Repair of aortic arch and the impact of cross-clamping time, New York Heart Association stage, circulatory arrest time, and age on operative outcome

Jeffrey P. Schwartz, Mamdouh Bakhos, Amit Patel, Sally Botkin, Siyamek Neragi-Miandoab

Abstract

Background: Aortic arch replacement is associated with high morbidity and mortality. Methods: We evaluated the postoperative complications and risk factors in 32 consecutive patients after aortic arch replacement. Results: The mean age was 61 ± 15 years and male to female ratio was 24/8. Diameter of ascending aorta was 6.0 ± 0.8 cm and diameter of aortic arch was 5.2 ± 1.2 cm. The average New York heart association (NYHA) class was 2 ± 1. The 30-day mortality was 6.2% (2 of 32 patients), one patient died intraoperatively (3%); all surviving 30 patients had f/u for at least six months, a total of 3 of 32 patients had died within six months, actuarial survival was 90% at six months. The overall incidence of neurologic adverse events was 9%; however, only one patient had a cerebrovascular accident (CVA) with a focal deficit (3%). The other two patients had global neurologic dysfunction. Other significant postoperative complications included atrial fibrillation in 15 patients (46%), ventricular fibrillation requiring cardiopulmonary resuscitation (CPR) in one patient (3%), and pericardial effusion requiring pericardicentesis in eight patients (25%). The need for blood transfusion correlated with the cross-clamping length (Pearson r 0.62; 95% confidence interval (CI), 0.35–0.79; P-value 0.0001; R = 0.38). Cross-clamp time (139 ± 58 min) did not have an impact on length of intensive care unit (ICU) stay (Pearson r = −0.09; 95% CI −0.39–0.23; P = 0.58; R = 0.008) nor did the length of circulatory arrest (95% CI −0.44–0.21; P = 0.44). The length of stay in the ICU (142 ± 128 h) correlated with the NYHA stage of the patient (95% CI 0.001–0.62, P = 0.04). The length of stay (LOS) (12 ± 6 days) correlated with age of the patients (95% CI 0.03–0.57, P = 0.03). Conclusion: Elderly patients and patients with high NYHA class need close postoperative monitoring in the ICU. A short circulatory arrest and aortic clamp time do not extend the LOS in ICU or in the hospital. © 2008 Published by European Association for Cardio-Thoracic Surgery. All rights reserved.

Keywords: Thoracic aorta; Aortic arch; Aortic rupture; Hypothermic circulatory arrest

1. Introduction

Repair of aortic arch has been a surgical dilemma, mainly due to the adverse neurologic sequelae ranging from 1% to 10% [1–4]. The surgical outcome has improved lately, however, the mortality ranges from 7% to 30% [2–4]. The indications for surgery include: presence of symptoms, a diameter of 50–60 mm for an ascending aortic aneurysm and 60–70 mm for a descending aortic aneurysm (>70 mm in high-risk patients), accelerated growth rate (>10 mm per year) in aneurysms <50 mm in diameter, and evidence of dissection [5]. Patients with Marfan’s disease should undergo early repair; 5.0 cm and 6.0 cm for ascending and descending aorta, respectively [6]. Independent preoperative predictors of operative mortality include previous aortic valve replacement, acute dissection with hypotension, shock, tamponade, and preoperative limb ischemia [2].

2. Methods

The design of the study is a retrospective review of existing data of patients (n = 32) undergoing replacement of aortic arch. We identified 32 consecutive patients who underwent either elective or emergent repair of aortic arch from January 2001 to April 2004. The relevant clinical variables, including information on patients’ demographics and history, clinical presentation, physical findings, and outcomes were documented. Table 1 demonstrates the patients’ characteristics. Computed tomogram (CT), coronary angiogram, and echocardiogram were used to evaluate the diameter of aorta, coronary status, and valve function. All patients had a preoperative echocardiogram to assess left ventricular function and valvular heart disease. All reported P-values are two-sided, and P < 0.05 was considered to indicate statistical significance.
2.1. Surgical approach

In the majority of cases, an extended median sternotomy was performed, a clamshell incision was utilized occasionally, as described in the literature [7]. Cannulation was carried out in the ascending aorta after selecting an atheroma-free site of aorta adjacent to or even included in the anticipated resection. The circulatory arrest was initiated and the arch was resected as indicated. The aneurysmal portion of the aorta was excised completely and the three arch vessels were transected 1 cm from their origin. The head vessels were dissected out anteriorly and laterally and encircled with vessel loops. The proximal anastomosis with the ascending aorta was performed first, followed by truncus brachiocephalicus utilizing a prefabricated trifurcated Hemashield graft (Boston Scientific, Wayne, NJ). Once the truncus anastomosis was completed the graft was clamped distal to truncus brachiocephalicus and the perfusion was started through a prefabricated cannula site. At this point the perfusion of head was initiated via truncus brachiocephalicus/right carotid artery. At this point the remaining anastomoses were performed. The main limb of the trifurcated graft was then unclamped and re-warming was initiated while the entire body was being perfused. The distal aortic anastomosis was then constructed. During the rest of the procedure, total body hypothermia supplemented with antegrade and retrograde blood cardioplegia and additional topical cooling was used for myocardial and brain preservation. We allowed cooling to a bladder or rectal temperature of 18 °C.

3. Results

The mean age was 61±15 years, male to female ratio was 24/8, and the average NYHA class was 2±1. The mean diameter of ascending aorta was 6.0±0.8 cm and aortic arch 5.2±1.2 cm. The patients were stratified in four groups as illustrated in Table 2. The mean operating time was 343±145 min, mean cardiopulmonary bypass (CPB) time was 184±93 min, and the mean circulatory arrest time was 38.5±18.9 min. A total of 17 patients had selective cerebral perfusion; the remaining patients had no selective cerebral perfusion during circulatory arrest time. Concomitant redo aortic valve replacement (AVR) was performed in three patients (9%), first time AVR in 12 patients (37%), and AVR and aortorrhaphy in one patient (3%). Concomitant coronary artery bypass grafting (CABG) was performed in five patients (15%) and mitral valve replacement (MVR) in one patient (3%). Postoperative length of hospital stay was 12±6 days. Mean intubation time was 54.4±105 h and mean ICU time 142±128 h.

There was one intraoperative death (3%, the patient presented with ruptured aorta); another patient died on postoperative day (POD) 2 (emergent group; 3), 30-day mortality was 6% (2 of 32 patients). All remaining patients had f/u for six months; another patient died within the first six months after the surgery, a total of 3 of 32 patients had died within six months, actuarial survival was 90% at six months. The overall incidence of neurologic adverse events was 9%, however, only one patient had CVA with focal deficit (3%). The other two patients had global neurologic dysfunction, in forms of anoxic encephalopathy and change in mental status. Other significant postoperative complications included atrial fibrillation in 15 patients (46%), ventricular fibrillation requiring CPR in one patient (3%), and pericardial effusion requiring pericardiocentesis in eight patients (25%). Postoperative atrioventricular block (AV block) occurred in three patients (9%), Renal insufficiency (elevated creatinine 2 mg/dl from the base line) occurred in four patients (12%) and renal failure requiring temporary dialysis occurred in three patients (9%). The overall respiratory complications in our patients included pneumothorax in two patients (6%) and pneumonia in five patients (15%). Mean intubation time 54.4±105 h and mean ICU time 142±128 h. Vocal cord paralysis was seen in one patient (3%).

The need for blood transfusion (870±1200 ml) correlated with the length of cross-clamping time (139±58 min) (Fig. 1) (95% CI 0.35–0.79, P=0.0001) but not with the circulatory arrest time (38.5±18.9 min) (95% CI −0.60–0.34, P=0.51). The average for platelet transfusion was 9.6±10.4 units). Three patients (9%) needed exploration for postoperative bleeding. Cross-clamp time (139±58 min) didn’t have any impact on length of ICU stay (95% CI −0.39–0.23, P=0.58) nor did the length of circulatory arrest time (95% CI −0.44–0.21, P=0.44). While the length of circulatory arrest didn’t have any impact on length of ICU stay (95% CI −0.44–0.21, P=0.44), the NYHA stage of the patient correlated with length of the ICU stay.

Table 1
Preoperative patient characteristics

<table>
<thead>
<tr>
<th>Condition</th>
<th>Preoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marfan’s syndrome</td>
<td>1</td>
</tr>
<tr>
<td>H/O CABG</td>
<td>2</td>
</tr>
<tr>
<td>Bicuspid aortic valve</td>
<td>7</td>
</tr>
<tr>
<td>Edocarditis</td>
<td>3</td>
</tr>
<tr>
<td>COPD</td>
<td>1</td>
</tr>
<tr>
<td>TIA</td>
<td>2</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>12</td>
</tr>
<tr>
<td>CAD</td>
<td>12</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>8</td>
</tr>
<tr>
<td>PVD</td>
<td>5</td>
</tr>
<tr>
<td>DM</td>
<td>3</td>
</tr>
<tr>
<td>HTN</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 2
Status of patients at the time of surgery

<table>
<thead>
<tr>
<th>OR status</th>
<th>n, %</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective</td>
<td>0, 0</td>
<td>Procedure could be deferred without increased risk</td>
</tr>
<tr>
<td>Urgent</td>
<td>13, 40.6</td>
<td>Procedure required during same hospitalization</td>
</tr>
<tr>
<td>Emergent</td>
<td>15, 46.8</td>
<td>Ischemic dysfunction, rest angina despite maximum therapy</td>
</tr>
<tr>
<td>Salvage</td>
<td>4, 12.5</td>
<td>Shock with or without circulatory support undergoing CPR, two patients had ruptured</td>
</tr>
</tbody>
</table>
Fig. 1. Correlation between blood transfusion and cross-clamping time. (95% CI 0.3576–0.7969, \( P = 0.0001 \).)

Fig. 2. Correlation between NYHA and ICU time. (95% CI 0.001300–0.6227, \( P = 0.0496 \).)

Fig. 3. Correlation between age and LOS. (95% CI 0.03126–0.5778, \( P = 0.0317 \).)

4. Discussion

The chief limitation of our study is the relatively small number of patients, which affects the power of the study. However, our results are in concert with the current data in the literature, and in some instances, reveal new insights into expected postoperative complications and caveats.

One of the observations in our study was the correlation between the severity of heart failure and the length of ICU stay (\( P = 0.04 \)). Patients with advanced heart failure might require longer monitoring in the intensive care unit. Another interesting observation in our study was the correlation between cross-clamping time and need for postoperative blood transfusion (\( P = 0.0001 \)). The 30-day mortality in our series was 6% (2 of 32 patients), and the actuarial survival was 90% at six months. Considering the stratification of our patients (elective 0 patients, urgent 13 patients, emergent 15 patients, salvage 4 patients), the majority of our patients (stage 3 and 4; \( n = 19 \); 59%) were in critical condition at the time of surgery, which might explain the high mortality and postoperative complications.

Apaydin et al. [8] reported in a series of 108 patients a hospital mortality of 25%; a high percentage of patients (34%) in their series had acute dissection requiring emergent intervention. Further, the surgical morbidity and mortality after aortic arch replacement seems to be higher if the aorta has already ruptured [9]. In a recent series of 290 patients, Trimarchi et al. [2] categorized the patients as high risk (hemodynamically instable) or low risk (stable patients). The overall in-hospital mortality was 25%; 31% for the high-risk group compared to 16% in the low-risk group. Long et al. [10] reported in a series of 70 patients an operative mortality of up to 50% for emergency patients compared to 9% for stable patients. The authors concluded that the operative outcome is determined by the status of patients at the time of presentation [10]. Other authors such as Safi et al. [11] reported a 30-day mortality of 5% in 117 patients undergoing stage I elephant trunk reconstruction. Czerny et al. [12] reported a mortality of 11% in a series of 202 patients who underwent arch repair under deep hypothermic circulatory arrest. Other authors reported a surgical mortality of 7–30% [2–4].

Neurologic adverse event is one of the most serious complications after aorta surgery. A focal injury is more likely due to the embolization of debris from the aorta or operative field [4], while global neurologic insults are believed to reflect generalized ischemia due to prolonged inadequate perfusion causing neuropsychologic dysfunction, which is usually reversible [2]. The incidence of neurologic
complications has been reported to range from 5% to 20% [7, 13]. Spielvogel et al. [14] reported in a series of 109 patients with non-emergent total arch replacement, using hypothermic circulatory arrest, a transient neurologic dysfunction of 5.5%. Some authors [15, 16] believe that the duration of hypothermic circulatory arrest is a predictor of transient neurologic dysfunction. A period of 40 min or less of circulatory arrest is rarely associated with neurologic complications. A prolonged circulatory arrest (longer than 50–60 min) is associated with increased incidence of neurologic adverse events [17]. Schepens et al. [18] reported for stage I elephant trunk reconstructions in 100 patients neurologic adverse events in 2% of patients. Univariate analysis in their series showed that operative period before 1990 and emergent nature of procedures are significant factors for postoperative neurologic dysfunction [18]. In Hilgenberg’s series of 67 patients who underwent aortic arch repair with hypothermic circulatory arrest (mean circulatory arrest time 37 min), the stroke rate was 4.5% and the incidence of temporary neurological dysfunction was 16%. The authors believed that circulatory arrest had no impact on mortality and adverse neurologic events [19]. However, the circulatory arrest time in their series was short. In Czerny’s series [12] with 369 patients, 202 patients (54%) had arch repair with deep hypothermic circulatory arrest. Permanent neurologic injury was observed in 5% [12]. The overall incidence of neurologic adverse events in our series was 9%, only one patient had a CVA with a focal deficit (3%) and two patients had global neurologic dysfunction in forms of anoxic encephalopathy and change in mental status, which improved significantly over their hospital course.

Atrial fibrillation is one of the most common postoperative complications in cardiothoracic surgery. Matsuura et al. [20] published a large series of 470 patients with total aortic arch repair. The incidence of early postoperative stroke was 5% (23/470), while the late postoperative stroke rate was 6% (28/470) [20]. The authors reported that postoperative atrial fibrillation was the culprit for late stroke in their series. The same group [21] reported a postoperative new onset of atrial fibrillation in 52% of 483 patients after total aortic arch repair, which resulted in prolonged postoperative hospital stay and intensive care unit. Atrial fibrillation occurred in 15 patients (46%) in our series, which prolonged the length of postoperative hospital stay and intensive care unit stay in our series (P = 0.0018). Spielvogel et al. [14] reported in their series a median intensive care unit stay of three days and hospital stay of nine days; 13% of patients in their series had prolonged intubation (>48 h). Postoperative length of hospital stay in our series was 12 ± 6 days, which correlated with the patients’ age (Fig. 3) (P = value 0.0317). Further, a significant number of patients developed postoperative paracordial effusion, which was hemodynamically significant and required pericardiocentesis (n = 8; 25%).

Postoperative respiratory failure (defined as ventilation >72 h, need for reintubation, or tracheostomy) after major operations is associated with increased morbidity, mortality, and prolonged hospital stay [14, 22]. In our series, six patients (18%) were intubated for longer than 72 h (mean 94 ± 150 h). Other respiratory complications in our patients included pneumothorax after removal of chest tubes in two patients (6%), and pneumonia in five patients (15%). Vocal cord paralysis was seen in one patient (3%). Factors associated with the development of vocal cord paralysis are extension of procedures into distal arch, chronic dilatation of the aorta at the left subclavian artery, and total arch repair [23]. Renal insufficiency (elevated creatinine >2 mg/dl from the base line) occurred in four patients (10%) and renal failure requiring temporary dialysis in three patients (9%). Renal failure is associated with increased mortality after aortic arch replacement [2, 8].

5. Conclusion

Emergent aortic arch replacement can be performed with acceptable morbidity and mortality. Elderly patients and patients with compromised cardiac function have a prolonged postoperative hospital stay. Patients with advanced heart failure require a prolonged monitoring in the intensive care unit. An echocardiogram shortly before discharge is recommended to assess the size of pericardial effusion. A pericardiocentesis should be performed in hemodynamically significant pericardial effusions.

References


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*Comment: Aortic arch replacement* in intraoperative (3%) and hospital mortality (6.2%), few incidences of neurologic adverse events (9%) and nice follow up results. The research has revealed a correlation with results of operation with the NYHA stage and the age of the patients. However, it is well known that both the method used by the authors for aortic arch replacement with the use of a prefabricated trifurcated Hemashield graft (Boston Scientific, Wayne, NJ) has allowed them to considerably reduce the time of circulatory arrest and has simplified the antegrade selective cerebral perfusion. In such a situation the greatest prognostic importance for the results of an aortic arch replacement is a preoperation NYHA stage and the age of the patient.

We have pretty long and large experience in surgical treatment of aortic arch aneurysm. In all cases, an bloc technique to reimplant the arch vessels was used and various methods of brain protection (profound hypothermic circulatory arrest, retrograde cerebral perfusion, and antegrade selective cerebral perfusion). It seems obvious now that unilateral antegrade cerebral perfusion has allowed us to simplify the technique of brain protection and significantly lower incidence of neurologic complications.

**References**


*Comment: Hybrid endovascular procedure for high risk elderly patients*

**Author:** Mehrab Marzban, Tehran Heart Center, North Kargar Ave, Tehran 1411713138, Iran
doi:10.1510/icvts.2007.164871B

An interestingly good result for aortic arch aneurysm repair [1]. Recently there are a few reports in the literature of hybrid surgical and endovascular aortic aneurysm repair as cerebral debranching and stenting of aortic arch with good results [2]. The main advantage of this procedure is avoidance of total circulatory arrest and deep hypothermia especially in elderly patients with major comorbidities. I personally have good experience with this technique and would like to know your opinion about considering this option for high risk elderly patients with high NYHA class or major comorbidities.

**References**


**eComment: Aortic arch replacement**

**Authors:** Leo A. Bockeria, Bakoulev Scientific Center for Cardiovascular Surgery, Roublevskoye Shosse 135, 121552 Moscow, Russia; Anatoliy I. Malashenkov, Sergey V. Rychin
doi:10.1510/icvts.2007.164871A

These are good results in aortic arch replacement [1]. Impressive low intraoperative (3%) and hospital mortality (6.2%), few incidences of neurologic adverse events (9%) and nice follow up results. The research has revealed a correlation with results of operation with the NYHA stage and age of the patients. However, it is well known that both the method used for cerebral protection during aortic arch repair and the operative technique for aortic arch reconstruction significantly influence operative outcome in patients undergoing repair of aortic arch aneurysms [2]. The operative technique used by the authors for aortic arch replacement with the use of a prefabricated trifurcated Hemashield graft (Boston Scientific, Wayne, NJ) has allowed them to considerably reduce the time of circulatory arrest and has simplified the antegrade selective cerebral perfusion. In such a situation the greatest prognostic importance for the results of an aortic arch replacement is a preoperation NYHA stage and the age of the patient.