorta are true aneurysms, dissections, ulcers, and parietal degenerative processes.

The complications of these disorders culminate in rupture requiring surgical treatment, whose indication and timing depend on weighing the risk of death vs. the risk of the operation.

It is generally assumed that diameters above 5.5 cm are indications for intervention; however, other factors should be taken into account.

Classically, surgical treatment consists in the removal of the diseased segment and replacement with a Dacron tube with the simple aortic “*clamp and go*” technique.[20] However, despite progress in treatment, there are still serious complications in the postoperative period, with paraplegia being the most severe, despite techniques to protect the spinal cord.[21]

Thus, the revolutionary and pioneering proposal of endovascular treatment by Parodi[22] was soon applied for the treatment of the descending aorta.[23-25]

The initial exciting results brought about a real revolution in the treatment of true aneurysms and dissections of the descending aorta, leading to increasing use of endovascular treatment, given the consistently good results now confirmed in the medium and long term.[26-30] (Figure 4)

Currently, the vast majority of descending thoracic aortic aneurysms can be treated with the endovascular approach, including acute aortic dissection and its variants.

The most complex problems such as the need for occlusion of the left subclavian artery in cases in which the proximal landing zone is limited, have been resolved with carotid-subclavian artery shunts or even with the chimney technique, guaranteeing the perfusion of the left arm and avoiding steal syndrome.

The massive investment of industry in stents has decreased the initial complications such as ruptures, leaks, and difficulties in femoral access, resulting in expansion of indications and better results.

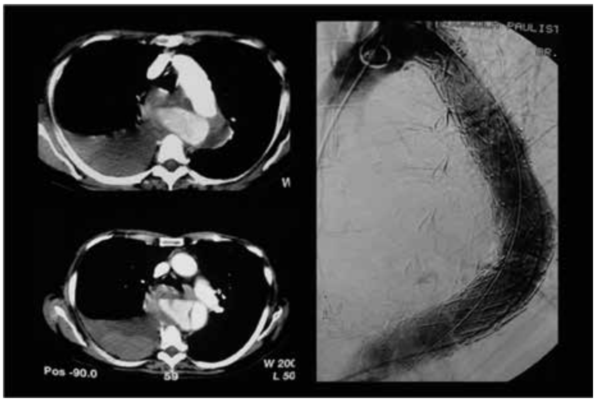

Figure 4. Postoperative computed tomography of a large and extensive aneurysm of the descending aorta treated by endovascular approach.

Currently the endovascular treatment of aneurysms and dissections of the descending aorta is the procedure of choice, with conventional surgery being reserved for special cases.

The use of branched stents and the concept of stents parallel to the main body, i.e., the "chimney" technique, are alternative treatments with promising initial results but requiring good results over the medium and long term to validate their application.

If the initial expectation is confirmed, endovascular treatment could replace open surgery for thoraco-abdominal and aortic arch aneurysms.

At present, these alternatives should be reserved for high-risk patients.

FINAL CONSIDERATIONS

Few subspecialties have undergone paradigm shifts as pronounced as those that manage pathology of the aorta.

In just two decades, endovascular treatment has dramatically changed the approach to aortic aneurysms and dissections, reducing the risk of intervention and the invasiveness of conventional open procedures.

Hybrid interventions have combined two tactics making the surgery friendlier. High technology rooms (hybrids) have enabled surgical procedures requiring multidisciplinary teams: surgeon, anesthetist, hemodynamicist, and echocardiographer, all adding skills for the benefit of the patient.

Moreover, 3-D technology gives us the possibility of preoperative planning with plaster or plastic molds obtained with computed tomography in order to perform complex treatments such as branched stenting, and provides precision in the choice of stent implantation (Figure 5).

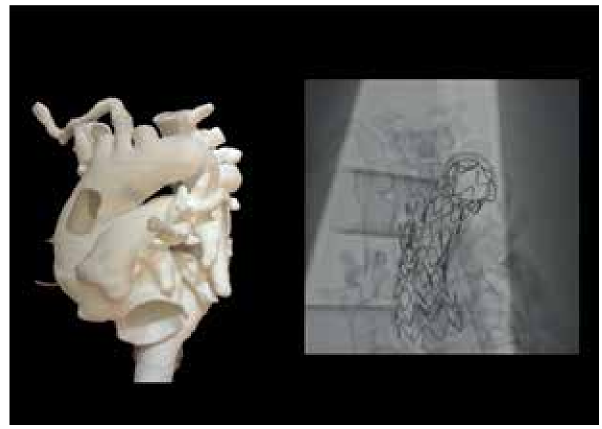

Figure 5. Preoperative 3D mold based on computed tomography, enablin development of custom prostheses.

The coming years will answer some questions as to the durability of stents in the long term, the patency of parallel "chimney" stents and branched stents, and whether the change in pressure curves in rigid implanted tubes will lead to dilatation or even aneurysms in the proximal or distal portions of the stents.

To answer this last question perhaps the industry should invest in stents with some elasticity as occurs in the natural wall of the aorta.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest in conducting this study.

CONTRIBUTIONS OF AUTHORS: Each author contributed significantly to the development of the manuscript. EB and JHAPF jointly participated in the drafting and final approval of the manuscript.

REFERENCES

1. Clouse WD, Hallet JWJr, Schaft HV, Gayari MM, Ilstrup DM, Melton LJ 3rd. Improved prognosis of thoracic aneurysms: a population-based study. JAMA. 1998;280(22):1926-9.
2. Bentall H, De Bonno A. A technique for complete replacement of the ascending aorta. Thorax. 1968;23(4):338-9.
3. Kouchoukos N, Wareing TH, Murphy S F, Perrillo JB. Sixteen-year experience with aortic root replacement. Results of 172 operations. Ann Surg. 1991;214(3):308-18.
4. Silva VF, Real DSS, Branco JNR, Catani R, Kim HC, Buffolo E, Fonseca JHA. Operação de Bentall e De Bonno para correção das doenças da raiz aórtica: analise de resultados a longo prazo. Rev Bras Cir Cardiovasc. 2008;23(2):256-61.
5. Tirone DE, Feindl CM. An aortic valve-sparing operation for patients with incompetence and aneurysms of the ascending aorta. J. Thorac Cardiovasc Surg. 1992;103(4):617-21.
6. Yacoub MH, Fogan A, Stessano P, et al. Results of valve-conserving operations for aortic regurgitation. Circulation. 1983;68:311.
7. van Son JAM, Battellini R, Mierzwa M, Walther T, Autschbach R, Mohr FW. et al. "Aortic reconstruction with preservation of native aortic valve and sinuses in aortic root dilatation with aortic regurgitation" J Thorac Cardiovasc Surg. 1999; 117(6):1151-6.
8. Cabrol C, Pavie A, Gandjbakhch I, Villemot JP, Guiraudon G, Laughlin L. et al. Complete replacement of the ascending aorta with reimplantation of the coronary arteries: new surgical approach. J Thoracic Cardiovasc Surg. 1981:81(2):309-15.

9. Hirasawa Y, Aomi S, Saito S, Kihara S, Tomioka H, Kurosawa H. - Long-term results of modified Bentall procedure using flanged composite aortic prostheses and separetely interposed coronary graft technique. Interact Cardiovasc Thorac Surg. 2006;5(5): 574-7.
10. Roselli EE, HASSAN SM, IDRES JJ. et al. Inoperable patients with aceite type A dissection: are them candidates endovascular repair?. Inter Cardiovasc Thorac Surg. 2017;25(4):582-88.
11. Rylski B. Endovascular repair of acute type A aortic dissection – we have the technology, but where is the courage? Inter Cardiovasc Thorac Surg. 2017;25(4):501-2.
12. De Bakey ME, Crawford ES, Cooley DA, Morris GC Jr. Successful resection of fusiform aneurysm of aortic arch and replacement by homograft. Surg Gynecof Obstret. 1957;105(6):656-64.
13. Carrel TP, Do DDai, Triller J, Schmidli J. A less invasive approach to completely repair the aortic arch. Ann Thorac Surg. 2005;80(4):1475-8.
14. Yoshitake A, Okamoto K, Yamasaki M. et al. Comparison of aortic arch repair using endovascular tecnique, total arch replacement and staged surgery. Eur J Cardiothorac Surg. 2017;51(6):1142-48.
15. Preventza O, Garcia A, Cooley DA, Haywood-Watson RJ, Simpson K, Bakaeen FG. et al. Total aortic arch replacement: a comparative study of 0 zone hybrid arch exclusion versus traditional open repair. J. Thoracic Cardiovasc Surg. 2015;150(6):1591-8.
16. Borst HG, Walterbusch G, Schaps D. Extensive aortic replacement using “elephant trunk” prosthesis. Thorac Cardiovasc Surg. 1983;31(1):37-40.
17. Palma J H, Almeida DR, Carvalho AC, Andrade JC, Buffolo E. Surgical treatment of type B aortic dissection using an endoprosthesis (elephant trunk). Ann Thorac Surg. 1997;63(4):1081-4.
18. Shrestha M, Martens A, Kaufeld T, Beckmann E, Bertele S, Krueger H, et al. Single-center experience with the frozen elephant trunk technique in 251 patients over 15 years. Eur J Cardiothor Surg. 2017; 52:856-66.
19. Ius F, Fleissner F, Pichlmaier M, Karck M, Martens A, Haverich A. et al. Total aortic arch replacement with the frozen elephant trunk technique: 10-year follow-up single center experience. Eur J Cardiothorac Surg. 2013;44(5):949-57.
20. Cooley DA, Golino A, Frazier OH. Single-clamp technique for aneurysms of the descending thoracic aorta: report of 132 consecutive cases. Eur J Cardiothorac Surg. 2000;18(2):162-7.
21. Safi HJ, Estrera AL, Miller CC, Huynh TT, Porat EE, Azizzadeh A. et al. Evolution of risk for neurologic deficit after descending and thoraco abdominal aortic repair. Ann Thorac Surg. 2005;80(6):2173-9.
22. Parodi JC, Palmaz JC & Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg. 1991;5(6):491-9.
23. Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP..l. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. New Engl J Med. 1994;331(26):1729-34.
24. Palma JH, de Souza JAM , Rodrigues Alves CM, Carvalho AC, Buffolo E. Self-expandable aortic stent-graftd for treatment of descending aortic dissections. Ann Thorac Surg. 2002;73(4):1138-41.
25. Buffolo E, da Fonseca JHAP, de Souza JAM, Alves CM. Revolutionary treatment of anerurysms and dissections of the endovascular approach. Ann Thorac Surg. 2002;74(5):S1815-7; discussion S1825-32.
26. Mitchel RS, Dake MB, Semba CP, Fogarty TJ, Zarins CK, Liddel RP. et al. Endovascular stent-graft repair of thoracic aortic aneurysms. J Thorac Cardiovasc Surg. 1996;111(5):1054-62.
27. von Segesser LK, Marty B, Tozzi P & Ruchat P. Impact of endoluminal stenting for aortic Surgery. Eur J Cardiothoracic Surg. 2004;26: s14-8.
28. Cheng D, Martin J, Pharm D, Shennib H, Dunning J, Muneretto C, et al. Endovascular aortic repair versus open surgical repair for descending thoracic aortic disease. JACC. 2010;55(10):986-1001.
29. Stewart A. Why are we still talking about open repair of descending aneurysms?. J Thorac Cardiovasc Surg. 2008;136:(2):278-9.
30. Dimers P, Miller DC, Mitchell RS, Kee ST, Sze D, Razavi MK, et al. Midterm results of endovascular repair of descending thoracic aortic aneurysms with first generation stent grafts. J Thorac Cardiovasc Surg. 2004;127(3):664-73.