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Angiología

Original

Short- and mid-term results of hybrid and endovascular surgery for aortic arch disease

Resultados a corto-medio plazo de la cirugía híbrida y endovascular del arco aórtico

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Abstract

Introduction and objective: the objective of our study is to describe the mid-term results and complications of patients with aortic arch disease who underwent surgery of the aortic arch and supra-aortic branches in our center.

Methods: retrospective, single center study. Consecutive patients with arch surgery and a diagnosis of thoracic aortic aneurysm (TAA) > 60 mm and aortic penetrating ulcer (PAU) from January 2017 through June 2022. We conducted a descriptive study including demographic variables, the mortality rate, and 30-day complications. Survival, readmissions and reinterventions were, then, analyzed using the Kaplan-Meier estimator.

Results: a total of 20 patients underwent surgery: 14 underwent TAA surgery and 6 due to PAU; 2 required emergency surgery. Zone 0 was the most common proximal landing zone (50 %), followed by zone 1 (30 %). In 5 cases, SAT debranching and 5 carotid-subclavian bypasses were performed prior to TEVAR implantation. The technical success rate reached 95 %, 2 patients died at 30 days, one patient developed transient spinal cord ischemia and the other experienced a major neurological event. The median follow-up was 18 months (IQR, 7-37). All-cause mortality rate was 20 % (5 % related to aortic disease). The 24-month estimated rate of readmission was 22.9 % and reoperation rate, 24.1 %. The most common cause for readmission was medical (15 %).

Conclusions: the short- and mid-term results of hybrid and endovascular surgery for aortic arch disease are acceptable in terms of morbidity and mortality.

Keywords:
Thoracic aorta. Aortic arch. Hybrid surgery. Endovascular surgery. Debranching.

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Resumen

Introducción y objetivo: el objetivo de nuestro estudio es describir los resultados y las complicaciones a medio plazo de los pacientes con patología de cayado aórtico que requirieron cirugías a nivel del arco aórtico y los troncos supraaórticos (TSA) en nuestro centro.

Métodos: estudio retrospectivo y unicéntrico. Pacientes consecutivos con cirugía del arco y diagnóstico de aneurisma de aorta torácica (AAT) de > 60 mm y úlceras penetrantes aórticas (UPA) desde enero de 2017 hasta junio de 2022. Se realizó un estudio descriptivo de las variables demográficas, de la mortalidad y de las complicaciones a 30 días y, posteriormente, un análisis de supervivencia, de reingresos y de reintervenciones con el método de Kaplan-Meier.

Resultados: se intervinieron 20 pacientes: 14 de aneurisma de aorta torácica y 6 con úlceras penetrantes aórticas, 2 de urgencia. La zona 0 fue la zona de anclaje proximal más frecuente (50 %), seguida de la zona 1 (30 %). En 5 casos se realizó un *debranching* de TSA y 5 bypass carótido-subclavios antes de la implantación del TEVAR. El éxito técnico fue del 95 %. 2 pacientes fallecieron a los 30 días, un paciente desarrolló isquemia medular transitoria y un paciente, un evento neurológico mayor. La mediana de seguimiento fue de 18 meses (IQR, 7-37). La mortalidad global fue del 20 %, del 5 % relacionada con patología aórtica. La tasa de reingreso estimada a los 24 meses fue del 22,9 % y la de reintervención, del 24,1 %. Las causas más frecuentes de reingreso fueron las causas médicas (15 %).

Conclusiones: los resultados a corto y medio plazo de la cirugía híbrida y endovascular de la patología del arco aórtico son aceptables en cuanto a morbilidad y mortalidad.

Palabras clave: Aorta torácica. Arco aórtico. Cirugía híbrida. Tratamiento endovascular. *Debranching.*

INTRODUCTION

The treatment of choice for thoracic aortic aneurysm disease is open surgery (1). This technique requires the use of extracorporeal circulation, deep hypothermia, and neurological protection strategies. However, the morbidity and mortality associated with open surgery are significant (2), making it a viable option only for patients with low surgical risk.

For high-risk or frail patients, hybrid or endovascular techniques should be considered as alternatives to open surgery. Proper implantation of thoracic stent grafts (3-5) requires, at least, 20 mm of proximal (along the lesser curvature) and distal landing zones. If this requirement is unmet, hybrid techniques such as the frozen elephant trunk, anatomic debranching of supra-aortic branches, and extra-anatomic bypasses are available (5).

Regarding endovascular treatment, pre-curved fenestrated stent grafts for the aortic arch have shown promising results for implantation in zones 0-3. However, proper implantation and the prevention of type I endoleak require strict anatomical criteria, although these devices can be implanted with a proximal landing zone < 15 mm (6).

Although the new branched stent grafts (7,8) require larger proximal landing zones (> 35 mm), they demonstrate acceptable short- and mid-term outcomes, albeit with a higher rate of major neurological events (8).

Before the advent of these fenestrated devices, procedures using conventional and parallel grafts (9) were viable alternatives, with acceptable results in very high-risk surgical patients and emergency situations (10).

OBJECTIVE

The primary aim of this study is to describe the mortality and short- and mid-term complications in patients with aortic arch disease requiring surgery at the aortic arch and supra-aortic trunks (SAT).

MATERIALS AND METHODS

Study design and patient selection

We conducted a single-center, retrospective, observational study with patients with aortic arch and descending aortic disease requiring treatment in the proximal landing zone (zones 0, 1, or 2) using endovascular procedures to maintain SAT patency from January 2017 through June 2022.

Patients included were asymptomatic individuals with thoracic aortic aneurysms > 60 mm in diameter or with an annual growth > 5.5 mm. For penetrating aortic ulcers, procedures were performed for lesions with a diameter > 20 mm or a neck > 10 mm. Symptomatic patients of any diameter were included.

Preoperatively, all patients were presented and evaluated by a multidisciplinary aortic committee including the cardiology, cardiovascular surgery, vascular surgery, and anesthesiology departments. These sessions assessed preoperative risk to offer the best therapeutic option based on comorbidities and baseline status.

No formal risk stratification scales (e.g., STS PROM or EUROSCORE) were used. Instead, transthoracic or transesophageal echocardiography was performed to assess

the cardiac valves and heart function. Coronary angiography was performed if ascending aortic surgery was considered, along with a SAT ultrasound and a coronary computed tomography angiography (CCTA) to assess calcification and patency of both the arch and its branches.

Demographic data, comorbidities, intraoperative data, pre- and postoperative CT scan measurements, the length of stay, reinterventions, and medical complications were collected.

For proper proximal implantation of the ascending module of the Nexus® stent graft, right ventricular rapid pacing was performed. For other devices, systolic blood pressure was momentarily reduced to < 80 mmHg in coordination with anesthesiology to facilitate proximal deployment.

Technical success was defined as the correct implantation of the stent graft in the thoracic aorta without the occurrence of early type IA, IC, or III endoleaks and with maintained SAT patency at the end of the procedure.

Left subclavian artery patency was preserved in all cases. Transesophageal echocardiography monitoring was performed for all patients. No surgical monitoring of evoked potentials or prophylactic cerebrospinal fluid (CSF) drainage was ever performed.

Postoperatively, patients were transferred to an intensive care unit (ICU) for strict neurological and hemodynamic monitoring, properly equipped for early CSF drainage in the presence of spinal ischemia symptoms.

A follow-up CCTA was performed 1 month after surgery and annually thereafter if no complications arose.

Patients with aortic dissection, traumatic aortic injuries, and aortic pseudoaneurysms were excluded.

Data analysis was conducted using SPSS v25.0 (IBM SPSS Statistics, IBM Corp, Armonk, NY, United States). Continuous variables were expressed as mean ± standard deviation or median and interquartile range, depending on their distribution. Categorical variables were expressed as absolute frequencies. Long-term survival, readmissions, and reinterventions were analyzed using Kaplan-Meier survival estimates.

RESULTS

Between January 2017 and June 2022, a total of 66 patients with the above-mentioned conditions were treated. Of these, 30 % (20 patients) required surgery to ensure the patency of the SAT. Their demographic characteristics are shown in table I.

Fourteen out of these 20 patients had aortic aneurysms > 60 mm, and 6 had penetrating aortic ulcers (PAUs). Regarding the urgency of the intervention, 6 patients presented with chest pain or aneurysm rupture, 2 of them requiring emergency surgery.

Table I. Demographic characteristics of our sample

	Total = 20
Age	73.6 ± 6.1 years
Males	18 (90 %)
Diabetes *mellitus*	4 (20 %)
Hypertension	13 (65 %)
Dyslipidemia	17 (85 %)
Smokers / Former smokers	4 (20 %) / 13 (65 %)
COPD	5 (25 %)
Chronic kidney disease	9 (45 %)
Stroke	4 (20 %)
AMI	3 (15 %)
Cancer in the last 5 years	4 (20 %)
ASA III/IV	16 (80 %)

COPD: chronic obstructive pulmonary disease; AMI: acute myocardial infarction; ASA: Classification in the pre-surgical risk scale by the American Society of Anesthesiologists.

Half of the treated patients (3) with 1 PAU were symptomatic. One of them exhibited an aortic rupture and required advanced resuscitation due to cardiac arrest prior to surgery.

The maximum diameter of the treated thoracic aortic aneurysms was 72.4 cm ± 14.4 cm.

The most common proximal landing zone was zone 0 (45 %), followed by zone 1 (30 %), as shown in figure 1. For the proper landing in these zones, the interventions listed in table II were performed; SAT debranching (25 %) and carotid-subclavian bypass (25 %) being the most common procedures of all.

Technical success rate was 95 %; the mean surgical time, 153.65 ± 75.6 minutes; the median fluoroscopy time, 15.5 [6-65] minutes, and the median contrast volume, 85 mL [25-260]. A total of 10 GORE® TAG® Conformable (W.L. Gore & Associates), 9 RELAY® PRO (Terumo Aortic), and 1 NEXUS® (Endospan) stent grafts were implanted.

More than 1 thoracic module was implanted in 60 % of the patients, with a mean total covered aortic length of 240 ± 99.12 cm. In most cases (65 %), the endovascular procedure was completed in 1 surgical act. The TEVAR procedure was performed via percutaneous femoral access in 95 % of the patients.

The 30-day mortality amounted to 2 patients. One patient died intraoperatively from a major stroke caused

by the dissection of the right carotid artery during the implantation of a Nexus® stent graft. The dissection occurred after placement of a bridging module between the distal region of the Nexus® and the proximal region of an E-nside™ device.

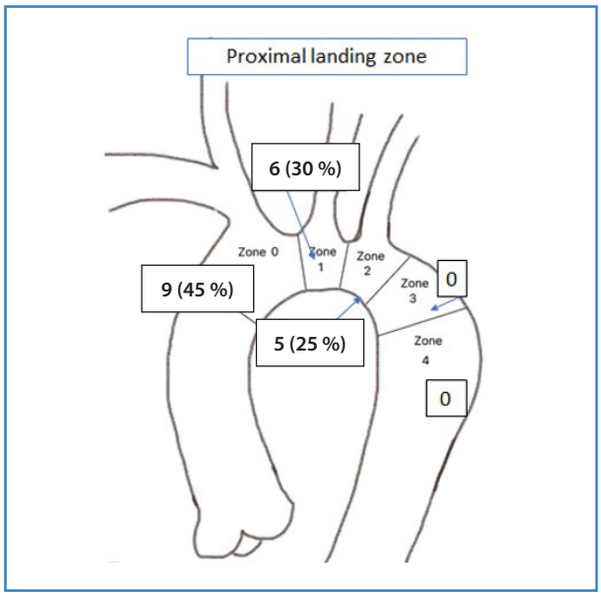

Figure 1. *The most frequent proximal landing zone was zone 0 (45 %), followed by zone 1 (30 %).*

Table II. Types of surgeries performed prior to stent-graft implantation

	n (%)
SAT debranching	5 (25 %)
Bentall + frozen elephant trunk	2 (10 %)
Carotid-subclavian bypass	5 (25 %)
Carotid-carotid + carotid-subclavian bypass	4 (20 %)
Parallel-grafts	4 (20 %)

The second case involved a patient who died on postoperative day 28 due to rupture of an aortic arch aneurysm. This patient presented with cardiac arrest and hemoptysis and had recently been diagnosed with a PAU with active thoracic bleeding. During the postoperative period, the patient developed an aortobronchial fistula and ultimately declined further interventions.

At 30 days, only 1 major neurological event (5 %) was reported, corresponding to the intraoperative event involving the Nexus® patient.

There was 1 case of transient spinal ischemia in a patient with a symptomatic thoracoabdominal aneurysm—6.7 cm maximum diameter—presenting with chest pain and treated in multiple stages. Initially, a replacement of the ascending aorta and aortic valve, a frozen elephant trunk, and SAT reimplantation were performed. Fifteen days later, 2 thoracic stent graft modules were implanted. In a third stage, 17 days after the previous intervention, a branched aortobiiliac stent graft was placed, during which the patient developed transient spinal ischemia within the first postoperative hours. The symptoms resolved completely within 24 hours after CSF drainage in the ICU. Other medical complications are shown in table III.

Table III. 30-day complications after stent-graft implantation

	n (%)
Mortality	2 (10 %)
Reinterventions	-
Major stroke	1 (5 %)
Transient spinal ischemia	1 (5 %)
Permanent spinal ischemia	-
Respiratory complications	3 (15 %)
Post-implant syndrome	1 (5 %)
Cardiological complications	2 (10 %)
Worsening of chronic kidney disease	2 (10 %)

After a mean follow-up of 18 months (IQR, 7-37), 4 patients had died. Two additional deaths occurred: one at 3 months due to community-acquired pneumonia in the context of advanced interstitial lung disease and another 16 months later due to an unrevascularizable AMI. The estimated 24-month mortality rate was 15 % (Fig. 2A).

There were no bypass-related complications. The estimated 24-month reintervention rate, according to the Kaplan-Meier estimator, was 24.1 % (Fig. 2B), with no significant differences in the causes of reintervention.

One patient had to undergo another intervention following the growth of the aneurysmal sac and due to suspicion of a type IB endoleak 11 months after thoracic module implantation. Two months later, further proximal extension was required due to persistent chest pain and sac growth, which solved the symptoms and trimmed the size of the aneurysmal sac on subsequent follow-ups.

Another patient required reintervention for a type III endoleak 4 years after thoracic stent graft implantation. A patient with a thoracoabdominal aneurysm and a branched aortobiiliac stent graft experienced a type IC endoleak due to shortening of the bridging stent between the branch and the right renal artery. A total of 3 type II endoleaks were seen at the follow-up, which resolved without intervention.

The estimated rate of readmission at 24 months, according to the Kaplan-Meier estimator, was 22.9 % (Fig. 2C). The main reasons for readmissions were medical

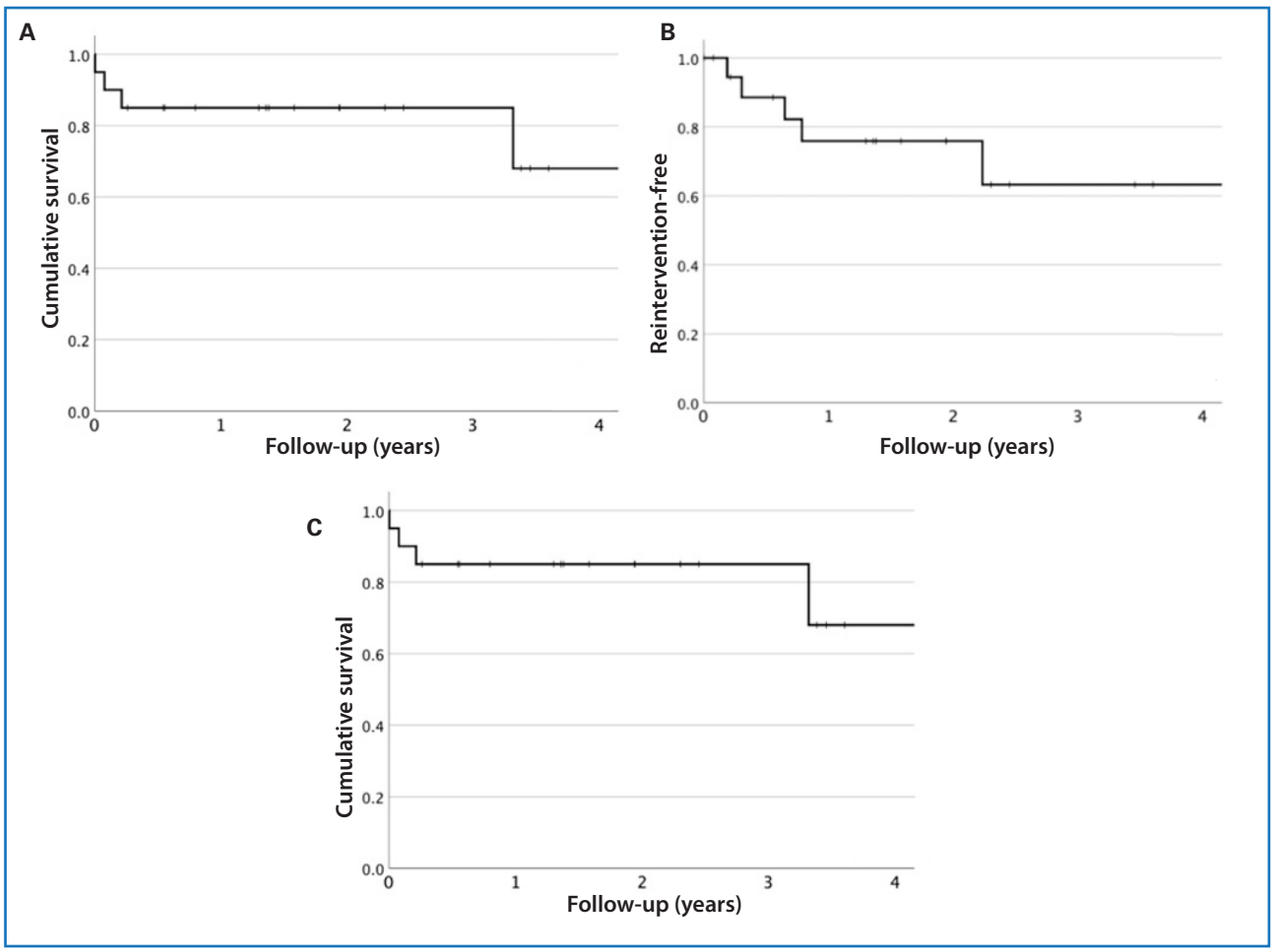

Figure 2. *Kaplan-Meier survival estimation curves with a mean follow-up of 18 months (7.37). A. Survival. The estimated 24-month survival rate was 15 %. B. Reintervention-free estimated at 24 months (24.1 %). C. Rare of readmissions estimated at 24 months (22.9 %).*

causes (50 %): acute pulmonary edema, heart failure, and COVID-19-related pneumonia, and aortic causes (30 %): treatment of previously mentioned endoleaks.

DISCUSSION

The hybrid treatment of the aortic arch has been accepted as a feasible alternative to open surgery, especially in patients with high surgical risk (11). The 30-day mortality rate reported by the literature is estimated to range between 2 % and 23 % in these patients (12,13).

In our series, we found a 30-day mortality rate of 10 %, which is reasonable considering the presence of emergency surgeries and the old mean age of these patients (73.6 years) (14). Advanced age, chronic obstructive pulmonary disease, and neoplasms negatively impact the outcomes of hybrid surgery for thoracic aortic disease (15).

The rates of stroke and neurological complications in our series are similar to, or slightly lower than those published previously (approximately 8.7 % and 14 %, respectively) (13). This prevalence is significantly lower than with open thoracic aortic repair (1), which is why we did not perform prophylactic CSF drainage. During the procedure, we also did not monitor evoked potentials or administered intrathecal papaverine injections. We consider it more important to monitor the patients' neurological functions within the first 24-48 hours at the ICU setting with measures aimed at preventing spinal ischemia (e.g., preserving the patency of the left subclavian artery, optimizing hemoglobin levels, maintaining a mean arterial pressure > 80 mmHg, etc. [16]), along with early CSF drainage in the presence of clinical symptoms (17).

If the subclavian artery has not been revascularized previously, especially in emergency cases, or its flow has been maintained using parallel grafts, revascularization should be considered in the event neurological symptoms occur or in the presence of signs of spinal ischemia (18,19).

In the mid- and long-term, the rates of mortality and reintervention are similar to those described in other series. Of note, compared to open surgery, the mortality rate is clearly lower, but the reintervention rate is higher due to the occurrence of endoleaks, primarily due to proximal anchoring issues (20).

CONCLUSIONS

Although, in our series, we found good results with hybrid surgery for the aortic arch, it is also associated with significant morbidity and mortality, especially after the first surgical act and in the short term; better results were observed in the mid-term though. Emergency procedures in patients with old age and significant comorbidities are associated with higher morbidity and mortality rates. For this reason, selecting the best therapeutic option is of paramount importante before surgically ruling out these patients.

To offer the therapeutic options described, a multidisciplinary team, including cardiologists, cardiac surgeons, vascular surgeons, anesthesiologists, radiologists, etc. is required, as well as strict follow-up to detect complications early.

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