Endovascular treatment of aortic arch aneurysms

Tratamento endovascular dos aneurismas de arco aórtico

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Abstract

Background: Endovascular approach to the aortic arch is an appealing solution for selected patients.

Objective: To compare the technical and clinical success recorded in the different anatomical settings of endografting for aortic arch disease.

Methods: Between June 1999 and October 2006, among 178 patients treated at our institution for thoracic aorta disease with a stent-graft, the aortic arch was involved in 64 cases. According to the classification proposed by Ishimaru, aortic zone 0 was involved in 14 cases, zone 1 in 12 cases and zone 2 in 38 cases. A hybrid surgical procedure of supra-aortic debranching and revascularization was performed in 37 cases.

Results: *Zone* 0. Proximal neck length: 44±6 mm. Initial clinical success was 78.6%: two deaths (stroke), one type Ia endoleak. At a mean follow-up of 16.4±11 months the midterm clinical success was 85.7%. *Zone 1*. Proximal neck length: 28±5 mm. Initial clinical success was 66.7%: 0 deaths, four type Ia endoleaks. At a mean follow-up of 16.9±17.2 months the midterm clinical success was 75.0%. *Zone 2*. Proximal neck length: 30±5 mm. Initial clinical success was 84.2%: two deaths (one cardiac arrest, one multiorgan embolization), three type Ia endoleaks, one case of open conversion. Two cases of delayed transitory paraparesis/paraplegia were observed. At a mean follow-up of 28.0±17.2 months the midterm clinical success was 89.5%.

Conclusions: This study and a literature review demonstrated that hybrid procedure for aortic arch pathology is feasible in selected patients at high risk for conventional surgery. Our experience is still limited by the relatively small sample size. We propose to reserve zone 1 for patients unfit for sternotomy or in cases with aortic neck length > 30 mm following left common carotid artery debranching. We recommend to perform complete aortic rerouting of the aortic arch in cases with lesser comorbidities and shorter aortic neck.

Keywords: Aortic arch, endovascular treatment, stent-graft, hybrid procedure.

Resumo

Contexto: O tratamento endovascular dos aneurismas do arco aórtico é uma solução interessante para pacientes selecionados.

Objetivo: Comparar os sucessos técnico e clínico registrados nas diferentes regiões anatômicas do arco aórtico após a colocação de endoprótese.

Métodos: Entre junho de 1999 e outubro de 2006, 178 pacientes foram tratados na nossa instituição devido a doenças da aorta torácica com a colocação de endoprótese, sendo que o arco aórtico estava envolvido em 64 casos. De acordo com a classificação proposta por Ishimaru, a zona aórtica 0 estava envolvida em 14 casos, zona 1 em 12 casos e zona 2 em 38 casos. Procedimentos de debranching do arco aórtico e revascularização extra-anatômica dos troncos supra-aórticos foram realizados em 37 casos para obter um adequado colo aórtico proximal.

Resultados: *Zona 0*. Comprimento do colo proximal: 44±6 mm. Sucesso clínico inicial de 78,6%: dois óbitos (acidente vascular cerebral), um vazamento do tipo Ia. Seguimento médio de 16,4±11 meses com sucesso clínico a médio prazo de 85,7%. *Zona 1*. Comprimento do colo proximal: 28±5 mm. Sucesso clínico inicial de 66,7%: 0 óbitos, quatro vazamentos do tipo Ia. Seguimento médio de 16,9±17,2 meses com sucesso clínico a médio prazo de 75%. *Zona 2*. Comprimento do colo proximal: 30±5 mm. Sucesso clínico inicial de 84,2%: dois óbitos (um infarto cardíaco e uma embolização de múltiplos órgãos), três vazamentos do tipo Ia, um caso de conversão para operação aberta. Dois casos de paraparesia/paraplegia transitória tardia foram observados. Seguimento médio de 28,0±17,2 meses com sucesso clínico a médio prazo de 89,5%.

Conclusão: Este estudo e a análise da literatura demonstram que o procedimento híbrido para moléstia do arco aórtico é factível em pacientes selecionados com alto risco para a operação convencional. Nossa experiência ainda é limitada pelo tamanho relativamente pequeno da amostra. Sugerimos reservar a zona 1 para pacientes inadequados para esternotomia ou em casos de comprimento do colo aórtico proximal > 30 mm apos revascularização da artéria carótida comum esquerda. Sugerimos realizar revascularização completa do arco aórtico em pacientes adequados com um colo aórtico proximal mais curto.

Palavras-chave: Arco aórtico, tratamento endovascular, endoprótese, procedimento híbrido.

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Introduction

A surgical approach to the aortic arch has been made possible for the first time in the 1960's by the introduction of cardiopulmonary bypass with deep hypothermia and circulatory arrest.[1] Despite improved results of open repair of the aortic arch with the aid of selective antegrade cerebral perfusion, complications remain high. Moreover, the presence of different preoperative comorbidities are associated with particularly poorer outcomes at univariate and multivariate analysis.[2] Such patients, ineligible for elective open repair, may benefit from an alternative approach.

The progress with branched stent-grafts that allow a totally endovascular approach has been slow,[2,3] therefore, nowadays, in order to provide a less invasive treatment that could also be offered to patients unfit for conventional surgery, a hybrid approach consisting of aortic arch debranching with rerouting of the supra-aortic trunks and aneurysm exclusion employing straight stent-grafts is still advisable. The availability of stent-grafts that can be easily delivered and deployed in the aortic arch and that can accommodate its curved anatomy have prompted many authors[3-10] to use them in this challenging alternative choice.

In this study we analyze our results with aortic arch aneurysm stent-graft repair in the different aortic arch zones, ranging from total rerouting of all the supra-aortic branches through median sternotomy (total arch debranching) to extra-anatomic revascularization of the left common carotid or the sole subclavian artery (hemi-arch debranching), according to the extent of the pathology into the aortic arch and to the availability of an adequate stent-graft landing zone.

Methods

Between January 1999 and October 2006, 178 patients underwent endovascular grafting of the thoracic aorta at our institution. The aortic arch was involved in 64 cases. There were 56 men and eight women with mean age of 69.6±11.3 years (range 25-86 years). Atherosclerotic aneurysm was observed in 53 cases, post-traumatic aortic rupture in two cases, aortic dissection in three cases, penetrating ulcer/intramural haematoma in three cases, pseudoaneurysm in two cases, and stent-graft collapse due to multiple stent fractures in one case.

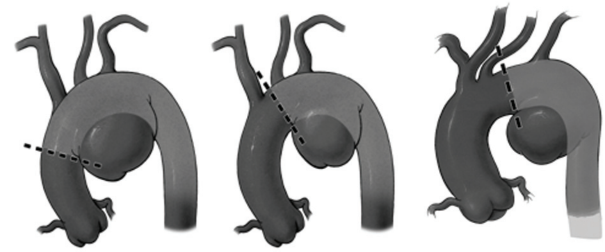


Figure 1 - Ishimaru classification of proximal landing zones

An additional surgical procedure of supra-aortic debranching and revascularization was performed in 37 cases to obtain an adequate proximal aortic landing zone (PLZ) and in four cases to achieve a satisfactorily access site. According to the classification proposed by Ishimaru,[11] patients were divided into three groups based on the PLZ involved (Figure 1): zone 0 – 14 cases (13 males; mean age: 73.4±5.3 years); zone 1 – 12 cases (nine males; mean age: 66.7±11.8 years); and zone 2, 38 cases (34 males; mean age: 70.4±12.1 years).

Risk factors of patients in the different groups are reported in Table 1. Two patients were treated urgently for symptomatic disease (one case of zone 1, and one case of zone 2) and two patients emergently for true rupture (two cases of zone 2).

The feasibility of the endoluminal intervention, sizing of stent-grafts and implant strategy were determined preoperatively, mainly using 16-row multislice computed tomography (CT) with multiplanar reconstructions (Aquilion 16; Toshiba Medical Systems). We considered the proximal aortic neck adequate to be a suitable PLZ when the maximum diameter was ≤ 38 mm, and the length was ≥ 20 mm. We used one of several different commercially available stent-grafts (Table 2).

All patients received preoperative duplex scanning of the iliac, femoral, carotid and vertebral arteries to assess access site and to evaluate the vertebral and carotid circulation.

Table 1 - Preoperative risk factors in the different three groups of patients based to the proximal stent-graft landing zone

	Zone 0 (n = 14)	Zone 1 (n = 12)	Zone 2 (n = 38)	Total (n = 64)
Age	73.4±5.3	66.7±11.8	70.4±12.1	70.4±10.9
Sex (men)	13	9	34	56
Tobacco use	7	5	19	31
Diabetes	2	3	5	10
Hypertension	8	6	22	36
Pulmonary disease	9	4	21	34
Renal disease	0	1	9	10
Cardiac disease	8	3	16	27
Cerebrovascular disease	2	3	7	12
Previous AAA repair	0	1	3	4

AAA = abdominal aortic aneurysm.

Table 2 - Different implanted endografts

	Zone 0 (n = 14)	Zone 1 (n = 12)	Zone 2 (n = 38)	Total (n = 64)
Excluder TAG – old device	0	1	3	4
Excluder TAG – new device	1	0	4	5
Talent	0	0	4	4
Endofit	0	1	3	4
Zenith TX1	5	3	14	22
Zenith TX2	8	7	9	24
Zenith TXD	0	0	1	1

Patients were evaluated with post-procedure chest X-ray and contrast CT scans with scheduled follow-up imaging at 1, 6 and 12 months, and yearly thereafter. Angiograms were obtained in selected cases (i.e., endoleaks). Clinical follow-up was also performed at regular 6-month intervals.

Procedure

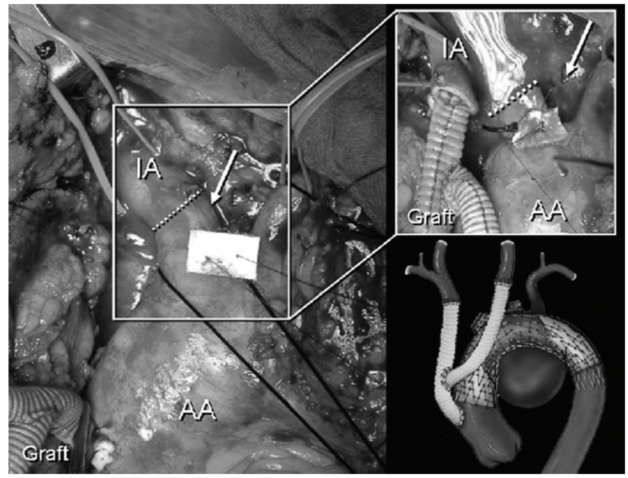
All the procedures were performed in the operating room, using a portable digital C-arm image intensifier with road-mapping capabilities. Intraoperative transesophageal echocardiography was used selectively in six patients including all dissection cases.

All cases of zone 0 and zone 1 were performed under general anaesthesia. In zone 2, 26 procedures (68%) were performed under general anaesthesia, while epidural or subarachnoid anaesthesia was used in 12 cases (32%). Cerebral activity was monitored by means of continuous electroencephalogram in all cases performed under general anaesthesia.

Preoperative cerebral spinal fluid drainage (CSFD) was instituted in two selected patients with previous abdominal aortic surgery and postoperatively in two patients developing symptoms of spinal cord ischemia.

In 60 cases the common femoral artery, exposed through an inguinal incision, was used as access vessel (93.8%), an iliac access was used in two cases (3.1%) and two cases (3.1%) had the device inserted through an infra-renal aortic tube graft during combined surgery for abdominal aortic aneurysm and aortic arch.

The different techniques of supra-aortic vessels debranching have been previously described.[3] In summary, debranching of supra-aortic vessels was performed for all zone 0 cases via revascularization of the brachiocephalic trunk and left common carotid artery from the ascending aorta (Figure 2). All zone 1 cases received a cervical cross-over carotid bypass to the left common carotid artery associated with revascularization of left subclavian artery (LSA) in two cases (Figure 3). Intentional overstenting of the LSA without revascularization was performed for zone 2 in 27 cases (11 cases of prophylactic revascularization: eight cases of left carotid-subclavian artery bypass, one case of bilateral carotid subclavian artery bypass in a patient with aberrant right subclavian artery, and two cases of subclavian artery transposition). Prophylactic revascularization of LSA was performed when it supplied coronary circulation through the left internal mammary, when the contralateral vertebral artery was inadequate (i.e., hypotrophy), in young patients, left-handed professionals or in cases of previous abdominal aortic surgery to prevent paraplegia. During all phases of endograft deployment pharmacological systemic hypotension was induced; no overpacing or cardiac arrest were used. After deployment a completion aortography was performed. Ballooning was performed selectively. In all the cases a hybrid one-stage procedure was performed.



AA = ascending aorta; IA = innominate artery.

Figure 2 - Total arch rerouting for zone 0 cases

Figure 3 - Hemi-arch rerouting for zone 1 cases

Results definition

Reported results and methods are in accordance with the current reporting standards for endovascular aortic repair prepared and revised by the Ad Hoc Committee for Standardized Reporting Practices in Vascular Surgery (SVS/AAVS). Data are shown as number (%) for categorical variables or as median, first quartile and third quartile (Q_1-Q_3) and mean for continuous variables, as they did not show a Gaussian distribution.

Results

Mean maximum diameter of PLZ was 33.5±3.7 mm: 34.3±3.7 mm for zone 0, 34.1±3.0 mm for zone 1, and 33.0±3.9 mm for zone 2. Mean length of PLZ obtained after supra-aortic vessels debranching or intentional coverage of LSA was 33.0±7.7 mm: 43.9±5.6 mm for zone 0, 28.4±4.8 mm for zone 1, and 30.4±5.0 mm for zone 2.

Table 3 - Results in the different proximal aortic landing zones

	Zone 0 (n = 14)	Zone 1 (n = 12)	Zone 2 (n = 38)	Total (n = 64)
Technical success	13 (92.9%)	8 (66.7%)	34 (89.5%)	55 (85.9%)
Type I or III endoleak	1 (7.1%)	4 (33.3%)	3 (7.9%)	8 (12.5%)
Intraoperative death	0	0	1 (2.6%)	1 (1.6%)
Procedural open conversion	0	0	0	0
30-day mortality	2 (14.3%)	0	2 (5.3%)	4 (6.3%)
Paraplegia	0	0	2 (5.3%)	2 (3.1%)
Stroke	2 (14.3%)	0	0	2 (3.1%)
Renal failure	0	0	1 (2.6%)	1 (1.6%)
Respiratory failure	1 (7.1%)	0	0	1 (1.6%)
ICU stay	6.4±8.5 d	2.3±3.6 d	0.7±1.1 d	2.2±4.8 d
Length hospital stay	11.1±8.1 d	7.7±4.4 d	4.8±3.2 d	6.7±5.5 d
Initial clinical success	11 (78.6%)	8 (66.7%)	32 (84.2%)	51 (79.7%)
30-day open conversion	0	0	1 (2.6%)	1 (1.6%)
Short clinical success	12 (85.7%)	11 (91.7%)	35 (92.1%)	58 (90.6%)
Resolution postoperative type I endoleak	1 (7.1%)	3 (25.0%)	3 (7.9%)	7 (18.4%)
Midterm clinical success	12 (85.7%)	9 (75.0%)	34 (89.5%)	55 (85.9%)
New onset type I or III endoleak	0	0	0	0
Aneurysm-related deaths	0	2 (16.7%)	0	2 (3.1%)
Open conversion	0	0	1 (2.6%)	1 (1.6%)

ICU = intensive care unit.

Overall primary technical success was achieved in 55/64 cases (85.9%). One patient died 1 hour after the procedure from cardiac arrest because of migration within the arch aneurysm of the stent-graft,[3,12] and eight patients (12.5%) had a residual proximal type I endoleak after deployment in the planned landing zone. Only three endoleaks were noticed after completion angiography and all were evident at predischarge CT scan. These endoleaks were temporarily left untreated because the aortic proximal neck was deemed inadequate for further endovascular procedures or required unplanned supra-aortic vessel debranching procedure. A type II endoleak was observed in three patients (4.7%).

The overall mean intensive care unit stay and the mean length of hospital stay are summarized in Table 3.

Initial (30 days) clinical success was obtained in 51/64 patients (79.7%) with a mortality rate of 4/64 (6.3%). The causes of perioperative death were stroke in two cases and multiorgan embolization in one case. One patient (zone 2) electively underwent a successful surgical conversion 2 weeks after the procedure because of stent fracture and graft collapse (Table 3).[3,12] No adjunctive cerebrovascular accidents were recorded. The major adverse rate, including early deaths and major stroke, was 9.4% (6/64). Paraplegia was observed in two cases (3.1%): in all cases paraplegia had a delayed onset (range 1-3 days) and resolved after CSFD institution.[13] Postoperative complications included acute renal failure reversed without dialysis in one patient (1.6%) and respiratory failure requiring intubation for more than 48 hours in one patient (1.6%).

Short-term clinical success was obtained in 58/64 patients (90.6%): seven cases of proximal type I endoleak

Table 4 - Review of outcomes of the main series reported in literature (> 10 patients) of aortic arch aneurysm hybrid repair

Authors	Cases	Total arch	Hemi-arch	Device	Death	Stroke	30 days conversion	Overall survival	Mean follow-up
Kieffer et al.[3]	16	8	8	HM	4 (25%)	4 (25%)	4 (25%)	56%	23 months
Bergeron et al.[7]	25	15	10	GE ,TM, ZC	2 (8%)	2 (8%)	0	88%	15 months
Czerny et al.[8]	11	2	9	EE, GE, TM	0	0	0	100%	18 months
Zhou et al.[9]	16	11	5	GE	1 (6%)	0	0	94%	16 months
Saleh et al.[10]	15	15	0	TM	0	0	0	93%	18 months
Schumacher et al.[6]	25	9	16	EE, GE, TM, ZC	5 (20%)	1(4%)	0	76%	21 months
HSR experience	26	14	12	EE, GE, ZC	2 (8%)	2 (8%)	0	82%	19 months
Total	134	74	60	CM, EE, GE, TM, ZC	14 (10.5%)	9 (6.7%)	4 (3.0%)	83.1%	r. 15-23 months

CM = custom-made; EE = Endofit Endomed; GE = Gore TAG Excluder; HM = home-made device; HSR = Scientific Institute H. San Raffaele; TM = Talent Medtronic; ZC = Zenith Cook.

resolved completely without any further intervention and one case of perioperative endoleak is being followed 2 months after the procedure (Table 3).

At a mean follow-up of 19.1±15.6 months (range 1-65 months), there was midterm clinical success in 55/64 patients (85.9%).

Two patients died from aneurysm rupture (zone 1) and one surgical conversion was performed because of a late fracture of the longitudinal support wire of a Gore Excluder TAG stent-graft 43 months after endovascular procedure for zone 2 aneurysm. We also recorded two late deaths unrelated to the aneurysm.

Discussion

In the 1990's, when cerebral perfusion was introduced as an adjunct during aortic arch open repair, a significant outcome improvement was reported. Several authors[2,5,8] have reported very significant outcome improvements and reduced mortality with these techniques. However, these excellent results require an accurate patient selection, a great technical experience in cardiac and thoracic aortic surgery, "high-volume" activity, and are not reproduced in many centres throughout the world.

Despite improved results of open repair of the aortic arch with the aid of selective cerebral perfusion, the leading causes of early postoperative mortality are still permanent cerebral dysfunction, myocardial failure and bleeding. Different case reports have demonstrated the technical feasibility of total or hemi-arch rerouting of the supra-aortic branches associated with endovascular treatment of aortic arch pathology, but only a few studies including more than 10 cases have been published (Table 4).

We previously reported our initial experience on hybrid treatment of aortic arch pathology.[4] From analysis of results of our overall contemporary experience, we reported a mortality rate of 6.3% and a stroke rate of 3.1%, however, initial clinical success rates are less satisfactorily than the results published for endovascular treatment of descending thoracic aortic pathology. The initial clinical success rate of our series has been affected by a high rate of type I endoleaks. Consistently with the reports of other authors,[3,7,8] we observed complete spontaneous resolution of these type I endoleaks within the first 6 months with an acceptable short and midterm clinical success rate. Type I endoleaks were discovered after a satisfactorily positioned endograft with adequate proximal neck length and could be related to incomplete endograft seal in the proximal neck possibly due to high blood stream flow. This may explain the high rate of spontaneous resolution in our series within the first 6 months of follow-up.

Although zone 2 is anatomically an aortic arch segment, it represents a very peculiar pattern of aortic arch disease with specific troubles and features. These "borderline" landing zones between the descending thoracic aorta and the aortic arch present some concerns typical of aortic arch and also of descending aortic stent-graft repair. They should be likely considered a specific separate pattern of disease and the definition of aortic arch stent-graft repair should be limited to the landing zones 1 and 0.

Management of the LSA arising from zone 2 PLZ remains a debated issue.[4,5,14-16] In our practice we intentionally overstented the LSA with revascularization only in selected cases. Unlike other authors,[15,16] we did not observe complications related to LSA occlusion. The only postoperative death in this PLZ was due to multiorgan embolization (cerebral and limbs) in a case of thoracic shaggy aorta. The neurological morbidity we recorded was delayed onset paraplegia in two cases of extensive descending thoracic aorta involvement. In this two cases a prompt CSFD institution completely resolved the spinal cord ischemia. Tiessenhausen et al.[17] proposed prophylactic revascularization of the LSA to prevent paraplegia in case of extensive thoracic aorta involvement and in previous abdominal aortic surgery.

For zone 1 hemi-arch debranching with extra-anatomical revascularization of the left common carotid has been performed, followed by overstenting of its origin.[3-9] This technical solution, in our experience, produced no mortality, however short and midterm clinical success was less satisfactory than in the other PLZ. This difference was not statistically significant, possibly due to sample size. The lower success rate is due to an excessive rate of immediate type I endoleak and to the two aneurysm-related deaths at midterm follow-up. The less satisfactory results in zone 1 group may be related to the shorter aortic neck length obtained rerouting blood flow only to the left common carotid artery and to the proximity of aortic arch major angulation. Initially, we judged an aortic proximal neck length ≥ 20 mm to be sufficient for endografting in the zone 1 in order to avoid sternotomy and complete rerouting of aortic arch. Currently we choose zone 1 PLZ if the aortic neck length was > 30 mm or in patients absolutely unfit for sternotomy with shorter aortic necks. Another concern of endovascular treatment of zone 1 PLZ is the durability of the extrathoracic revascularization of the left common carotid artery. In fact, experience derived from treatment of obstructive disease of supra-aortic vessels showed that long-term patency of extrathoracic reconstruction was lower that intrathoracic anatomical reconstructions.[18] An interesting alternative proposed by Czerny et al.[8] is to perform revascularization of left common carotid and subclavian artery for zone 1 with intrathoracic autologous double transposition. This approach, however, requires the invasiveness of a median sternotomy and does not provide any advantage in terms of proximal aortic neck gained compared with a total arch debranching feasible with a median sternotomy.

Complete rerouting of the aortic arch was reported in the literature but only few centres have presented series of more than 10 cases (Table 4). Kieffer et al.[3] reported the first large series on 16 cases of zone 0 and 1, employing a homemade stent-graft with mortality, perioperative morbidity and conversion rates of 25, 62.5 and 12.5%, respectively. Schumacher et al.[6] reported more encouraging results with commercially available endografts: in their recently updated series of 25 high risk patients affected by an aortic arch aneurysm, they recorded two deaths in seven zone 0 cases. More recently four large series[7-10] were published involving 43 zone 0 cases with only three deaths reported. No cerebrovascular accidents were described. Our updated experience in zone 0[3] confirmed that the procedure can be performed safely and with reasonably technical success rate; however, the main drawback in our series were cerebrovascular accidents. Our two deaths were related to fatal stroke. This evidence differs from other published series in which all deaths were mainly related to complication of endovascular procedures itself (i.e., guide-wire or device tip ventricle perforation, iliac rupture, etc.).

A controversial issue is timing of supra-aortic debranching and endovascular procedure. Some authors[7,8,10] prefer to perform a staged procedure with a free interval, ranging from 1 to 3 weeks, between open surgery and endovascular procedure. We prefer to perform both the procedures in the same operation for several reasons. A single general anesthesia is required that gives us the advantage to easily use an aortoiliac access when needed. Moreover, adjunctive surgical maneuvers, such as aortic banding or more proximal ligature of supra-aortic stumps, can be performed selectively to correct type I endoleak. Saleh et al.[10] performed routinely aortic banding of proximal aortic neck in a staged approach strategy, however this adjunctive maneuver carries some risks of surrounding tissue damage and we suggest to perform only if required after endograft deployment (i.e., endoleaks). Furthermore, a single stage approach does not leave a time at risk of rupture between the complete recovery from median sternotomy and endovascular procedure.

Conclusion

Overall, this study and literature review demonstrated that hybrid procedure for aortic arch pathology is feasible in selected patients at high risk for conventional surgery. The outcomes are promising, but nowadays mortality and morbidity rates cannot be neglected.

Our experience is still limited by the relatively small sample size. However, the analysis of our results may have practical implications on the ongoing evolution of hybrid procedures in the aortic arch. Currently we propose to reserve zone 1 for patients unfit for sternotomy or in cases with aortic neck length > 30 mm following left common carotid artery debranching and we recommend to perform complete aortic rerouting of the aortic arch in cases with lesser comorbidities and shorter aortic neck.

This recommendation, standardization of procedures, technological evolution of materials, and stent-grafts will probably improve initial and midterm clinical success rate. Moreover, hybrid treatment of aortic arch pathology may be reserved to patients unfit for open repair.

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