Chapter

Alternative Techniques for Treatment of Thoracic Aneurysms without Ideal Anatomy

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Abstract

The combination of open surgery and thoracic endovascular repair [TEVAR] are considered hybrid procedures, they are used today to solve the different pathologies of the thoracic aorta, these procedures are presented as a therapeutic alternative for those patients who are not candidates for a procedure conventional surgical procedure, either because they are considered "high risk" patients, due to their pathological history, or in those patients who present a complex anatomy that makes it difficult to complete the repair with endovascular therapies in its entirety. To familiarize ourselves with these therapies, we consider it important to classify them by anatomical segments according to the Ishimaru classification to facilitate their understanding.

Keywords: thoracic aorta, aneurysm, hybrid, endovascular, bypass, endovascular, debranching

1. Introduction

Managing thoracic aortic aneurysms involving the aortic arch poses a surgical challenge. Open surgery it is the gold standard procedure that uses a medium sternotomy and cardiopulmonary bypass [CPB] and hypothermic circulatory arrest is associated with significant morbidity and mortality which causes patients at "high risk" determined by the American Society of Anesthesiologists [ASA] do not be candidates for this kind of repair. Endovascular therapy has revolutionized the treatment of complex chest aortic disease, but supra-aortic arch anatomy represents a more complex challenge for endovascular therapy, although new techniques have resulted such as fenestrated and branched stents these are still in the experimental stage. Treatment hybrid is a combination of debranching procedures of the branches of the supra-aortic arch with endovascular repair of the chest aorta, it is a good alternative in patients with difficult anatomy and high-risk, obtain technical satisfaction in most cases. Hybrid therapy has several studies with promising results but has not been validated as an option of treatment today.

2. Classification of techniques alternative for treatment of thoracic aneurysms involving the aortic arch

Volodos team performed the first hybrid aortic arch repair in 1991. Since then, it has grown enormously by the development of these alternative therapies to conventional open surgery [1].

Indications for repair of thoracic aortic aneurysms are mostly from aneurysm degeneration greater than 5.5 cm in 54% al 63% and secondly dissections by 22% al 43% emergency procedures are performed in up to 20% of cases.

Patients undergoing hybrid repair mention among their history chronic obstructive pulmonary disease secondary to smoking and ischemic cardiac history in 12%, ischemic brain events at 10%, and 16% of patients have the antecedent of a repair of an abdominal aortic aneurysm [2, 3].

The reported complication rates for thoracic aortic interventions are estimated to be 36% in procedures performed entirely with endovascular therapy using fenestrated/branched endografts. When hybrid procedures are performed, the complication rate is 33%, and 50% for open surgery [4].

Regarding the complications reported after hybrid therapies, we found that patients present endoleaks with rates between 9% and 22% of cases, most endoleaks are type 1 and are resolved in the vast majority of cases with the placement of a proximal prosthesis or extension, stroke is reported in 7% to 14% of patients, mainly related to the posterior circulation, probably related to the occlusion of the left subclavian artery that is performed in a programmed way in the majority of cases, paraplegia in 0.5% to 6% with response to cerebrospinal fluid drainage in one third of patients, this drainage is recommended in patients with extensive aortic disease or after placing an endoprosthesis with an extension greater than 15 cm in length. The descending aorta, retrograde aortic dissection in 4.1%, this occurs more frequently in hybrid therapies in which covered stents parallel to the aortic are used, and graft bypass occlusion 4% and cardiopulmonary complications 14%. [5–8].

The technical satisfaction of hybrid procedures is estimated between 69% and 100% with an average of 87% of the cases, with a conversion to open surgery of 3% for the repair of any complication. Rate survival to 12-month after the procedure is 78%, and the 3-year follow-up is reported at 73% [5, 6, 8].

Regarding the surgical approaches used to access the carotid arteries, a longitudinal or transverse incision in the neck is used more frequently, for the left subclavian artery a horizontal infraclavicular or supraclavicular incision is used, the latter being the most used, some patients require of a median sternotomy to approach a healthy segment of the ascending aorta and place a graft with 2 or 3 branches in it to completely reimplant the aortic arch. Hybrid repair offers good short-term results, but more long-term follow-up studies of bypass results and permeability are needed in these patients. Follow-up studies of complex thoracic aneurysms with hybrid procedures are mostly retrospective some with 36-month follow-up [1, 4].

The debranching procedures are divided into complete procedures when the debranching corresponds to zone 0 of the Ishimaru classification with which the three main branches of the aortic arch are reconstructed, the partial procedures are those that correspond to the zone 1 and 2 of Ishimaru, in zone 1 the left carotid artery and the left subclavian artery are reconstructed and in zone 2 the left subclavian artery only [9].

2.1 Zone 0

Zone 0 corresponds to the ascending aorta and the origin of the innominate artery. Hybrid reconstructions in this area can be subdivided into two types:

2.1.1 Type 1

Type 1 is used when a segment of the ascending aorta is healthy, this repair consists of the reimplantation of the aortic arch vessels, using a 2 or 3-branch dacron graft that is anastomosed to a healthy ascending aorta segment above of the tubular sinus junction. The left subclavian artery is the first to anastomosed followed by the left carotid artery and later the brachiocephalic trunk, in the case that the left subclavian artery is not accessible by a sternotomy, a left carotid artery bypass is performed to the left subclavian artery through a supraclavicular incision. This procedure can be performed with a cardiopulmonary pump or by lateral clamping of a segment of the aorta, using a mean time of 193 ± 58 minutes and a mean clamping time of 44 ± 27 minutes. When using a 2-limb graft, the need to bypass the left carotid artery to the left subclavian artery should be evaluated at the time of surgery or later **Figure 1** [1, 8, 10, 11].

2.1.2 Type 2

This type of repair is performed in those patients with extensive disease of the ascending aorta in which there is no healthy segment to perform a type 1 repair, or when the ascending aorta that corresponds to the proximal landing zone of the endoprosthesis is greater than 3.7 cm since this diameter is associated with a greater risk of type A dissection. This repair consists of the substitution of the ascending aorta with a dacron graft and a 2 or 3-branch dacron graft is anastomosed on this graft. This repair requires the use of a cardiopulmonary pump and sometimes a

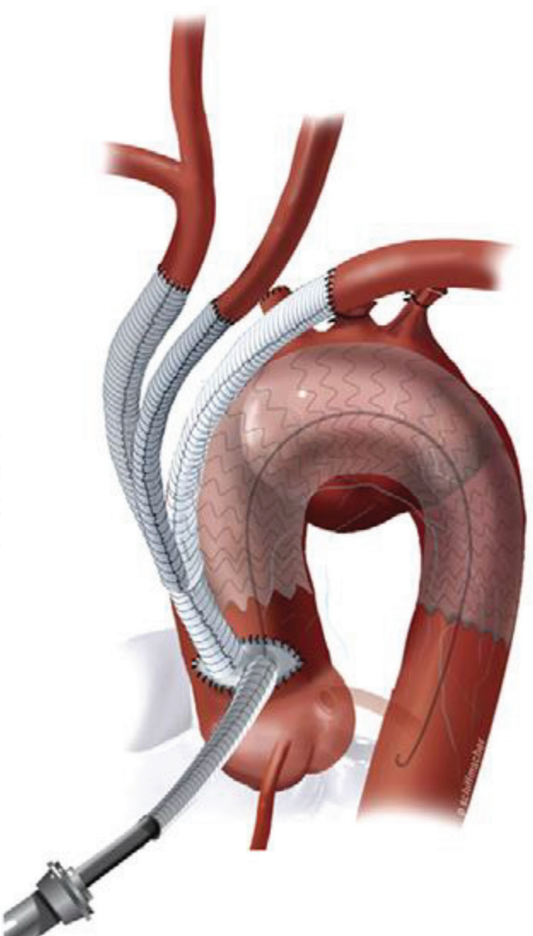

Figure 1.
Debranching zone 0 type 1, using a 3 branch dacron graft, the endoprosthesis covering the three main branches of the aortic arch.

short period of circulatory arrest with a mean time of 259 ± 54 minutes with clamping time of 121 ± 63 minutes of circulatory arrest **Figure 2** [1, 8, 10].

The following are recommendations when performing aortic arch reconstruction:

1. Mean arterial pressure of 80-100 mmHg during anastomosis of the arteries supplying the head.

2. Have prefabricated grafts of 2, 3 or 4 branches.

3. Start the reconstruction with the anastomosis on the anterolateral aspect of the ascending aorta.

4. During the anterior anastomosis maintain a mean arterial pressure of 50-60 mmHg.

5. Continue with the revascularization from distal to proximal starting with the left subclavian artery, followed by the left common carotid artery and finally the brachiocephalic trunk.

6. During the previous anastomosis, maintain a mean arterial pressure between 80-100 mmHg.

7. When the left subclavian artery is not accessible through the median sternotomy, a carotid-subclavian bypass is performed through a supraclavicular incision at the same time or later.

Figure 2.
Debranching zone 0 type 2, using a 3 branch dacron graft, the substitution of the ascending aorta with a dacron graft and endoprosthesis covering the three main branches of the aortic arch.

In general, the 30-day in-hospital mortality reported for these procedures is 8% to 14%, with the highest mortality for type 2 procedures, a neurological deficit of 7% to 14%, and kidney failure requiring hemodialysis in 3%. Atrial fibrillation is reported in up to 42% of these patients, the reported survival is 71%, 60%, and 48% at 12 months, 3, and 5 years, respectively [1, 8, 11].

2.2 Zone 1

Zone 1 corresponds to the area of the ascending aorta between the brachycephalic trunk and the left common carotid artery. Repair of the left subclavian artery may or may not be necessary, depending on the clinical context, this repair is performed in up to 70% of cases, so repair is recommended whenever possible. The debranching of zone 1 is a partial procedure and is subdivided into three types:

2.2.1 Type 1

Sequential bypass from right carotid to left carotid and left subclavian artery is carried out by performing a sequential bypass that is: An anastomosis of the right carotid artery to the left carotid artery and from this a bypass to the left subclavian artery, so this procedure can be completed without the need for extracorporeal circulation, median sternotomy, or thoracotomy (**Figure 3**).

2.2.2 Type 2

Double arterial transposition this is to perform an anastomosis first from the left carotid artery to the right carotid artery or the brachiocephalic trunk followed

Figure 3.
Debranching zone 1 type 1, using bypass sequential bypass from right carotid to left carotid and left subclavian artery. Note closure of the left carotid artery lumen and ligation of the left subclavian artery, with a endoprosthesis covering two branches of the aortic arch.

by an anastomosis between the left subclavian artery to the left carotid artery. A single transposition of the left carotid artery to the right carotid artery can also be performed followed by a left carotid artery bypass to the left subclavian artery using a graft [1, 8] (**Figure 4**).

2.2.3 Type 3

Bypass with graft of the right carotid artery to the left subclavian artery, then the insertion of the left carotid artery over the graft is performed [6].

There are no studies comparing the three types of hybrid revascularization for zone 1 (**Figure 5**).

2.3 Zone 2

The debranching of zone 2 is a partial procedure too.

Many patients with thoracic aortic disease have extension of the disease to the left subclavian artery, so it may need to be covered between 40% and 50% to achieve a seal and adequate proximal fixation. In general, after TEVAR the rates of neurological complications are up to 15%, the etiology is related to athero-embolization and decreased flow of the left vertebral artery [7, 10, 12]. Some authors suggest that the coverage of the left subclavian artery is associated with an increase in neurological complications related to the reduction of the flow of the posterior circulation, while others report that revascularizing the left subclavian artery does not offer any benefit, on the contrary, it increases the surgical time and the risk of complications, especially in emergency surgeries such as ruptured aortic aneurysm [10, 12].

In 2010 the published guidelines of the Society for Vascular Surgery [SVS] and in 2017 the guidelines of the European Society for Vascular Surgery [ESVS] recommend early revascularization of the left subclavian artery to reduce the

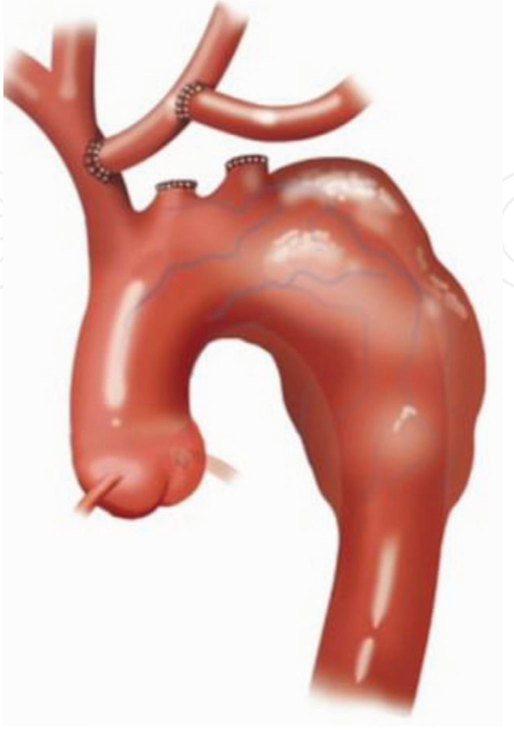

Figure 4.
Debranching zone 1 type 2, using double arterial transposition. Note closure of the lumen of the left carotid artery and the left subclavian artery with a suture line.

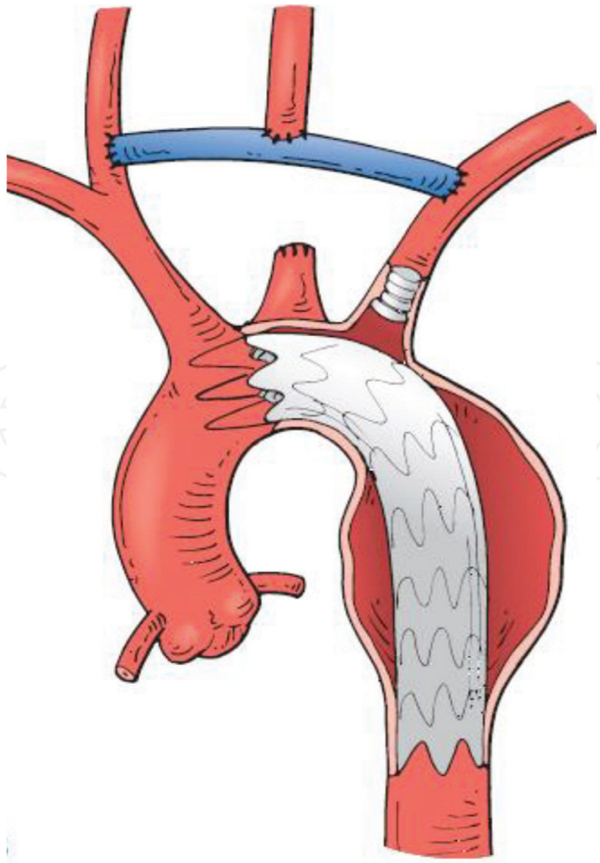

Figure 5.
Debranching zone 1 type 3, using bypass with graft. Note closure of the lumen of the left subclavian artery whit coils and the left carotid artery with a suture line, with a endoprosthesis covering two branches of the aortic arch.

risk of neurological complications, but this recommendation is based on low-quality evidence [13, 14].

In the meta-analysis published in 2016 [15], which compared retrospective studies, they found a stroke rate of 2.2% to 5.8% for patients with left subclavian artery revascularization and from 7.8% to 9.1% In those who did not revascularize, with respect to spinal cord ischemia, a rate of 2.7% was reported for those patients with revascularization and 4.3% for those patients without revascularization of the left subclavian artery, without statistical significance for these results, but with a trend in favor of revascularization of the left subclavian artery.

Factors related to stroke and spinal ischemia include the duration of the procedure, the degree of underlying aortic disease, device navigation and release, the number of prostheses used in aortic repair, occlusion below T10, insufficiency renal and female sex [15–18]. Mortality from revascularization and non-revascularization of the left subclavian artery in hybrid procedures is similar, 3.1% to 4.3% respectively.

There is no significant difference in the effectiveness between open revascularization surgery techniques (left carotid-subclavian shunt or subclavian carotid transposition), finding 100% patency in the two techniques. Open revascularization is not without complications such as lymphatic leakage, vocal cord paralysis in 5% to 13%, and phrenic nerve injury in 4.4% of cases [10, 19].

In recent years, a tendency has been observed to revascularize the left subclavian artery with endovascular techniques; Some studies suggest that these revascularization techniques present similar results to open surgery, whether it is the transposition of the left subclavian artery to the left carotid artery or the bypass of the left carotid artery to the left subclavian artery, in selected patients, such as:

Preoperative	Intraoperative	Postoperative
• Bypass in the internal mammary artery (IMA).	• Loss of left radial pulse after device deployment.	• Clinical symptoms of vertebrobasilar insufficiency (ataxia, blurred vision, dizziness).
• Left vertebral artery (LVA) direct branch of the aortic arch.		• Claudication of the left arm.
• Access for hemodialysis in the left thoracic limb (LTL).		
• Dominant left vertebral artery.		
• Protection of the spinal cord.		
• Extensive coverage of the aorta		

Table 1.
Indications for revascularization of the left subclavian artery. This table considers three moments in which we can perform a surgery.

patients with severe obesity, very short and stiff necks, previous neck surgeries. For endovascular therapy of the left subclavian artery to be performed, anatomical aspects should be considered such as: a distance greater than 40 mm between the left vertebral artery and the subclavian artery left, an angle less than 75 degrees to the aortic arch of the left subclavian artery [3, 17].

Most of these studies do not describe anatomical details that determine the result, and the evidence is based on a small number of clinical cases with short-term follow-up of [17, 18]. Therefore, the surgeon must individualize the best therapeutic option for each patient based on the least morbidity and the longest possible duration.

The indications for elective revascularization of the ASI can be summarized in **Table 1** [16, 18].

3. Conclusion

There are no data from randomized controlled trials comparing conventional therapy with hybrid procedures for the treatment of aortic arch pathology; some studies comparing the results between open surgery and hybrid therapies show a statistically significant findings found in recent studies a reduction in mortality. However, hybrid procedures are an alternative for those patients with high surgical risk who cannot tolerate open repair or complex anatomy for endovascular therapy.

Conflicts of interest

The authors have no conflicts of interest to declare.

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