Research Highlight

Open aortic arch reconstruction

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Submitted Jan 20, 2013. Accepted for publication Feb 25, 2013.
doi: 10.3978/j.issn.2225-319X.2013.02.07
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Introduction

Aortic arch reconstruction remains a formidable operative procedure. Pioneering work by DeBakey *et al.* in 1957 identified neurological complications as a predominant cause of high mortality rate (1). The introduction of deep hypothermic circulatory arrest (HCA) by Griepp *et al.* simplified the operative approach and established a safe strategy for neuroprotection (2). Seminal work by Crawford and associates demonstrated that these techniques could result in death and stroke rates of 10% and 7% respectively (3). Given the emerging role of thoracic aortic endovascular repair (TEVAR) and its encroachment into the arch segment, we initiated an evaluation of open arch reconstruction to identify the important risk factors for poor outcomes, and define its late results (4).

Methods

This study was approved by the Institutional Review Board (IRB) of the University of Michigan Hospitals (IRB study #2003-0128).

A retrospective analysis of data from all patients admitted to the University of Michigan Hospitals from 1993 to 2009 who underwent aortic arch replacement via a median sternotomy was performed (n=721). Details of the operative technique have been described in our previous work (5).

Statistical methods

The primary late outcome of interest was vital status. Follow-up was 100% complete (mean 52.6±39.9 months). Statistical analysis was performed using SPSS (SPSS Inc., Chicago, IL,USA). All data are expressed as mean ± standard deviation where applicable. Univariate analysis was performed with chi-square analysis and independent t-tests. Multivariate models were constructed to identify factors that were independently associated with each of the outcomes of interest. Survival was analyzed by Kaplan-Meier methods. All results with $P<0.05$ were considered statistically significant.

Results

Demographics and comorbidities are listed in *Table 1*. The procedure was elective in 404 (56%), urgent in 128 (17.8%) and emergent in 188 (26.1%).

Early results

Early mortality was seen in 36 patients (5.0%). By multivariate analysis, older age (P=0.001; OR, 1.07; 95% CI, 1.0-1.2), lower ejection fraction (P=0.02; OR, 0.97; 95% CI, 0.95-0.99), prolonged cardiopulmonary bypass (P<0.0001; OR, 1.01; 95% CI, 1.007-1.02) and hypothermic circulatory arrest time (P=0.02; OR, 1.03; 95% CI, 1.004-1.05) were independently associated with early mortality. Stroke was identified in 34 patients (4.7%). By multivariate analysis, independent predictors of stroke included history of COPD (P=0.01; OR, 3.3; 95% CI, 1.3-8.2), procedure for type A dissection (P=0.003; OR, 4.05; 95% CI, 1.6-10.1), prolonged HCA time (P=0.03; OR, 1.02; 95% CI, 1.002-1.04), resection into proximal descending aorta (P=0.03; OR, 4.63; 95% CI, 1.12-19.1), and occurrence of permanent postoperative dialysis (P=0.003; OR, 7.14; 95% CI, 2.0-26.1). Finally, other early adverse events included the occurrence of postoperative renal failure in 42 patients (5.8%), with permanent dialysis required in only 14 (1.9%).

Late results

The crude mortality rate at last follow-up was 21.6%

Table 1 Patient characteristics

Variable	Frequency (%)
Preoperative demographics	
Age (years)	59.3±13.9
Male sex	497 (68.9%)
History of tobacco use	377 (52.2%)
Diabetes	51 (7.1%)
Hypertension	464 (64.4%)
Cerebrovascular accident	32 (4.4%)
Mean preoperative creatinine (mg/dL)	1.1±0.7
History of connective tissue disease	22 (3.1%)
Peripheral vascular occlusive disease	67 (9.3%)
Coronary artery disease	145 (20.1%)
Congestive heart failure	88 (12.3%)
Preoperative ejection fraction (%)	52.5±14%
Elective status of operation	404 (56.0%)
Maximum aortic diameter	5.7±1.2
Diagnosis acute type A dissection	284 (39.4%)
Prior CABG	29 (4.0%)
Prior aortic valve/root replacement	85 (11.8%)
Prior ascending thoracic aortic repair	23 (3.2%)
Prior descending aortic repair	9 (1.3%)
Intraoperative variables	
Aortic valve/root replacement	403 (55.9%)
Aortic valve resuspension	222 (30.1%)
Isolated arch procedure	14 (1.9%)
Extended arch procedure	308 (42.7%)
Innominate artery bypass	296 (41.1%)
Left carotid artery bypass	216 (30.0%)
Left subclavian artery bypass	75 (10.4%)
Descending aortic repair	24 (3.3%)
Elephant trunk procedure	42 (5.8%)
CABG	91 (12.6%)
Mitral valve repair/replacement	21 (2.9%)
Use of retrograde cerebral perfusion	641 (89.0%)
Use of antegrade cerebral perfusion	400 (55.5%)
Cerebral ischemic time (mins)	16.6±14.0
Lower body hypothermic arrest time (mins)	36.6±15.6
Cardiopulmonary bypass time (mins)	216.9±74.3
Cross clamp time (mins)	168.2±62.3

CABG, coronary artery bypass graft

(n=156). The Kaplan-Meier survival curve generated for the entire cohort is demonstrated in *Figure 1*. Independent predictors of late mortality identified through Cox proportional hazards analysis include, increasing age (P<0.0001, HR=1.05), preoperative creatinine (P=0.005, HR=1.57), prior history of CABG (P<0.0001, HR=5.62), descending aortic replacement (P=0.001, HR=11.14), and prolonged circulatory arrest time (P=0.008, HR=1.021), as well as requirement for postoperative tracheostomy (P=0.032, HR=3.16). Although not identified as an independent risk factor on multivariate analysis, type A dissection did have an important time-dependent effect on mortality, particularly during the early postoperative period (*Figure 2*). Freedom from late aortic reoperation at 10 years was 72.6%.

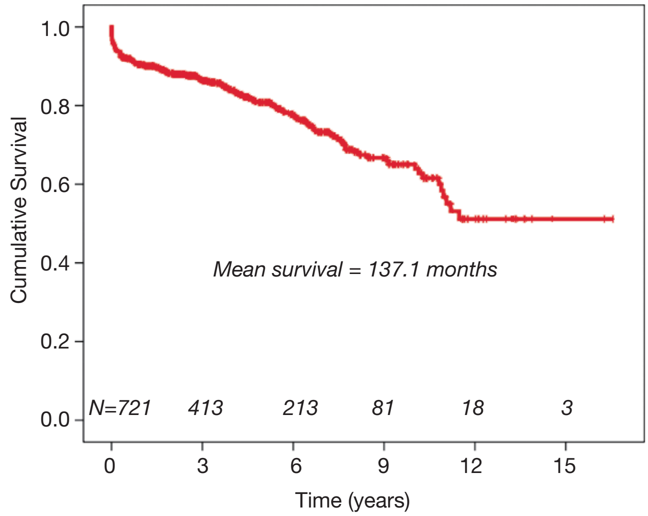

Figure 1 Kaplan-Meier survival analysis for the entire cohort. This figure demonstrates that the 12-year survival for the entire cohort is 51.2±0.5%

Discussion

The data in this study suggest that open arch reconstruction can be performed safely. Early results indicate that the dreaded complications of arch repair, namely death and stroke, can occur at rates under 5%. The rates of these complications in our study are comparable to those reported in the contemporary era, despite a high frequency of acute type A dissection (39.3%), reoperative procedures (15.4%), and extended arch repair (42.7%) (6-10). Late results suggest important risk factors for death include age, impaired renal function and a prior history of CABG.

While TEVAR was not an option for the majority of patients in this study, it is important to note that certain

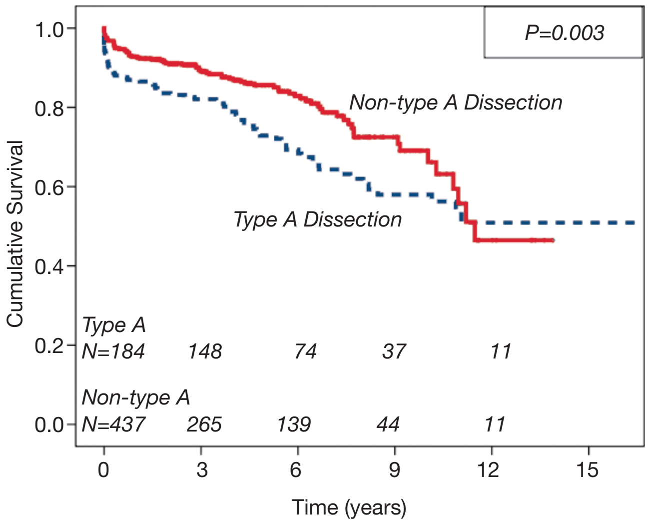

Figure 2 Kaplan-Meier survival analysis stratified by presence of type A aortic dissection. When separated by indication for intervention, the survival of the group presenting with acute type A aortic dissection has a poorer prognosis than those presenting with other pathology. The 10-year survival for the type A group is 58.0±0.4% and contrasts with the non-type A group at 69.1±0.4% (log rank P=0.003)

groups emerge as ideal candidates for application of this newer technology for the arch aorta. These include older patients, those with renal failure, and those with acute type A dissection. As the Stanford group has suggested in their analysis of patients presenting with bicuspid aortic valve and ascending aneurysms, most patients will have enlargement in the root and proximal ascending aorta, where the complex anatomy of the sinuses, sinotubular junction and the coronary ostia make TEVAR unfeasible with current technology (11). Their work suggests that in identifying an endovascular solution to the ascending aorta, a valved conduit that addresses the coronary arteries may need to be considered as an option.

Acknowledgements

Disclosure: The authors declare no conflict of interest.

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Cite this article as: Patel HJ, Deeb GM. Open aortic arch reconstruction. Ann Cardiothorac Surg 2013;2(2):181-183. doi: 10.3978/j.issn.2225-319X.2013.02.07

