Long-term outcomes after aortic arch surgery: results of a study involving 623 patients

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Abstract

OBJECTIVES: To assess early and long-term outcomes in a large cohort of patients undergoing open aortic arch surgery.

METHODS: From 1996 to 2012, 623 consecutive patients (mean age: 62.8 years) underwent aortic arch interventions in our institution. Of these, 208 (33.4%) presented with an acute aortic syndrome (AAS) and 415 (66.6%) with a chronic aortic pathology (CAP). During the study period, our surgical strategy involved extensive resections of the diseased aortic tissue at elective interventions, and a tear-oriented aortic replacement in patients with acute dissection. More extensive interventions were often performed in younger patients, and in those with connective tissue diseases and bicuspid aortic valves. A total arch replacement was frequently performed (53.3%). Antegrade selective cerebral perfusion was used in all cases.

RESULTS: Overall in-hospital mortality was 23.1% in patients with AAS and 11.1% in patients with a CAP; in the same groups, postoperative permanent neurological dysfunction (PND) occurred in 9.6 and 5.6%, respectively. The follow-up was 94.4% complete. For in-hospital survivors, 5- and 10-year survival (%) were 79.4 ± 2.1 and 60.9 ± 3.2, respectively, not influenced by the underlying aortic disease. Cox regression identified age (hazard ratio [HR]: 1.048; P < 0.001), preoperative renal failure (HR: 2.3; P = 0.003), diabetes (HR: 1.805; P = 0.005) and PND (HR: 2.4; P = 0.03) to be independent predictors for the follow-up mortality. Overall, 109 (59% endovascular) aortic reinterventions were performed: 18.3% were proximal and 81.7% distal to the aortic arch. Five- and 10-year freedom from aortic redo (%) were 82.8 ± 1.9 and 77.7 ± 2.6, respectively. Aortic dissection (HR: 1.7; P = 0.03) was the only independent predictor of reoperative surgery at the follow-up.

CONCLUSIONS: Aortic arch surgery was associated with satisfactory early and long-term outcomes. Survival was largely determined by patient comorbidities and postoperative PND. While the underlying aortic disease did not affect long-term mortality, chronic dissection was associated with increased need for aortic reinterventions.

Keywords: Aorta • Brain protection • Aortic arch

Over the past two decades, the early outcomes of patients undergoing elective aortic arch interventions have dramatically improved, mainly due to major advances in surgical techniques and methods for organ protection [1–6]. However, very few data are available regarding long-term outcomes after aortic arch surgery. In the present study, we assessed early and long-term results in a large cohort of consecutive patients (n = 623) undergoing open aortic arch intervention in our institution.

PATIENTS AND METHODS

Patients’ characteristics

Pre-, intra- and postoperative data were obtained using a prospective database supplemented by a chart review. The main perioperative variables are described in the Supplementary material, Appendix. The study was approved by an institutional review board and did not require individual patient consent.

From 1996 to 2012, 623 consecutive patients underwent aortic arch surgery in our institution. Of these, 208 (33.4%; mean age: 63.9 ± 11.6 years; male: 66.3%) presented with an acute aortic syndrome (AAS) (type A acute aortic dissection (n = 186; 89.4%), type A intramural haematoma ([IMH]; n = 20; 9.6%) symptomatic proximal aortic ulcer (n = 2; 1.0%) and 415 (66.6%; mean age 62.3 ± 12.5 years; male: 71.3%) with a chronic aortic pathology (CAP) (degenerative aneurysm (n = 260; 62.7%) post-dissection/IMH aneurysm (n = 106; 25.5%), uncomplicated penetrating aortic ulcer ([PAU]; n = 9; 2.2%) and false aneurysm (n = 28; 6.7%). Twenty patients (12%) with type A AAS presented with cardiogenic shock, 7 (4.2%) were complicated by stroke or coma and 8 (4.8%) by cardiac tamponade. Ten (4.8%) patients had undergone previous cardiac surgery.
Preoperative comorbidities of CAP patients included arterial hypertension (n = 302; 73.1%), coronary artery disease (n = 70; 16.9%), history of cerebrovascular disease (n = 31; 7.5%), chronic renal insufficiency (n = 16; 3.9%) and chronic obstructive pulmonary disease (COPD) (n = 22; 5.3%). Patient demographics are listed in Table 1.

Surgical technique

The aorta was approached using a median sternotomy in all cases. After systemic heparinization, cardiopulmonary bypass (CPB) was instituted using a central arterial cannulation site (ascending aorta, aortic arch, right axillary or innominate arteries) in 320 (52.8%) patients, the femoral artery in 283 (46.7%) patients and a simultaneous cannulation of the axillary and femoral arteries in 3 (0.5%) patients. Venous drainage was obtained by means of right atrium, bicaval or femoral cannulation, as indicated. The left side of the heart was vented through the right superior pulmonary vein, the pulmonary artery trunk or the left ventricular apex (through a left anterior mini-thoracotomy). Myocardial protection was achieved with antegrade or retrograde intermittent infusion of cold crystalloid cardioplegia. Brain protection was achieved with antegrade selective cerebral perfusion (ASCP) and moderate hypothermia in all cases. Our technique for ASCP has been previously described [6]. Briefly, it involves moderate hypothermia (nasopharyngeal 26°C), bilateral hemisphere perfusion and a cerebral flow rate of 10–15 ml/kg/min adjusted to maintain a right radial arterial pressure between 40 and 70 mmHg.

For spinal cord protection, cerebrospinal fluid drainage was frequently used in elective patients undergoing total arch replacement (TAR) with frozen elephant trunk (FET). Various aortic procedures were performed according to the underlying pathology. A TAR was performed in 335 (35%) patients using the elephant trunk (ET) and the frozen elephant trunk (FET) techniques in 53 (8.5%) and 109 (17.5%) patients, respectively [7, 8]. The entire proximal thoracic aorta (root + ascending aorta + total arch) was replaced in 81 patients (13.1%); associated cardiac procedures (most frequently, aortic valve replacement and coronary artery bypass grafting) were often performed (n = 161; 25.8%). All surgical procedures and operative data are given in Table 2.

Statistical analysis

Continuous variables were expressed as mean ± 1 SD and were analysed using the unpaired two-tailed t-test. Categorical variables were presented as percentages and were analysed with the $\chi^2$ test or Fisher’s exact test, when appropriate. A two-tailed P-value less than 0.05 was considered statistically significant. All the pre- or intraoperative variables that achieved a P-value of <0.05 in the univariate analysis were examined with multivariate analysis using stepwise logistic regression to evaluate the independent risk factors for hospital mortality.

The patients were followed by outpatients’ clinic, computed tomography/magnetic resonance imaging review, telephone calls and civil registry. Patients operated on for acute aortic dissection and chronic post-dissection aneurysm, at the time of surgery, were both accounted as ‘aortic dissection’ in the follow-up analysis. Survival curves and freedom from aortic reoperation were estimated, in the surviving patients, at 1, 3, 5 and 10 years using the Kaplan–Meier method. Independent predictors of long-term survival were determined with Cox proportional hazards analysis. Statistical analysis was carried out using SPSS 18.0.
RESULTS

Early results

Overall hospital mortality was 15.1%, being 10.4% (40/343) after elective surgery and 22.5% (54/186) after urgent/emergent surgery (P < 0.001). The underlying aortic disease greatly influenced early outcomes. Overall in-hospital mortality was 23.1% in AAS patients and 11.1% in CAP patients (P < 0.001); in the same groups, postoperative permanent neurological dysfunction (PND) occurred in 9.6 and 5.6%, respectively (P = 0.043). Similarly, postoperative renal and respiratory failure (P < 0.001), transient neurological deficit (TND) (P = 0.03), spinal cord injury (P = 0.05) and bleeding requiring rethoracotomy (P < 0.001) were relatively more frequent in patients with AAS as compared with those operated on for CAP (Table 3). The causes of death were cardiac (AAS = 20, CAP = 17), multiorgan failure (AAS = 14; CAP = 16), septic shock (AAS = 7; CAP = 7), respiratory failure (AAS = 6; CAP = 2), neurologic-al (AAS = 0; CAP = 3) and intestinal ischaemia (AAS = 1; CAP = 1). For the AAS group, on multivariate analysis, age at increments of 1 year [odds ratio (OR) = 1.044; confidence interval (CI): 1.009–1.081; P = 0.01] and CPB time (OR = 1.009 per min; CI: 1.004–1.015; P = 0.002) emerged as independent risk factors for hospital mortality. In patients with CAP, independent predictors of hospital mortality were female gender (OR = 2.399; CI: 1.025–5.614; P = 0.04), preoperative COPD (OR = 6.128; CI: 1.713–21.928; P = 0.005), preoperative renal failure (OR = 4.972; CI: 1.001–24.763; P = 0.05) and CPB time (OR = 1.014 per min; CI: 1.005–1.022; P = 0.002).

Long-term survival

The follow-up was 94.4% complete at a mean time of 5.3 ± 3.9 years (range: 0.2–16.8 years). Four hundred and ninety-four
patients were available for the follow-up analysis (Fig. 1). One hundred and thirty-seven (27.7%) patients died during the follow-up. Of them, 8 died after a complicated postoperative course following aortic reoperations. Other causes of death were cardiac-related in 27 patients, aortic rupture in 11, neurological in 9, sepsis in 8, pulmonary in 7, aortic graft detachment in 4, gut ischaemia in 1 and non-cardiac/aortic related in 62 (neoplasm n = 24; vehicular crash n = 2; senility n = 1; unknown in 35). Kaplan-Meier estimate of survival at 1, 3, 5 and 10 years was 92.1 ± 1.3%, 87.6 ± 1.6%, 83.8 ± 1.9% and 77.7 ± 2.6%, respectively. The reoperation rate in Marfan patients was 28.6% (2/7). One patient underwent TAR for active endocarditis and 1 underwent hybrid aortic repair, involving visceral vessels debranching and endovascular exclusion of the thoracic and abdominal aorta, for aneurysmal progression of chronic dissection. Aortic dissection (HR: 1.7; CI: 1.055–2.793; P = 0.03) was the only independent predictor of reoperative surgery at the follow-up. The 1-, 5- and 10-year, freedom from aortic reoperation for patients with and without aortic dissection was 92, 79 and 71% vs 92, 86 and 82%, respectively (log-rank P = 0.05) (Fig. 4).

In-hospital mortality after aortic reinterventions was 10% (8 deaths in 80 patients undergoing 109 aortic reoperations). Seven patients underwent a distal aortic intervention to the aortic arch (TVEAR, n = 3; thoracoabdominal aorta replacement, n = 2; abdominal aorta replacement, n = 2) and 1 underwent an aortic root and arch replacement. The hospital mortality rate was 7.9% (n = 7/89) for reoperations involving the thoracoabdominal aorta, 5% (n = 1/20) for reinterventions on the proximal thoracic aorta, 4.6% (n = 3/65) and 11.4% (n = 5/44) for TEVAR and open/hybrid aortic surgery, respectively (P = ns).

### DISCUSSION

Aortic arch surgery is a particularly challenging subspecialty of cardiac surgery. It involves the use of sophisticated methods and strategies to protect the brain and other organs from ischaemic injuries during circulatory arrest, it requires robust experience and advanced surgical skills to adequately face certain complex pathological settings (acute dissection, severely atherosclerotic aneurysm etc) and it necessitates a thorough assessment of the patient’s preoperative morbid conditions in order to adequately decide upon the extent of the operation, selecting the most appropriate strategies and techniques. Due to the progressive nature of aortic diseases, arch surgery also mandates close patients surveillance to determine the optimal timing and the type of aortic surgery should reinvention be necessary.

In our institution, aortic arch surgery contemplates extensive resections of all diseased aortic tissues at primary elective interventions, with liberal use of the ET techniques and a tear-oriented approach for aortic replacement in patients with acute dissection. While less extensive aortic reconstructions are performed in patients who are deemed unable to withstand TAR, more aggressive interventions are often performed in younger patients, in patients with a low risk profile or in those with connective diseases and bicuspid aortic valves. Arch vessels debranching with aortic arch stenting interventions represent an option of treatment only for patients who are judged inoperable using a standard approach. While ASCP has been our favourite method of brain protection since 1996, our cannulation strategy has progressively changed, with a significantly decreasing use of femoral artery cannulation (still of value in shocked patients with acute dissection) in favour of right axillary or innominate artery cannulation, which facilitate ASCP management [6, 9, 10]. In our institution, all possible attempts are made to the follow-up of our patients at 1, 3 and 6 months, and then annually, using appropriate clinical examinations and imaging tests.

The aim of the present study was to evaluate the above-mentioned surgical approach. To our knowledge, with 623 patients and a 94.4%
Figure 1: Flow chart of study population. FU: follow-up.

Figure 2: Kaplan–Meier estimate of survival in surviving patients (left), and according to underlying aortic disease: degenerative aneurysm (blue line), aortic dissection (green line) (right).
complete 10-year follow-up, this study represents one of the largest single-institutional studies on arch surgery published to date.

In the present series, hospital death, postoperative PND, permanent dialysis and bleeding requiring surgical re-exploration occurred in 15.1, 6.9, 1.8 and 8.2% of patients, respectively. Given the complexity of our interventions and the risk profile of our series, we believe our early results are satisfactory and in line with those reported by others [1, 3, 5, 11–16]. Not surprisingly, underlying aortic diseases strongly influenced hospital outcomes, as demonstrated by the substantially higher mortality and morbidity observed in patients with AASs. Once more, this emphasizes the importance of timely elective surgery in patients with known risk factors for aortic dissection, and the fact that we need to expand our knowledge on predisposing conditions and triggers of acute dissection in order to identify patients who might benefit from earlier elective lower risk prophylactic aortic resections. In addition to urgent/emergent status and other known risk factors for adverse outcomes (age, female gender, COPD, preoperative renal failure), the CPB time was the only intraoperative independent predictor of hospital mortality both for AAS and CAP patients. While this was expected, it is of note that ASCP time, TAR and cannulation technique (central versus peripheral) had no impact on early outcomes. In our opinion, this confirmed that ASCP is a valuable method for brain protection, and that a thorough selection of arterial cannulation strategy, based on patient and aortic characteristics more than on meaningless radical attitudes, is a winning approach [6, 10].

The estimated long-term survival was consistent with the data reported by others [1, 2, 11, 17–19]. Age, chronic renal failure, diabetes and postoperative PND emerged as independent predictors of late mortality whereas underlying aortic disease did not influence survival. The fact that long-term survival was affected more by cardiovascular risk factors and comorbidities than by the underlying aortic diseases, may allow speculation that our surgical management involving aggressive elective primary operations and close patient surveillance controlled catastrophic aortic complications during the follow-up satisfactorily. Operating more under elective conditions, on the one hand, and future research aimed at further improving ASCP management (i.e. optimal antegrade brain flow) and decreasing the postoperative occurrence of PNDs on the other will likely promote enhanced patient late survival and quality of life.

Freedom from aortic reoperation was satisfactory: 82.8% at 5 years and 77.7% at 10 years; the vast majority of aortic reinterventions

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AVR: aortic valve replacement; FET: frozen elephant trunk; hemiarch replacement: partial arch replacement without arch vessels reimplantation.

Figure 3: Follow-up: TEVAR procedures over the years.

Figure 4: Kaplan–Meier estimate of freedom from aortic reoperation in surviving patients (left), and according to the presence of aortic dissection (green line: aortic dissection; blue line: other aortic diseases) (right).
were performed on the distal descending or thoracoabdominal aorta (81.7%) using endovascular or hybrid techniques (73%). In our series, Marfan disease did not emerge as risk factor for late aortic re-intervention ($P = 0.5$) likely due to the limited number of Marfan patients in the study cohort ($n = 10$). Aortic dissection was the only discernable risk factor for aortic re-intervention at the follow-up; aortic re-interventions did not affect long-term survival. These observations permit some considerations; in particular, they support the notion that, when opportunely performed, extensive elective primary interventions using TAR and the liberal use of the ET techniques may remarkably reduce the need for late proximal reinterventions and facilitate less hazardous endovascular interventions on the distal thoracic aorta. The facts that the majority of re-interventions were performed on the distal aorta and that chronic aortic dissection was the only independent predictor for late re-intervention are clearly correlated. During surgery for acute dissection, unless technical errors or complications exist, the likelihood that entry tears are left unresected at the aortic root is virtually null while, almost invariably, numerous re-entry tears are left in the thoracoabdominal aorta. Such tears perfume and pressurize the false lumen of the distal aorta, lead to aeurysmal degeneration of the dissecting aorta, eventually imposing re-interventions aimed at preventing aortic rupture and patient death. Considering this, in acute dissection surgery, the FET technique has gained interest. The FET technique, by expanding the true lumen and covering secondary entry tears at the aortic arch and proximal descending thoracic aorta, may facilitate false lumen thrombosis and thoracic aorta remodelling, improve long-term survival and reduce the need for late reinterventions. Several studies have shown encouraging radiological data, with false lumen persistent thrombosis ranging from 48.4 to 100% [20–24]. While experienced aortic teams have demonstrated that FET interventions can be performed with excellent clinical results, it should be remembered that potential late advantages have to be offset by the increased technical complexity and increased risk of spinal cord injury associated with FET operations [25]. With this in mind, in our institution, the use of the FET technique in acute dissection patients depends on surgeon-, patient- and aortic-related factors. Such factors include surgical experience, young age, low risk profile, distal malperfusion and distal and complex arch tears [25].

Limitations and strengths

Our study limitations are related to its retrospective and single-institutional nature. However, while randomized controlled trials are considered to provide the best level of evidence in clinical and surgical practice, the complex clinical and anatomical scenario offered by aortic pathologies often make their use less pertinent, and observational studies, such as ours, gain interest and significance. Our study has the merit of assessing one of the largest series published to date regarding patients undergoing arch surgery with well-defined techniques and protocols. This study evaluated the long-term efficacy of our surgical management of patients with arch disease, likely adding valuable information to the data currently available with regard to this topic.

CONCLUSION

In our experience, early and long-term outcomes after open aortic arch surgery were satisfactory. Long-term survival was largely determined by patient’s comorbidities and postoperative PND. During the follow-up, while underlying aortic disease did not emerge as a risk factor for reduced survival, aortic dissection was associated with an increased risk of re-intervention. The vast majority of reoperations were distal to the aortic arch, were performed, for the most part, using endovascular techniques, and were associated with favourable outcomes. While aortic dissection represents a progressive disease requiring continued surveillance and frequent reinterventions, our experience consolidated the notion that, in selected patients, the use of aggressive aortic resection at primary elective surgery is a valuable approach.

SUPPLEMENTARY MATERIAL

Supplementary material is available at EJCTS online.

Conflict of interest: none declared.

REFERENCES


