Debate: Is Pure Endovascular Treatment the New Frontier?

Chimney and sandwich techniques offer promising options for aneurysm exclusion.

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Aortic aneurysm is defined as a dilatation of all wall layers > 50% in comparison to the normal diameter. This is dependent on age, sex, body type, and underlying diseases, which in most cases is atherosclerotic disease.

Surgical treatment of the ascending aorta, aortic root, and aortic arch is carried out in patients without connective tissue diseases who have aortic diameters ≥ 55 mm. Earlier indications for surgery were an aortic diameter of ≥ 45 mm in patients with familial disposition for aortic dissection and annual growth rate ≥ 10 mm.

The treatment of patients with large aneurysms of the ascending aorta and aortic arch often represents a challenge due to the complexity of the procedure. Open surgical repair, hybrid procedures, and pure endoluminal treatment constitute the three management options for patients with this pathology.

Conventional total aortic arch replacement (TAR) remains among the most challenging and complex cardiovascular operations, with associated high mortality and complication rates.[1-3]

Standard surgical procedures include ascending aorta replacement and TAR. Aortic valve reconstruction with aortic root may also be warranted, depending on the extent of the aneurysm.

TAR is traditionally challenging and high risk; however, it has been the mainstay of therapy for aortic arch pathologies. This operation requires cardiopulmonary bypass and a period of profound hypothermia and circulatory arrest, which carries a substantial rate of morbidity and mortality.[4,5] Despite higher standards of perioperative care, advances in operative techniques, and use of protective adjuncts, the morbidity associated with TAR is significant and includes stroke, myocardial infarction, and excessive bleeding.[4,5] To avoid these complications, different technical solutions have been developed, such as the elephant trunk (by Borst in 1983)[6] and hybrid procedures such as the frozen elephant trunk (developed by Kato in 1996).[7]

Hybrid arch repair with supra-aortic debranching and endografting into the ascending aorta, developed by Buth in 1998,[8] is feasible and has been considered to be a less-invasive method. This is therefore an appealing option for high-risk patients for whom open repair is unsuitable.[9,10]

The advantages of hybrid repair compared to TAR are clear: there is no need for deep hypothermic cardiac arrest, and an off-pump ascending side clamping through a median sternotomy is required for zone 0 cases to perform the debranching of the supra-aortic vessels in the hybrid technique.

With the advancement of endovascular procedures, in 2007, Criado[11] suggested the use of the chimney technique for partial aortic arch repair (zone 1 or 2). Later, Lobato[12] reported a total endovascular aortic arch replacement (zone 0) with the sandwich technique, breaking new barriers in the aortic arch. Lobato has previously described the sandwich technique step by step.[12]

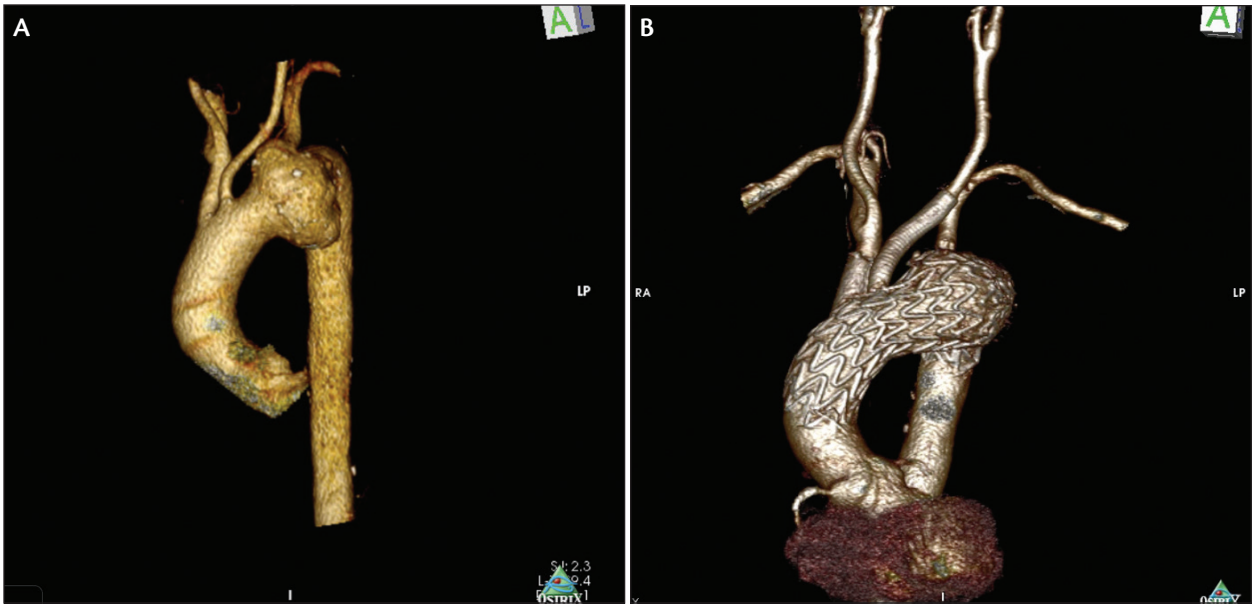

Figure 1. Total endovascular aortic arch replacement using the sandwich technique. CTA of an aortic arch with no adequate proximal landing zone (zone 0) (A). Six-month CTA follow-up (B).

Currently, fenestrated or branched endografts offer promising results in arch aneurysms (zone 1 and 2). However, these techniques are complex, technically challenging, and expensive, and all of the available endografts are still under multicenter investigational device exemption.[13-16]

The alternative, using standard endografts, is the chimney technique (zones 1 and 2) or the sandwich technique (zone 0), which is becoming more common as more promising results are shown.[11,12,17]

In our institution, a prospective study was conducted of all consecutive patients undergoing endovascular repair of complex aortic arch aneurysms (zone 0) with the sandwich technique between January 2010 and May 2014 (Figure 1). In the observation period, 11 patients underwent total endovascular aortic arch replacement with the sandwich technique.[17]

The 30-day survival rate was 90%. One patient died from complications related to an ischemic myocardial infarction.[17]

There were two late deaths (> 30 days) in our series (18% of the cases), one of which was considered procedure-related. One patient with previous aortoesophageal fistula died from pulmonary complications 4 months postprocedure. The other death was due to concomitant thoracoabdominal aortic aneurysms; the patient died during attempted elective thoracic aneurysm repair in a different hospital 6 months after the sandwich technique.[17]

The sandwich technique offers a safe option to treat zone 0 without deep hypothermic cardiac arrest and without sternotomy. The 30-day mortality rate for the sandwich technique demonstrated promising results compared to hybrid procedures and TAR (with different ranges): sandwich, 9%[17]; hybrid procedures, 11.9%[18]; and TAR, 3.9% to 16%,[19] respectively.

Stroke is the biggest concern related to aortic arch aneurysm repair, and different techniques show significant, varying rates of stroke: 2.4% in TAR[19] and 6.6% for hybrid repairs.[20] Using the sandwich technique, we had one case of fully reversible transient ischemic attack (9%) during the first months of the study, suggesting the effects of a learning curve.[17]

Spinal cord ischemia (SCI) is a devastating complication with a severe negative impact on health-related quality of life, lifestyle, and late survival rates. Overall, SCI (paraplegia, paraparesis, or transient lower extremity weakness) has been reported in 0.4%[21] to 8.8%[22] of patients undergoing open surgical repair, up to 24%[23] in hybrid procedures, and 7.7%[24] in chimney procedures.

There were no cases of SCI reported with the sandwich technique, which might be due to the use of protective measures (cerebrospinal fluid drainage) and microchannels developing between the parallel self-expandable covered stents and the endografts, which help maintain the blood supply to the intercostal arteries during the first month of follow-up.[17]

Two patients (18.1%) had endoleaks detected intraoperatively on the completion angiogram: one type I and one type II. The type I endoleak was successfully managed during the main procedure with the deployment

TABLE 1. PUBLISHED SERIES IN THE LITERATURE FOR AORTIC ARCH ANEURYSMS

Author	Type	No. of Cases	30-Day Mortality	Stroke/TIA	Spinal Cord Ischemia
Kouchoukos NT et al[25]	Open	69	5 (7.2%)	1 (1.4%)	1 (1.4%)
Coselli JS et al[26]	Open	38	7 (18.4%)	2 (5.3%)	1 (2.6%)
Beaver TM et al[27]	Open	14	2 (14.3%)	1 (7.1%)	2 (14.3%)
Massimo CG et al[20]	Open	34	5 (14.7%)	0 (0%)	3 (8.8%)
Safi HJ et al[28]	Open	1193	111 (9.3%)	36 (3.0%)	NR
Okita Y et al[29]	Open	423	19 (4.5%)	14 (3.3%)	NR
Uchida N et al[30]	Hybrid	58	1 (1.7%)	2 (3.4%)	2 (3.4%)
Kotelis D et al[31]	Hybrid	88	17 (19.3%)	3 (3.4%)	1 (1.1%)
Chiesa R et al[23]	Hybrid	179	18 (10.1%)	6 (3.4%)	2 (1.1%)
Holt PJ et al[32]	Hybrid	78	6 (7.7%)	5 (6.4%)	3 (3.8%)
Canaud L et al[33]	Hybrid	44	9 (20.5%)	3 (6.8%)	2 (4.5%)
Czerny M et al[34]	Hybrid	27	2 (7.4%)	NR	NR
Chan YC et al[35]	Hybrid	16	0 (0%)	3 (18.8%)	0 (0%)
Melissano G et al[36]	Hybrid	143	6 (4.2%)	4 (2.8%)	4 (2.8%)
Mangialardi N et al[37]	Chimney	26	1 (3.8%)	3 (11.5%)	2 (7.7%)
Moulakakis K et al[38]	Chimney	124	6 (4.8%)	5 (4%)	2 (1.6%)
Haulon S et al[16]	Branched	38	5 (13.2%)	6 (15.8%)	1 (2.6%)
Lobato AC, Cury M[17]	Sandwich	11	1 (9.1%)	1 (9.1%)	0 (0%)

Abbreviation: NR, not reported; TIA, transient ischemic attack.

of a proximal thoracic endograft. The type II endoleak sealed spontaneously after a 30-day CT scan. Over a mean follow-up of 9 months, one (9%) late type III endoleak was encountered, due to device migration noted previously at 3-month follow-up. It was effectively treated with a thoracic stent graft deployed inside the aortic arch.[17] The overall rate of endoleaks was up to 26% in hybrid procedures[38] and 18.5% for the chimney technique.[39] Each approach has shown different technical advantages as well as complications, as shown in Table 1.

Over the past 27 years, technical development of both open surgery and endovascular intervention has undoubtedly made the treatment of an ever-growing percentage of patients possible, including those at high surgical risk and not previously considered surgical candidates.

The sandwich technique is safe and effective in aneurysm exclusion and target vessel revascularization, especially for proximal aortic arch aneurysms (zone 0), improving outcomes with sustained durability in mid-term follow-up. ■

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COVER STORY

1. Quintana E, Bajona P, Schaff HV, et al. Open aortic arch reconstruction after previous cardiac surgery: outcomes of 168 consecutive operations [published online ahead of print July 29, 2014]. J Thorac Cardiovasc Surg. PMID: 25152481.
2. Leontyev S, Misfeld M, Mohr FW. Aneurysms of the ascending aorta and aortic arch. Chirurg. 2014;85:758-766.
3. Coselli JS, Green SY, Zarda S, et al. Outcomes of open distal aortic aneurysm repair in patients with chronic DeBakey type I dissection [published online ahead of print August 2, 2014]. J Thorac Cardiovasc Surg. PMID: 25212053.
4. Bachet J, Guilmet D, Goudot B, et al. Antegrade cerebral perfusion with cold blood: a 13-year experience. Ann Thorac Surg. 1999;67:1874-1878; discussion 1891-1894.
5. Di Eusanio M, Schepens MA, Morshuis WJ, et al. Separate grafts or en bloc anastomosis for arch vessels reimplantation to the aortic arch. Ann Thorac Surg. 2004;77:2021-2028.
6. Borst HG, Walterbusch G, Schaps D. Extensive aortic replacement using "elephant trunk" prosthesis. Thorac Cardiovasc Surg. 1983;31:37-40.
7. Kato M, Ohnishi K, Kaneko M, et al. New graft-implanting method for thoracic aortic aneurysm or dissection with a stented graft. Circulation. 1996;94(suppl. II):II188-II193.
8. Buth J, Penn O, Tielbeek A, Mersman M. Combined approach to stent-graft treatment of an aortic arch aneurysm. J Endovasc Surg. 1998;5:329-332.
9. Zerwes S, Leissner G, Gosslau Y, et al. Clinical outcomes in hybrid repair procedures for pathologies involving the aortic arch [published online ahead of print March 12, 2014]. Vascular. PMID: 24621559.
10. 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.
11. Criado FJ. Chimney grafts and bare stents: aortic branch preservation revisited. J Endovasc Ther. 2007;14:823-824.
12. Lobato AC, Camacho-Lobato L. Endovascular treatment of complex aortic aneurysms using the sandwich technique. J Endovasc Ther. 2012;19:691-706.
13. Greenberg R, Eagleton M, Mastracci T. Branched endografts for thoracoabdominal aneurysms. J Thorac Cardiovasc Surg. 2010;140(6 suppl):S171-178.
14. O'Callaghan A, Mastracci TM, Greenberg RK, et al. Outcomes for supra-aortic branch vessel stenting in the treatment of thoracic aortic disease. J Vasc Surg. 2014;60:914-920.
15. Murphy EH, Stanley GA, Ilves M, et al. Thoracic endovascular repair (TEVAR) in the management of aortic arch pathology. Ann Vasc Surg. 2012;26:55-66.
16. Haulon S, Greenberg RK, Spear R, et al. Global experience with an inner branched arch endograft. J Thorac Cardiovasc Surg. 2014;148:1709-1716.
17. Lobato AC, Cury M. Total endovascular arch replacement with sandwich grafts and TEVAR for the treatment of arch lesions. J Cardiovasc Surg (Torino). In press.
18. Moulakakis KG, Mylonas SN, Markatis F, et al. A systematic review and meta-analysis of hybrid aortic arch replacement. Ann Cardiothorac Surg. 2013;2:247-260.
19. Ius F, Hagl C, Haverich A, Pichlmaier M. Elephant trunk procedure 27 years after Borst: what remains and what is new? Eur J Cardiothorac Surg. 2011;40:1-11.
20. Safi HJ, Miller III CC, Estrera AL, et al. Optimization of aortic arch replacement: two-stage approach. Ann Thorac Surg. 2007;83:S815-S818.
21. Massimo CG, Perna AM, Quadron EAC, Artounian RV. Extended and total simultaneous aortic replacement: latest technical modifications and improved results with thirty-four patients. J Card Surg. 1997;12:261-269.
22. Flores J, Kunihara T, Shiiya N, et al. Extensive deployment of the stented elephant trunk is associated with an increased risk of spinal cord injury. J Thorac Cardiovasc Surg. 2006;131:336-342.
23. Mangialardi N, Serrao E, Kasemi H, et al. Chimney technique for aortic arch pathologies: an 11-year single-center experience. J Endovasc Ther. 2014;21:312-323.
24. Chiesa R, Bertoglio L, Rinaldi E, Tshomba Y. Hybrid repair of aortic arch pathology. Multimed Man Cardiothorac Surg. 2014 May 22;2014. pii: mmu003. doi: 10.1093/mmcts/mmu003. Print 2014.
25. Kouchoukos NT, Mauney MC, Masetti P, Castner CF. Optimization of aortic arch replacement with a one-stage approach. Ann Thorac Surg. 2007; 83:S811-S814.
26. Coselli JS, LeMaire SA, Carter SA, Conklin LD. The reversed elephant trunk technique used for treatment of complex aneurysms of the entire thoracic aorta. Ann Thorac Surg. 2005;80:2166-2172.
27. Beaver TM, Martin TD. Single-stage transmediastinal replacement of the ascending, arch, and descending thoracic aorta. Ann Thorac Surg. 2001;72:1232-1238.
28. Safi HJ, Miller 3rd CC, Lee TY, Estrera AL. Repair of ascending and transverse aortic arch. J Thorac Cardiovasc Surg. 2011;142:630-633.
29. Okita Y, Minatoya K, Tagusari O, et al. Prospective comparative study of brain protection in total aortic arch replacement: deep hypothermic circulatory arrest with retrograde cerebral perfusion or selective antegrade cerebral perfusion. Ann Thorac Surg. 2001;72:72-79.
30. Uchida N, Shibamura H, Katayama A, et al. Long-term results of the frozen elephant trunk technique for the extensive arteriosclerotic aneurysm. J Thorac Cardiovasc Surg. 2009;10:1-5.
31. Kotelis D, Geisbusch P, Hinz U, et al. Short and midterm results after left subclavian artery coverage during endovascular repair of the thoracic aorta. J Vasc Surg. 2009;50:1285-1292.
32. Holt PJ, Johnson C, Hinchliffe RJ, et al. Outcomes of the endovascular management of aortic arch aneurysm: implications for management of the left subclavian artery. J Vasc Surg. 2010;51:1329-1338.
33. Canaud L, Hireche K, Berthet JP, et al. Endovascular repair of aortic arch lesions in high-risk patients or after previous aortic surgery: midterm results. J Thorac Cardiovasc Surg. 2010;140:52-58.
34. Czerny M, Gottardi R, Zimpfer D, et al. Mid-term results of supraaortic transpositions for extended endovascular repair of aortic arch pathologies. Eur J Cardiothorac Surg. 2007;31:623-627.
35. Chan YC, Cheng SW, Ting AC, Ho P. Supra-aortic hybrid endovascular procedures for complex thoracic aortic disease: single center early to midterm results. J Vasc Surg. 2008;48:571-579.
36. Melissano G, Tshomba Y, Bertoglio L, et al. Analysis of stroke after TEVAR involving the aortic arch. Eur J Vasc Endovasc Surg. 2012;43:269-275.
37. Mangialardi N, Serrao E, Kasemi H, et al. Chimney technique for aortic arch pathologies: an 11-year single-center experience. J Endovasc Ther. 2014;21:312-323.
38. Kotelis D, Geisbüsch P, Hinz U, et al. Short and midterm results after left subclavian artery coverage during endovascular repair of the thoracic aorta. J Vasc Surg. 2009;50:1285-1292.
39. Moulakakis KG, Mylonas SN, Dalainas I, et al. The chimney-graft technique for preserving supra-aortic branches: a review. Ann Cardiothorac Surg. 2013;2:339-346.