ORIGINAL ARTICLE

In-hospital and Long-term Outcomes of Aortic Arch Surgery

Resultados hospitalarios y alejados de la cirugía del arco aórtico

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ABSTRACT

Background: Treatment of patients with acute or chronic aortic arch disease has been historically associated with poor outcomes.
Objective: The aim of this study was to analyze in-hospital and long-term outcomes of aortic arch replacement comparing emergency and elective procedures.
Methods: We conducted a retrospective cohort study in patients undergoing aortic arch surgery in a high complexity center between January 2010 and December 2016, with one-year follow-up.
Results: A total of 65 patients were included; 65% were men and median age was 71 years. Among postoperative complications, prolonged mechanical ventilation was more common in the emergency than in the elective surgery group (52% vs. 19%, p=0.006). The incidence of reoperation due to bleeding, mediastinitis, stroke, and renal failure requiring dialysis in the postoperative period was not significantly different between both groups. In-hospital mortality was 15% and observed mortality 24%, without significant differences according to emergency or elective procedure.
Conclusions: In this cohort of patients undergoing aortic arch surgery, in-hospital mortality and 1-year mortality was similar in patients undergoing emergency or elective surgeries. The risk of mortality during the first year was 4 times greater in patients >75 years than in younger ones. The incidence of mortality and postoperative stroke was similar to that reported by recent registries. The incidence of reoperations due to bleeding was remarkably low. The rate of complications (reoperations due to bleeding, stroke, acute renal failure or infection) was not statistically different between both groups, probably because of lack of power of the sample.

Keywords: Aneurysm - Aortic arch - Dissection - Aortic arch replacement

RESUMEN

Introducción: El tratamiento de los pacientes con patología aguda o crónica del arco aórtico ha estado asociado históricamente a pobres resultados.
Objetivo: El propósito de este trabajo fue analizar los resultados hospitalarios y de seguimiento alejado del reemplazo de arco aórtico según cirugía de emergencia o electiva.
Material y métodos: Estudio de cohorte retrospectivo en el que se incluyeron pacientes intervenidos en el Arco Aórtico entre enero de 2010 y diciembre de 2016 en un solo centro y se los siguió durante un año.
Resultados: De los 65 pacientes incluidos el 65% fueron de sexo masculino y tuvieron una mediana de edad de 71 años. De las complicaciones postoperatorias se halló que el requerimiento de asistencia ventilatoria mecánica prolongada fue mayor en las cirugías de emergencia que en las electivas (52 vs. 19%, p=0,006). No se observaron diferencias estadísticamente significativas en la incidencia de reoperación por sangrado, mediastinitis, accidente cerebrovascular e insuficiencia renal con requerimiento de diálisis en el postoperatorio. La mortalidad intrahospitalaria fue del 15% y la observada al año de 24%, no presentando diferencias estadísticamente significativas según si el procedimiento fue de emergencia o electivo.
Conclusiones: En esta cohorte de pacientes operados en el Arco Aórtico no se encontró diferencias estadísticamente significativas en la mortalidad hospitalaria y anual entre aquellos intervenidos de emergencia y en forma electiva. Los pacientes mayores de 75 años presentaron casi 4 veces más riesgo de muerte durante el primer año que los menores. La mortalidad y el accidente cerebrovascular postoperatorio observados fueron semejantes a los reportados en registros recientes. Se encontró una llamativamente baja tasa de reoperaciones por sangrado. Si bien las tasas de complicaciones (ya sea reoperación por sangrado, ACV, IRA o infección) no fueron estadísticamente diferentes, esto puede deberse a la baja potencia de la muestra.

Palabras Clave: Aneurisma - Arco Aórtico – Disección – Reemplazo del arco aórtico

Abbreviations

AA	Aortic arch	**HR**	Hazard Ratio
AAS	Acute aortic syndrome	**MV**	Mechanical ventilation
ARF	Acute renal failure	**RBP**	Retrograde brain protection
BCT	Brachiocephalic trunk	**TAAR**	Total aortic arch replacement
CPB	Cardiopulmonary bypass	**TEVAR**	Thoracic endovascular aortic repair
HAR	Hemi-arch replacement		

Rev Argent Cardiol 2015;85:435-439. http://dx.doi.org/10.7775/rac.v85.i5.11688

Received: 11/10/2017 - *Accepted:* 11/27/2017

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INTRODUCTION

Until a few years ago, aortic arch (AA) surgery was either reserved for high-volume surgical centers or avoided given the poor results obtained due to the high percentage of complications, mainly intra- and postoperative bleeding and neurological sequelae derived from insufficient brain protection.

In 1975, Griepp et al. described the use of deep hypothermia with circulatory arrest to treat this condition. (1) Since then, the number of AA interventions has increased, improving the strategies of peripheral artery cannulation to achieve selective cerebral or visceral organ perfusion with moderate hypothermia. (1-4)

In the following years, the AA approach through hybrid procedures of debranching and extra-anatomic bypass of supra-aortic vessels, using thoracic endovascular aortic repair with an endograft (TEVAR) which covered from the distal ascending aorta to the entire AA, simplified AA surgery in some patients. (5)

The use of three-branched or four-branched grafts deserves to be specially mentioned to achieve the total resection of the vascular tissue of the AA and direct blood flow to the descending aorta and supraaortic vessels. (6)

The procedures involving AA replacement may be elective or emergency surgeries. Acute aortic syndromes (AAS) are associated with greater morbidity and mortality due to the critical condition of the patient. There is little information comparing both populations.

The aim of this study was to analyze the results obtained in patients undergoing AA replacement, comparing in-hospital and at one year follow-up morbidity and mortality according to surgical timing (emergency vs. elective surgery).

METHODS

A retrospective cohort study was conducted in consecutive patients undergoing AA replacement in a high complexity medical center between January 2010 and December 2016, with one-year follow-up after surgery. Patients were excluded if they arrived at the operating room receiving cardiopulmonary resuscitation maneuvers or presented uncontrolled pericardial or pleural bleeding at procedure initiation.
Preoperative information, details of the procedure and of postoperative follow-up was retrieved from the electronic medical records of the institution.

The variables evaluated in this study were in-hospital mortality and during the first year of follow-up, length of hospital stay and in-hospital complications [need for prolonged mechanical ventilation (MV), reoperation due to bleeding, mediastinitis, stroke and acute renal failure (ARF) requiring dialysis].

Criteria for AA surgery

Surgery was indicated in the presence of symptoms attributable to AA disease. In asymptomatic patients, the indication was made when the diameter of the vessel was 5.5 cm with atherosclerotic disease and 5 cm in patients with connective tissue diseases. Other indications were AAS, pseudoaneurysm and infection. In patients with coronary artery disease, heart valve disease or aortic root or ascending aorta disease requiring surgery, AA replacement was indicated when the diameter was 4.5 cm.

Surgical technique

1) Total aortic arch replacement (TAAR): two variants were used. In the first variant, the AA is opened and completely resected under cardiopulmonary bypass (CPB), with arterial cannulation of the right axillary artery, deep hypothermic circulatory arrest with unilateral or bilateral antegrade selective cerebral perfusion. The AA is replaced by a four-branched Dacron graft which is distally anastomosed to the descending aorta, left subclavian artery, left carotid artery and brachiocephalic trunk (BCT), and finally the proximal end of the graft is anastomosed to the ascending aorta (Figure 1). In the other technique, under the same type of brain perfusion and protection, a complete or incomplete "Carrel island" is created involving 2 or 3 supraaortic vessels and a termino-terminal anastomosis is performed to a Dacron graft, using another Dacron graft to replace the AA from the ascending to the descending aorta. A termino-lateral anastomosis connects the latter graft with the other prosthesis, near its proximal anastomosis (Figure 2).
2) Hemi-arch replacement (HAR): the inferior curvature or concavity of the AA is resected up to the origin of the descending aorta and a wedge-shaped or half-pipe-shaped graft is sutured as distal anastomosis, accompanying a resection of the ascending aorta (Figure 3).

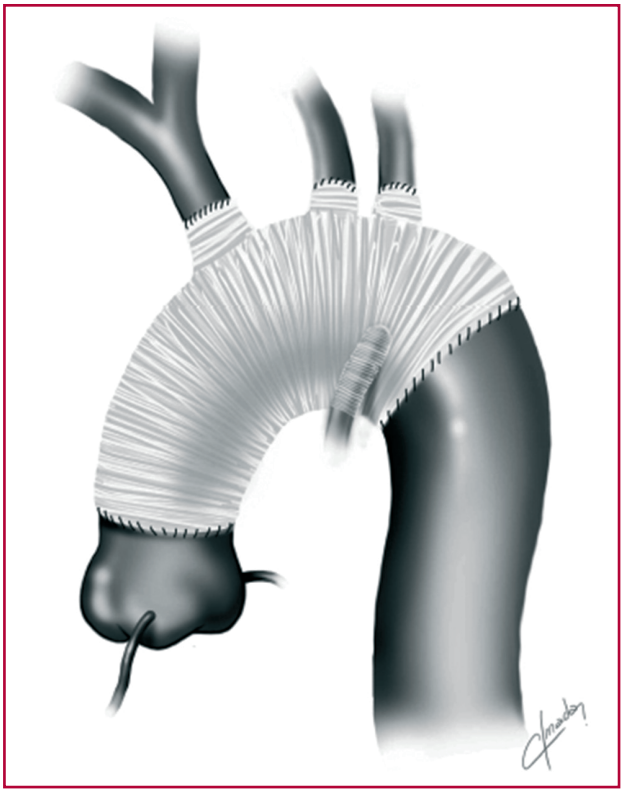

Fig. 1. Total replacement of the ascending aorta and aortic root with a four-branched graft.

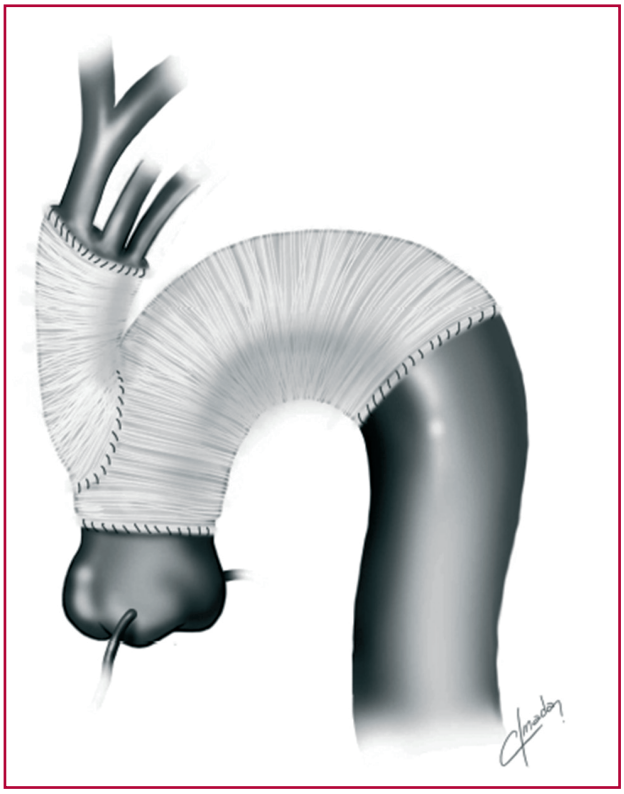

Fig. 2. Total replacement of the ascending aorta and aortic root with "arch-first" or "central debranching" technique.

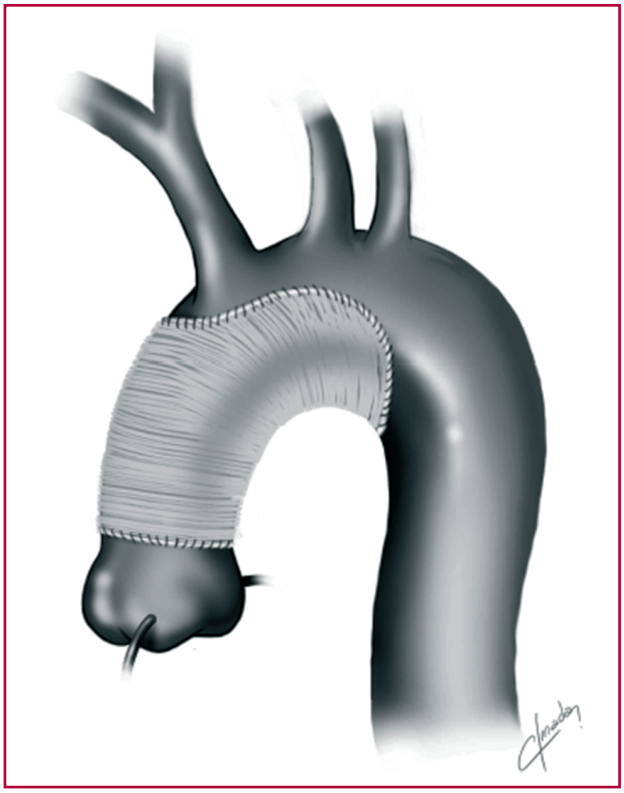

Fig. 3. Partial replacement of the aortic arch.

3) Thoracic endovascular aortic repair (TEVAR): it consists in the implantation of an endograft in the AA from the ascending aorta with debranching of the supraaortic vessels.

Statistical analysis

Continuous variables were compared between groups using Student's t test or the Mann-Whitney test for normal and non-normal distributions, respectively. Categorical variables were analyzed with the chi-square test or Fisher's exact test, as applicable. Continuous variables were expressed as mean ± standard deviation and categorical variables as absolute and relative frequencies.

The cumulative incidence and the incidence rate of death during the first year was determined. Cox proportional hazard models were used to analyze the association between surgical timing and age group with mortality at one year.

Hazard ratio (HR) with its corresponding 95% CI was used as a measure of effect. Survival was represented by Kaplan-Meier curves.

A two-tailed p value <0.05 was considered statistically significant. All statistical calculations were performed using STATA 13.1 software package.

Ethical considerations

The study was conducted following medical research recommendations of the Declaration of Helsinki, Good Clinical Practice Guidelines and current ethical regulations.

RESULTS

Between January 2010 and December 2016, 398 patients underwent thoracic aorta surgery (aortic root, ascending or descending aorta). Among them, 71 patients undergoing AA surgery were candidates to enter the study. Six patients who arrived at the operating room with cardiopulmonary resuscitation maneuvers or presented uncontrolled pericardial or pleural bleeding at procedure initiation were excluded from the analysis. Thus, 65 patients were followed-up for 1 year, with 18.5% lost to follow-up.

Median age was 71 years (IQR 64-77 years) and 65% were men.

The etiology of aortic disease was associated with atherosclerosis in 52% of cases and degenerative disease in 48%.

In 35% of cases, the procedures were emergency surgeries due to AAS. The rest of the cases were elective procedures for chronic aneurysm (52%), aortic dissection (9%), pseudoaneurysm (2%) and acute type B aortic dissection (2%).

Sex, age and prevalence of comorbidities were not statistically different between the emergency and the elective surgery groups, except in the case of dyslipidemia (22% vs. 57%, p=0.01), peripheral vascular disease (4% vs. 29%, p=0.02), and chronic heart failure (10.5% vs. 19%, p=0.02) which were more prevalent in the group of patients undergoing elective procedures (Table 1).

Previous cardiac surgery was present in 4% of the patients in the emergency surgery group and 12% in the elective group (p=0.31).

There were no differences between surgical timing and the technique used (TAAR, HAR, TEVAR or combined procedures). Cardiopulmonary bypass time and aortic cross-clamp time did not present statistically significant differences, but circulatory arrest time was longer in emergency procedures (median 34 min vs. 24 min, p <0.0028).

The length of hospital stay was longer in the emergency surgery group [19 days (IQR 12-36) vs. 8 days (IQR 6-20) in the elective surgery group; p=0.004],

Among postoperative complications, prolonged mechanical ventilation was more common in the emergency surgery group compared with the elective surgery group (52% vs. 19%, p=0.006). No significant differences were found in the incidence of reoperation due to bleeding, mediastinitis, stroke, confusion and renal failure requiring dialysis in the postoperative period between both groups.

In-hospital mortality was 15% and observed mortality 24%, without significant differences according to surgical timing (Table 2).

At 1-year follow-up, 4 patients died in the emergency surgery group and 9 patients in the elective surgery group. There were no significant differences in mortality rate between both groups (22 events per 100 patient years; 95% CI, 8.2-58.5 in the emergency surgery group vs. 30 events per 100 patient years; 95% CI, 15.4-57.1) in the elective group.

Univariate analysis did not show differences in 1-year mortality between both surgical timing groups (HR 0.79; 95% CI, 0.24-2.57; p=0.7).

In the multivariate analysis adjusted for age group >75 years, surgical timing did not show any association with 1-year mortality (HR 0.9; 95% CI, 0.27-2.93; p=0.857). In this model, age >75 years was strongly associated with higher mortality at 1 year (HR 3.81; 95% CI, 1.24-11.74; p=0.019).

DISCUSSION

Aortic arch surgery due to degenerative or atherosclerotic aneurysm has evolved over the past years due to better surgical techniques and to the design of novel brain and visceral organ protection strategies. In this sense, direct antegrade or retrograde brain protection (RBP) has proved to be useful to reduce brain circulatory arrest time and hypothermia to a mini-

Table 1. Baseline and operative characteristics according to surgical timing

	Total (n=65	Emergency (n=23)	Elective (n=42)	p
Baseline characteristics				
Age, years, [median (IQR)]	71 (64-77)	71 (54-76)	71 (64-78)	0.77
Male sex, %	65	70	62	0.54
Comorbidities, %				
Obesity	23	22	24	0.85
Smoking habits	43	48	40	0.57
Diabetes	8	4	9	0.45
HT	78	65	86	0.05
Dyslipidemia	45	21	57	0.01
COPD	11	13	9	0.66
Peripheral vascular disease	20	4	29	0.02
CRF	12	0	19	0.02
Previous stroke	12	9	14	0.51
Functional class III-IV, %	6	4	7	0.65
Reoperation, %	9	4	12	0.31
Characteristics of the procedure				
AA technique, %				
TAAR	37	39	36	0.67
HAR	49	52	48	
TEVAR	14	9	17	
Combination surgery, %	72	83	67	0.17
Surgical times, minutes [median, (IQR)]				
CBP	202 (166-257)	228 (171-268)	186 (154-241)	0.14
Aortic-cross clamp	127 (101-166)	140 (101-195)	125 (113-156)	0.39
Circulatory arrest	27 (20-41)	34 (26-54)	24 (15-32)	<0.00
Days of hospitalization [median (IQR)]	11 (6-22)	19 (12-36)	8 (6-20)	<0.00

IQR: Interquartile range. HT: Hypertension. COPD: Chronic obstructive pulmonary disease. CRF: Chronic renal failure. AA: Aortic arch. TAAR: Total aortic arch replacement. HAR: Hemi-arch replacement. TEVAR: Thoracic endovascular aortic repair. CPB: Cardiopulmonary bypass.

Table 2. Morbidity and mortality according to surgical timing

	Total (n=65	Emergency (n=23)	Elective (n=42)	p
Postoperative complications, %				
Prolonged MV	31	52	19	<0.00
Reoperation for bleeding	1	4	0	0.35
Mediastinitis	5	9	2	0.25
Stroke	15	22	12	0.29
ARF requiring dialysis	17	26	12	0.14
Mortality, %				
In-hospital	15	13	17	0.69
1 year	24	20	27	0.55

MV: Mechanical ventilation. ARF: Acute renal failure.

mum, allowing slightly higher body temperatures. Although antegrade brain perfusion, either unilateral or bilateral, is currently the strategy of choice, a recent randomized study by Svensson et al. and another by Stamou and Kouchoukos did not show significant differences between both techniques. (10, 11) These authors emphasize the potential benefit of RBP to reduce the risk of gaseous emboli or catheter-induced embolization.

In our population, the analysis of comorbidities showed high baseline prevalence of hypertension (79%), smoking habits (43%) and dyslipidemia (45%) as compared with the general population. These values are comparable to those reported by similar populations undergoing AA surgery. (8, 9, 12)

Although patients undergoing elective procedures did not differ in age from those undergoing emergency surgery, the prevalence of peripheral vascular disease and chronic renal failure was higher, suggesting that these patients had greater burden of vascular disease.

The surgical technique used was left to the discretion of the treating surgeon. The hybrid technique consisted on debranching followed by implantation of a TEVAR graft. This technique was used to avoid open surgery in high-risk patients.

Patients undergoing emergency procedures had longer circulatory arrest time probably due to technical issues related to suturing tissues with acute dissection.

Prolonged mechanical ventilation was more common in emergency surgery patients who also had longer hospital stay than those undergoing elective surgery. The incidence of stroke was greater in the emergency surgery group (22% vs. 12% in the elective surgery group), but this difference was not statistically significant probably for lack of power due to the small number of events observed.

The incidence of reoperations due to bleeding was low (1%), a percentage far below the one reported by other authors. (9, 12)

Publications from specialized centers have reported surprisingly low mortality rates. (7, 8) However, a multicenter European registry including 1,200 patients operated on in 11 centers reported a mortality rate above 11% with 11% of neurological events. (9) In our cohort, overall in-hospital mortality was 15%, and our population was older than the one of the European registry.

Mortality rate did not present statistically significant differences between emergency and elective groups, probably for lack of power to detect these differences due to the low number of events observed during follow-up. Of importance, after mortality was adjusted for age, the risk of mortality was 4 times greater in patients >75 years and this difference was statistically significant.

The main limitations of this study are its retrospective design and the low number of patients included from a single center.

CONCLUSIONS

In this cohort of patients undergoing AA surgery, in-hospital mortality and one-year mortality were similar in patients with emergency or elective surgery. Noteworthy, patients >75 years presented 4 times greater risk of mortality during the first year than younger ones.

The incidence of mortality and postoperative stroke were similar to those reported in recent registries.

The incidence of reoperations due to bleeding was conspicuously low.

The rate of complications (reoperations due to bleeding, stroke, ARF or infection) was not statistically different between both groups probably due to lack of statistical power.

Conflicts of interest

The author Vadim Kotowicz declares he is a Consultant at Johnson & Johnson Medical Care and Medtronic Inc.

(See authors' conflicts of interest forms on the website/ Supplementary material).

Acknowledgement

The surgical technique illustrations were performed by Mr. Guillermo Almada.

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