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Hybrid procedures for complex thoracic aortic diseases

Tratamento híbrido das doenças complexas da aorta torácica

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Abstract

Background: **Hybrid procedures for the treatment of complex thoracic aortic diseases (CTAD) require the revascularization of one or more supra-aortic arteries, followed by the deployment of one or more aortic endoprosthesis, with lower morbidity and mortality compared to conventional surgery.**

Objectives: **To evaluate the technique and results of hybrid procedures for CTAD.**

Methods: **During two years, 12 patients with CTAD underwent hybrid procedures, including aortic arch aneurysms and acute Stanford A and B aortic dissections. All patients had formal indications to invasive treatment, and inadequate proximal landing zone (less than 20 mm). Half were male and the mean age was 55.5 years (42 to 78). At least three cardiovascular risk factors were present in 75% of patients. The average follow-up was 10.9 months (2 to 25), with periodic consultations and CT scans.**

Results: **The initial technical success was achieved in 10 patients. Bypasses of supra-aortic vessels were performed in a surgical environment and endovascular procedures in an interventional radiology facility. "Through-and-through" technique was used in six patients. Two deaths occurred in the first 30 days after the procedure. No endoprosthesis migration was observed. No patient had paraplegia, stroke, renal failure, bleeding or coagulopathy, elective or emergency surgical conversion.**

Conclusion: **Hybrid treatment of CTAD is feasible, especially in high risk patients. Proper integration of surgical and endovascular techniques, in addition to clinical and radiological surveillance, makes this technique a great alternative to conventional surgery.**

Descriptors: **Aortic aneurysm, thoracic. Aorta, thoracic. Aneurysm, dissecting. Ultrasonography, interventional. Blood vessel prosthesis implantation.**

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Resumo

Introdução: **O tratamento híbrido das lesões complexas da aorta torácica (LCAT) requer a revascularização de uma ou mais artérias supra-aórticas, seguida do implante de endoprótese, com morbidade e mortalidade presumidamente mais baixas que a cirurgia convencional.**

Objetivos: **Avaliar a técnica e resultados do tratamento híbrido das LCAT.**

Métodos: **Durante dois anos, 12 pacientes com LCAT foram submetidos a procedimentos híbridos, incluindo aneurismas do arco aórtico e dissecções aórticas agudas Stanford A e B. Todos possuíam indicação de tratamento invasivo, além de zona de ancoragem proximal inadequada (menor que 20 mm). Metade era do sexo masculino e a média de idade de 55,5 anos (42 a 78). Pelo menos três fatores de risco cardiovascular estavam presentes em 75% dos pacientes. A média de seguimento foi de 10,9 meses (2 a 25), com acompanhamento clínico e tomográfico.**

Resultados: **O sucesso técnico inicial foi alcançado em 10 pacientes. Todas as derivações dos vasos supra-aórticos foram realizadas em ambiente cirúrgico e os procedimentos endovasculares em sala de radiologia vascular. A "técnica do varal" foi empregada em seis casos. Dois óbitos ocorreram nos primeiros 30 dias do procedimento. Nenhuma migração da endoprótese foi observada. Nenhum paciente apresentou paraplegia, acidente vascular cerebral, insuficiência renal, hemorragia ou coagulopatia, conversão cirúrgica eletiva ou de emergência.**

Conclusão: **O tratamento híbrido das LCAT é viável, especialmente em pacientes de alto risco. Uma adequada integração das técnicas cirúrgica e endovascular, além do acompanhamento clínico e radiológico adequado, tornam esta técnica uma ótima opção à cirurgia convencional.**

Descritores: **Aneurisma da aorta torácica. Aorta torácica. Aneurisma dissecante. Ultrassonografia de intervenção. Implante de prótese vascular.**

INTRODUCTION

The complex thoracic aorta diseases (CTDA) include a number of diseases that involve the ascending aorta, aortic arch and descending aorta, which requires surgical intervention in one or more supra-aortic trunks for possible correction of the original lesion. There are some main diseases of CTDA, such as: degenerative aneurysms, pseudoaneurysms, dissections, penetrating aortic ulcers, trauma, and mycotic aneurysms. Among these diseases, we highlight the thoracic aortic aneurysms (TAA), with an estimated incidence of 6:100.000 person-year [1,2] and the aortic dissections (AD) with an incidence of 10 to 20:1.000.000 person-year [3]. Aneurysms and dissections are at risk of progressive growth and rupture [4]. The five-year survival rate is 15% to 55% for patients with TAA [5], and where the arch is involved the survival rate is even lower.

The conventional method for surgical repair of the aortic arch with thoracotomy, use of non-biological prosthesis to exchange the whole affected aortic segment, and reconstruction of one or more of its three large vessels are commonly accompanied by significant morbidity and high mortality [6,7] . In this type of treatment, in general, the need for extracorporeal circulation and induced hypothermia result in complications such as blood loss, hemodynamic instability and coagulopathy [8,9]. Despite the use of methods of intraoperative neurological protection, these procedures are linked to relevant incidence of paraplegia (6% to 11%) and cerebrovascular accident (3% to19%) [10].

Although endovascular treatment of originated and confined lesions to the descending and abdominal aorta represent an important advance in medical practice, the repair of CTDA is difficult as a result of the necessity of surgical intervention in one or more supra-aortic trunks [11,12]. This approach is necessary in order to increase the zone of proximal anchor stent, while preserving the upper limbs and cerebral blood flow. In contrast, recent technological advances in making these devices allowed the treatment of lesions with complex anatomy, previously considered contraindicated for endovascular treatment [13]. The three-dimensional knowledge of anatomy and the involvement of its branches are crucial for the hybrid treatment planning, especially for the aortic arch. The open anatomical surgeries (in-situ) and extra-anatomic revascularization of the supra-aortic trunks provide a proximal segment of the aorta free from disease suitable for anchoring the stent.

This study was conducted with the purpose of exposing the hybrid correction results of CTDA, in terms of immediate and medium-term results and its complications.

METHODS

It is about longitudinal, retrospective and observational case series. From July 2007 to July 2009, 22

patients underwent endovascular treatment for thoracic aortic diseases. Among these patients, 16 of them had involvement of the aortic arch. It was only included in this work twelve patients with CTDA, who received the hybrid treatment in this period. Patients who showed involvement of the arch but with no need for supra-aortic arteries revascularization were excluded, and underwent only left subclavian artery embolization. The gender distribution was equal in our sample. The mean age was 55.5 years (42-78). All patients were hypertensive, 50% diabetics and 75% had three or more risk factors for cardiovascular disease (Table 1).

Table 1. Demographic characteristics, comorbidities and types of diseases in patients.

Pacient	Age	Gender	Comorbidities	Disease / clinical status
1	52	F	SAH / COPD / DM /CHF	Type B AD + bicarotid trunk + chest pain
2	51	M	SAH / COPD/smoking	Type B AD + retrograde dissection + pain
3	53	M	SAH / COPD/smoking/CHF	Type B AD + retrograde dissection + pain + dysphagia
4	50	M	SAH / DM	Aortic arch aneurysm (6.5 cm diameter) + dysphagia
5	63	F	SAH / DM / CI /smoking	Aortic arch aneurysm (6.0 cm diameter) + pain + hoarseness
6	49	M	SAH / smoking /CI	Type B AD + pain + IMA-ADC transposition
7	49	M	SAH / DM / smoking / COPD	Type B AD + pain + CHF
8	45	F	SAH / DM	Type B AD + retrograde dissection + pain
9	66	M	SAH / DM / COPD / CI	DTAA (6.5 cm diameter) + pain
10	42	F	SAH / smoking / COPD / CHF	Type B AD + pain
11	78	F	SAH / DM / CI / CHF	Type B AD + pain
12	68	F	SAH / smoking	Type B AD + bicarotid trunk + pain + hemoptysis

SAH: systemic arterial hypertension, COPD: chronic obstructive pulmonary disease, DM: diabetes mellitus; CI: coronary insufficiency, CHF: congestive heart failure; AD: aortic dissection, IMA: internal mammary artery; ADA: anterior descending coronary; DTAA: descending thoracic aortic aneurysm

Table 2. Clinical and anatomic characteristics of patients.

Aortic dissection	Number of patients
Median age (years)	54.1 (42-78)
Acute dissection (< 14 days)	9
Chronic dissection (> 14 days)	-
Stanford Type A AD (aortic arch involved)	3
EH before BT	1
EH between BT and LSA	2
Standford Type B AD	6
EH after LSA without retrograde dissection	3
EH after LSA with retrograde dissection	3
Proximal anchor stent	
Zone 0	3
Zone 1	6
Aortic aneurysm	Number of patients
Median age (years)	59.6 (50-66)
Mean diameter of the aneurysm (cm)	6.25 ± 0.25 cm
Aortic arch involvement between BT and LCCA	1
Aortic arch involvement between LCCA and LSA	1
LSA involvement	1
Proximal anchor stent	
Zone 0	1
Zone 1	2

BT: Brachiocephalic trunk; LCCA; Left common carotid artery; LSA; Left Subclavian Artery. AD: aorta dissection; EH: entrance hole

One patient had descending TAA, two of them had aortic arch aneurysm, three had type-A AD and six had Stanford type B (Tables 2 and 3). The indications of the hybrid treatment for TAA were the presence of one or more symptoms, such as pain and extrinsic compression, as well as the aneurysm sac diameter greater than 6.0 cm, with zone of proximal anchor in the aorta shorter than 20 mm. For the cases of AD, the indication was based on radiological signs of imminent collapse and hemothorax, compressive symptoms, hemoptysis, or chest pain (refractory to appropriate use of antihypertensive medications).

The indication of hybrid treatment in Stanford type B AD occurred in two patients with bicarotid trunk, three with proximal extension of dissection involving the left subclavian and the left common carotid artery, and one with previous myocardial revascularization, associated with the implementation of the left internal mammary artery. All patients were symptomatic and had received a prior TAA treatment from another service. The diagnosis was made by chest X-rays, computed tomography (CT) and angiography in all cases. We had the opportunity to use intravascular ultrasound (IVUS) in two selected cases.

The preoperative planning on the adequacy of the stent proximal colon was based on the map of the aortic arch containing five areas, described by Mitchell et al. 14 (Figure 1)

The desired zone of proximal anchor was based on the presence of a 20 mm segment of aorta free from disease. The proximal neck diameters of the thoracic aorta were measured by computed tomography, and the stents were oversized by 20% for the cases of aneurysm and 10% for dissections. In cases in which the proximal colon was consisted of a Dacron graft surgery in an aorto-aortic bypass, we chose the oversize of 15%.

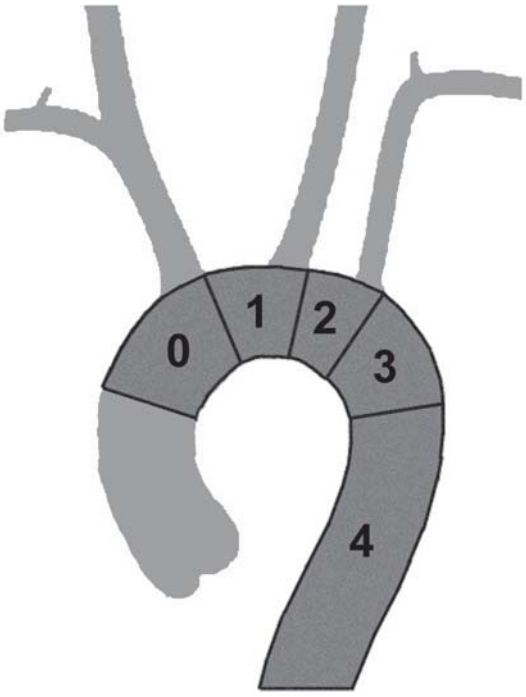

***Fig.** 1 - Anchoring zones of the thoracic aorta classification, according to Mitchell et al. [14]*

The supra-aortic trunk revascularizations were performed in surgical centers and accomplished in the second half, in an interventional radiology suite. All procedures were performed under general anesthesia and orotracheal intubation, and cerebrospinal fluid drainage during the endovascular procedure. The vascular conduit used in surgeries involving the ascending aorta was the Dacron, while the expanded polytetrafluoroethylene (ePTFE) was used in those with exclusive cervicotomy.

RESULTS

The revascularization procedures were carried out in five anatomical reconstructions (two aorto-aortic bypass with the brachiocephalic trunk and left carotid artery revascularizations, two aorto-brachiocephalic bifurcated bypass, an aorto-left carotid and an aorto-bicarotid bypass) and seven extra-anatomic reconstructions (five sequential left carotid-carotid-subclavian bypass and two left carotid-subclavian associated with right subclavian-carotid transposition). The femoral artery dissection to access the stents was necessary in eight cases and in four of them a totally percutaneous technique was performed. The revascularizations requiring the segment exchange of the ascending aorta were performed with total cardiac arrest

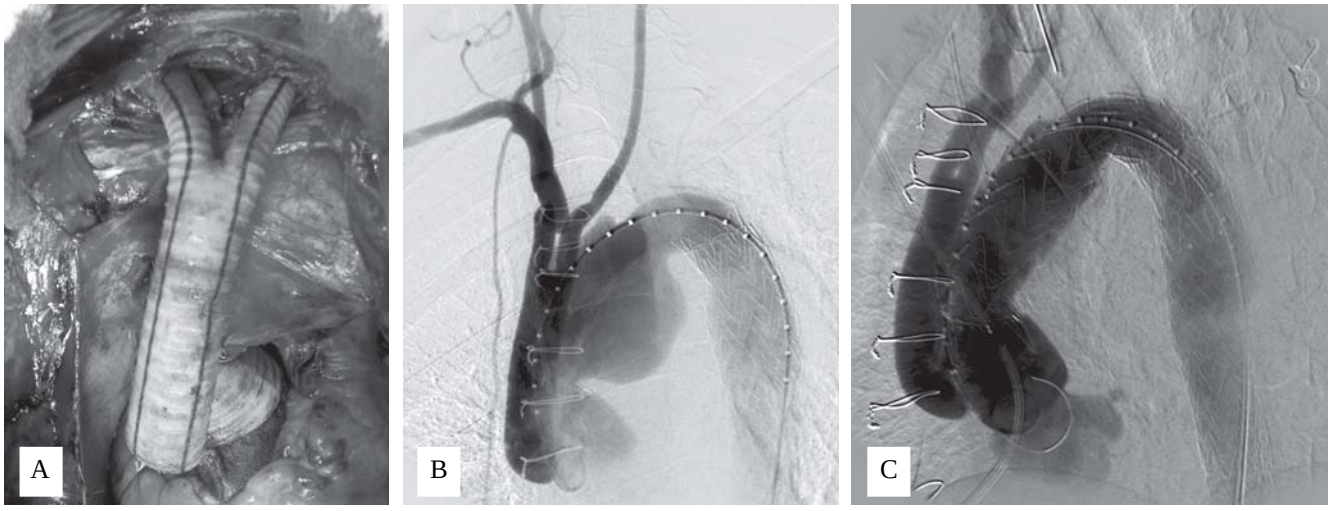

***Fig. 2** – A: Patient No. 5, carrier of aortic arch aneurysm, having undergone endovascular aneurysms repair of the descending aorta four years ago. A: intraoperative aspect of proximal segment correction of the ascending aorta and the Dacron bifurcated prosthesis. The pacemaker wire works as a guide for the stent placement. B: Stent preimplantation aortography, showing patency of vascular reconstruction. C: Final aspect after stent implantation 44x44x200mm*

and extracorporeal circulation, while in cases in which only the supra-aortic revascularization was used, the proximal anastomosis was performed by clamping the aorta, without interruption flow (Figure 2). The bypass' anastomosis for the cervical artery was identified through the implantation of the radiopaque material (pacemaker wire) in order to facilitate the release of the stent. All aortic accesses were performed by median sternotomy. The type A aortic dissections (AD) that involved the aortic arch and descending aorta were treated with hybrid procedures to reduce the extracorporeal circulation time, the surgery duration, and coagulopathies. All carotid-carotid bypasses were retroesophageal (Figure 3).

The stents used were: eleven Valiant (Medtronic), four Relay (Bolton Medical), a Zenith TX2 (Cook Medical) and a TAG (Gore), in which eleven of them had free stents for proximal anchoring. The "through-and-through technique" [15] was used in six cases to identify the true light, aid in support, rise of accuracy in positioning the prosthesis in angled arches or in tortuous thoracic aortas. The stents proximal anchoring occurred in four cases in Zone 0 and Zone 1 in eight cases.

The immediate technical success was achieved in ten (83.3%) cases. Two deaths occurred in the first 30 days after the procedure, one in the first 24 hours due to progression of the dissection in retrograde motion, and another on the 10th postoperative day due to pulmonary infection and septicemia. There were no additional deaths until this follow-up period and none of the cases had stent migration. No patient had paraplegia, cerebrovascular accident, acute renal failure, hemorrhage or coagulopathy. Two patients had persistent proximal leakage (endoleak) and need for reintervention in the first 30 days. The leakages due to the reflux of the left subclavian artery were resolved

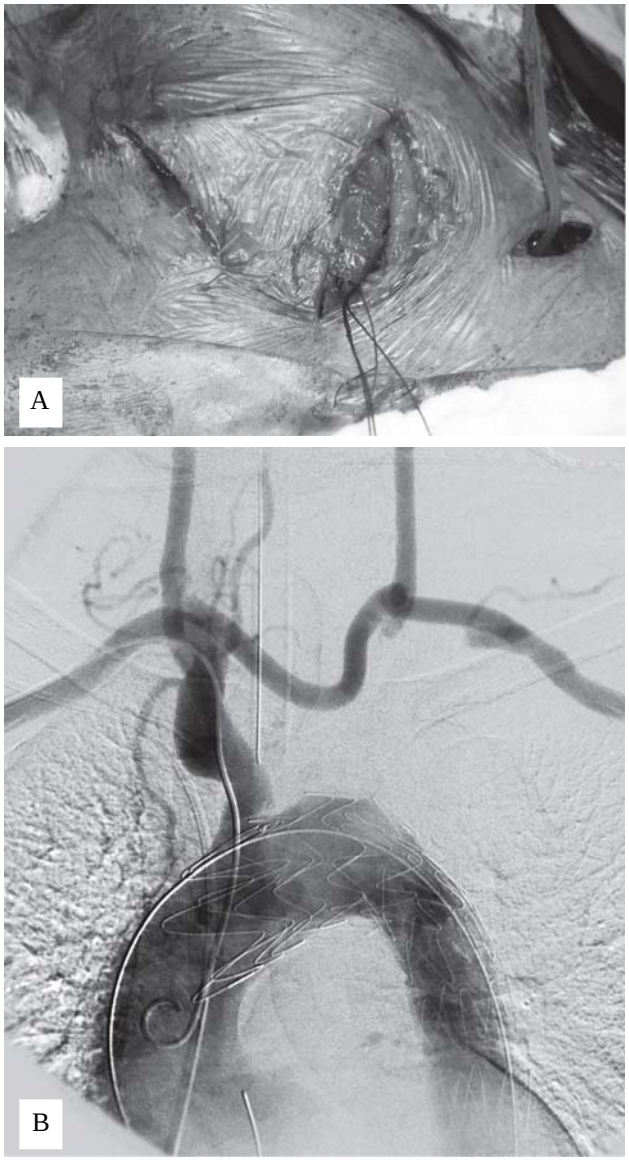

Fig. 3 – *A: Patient No. 8, the carrier of aortic dissection involving the origin of the left common carotid artery. A: aspect of the cervical access for making the left carotid-carotid-subclavian artery sequential bypass. B: Final aortography after stent implantation with patency of extra-anatomic cervical conduits, which was created and adapted to the sealing of the aortic wall*

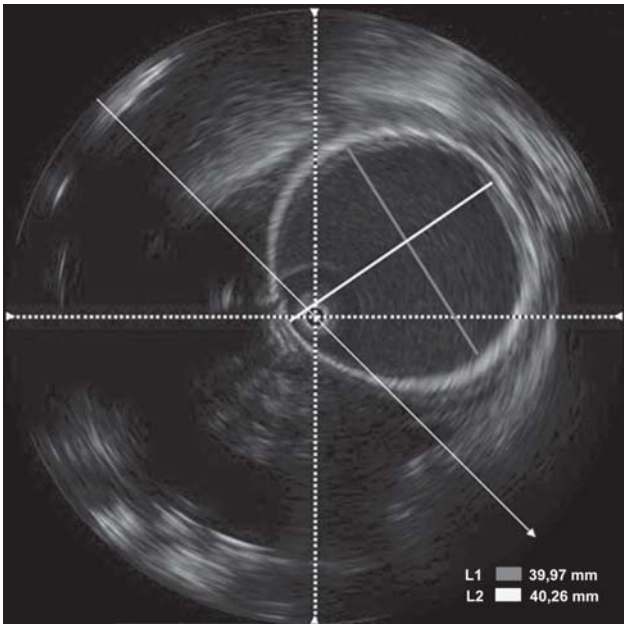

Fig. 4 *- Intravascular ultrasound in patients (nº5) subjected to the segment exchange of the ascending aorta by a Dacron prosthesis, which is intended as a zone of proximal anchor stent. Although the nominal diameter of the prosthesis used is 34mm, an increase to about 40mm is noticed, corresponding to a dilation of 18%*

with embolization, using the fiber springs with free release at the same operative time. The resolution of the proximal leakage was obtained by means of a new endovascular intervention, in which was performed another stent placement for proximal extension of the diseased area coverage. In none of the cases the emergency or elective surgery were required.

In two cases, the intravascular ultrasound (IVUS) was used during surgery with the aim of obtaining additional information on the characteristics of the proximal colon, stent adaptation to the aortic wall and navigation of this femoral access device to the implant site (Figure 4). We noted that, the aortic dissection in a patient who underwent segment exchange of the ascending aorta with a Dacron graft 34 mm in diameter, the tissue had suffered dilation of 18% after 3 days, corresponding to a final diameter of 40mm. This new measurement with the aid of IVUS was extremely valuable to the proper stent selection with compatible diameter.

The mean postoperative follow-up time of these patients was 11 months (2-25) with outpatient appointments and tomographic control in 3, 6 and 12 months in the first year and annually thereafter. Until now, no patient had recurrence of symptoms or new symptoms suggestive of possible stent migration, aortic rupture or vascular grafts occlusion.

DISCUSSION

After introducing the cerebral perfusion devices for aortic arch open surgery in 1990, significant advances were achieved in the operative results and mortality was reduced [16,17]. However, it was noted that these results required a proper selection of patients, improved technical expertise in cardiothoracic surgery, surgical volume, although they could not be reproduced in many medical centers around the world, exhibiting mortality that remained close to 25% [5]. Over the past ten years, the development of endovascular methods combined with the established conventional surgery, proved to be a safe and effective alternative for the treatment of CTDA.

In 1998, Buth et al. [18] reported a case of an aortic arch aneurysm successfully treated using endovascular techniques. A bifurcated bypass was made from the ascending aorta to left common carotid artery and left subclavian artery, beside a stent placement in Ishimaru Zone 1, through a transaortic access in the same surgical procedure. In 2003, Dietl et al. [19] reported two cases of a Stanford type A AD restricted to the ascending aorta and treated with aorto-aortic bypass. The dissection then, progressed to the aortic arch, and was solved with the brachiocephalic trunk and left common carotid artery revascularization, in addition to a stent placement in zone 0. Bergeron et al. [5] in 2006, reported a group of 25 patients with CTDA treated with hybrid surgery, with a success rate of 92%. In our series, despite the various treated diseases (75% of acute dissections in our study), technical success was achieved in 83.3% of these cases. In the same year, Saleh & Inglese [20] treated 15 patients with CTDA for aneurysmal disease with supra-aortic trunks revascularization, and in a second surgical procedure, they excluded the aneurysm with endoprosthesis. Left subclavian artery revascularization was only performed in patients with right vertebral artery occlusion in order to preserve the vertebral-basilar system. In our study, the left subclavian artery revascularization was performed in two patients with bicarotid and bisubclavian trunks, with a history of coronary artery bypass graft surgery with left internal mammary artery transposition and four with angiographic dominance of the left vertebral artery.

Paraplegia and cerebrovascular accidents are known complications associated with the aortic arch intervention. The etiology of these complications after conventional or hybrid surgical treatment is usually multifactorial and hardly defined, but it is associated with the extent of the treated aortic segment, the use of extracorporeal circulation and clamping time [21]. As reported by Dillavou et al. [22], analyzing only patients treated with TAA, the incidence of paraplegia and mortality was significantly lower with the hybrid treatment (3% and 2% respectively) than with conventional treatment (13% and 10%). The incidence of cerebrovascular accident (CVA) in both methods was similar (4%). In our study, involving patients with acute AD, no patient had paraplegia or cerebrovascular accident and mortality was 17%. There are many studies that evaluate the results of conventional surgery in patients with acute AD, varying the mortality rate from 6% to 69%. Complications during the endovascular procedure, such as aortic rupture, acute visceral ischemia or leakages that require immediate conversion to open surgery are described, although they were not observed in this series. Thus, we believe that these factors are extremely important when it comes to the procedures performed in experienced and infrastrature centers in cardiothoracic surgery.

The surgical options for TSA revascularization that are required for the subsequent complement of endovascular treatment differ among the publications found. For those situations where it is necessary the stent anchoring in Zone 0, extrathoracic techniques are described, using the right common femoral artery or abdominal aorta as a source of bypass to the right axillary artery, apart from a right subclavian-carotid transposition and right to left carotid-carotid sequential bypass. The intrathoracic techniques or "in-situ" are made with side clamping of the ascending aorta (in cases of isolated revascularization of the brachiocephalic trunk, carotid and subclavian arteries) or with extracorporeal circulation [23,24].

There are no published studies, so far, comparing the results of patency and complications of both techniques. The revascularization procedures "in-situ" were chosen because they require shorter conduits, with lower probability of local trauma and creases, and obey the anatomical direction of blood flow[25]. For situations where there is need for anchoring in Zone 1, the cervical extra-anatomic bypasses are described in the study along with the carotid-carotid bypasses, carotid-subclavian bypasses and transposition or combination of both. Femoral-auxiliary bypasses are also described as other extra-anatomic bypasses. For theses cases, the grafts with exclusive cervicotomy were chosen by our team for the same reason as the use of shorter conduits. The retroesophageal course to carotid-carotid bypass was chosen because it provides natural protection from anterior cervical structures to the conduit, allowing the realization of the anterior surgical access to the trachea.

The accelerated development of the thoracic aortic stent makes the endovascular surgeon more confident when dealing with the treatment of CTDA. Its implementation into diseases of the descending aorta was safe as an alternative to open surgical treatment in a 1-year follow-up period [26]. However, the works published so far on the hybrid treatment of CTDA, showed no exclusive use of any type of stent or analysis of their impact on results. In our series, the choice of this device was based on the availability offered by our health institution, with no conflict of interest. At the beginning of our casuistry, aiming to ensure better fixation in the proximal colon, devices with uncoated distal end were used.

We noted that, in cases of aortic dissection, the use of devices with these characteristics could contribute to the endothelial lesion and generate new entry of dissection areas. Thus, we currently use stents without uncoated end for the treatment of this disease. However, in patients with Stanford type A AD treated with reconstruction of the ascending aorta with a Dacron graft, the proximal anchor used is uncoated. The presence of the radiopaque pacemaker wire, which was implanted during surgery, facilitated the stent placement, without requiring additional use of iodinated contrast. Although previously described [27], in neither case had migration or stent kinking.

Regarding the use of the intravascular ultrasound, we believe that in the future this method will be a part of the aortic procedures, reducing exposure to ionizing radiation and minimizing the use of iodinated contrast, aside from bringing greater security to the stent implantation. It can be extremely useful in cases where the measurement of the proximal colon, as well as the determination of its intraluminal characteristics, make an appropriate choice of stents.

A totally percutaneous technique ("preclose technique) [28] has already been routinely used in major centers and has the advantage of reducing the complications inherent in the dissection of the femoral region, with less recovery time, pain and infection. It is recommended to avoid its use in highly calcified arteries, in obese patients and in small caliber arteries (less than 8mm).

Our experience suggests that, the hybrid treatment for complex thoracic aorta diseases, presents an acceptable risk of complications and morbidity in the short and medium term period, especially in high risk patients. In these cases, partial or complete supra-aortic trunk revascularizations, performed to maintain upper limbs and cerebral blood flow is feaseble and effective, and it also allows sufficient area to anchor the stent in the aorta. Due to the small number of patients undergoing this procedure and the short follow-up period, there is no assurance that the results obtained so far remain in long term period. However, we consider that the observational follow-up of treated patients, improvement of techniques and experience gained by the teams in addition to the ever-present technological developments, give us the scientific basis to introduce the best individualized treatment for each patient.

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