Open aortic arch reconstruction after previous cardiac surgery: Outcomes of 168 consecutive operations

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Objective: Open arch interventions after previous cardiac surgery are considered high risk. We reviewed our outcomes in patients requiring aortic arch reconstruction after previous cardiovascular surgery.

Methods: From March 2000 to March 2014, the data from 168 patients with previous sternotomy requiring aortic arch replacement were reviewed. The indications for surgery, perioperative data, and outcomes of reoperation were analyzed.

Results: The mean age was 61 ± 14 years, and 119 were men (70%). The indications for reoperation were aneurysm (57%), valvular disease (13%), impending rupture (12%), aortic dissection (9.0%), and endocarditis (7.7%). The median time from the previous operation to reoperation was 7 years. The mean aortic diameter was 55 mm. Total or partial arch replacement was performed in 38% and 62% of patients, respectively. Fifty-five patients (32.7%) had undergone previous ascending dissection repair and 45 (26.8%) had previous coronary bypass surgery. Deep hypothermic circulatory arrest was used in all. Selective cerebral perfusion was used in 39% and retrograde cerebral perfusion in 14%. The incidence of permanent stroke was 5.4%. Operative mortality (30-day) was 8.3%. Older age (odds ratio, 1.05; 95% confidence interval, 1.00-1.10; $P = .04$), New York Heart Association class III/IV (odds ratio, 3.15; 95% confidence interval, 1.01-9.86; $P = .04$), and extracorporeal circulation time (odds ratio, 1.01; 95% confidence interval, 1.00-1.02; $P = .001$) were predictors of perioperative death. The median follow-up was 3.0 years. Survival was 85%, 78%, and 68% at 1, 3, and 5 years, respectively.

Conclusions: Reoperations to address the aortic arch have acceptable mortality and morbidity. Open repair under circulatory arrest is the benchmark to which endovascular therapies should be compared. (*J Thorac Cardiovasc Surg* 2014;148:2944-50)

Open aortic arch replacement in patients who have undergone previous cardiovascular surgery can be technically challenging. Despite assertions that emerging endovascular technology carries a lower risk in the treatment of aortic arch pathology compared with open approaches, scant reports are available to delineate the contemporary risks of these complex open arch operations. The overall operative mortality and incidence of stroke in patients undergoing distal ascending aortic or proximal arch surgery in North America have been reported at 11.6% and 11%, respectively.¹ Up to 5% of patients after ascending aortic surgery will require reoperation involving the aortic arch.² The reoperations are secondary to distal progression of aortic disease or

complications of previous open or endovascular procedures. Such patients in need of re-do sternotomy and arch replacement have typically been either denied surgery or referred to high-volume aortic centers. Because the risks of reoperation are perceived to be greater than those for primary aortic arch repair,¹ often without concrete data, many of these patients have been channeled toward hybrid reconstructions or denied repair, even at the referred high-volume centers. The aim of the present study was to establish contemporary data for assessing the risk profile in patients who require re-do sternotomy to repair or re-repair the aortic arch.

METHODS

From March 2000 to March 2014, 650 patients underwent aortic arch surgery with hypothermic circulatory arrest at the Mayo Clinic (Rochester, Minn). Of these patients, we identified 172 (26%) who had undergone aortic arch surgery after previous cardiac or aortic surgery. We included patients who had undergone 1 or multiple previous operations through a median sternotomy. The Mayo Clinic College of Medicine institutional review board reviewed and approved the present clinical study, and all but 4 patients authorized the use of their clinical data for clinical research. Those 4 patients were excluded from additional analysis, and 168 patients constituted the focus of our study. Our cardiovascular database and the hospital electronic medical records were used to obtain the data for the present study. The patient characteristics, operative interventions, and morbidity and mortality data were collected, keeping with the standard definitions set forth by the Society of Thoracic Surgeons as a part of the National Adult Cardiac Surgery Database. Operative mortality was defined as

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Abbreviations and Acronyms

ACP = antegrade cerebral perfusion

CI = confidence interval

CPB = cardiopulmonary bypass

death occurring within 30 days of surgery or at any time during the index hospitalization. Surgery was considered emergency when the patients were transferred immediately to the operating room once the diagnosis had been made. Surgery was defined as urgent when performed on the day of diagnosis. Follow-up data were obtained from all repeat visits and from health assessment questionnaires sent to the patients and families at 1, 3, 5, and 10 years postoperatively. These data were supplemented by written correspondence from the referral physicians or patients and by checking the vital status from the Social Security Death Index.

Perioperative Management

All patients had undergone preoperative echocardiographic evaluation and computed tomography to define the relations of the intrathoracic structures. The specific aortic information evaluated in all patients included the diameter, wall integrity, atherosclerotic disease, and branch perfusion in the dissections. If feasible, coronary angiography was obtained for patients >40 years old and for younger patients if coronary intervention had been performed at the first operation. The patients were monitored by arterial lines placed in ≥ 1 of the upper extremities (often both radials), with 1 femoral line added in most patients. The goal was to monitor the regional perfusion pressures during arch reconstruction. Central venous access, large bore peripheral vein access, and a pulmonary artery catheter were used routinely. The core (bladder) and nasopharyngeal temperatures were monitored in all patients. Standard methods for repeat median sternotomy or bilateral thoracosternotomy for single-stage extensive aortic repair were used. Cardiopulmonary bypass (CPB) was initiated at an indexed flow of 2.4 L/min/m², and the desired level of hypothermia was achieved by actively cooling the patient with a heat exchanger connected to the oxygenator, keeping a gradient of no more than 10°C. Cannulation strategies were customized to the patient's anatomy as feasible, and safe central cannulation was preferred.^{3,4} Central cannulation was instituted with conventional arterial cannulas in the nondissected aorta. If the aorta was dissected, peripheral cannulation was commonly used, with direct cannulation over a wire using echocardiographic control to guide the tip of the cannula into the true lumen. Peripheral arterial cannulation was achieved through axillary or femoral artery cannulation through an 8- to 10-mm Dacron graft or by direct arterial femoral cannulation using the Seldinger technique.⁵ If treacherous anatomy or computed tomographic evidence of rupture was demonstrated, establishment of peripheral cannulation was selected as the first operative step. When the proximity of the cardiovascular structures precluded safe reentry, full CPB without cooling was used to decompress the circulation before sternal sawing was performed. In cases in which contained vascular rupture was present, deep hypothermic CPB was established before redo sternotomy. Neurologic monitoring was accomplished using the bispectral index and/or continuous electroencephalography. All patients were cooled to a target temperature and/or electroencephalographic silence. The patient was then placed in the Trendelenburg position, and circulation to the body was interrupted. For extensive arch repairs, selective antegrade cerebral perfusion (ACP) was performed either using the axillary cannula or by individually cannulating the arch vessels at flows of 10 to 15 mL/kg/min, with a perfusion pressure of 50 to 60 mm Hg.⁶ When simple arch reconstruction could be accomplished quickly (<30 minutes), isolated circulatory arrest or retrograde cerebral perfusion was used in most cases.⁷ The techniques of arch reconstruction ranged from hemiarch repair to complete intrathoracic aorta replacement through a bilateral thoracosternotomy. In cases of total arch replacement, the arch

vessels were connected to the Dacron arch graft using either a Carrel patch or by individual branch reimplantation. Cold blood cardioplegia in a 4:1 blood to crystalloid solution at 4°C was used for myocardial protection in all patients. An antegrade induction dose of 800 to 1000 mL was administered in the aortic root or coronary ostia. This was supplemented with repeated doses of antegrade and/or retrograde cardioplegia according to the clinical details and surgeon preference. Concomitant cardiac procedures were performed during cooling and rewarming.

Statistical Analysis

Statistical analyses were performed using SAS software, version 9.1 (SAS Institute, Inc, Cary, NC). Descriptive statistics for categorical variables are reported as frequencies and percentages and continuous variables as the mean $\pm$ standard deviation. Potential risk factors for early mortality were assessed using logistic regression models.

The Kaplan-Meier method was used to estimate late survival, with the estimates extending to 5 years. Observed mortality was compared using a 1-sample log-rank test to the expected survival of an age- and sex-matched Minnesota population for the entire follow-up period.

RESULTS

The mean age at the time of re-do sternotomy/thoracosternotomy arch surgery was 61 ± 14 years, and 119 patients were men (70.8%). The median time from the previous cardiovascular surgery to reoperation was 7 years (range, 15 days to 48 years). One hundred seventeen patients (69.6%) had undergone their previous operation at a different institution and the remaining patients had their previous operation at Mayo Clinic Rochester. The patient characteristics and details of the previous cardiac operations are listed in Table 1. Forty-seven patients (27.9%) had a bicuspid aortic valve, 16 (9.5%) had Marfan disease, and 2 (1.2%) had Loeys-Dietz syndrome. Giant cell arteritis was documented from the surgical specimens of 10 patients (5.9%). The overall median aortic diameter was 55 mm (range, 29-88 mm). Heart failure was documented in 104 patients (61.9%), with evidence of New York Heart Association class III or IV in 65 (38.7%). Twenty-two patients (14.4%) had undergone 2 previous sternotomies and 6 (3.6%) had undergone ≥ 3 previous sternotomies. Surgery was performed urgently in 24 patients (14.3%). Two patients had a stent graft in the aortic arch at the time of reoperation. One patient underwent total arch repair with a hybrid procedure.

Indications for Surgery and Repair Type

The primary indication for reoperation was aneurysmal disease in 96 patients (57%). Severe valvular disease (primarily aortic valve) was the leading indication in 23 patients (13%). Aortic pseudoaneurysm or contained rupture was the third most common indication, present in 21 patients (12%). The other indications for surgery were acute aortic dissection in 15 patients (9%) and infective endocarditis in 13 (7.7%). Aneurysmal expansion of a chronic aortic dissection was present in 14 patients in the aneurysmal group (8.3% of the total).

TABLE 1. Patient characteristics and details of previous cardiac operations

Variable	Value
Patient data	
Age (y)	61 ± 14
Male sex	119 (70.8)
COPD	7 (4.7)
Hypertension	88 (52.4)
Chronic renal failure (creatinine > 1.4 mg/dL)	36 (21.4)
Dialysis	3 (1.8)
Diabetes mellitus	19 (11.3)
NYHA class III-IV	65 (38.7)
Cerebrovascular disease	46 (27.4)
Previous CVA	31 (18.5)
Peripheral vascular disease	21 (12.5)
Coronary artery disease	75 (44.6)
Previous AMI	19 (11.3)
Marfan syndrome	16 (9.5)
LVEF (%)	58 ± 10
Aortic diameter (mm)	55 ± 12
Aortic valve regurgitation (grade III-IV)	53 (31.5)
Aortic valve stenosis (grade III-IV)	17 (10)
Previous cardiac interventions	
Arch replacement	39 (23.2)
Hemiarch	34 (20.2)
Total arch*	5 (3)
Ascending aorta replacement	93 (55.4)
Type A aortic dissection repair	55 (32.7)
CABG	45 (26.8)
Aortic valve replacement	52 (31)
Aortic root surgery	56 (33)
Bentall	26 (15.5)
Root repair	17 (10)
Homograft	10 (6)
Ross	3 (1.8)

Data presented as mean ± standard deviation or n (%). *COPD*, Chronic obstructive pulmonary disease; *NYHA*, New York Heart Association; *CVA*, cerebrovascular accident; *AMI*, acute myocardial infarction; *LVEF*, left ventricular ejection fraction; *CABG*, coronary artery bypass grafting. *One patient had undergone a previous hybrid total arch procedure.

TABLE 2. Surgical indications and operative data

Variable	Value
Indications for surgery	
Aneurysm	96 (57)
Valvular	23 (13.7)
Pseudoaneurysm	21 (12.5)
Acute type A dissection	15 (8.9)
Endocarditis	13 (7.7)
Aortic arch reconstruction type	
Ascending plus hemiarch	104 (61.9)
Ascending plus total arch	25 (14.9)
Total arch	28 (16.7)
Single-stage total thoracic aortic repair (clamshell)	11 (6.5)
Emergency	14 (8.3)
Urgent	10 (6)
Perfusion data	
Cardiopulmonary bypass (min)	211 ± 75
Cardiac ischemia (min)	119 ± 66
Circulatory arrest body (min)	37 ± 26
Circulatory arrest brain (min)	16 ± 14
Lower temperature (core) achieved (°C)	18 ± 6
Arterial cannulation	
Aorta	69 (41)
Axillary	74 (44)
Femoral	24 (14)
Innominate artery	1 (0.6)
Venous return	
Central	135 (80.4)
Femoral vein	33 (19.6)
Concomitant cardiac procedures	
Aortic root replacement	34 (20.2)
CABG	30 (17.9)
Redo root replacement	23 (13.7)
Redo aortic valve replacement	20 (11.9)
Aortic valve replacement	18 (10.7)
Mitral valve surgery	7 (4.2)
Tricuspid valve surgery	5 (3)
Valve-sparing root replacement	4 (2.4)

Data presented as n (%) or mean ± standard deviation. *CABG*, Coronary artery bypass grafting.

The details of the indications, type of aortic repair, and concomitant cardiac procedures are listed in Table 2. One hundred nine patients (65%) underwent partial arch replacement and 59 (35%) underwent total arch replacement. Island-type reimplantation of the arch vessels was performed in 12 patients undergoing total arch replacement (19.7%), with individual branch reimplantation performed in 49 (80.3%). Twelve patients (7.1%) underwent total arch replacement and additional partial or total descending thoracic aorta replacement by way of a bilateral thoracosternotomy. Twenty-one patients (12.5%) underwent a classic elephant trunk procedure at total arch replacement in preparation for future descending thoracic aortic replacement, either open or endovascular. None of the patients in the present series underwent a frozen elephant trunk procedure. A cryopreserved human homograft was used in

14 patients (8.3%), with all remaining patients undergoing aortic replacement with a Dacron graft.

Reentry and Perfusion Strategy

Individualized strategies to achieve safe thoracic reentry and the specific organ protection techniques used in the present series are listed in Table 2. Unexpected aortic injury at reentry that required emergency institution of CPB occurred in 2.4% of the reentries (4 cases) in our series. A retrospective review of the preoperative computed tomographic angiograms revealed flattening of the ascending aorta in contact with the posterior wall of the sternum in 2 patients. Seventy-four individuals (44%) underwent peripheral cannulation by way of the axillary artery before repeat sternotomy. In 10 patients (6%), CPB was established before re-do sternotomy, with 14 patients

TABLE 3. Postoperative outcomes and complications

Outcome	Value
Operative mortality	14 (8.3)
ICU length of stay (d)	3.3 ± 5.4
Hospital length of stay (d)	10.1 ± 7.5
Complications	
Stroke (permanent)	9 (5.4)
Spinal cord deficit	1 (0.6)
Reoperation for bleeding	16 (9.6)
Tamponade	4 (2.4)
Low cardiac output syndrome	14 (8.5)
Myocardial infarction	6 (3.6)
ECMO	3 (1.8)
IABP	7 (4.2)
Renal failure dialysis	7 (4.2)
Respiratory (pneumonia/atelectasis/pleural effusion)	20 (12.2)
Mesenteric (ischemia/hemorrhage)	4 (2.4)
Sepsis	8 (4.9)
Wound complication (infection/dehiscence)	7 (4.2)
Laryngeal nerve injury	11 (6.7)

Data presented as n (%) or mean ± standard deviation. ICU, Intensive care unit; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump.

(8.3%) undergoing reentry either under deep hypothermic perfusion or with hypothermic circulatory arrest. Eight patients (4.8%) required a change in the overall planned perfusion strategy during the operation because of either inadequate flow or malperfusion.

For all arch replacements, after deep hypothermia was achieved, ACP was used in 66 patients (39.3%) and retrograde cerebral perfusion in 23 (13.7%), with 79 patients (47%) not receiving adjunct cerebral perfusion during the circulatory arrest period. For patients with extensive aortic arch reconstruction, ACP was delivered unilaterally in 20 patients (30.3%) and bilaterally in 46 (69.7%). The routes of ACP administration in this population were direct cannulation of the arch vessels with individual cannulas in 16 (24.2%) and different configurations involving perfusion by way of the right axillary artery with or without individual cannulas to the left carotid and left subclavian artery in 60.

Early Mortality and Complications

There were 14 operative deaths (8.3%). Three patients could not be weaned successfully off CPB and died in the operating room, because they were not candidates for mechanical support. Five patients died in the intensive care unit of complications related to low cardiac output. Two patients died of aortic rupture, 1 in the hospital after repair of a mycotic pseudoaneurysm and 1 at home while waiting for completion of a staged aortic reconstruction. An additional 2 patients died of perioperative stroke (cerebrovascular accident). An 83-year-old patient developed acute renal failure requiring dialysis. In accordance with his living will, dialysis was not performed, and he was allowed to die. One patient died of unknown reasons at home within 30 days after surgery, and an autopsy was not performed.

TABLE 4. Predictors of perioperative mortality

Variable	OR (95% CI)	P value
Age (y)	1.05 (1.00-1.10)	.04*
Female sex	0.64 (0.17-2.40)	.5
NYHA class III-IV	3.15 (1.01-9.86)	.04*
Coronary artery disease	0.57 (0.19-1.74)	.3
Peripheral vascular disease	0.48 (0.12-1.91)	.3
LVEF	1.00 (0.94-1.05)	.9
CVA	0.81 (0.21-3.11)	.8
Creatinine	1.39 (0.76-2.55)	.3
Marfan syndrome	1.72 (0.21-13.95)	.6
Redo arch	0.51 (0.16-1.62)	.3
Type of arch surgery	1.42 (0.47-4.33)	.5
Circulatory arrest time (brain)	1.01 (0.97-1.05)	.5
Circulatory arrest time (body)	1.01 (0.99-1.03)	.07
Cannulation site	1.26 (0.60-2.65)	.5
Extracorporeal circulation time	1.01 (1.00-1.02)	.001*
Cardiac ischemic time	1.00 (1.00-1.01)	.06
Previous CABG	0.45 (0.14-1.38)	.2
Previous type A repair	1.86 (0.50-6.99)	.4
CABG	0.77 (0.20-2.98)	.7
Redo aortic root	2.16 (0.27-17.40)	.5

OR, Odds ratio; CI, confidence interval; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; CVA, cerebrovascular accident; CABG, coronary artery bypass grafting. *Statistically significant.

A prolonged hospital stay (defined as >14 days) was required for 31 patients (18.4%) and a prolonged intensive care unit stay (>10 days) for 10 patients (5.9%). The perioperative outcomes are detailed in Table 3. The results of univariate logistic regression of variables predictive of operative mortality are listed in Table 4.

Long-Term Results and Reoperations

Follow-up information after surgery was available for the entire study population (100%), and the mean follow-up time was 3 years. The median survival for the entire population, including operative mortality, was 7.6 years. After the perioperative period, the causes of death were aortic disease-related complications in 2 patients (5.2%), heart failure in 9 (23.7%), cerebrovascular accident in 3 (7.9%), infections in 3 (7.9%), trauma or unrelated medical conditions in 3 (7.9%), and unknown reasons in 18 (47.4%).

The conditioned overall survival (excluding perioperative mortality) for this population was 93% (95% confidence interval [CI], 88%-98%), 86% (95% CI, 79%-93%), and 77% (95% CI, 69%-87%), at 1, 3, and 5 years, respectively. Compared with an age- and sex-matched population for whom the expected survival was 88% at 5 years, the difference was significant ($P < .001$; Figure 1).

Patients with previous coronary artery bypass grafting had worse long-term outcomes than the remaining patients, with a 5-year survival of 52% versus 76% ($P = .003$; Figure 2). The presence of a previous type A dissection

FIGURE 1. Compared with an age- and sex-matched population, patients undergoing redo sternotomy arch replacement had lower survival at 5 years ($P < .001$).

repair or the extent of arch reconstruction did not affect long-term survival ($P = .21$ and $P = .44$, respectively). The survival of patients operated on for endocarditis was 36% at 5 years.

Seventeen patients required late aortic reoperation. The reoperation rate at 5 years was 17% (95% CI, 8%-26%). Re-do aortic valve replacement was performed in 4 patients (2 for endocarditis), open thoracoabdominal repair in 6, descending thoracic replacement in 4, and endovascular aortic repairs in 3.

DISCUSSION

Aortic arch surgery has seen significant improvement in outcomes during the past decade. Also, endovascular treatment of all aortic pathologic findings has progressed to the point that it is now starting to be used to treat aneurysms involving the aortic arch. Endovascular techniques to treat the aortic arch are still in their infancy and continue to carry a high risk of neurologic injury. Although the appropriate role of endovascular arch repair will eventually be defined, in this early stage of development, its application has often been justified by the perceived prohibitive risk of open aortic arch surgery. The data supporting the perceived high risk of open aortic arch intervention has been highly variable, with stroke rates ranging from 2% to 17%, the lowest rate for hemiarch replacements and the highest for the more complex repairs. The reported mortality for open arch repairs in published studies has ranged from 5.2% to 26%.^{1,6,8-11} Furthermore, even more limited data are available for the surgical results of arch surgery in the reoperative cardiac scenario.² In isolated reports,¹² mortality was not increased in transverse arch reoperations compared with primary arch surgery.

In the present study, we sought to better define the outcomes of higher risk patients undergoing aortic arch surgery: those requiring redo sternotomy. The results achieved showed acceptable mortality of 8.3% despite the many

FIGURE 2. Overall mortality during follow-up stratified by whether the previous operation included coronary artery bypass grafting (CABG).

challenging clinical scenarios encountered. Even with a preoperative stroke incidence of 18.5%, the postoperative stroke rate was only 5.4%. Furthermore, this population included patients with very complex problems such as acute aortic dissection, endocarditis, and many pseudoaneurysms (mostly infectious in etiology), in addition to the prevalence of New York Heart Association class III and IV heart failure.

A detailed evaluation of the individual anatomic risk factors extracted from the imaging studies and previous operative reports helped define the best strategy to achieve safe thoracic reentry. Establishment of CPB before sternotomy in 14.3% of patients might have contributed to the low incidence of unexpected injury at redo sternotomy (2.4%). Universal use of hypothermia, with increasing use of selective ACP during the study period, kept the rate of neurologic injury to a minimum. Most of the early deaths were secondary to low cardiac output syndromes in patients with established severe heart failure preoperatively.

Although most of the patients evaluated had undergone hemiarch replacement, the extent of arch reconstruction did not affect the overall outcome.

Our clinical experience, especially during the past 5 years, has shown that many of the patients presenting with arch aneurysms after previous cardiovascular interventions are referred late, often after other hybrid approaches have failed. It is our sense that a general reluctance exists on the part of the cardiac surgical community to treat such patients, who are then offered alternate treatment by “endovascular specialists.”

Hybrid aortic repairs involving a variety of configurations in arch branch rerouting and different landing zones carry a pooled risk of mortality exceeding 10% and a perioperative stroke rate of 0.8% to 18.8%.¹³ However, many of the published series have included hybrid replacement of less than a total arch (zone 1 and zone 2 coverage), making interpretation of the data rather difficult. In a more

recent report focused on hybrid zone 0 coverage (true total arch endovascular repair), the best results were in those patients who had undergone ascending aortic replacement first to create a proximal landing zone for the endovascular arch exclusion, often requiring a period of circulatory arrest.¹⁴ The findings from that report would suggest that circulatory arrest is not, itself, a significant risk and that embolic events from the diseased ascending aorta continue to be the more vexing problem.

As others have also reported,¹⁵ our results have demonstrated that open reoperations with direct anatomic reconstruction of the arch conducted in high-volume centers should be the benchmark by which other approaches are scrutinized. Using such a benchmark, newer technology needs to be realistically appraised and compared with contemporary therapies, at the same time resisting the enormous financial pressure exerted by the medical device industry.

An additional factor often minimized by catheter-based practitioners and manufacturers is the need for reintervention. In our series, the freedom from reoperation at 5 years was 83%, with all but 2 patients receiving intervention distal to the aortic arch repair. The only 2 patients requiring additional arch reoperation had had infectious pseudoaneurysms at their previous intervention. This low reoperation rate is superior to the high reintervention rates recently reported with endovascular approaches.^{16,17} With a stable aorta, this patient group, despite significant cardiovascular risk factors, fared reasonably well in the long term compared with an age-matched general population (77% vs 88% 5-year survival), further demonstrating that open aortic arch repair is a durable solution to complex aortic pathology.

The current trends in healthcare management have been moving toward ultraspecialization, together with the merging of physicians of differing backgrounds into specific disease management teams.^{18,19} Only such teams can be capable of offering open and endovascular options with equally outstanding results. It is unfortunate to occasionally observe that a given patient has been offered the intervention most comfortable to the surgeon consulted rather than the best operation available. Only a high-volume aortic center is likely to have the team approach required to critically assess all risk factors and anatomic variables and be able to offer the right operation to a given patient and, in the process, improve on the presently accepted aortic surgical outcomes in North America.¹

Study Limitations

The present study had the limitations inherent to a single-center retrospective cohort analysis. Owing to the low number of events (operative deaths), multivariate analysis to further define the predictors of perioperative death was not possible. The present study does not reflect the

outcomes of true redo arch procedures but, rather, reoperations involving arch surgery after previous cardiac surgery. Additionally, our population was a heterogeneous population that included “all comers” to arch surgery after a previous cardiac operation. Thus, different approaches to organ protection, surgical strategies, and repairs were used. It was not the aim of the present study to demonstrate that one approach is best but to acknowledge that in those clinical scenarios the therapy was customized. Another limitation of the present study was that the patients underwent different extensions of arch repair, with more than one half undergoing aggressive hemiarch repair. Although the surgical complexity of surgical arch reconstruction depends on the extension of the arch repair, physiologically, no difference could be demonstrated when stratified by the type of arch reconstruction. We sought to establish the outcomes of this complex clinical scenario. No randomized clinical trials on this issue comparing the results of open surgery and endovascular interventions have been performed.

CONCLUSIONS

Open aortic arch repair after cardiovascular surgery under circulatory arrest is the benchmark to which endovascular therapies should be compared. This arch repair technique is durable and provides good midterm results.

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