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 cardiovascu lar operations, with associated high mortality and complication rates. 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. To avoid these complications, different technical solutions have been developed, such as the elephant trunk (by Borst in 1983) and hybrid procedures such as the frozen elephant trunk (developed by Kato in 1996).

Hybrid arch repair with supra-aortic debranching and endografting into the ascending aorta, developed by Buth in 1998, 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.

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 suggested the use of the chimney technique for partial aortic arch repair (zone 1 or 2). Later, Lobato 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.
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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{17}

The 30-day survival rate was 90%. One patient died from complications related to an ischemic myocardial infarction.\textsuperscript{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.\textsuperscript{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%\textsuperscript{17}; hybrid procedures, 11.9%\textsuperscript{18}; and TAR, 3.9% to 16%,\textsuperscript{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\textsuperscript{19} and 6.6% for hybrid repairs.\textsuperscript{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.\textsuperscript{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%\textsuperscript{21} to 8.8%\textsuperscript{22} of patients undergoing open surgical repair, up to 24%\textsuperscript{23} in hybrid procedures, and 7.7%\textsuperscript{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.\textsuperscript{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
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.

The overall rate of endoleaks was up to 26% in hybrid procedures and 18.5% for the chimney technique. 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 midterm follow-up.

Armando C. Lobato, MD, PhD, is a vascular and endovascular surgeon, Director of the São Paulo Vascular & Endovascular Institute (ICVE-SP) and Professor at the Translational Medicine Research Program, Federal University of São Paulo (UNIFESP-EPM) in São Paulo, Brazil. He has stated that he has no financial interests related to this article. Dr. Lobato may be reached at 55 11 996127343; aclobato@icve.com.br.

Marcelo Cury, MD, is a vascular and endovascular surgeon with São Paulo Vascular & Endovascular Institute (ICVE-SP) and Research Fellow at Federal University of São Paulo (UNIFESP-EPM) in São Paulo, Brazil. He has stated that he has no financial interests related to this article.

Fabio Luiz Costa Pereira, MD, is a vascular and endovascular surgeon with Hospital Metropolitano in Vitoria, ES, Brazil. He has stated that he has no financial interests related to this article.

Vasco Gama Ribeiro, MD, is a vascular and endovascular surgeon with Hospital Vil Nova de Gaia in Porto, Portugal. He has stated that he has no financial interests related to this article.

Luciana Camacho-Lobato, MD, PhD, is with Internal Medicine, São Paulo Vascular & Endovascular Institute (ICVE-SP) and is Adjunct Professor, Department of Medicine, Federal University of São Paulo (UNIFESP-EPM) in São Paulo, Brazil. She has stated that she has no financial interests related to this article.


