Early and mid-term outcomes of surgery of the ascending aorta/arch: is there a relationship with caseload?☆


Bristol Heart Institute, Bristol Royal Infirmary, Bristol BS2 8HW, UK

Received 5 November 2003; received in revised form 7 January 2004; accepted 12 January 2004

Abstract

Objectives: The relationship between caseload and early outcome remains a subject for debate in cardiac surgery. Surgery of the thoracic aorta is an area of specialist expertise within the adult cardiac surgical field. There is, however, a conflict between the concentration of expertise and the provision of effective emergency cover. This study evaluates the early and mid-term outcomes of patients undergoing surgery of the ascending aorta/aortic arch in a single institution and compares the results of a single higher volume surgeon with lower volume operators.

Methods: From March 1992 till August 2003, 296 procedures were carried out on 291 patients (aged 17–80, median 62) who underwent operations for replacement of the ascending aorta/aortic arch. One hundred and thirty procedures were carried out by the higher volume surgeon and 160 by one of the six lower volume surgeons (range 10–57). Emergency operation was performed in 138 (47%) patients. One or more other associated cardiac procedures were carried out in 65 patients (22%).

Results: The overall early mortality was 37 (12.5%). After adjustment for baseline differences, era and surgical risk/complexity, the risk of in-hospital death was lower in the higher volume group, but not significantly so. For survival to 3 years the overall risk of death was significantly lower for patients in the higher volume group (hazard ratio 0.72; 95% CI 0.54–0.95). Apart from post-operative renal failure no other significant differences between the two groups were observed.

Conclusions: Elective surgery of the ascending aorta/arch was associated with low mortality. Outcomes after emergency surgery conformed to contemporary expectations. Only limited differences were identified both with respect to the case profile and early clinical outcomes. Better outcomes in the mid-term in the higher volume group persisted despite adjustment for differences in caseload and are worthy of further study. We believe that these data support our hypothesis that dissemination of appropriate techniques among a group of surgeons represents the most practical method of service provision.

© 2003 Elsevier B.V. All rights reserved.

Keywords: Ascending aorta/arch; Caseload; Outcome

1. Introduction

There has been great interest in general and cardiac surgery with respect to the relationship between caseload and clinical outcome [1]. Indeed, it has been suggested that mortality rates might be reduced by 20–50% for a range of procedures including carotid endarterectomy, abdominal aortic aneurysm repair, pancreatectomy and oesophagectomy if carried out by high volume surgical groups [2]. In the cardiac surgical arena, not surprisingly, attention has focused on coronary artery bypass grafting and programmes undertaking lower numbers of procedures have been discouraged [3], although this relationship is by no means a clear one. Similarly in paediatric cardiac surgery [4,5] and cardiac transplantation outcomes have been related to a centre’s level of activity [6].

It has been suggested that volume-based referral strategies are most appropriate for operative interventions, which are relatively infrequent, technically complex and with challenging post-operative care [1]. Surgery of the thoracic aorta would seem to be one area where such considerations might apply. In the United Kingdom in 2000–2001, 575 procedures on the thoracic aorta were distributed between 40 cardiac surgical centres, comprising 3% of the cardiac surgical workload. Published mortalities for the surgical treatment of acute type ‘A’ dissection range...
from 5 to 26% [7,8] and major series from a small number of institutions have set high standards for others to try and emulate [9]. Based on these observations it seems reasonable to propose a relationship between case volume and outcome for surgery of the thoracic aorta.

The practical problems inherent on focusing surgery of the thoracic aorta on a small number of individuals or centres with particular expertise relates particularly to the disease processes treated. Acute aortic dissection has a high early mortality with an exponential decline in survival within a short time. Transfer to a distant specialist centre may compromise rather than improve overall survival. Even within centres with specialist expertise there will rarely be the workload to allow more than one surgeon to develop such expertise. The relatively high proportion of emergency cases makes focusing all activity on a single surgeon impractical, particularly in a healthcare environment striving to reduce doctors’ working hours.

There is therefore a conflict between concentration of expertise and the provision of comprehensive and effective emergency cover. We sought to examine the relationship between caseload and early and mid-term outcomes with respect to surgery of the ascending aorta/aortic arch. This retrospective analysis of prospectively collected data examined the strategy applied in a single centre, with a particular emphasis on the comparison of early and mid-term outcomes between a single higher volume operator and a group of low volume operators.

2. Materials and methods

2.1. Patient population

A consecutive series of patients undergoing surgery of the ascending aorta/aortic arch from March 1992 to August 2003 were identified in a single institution. Over this period a total of 296 procedures were carried out in 291 patients. The median age was 62 years (range 17–80 years) with a male preponderance (71%, 209 patients). A high proportion of the cases were carried out on an emergency basis (emergency 138 (47%) vs. elective 158 (53%).) There were 29(9.8%) patients with a history of previous cardiac surgery. The distribution of cases among the consultant surgeons revealed a distinct pattern: a single higher volume surgeon performed 130 (44%) procedures and group of lower volume operators (n = 6) performed 166 (56%) procedures (range 10–57) between them.

2.2. Data collection and definitions

Demographic data and perioperative data for the period 1992–1996 were collected by retrospective case-note review. Between 1996 and 2003 the data was collected prospectively on a computer database (Patient Analysis and Tracking System, Dendrite Clinical Systems Inc.), which has been analysed retrospectively.

Early deaths were considered as those deaths occurring during the primary hospital stay at the base hospital. Late deaths were identified from data provided from the NHS Strategic Tracing Service (NSTS). All patients were successfully matched to the NSTS database.

Definitions with respect to the operative priority, pre-morbid conditions and post-operative complications are those used in the National Adult Cardiac Database and accepted by the Society of Cardio-thoracic Surgeons of Great Britain and Ireland available at www.scts.org

Any operation on the ascending aorta with a single distal anastomosis, whether or not the under-surface of the aortic arch was replaced (hemi-arch replacement), was classified as an ascending aortic operation. Only those operations involving two or more distal anastomoses, one to the distal aorta and one or more aortic arch branches, were considered as aortic arch operations.

2.3. Operative techniques

Over the 11-year period a range of surgical techniques was practiced; nevertheless there was broad consensus with respect to the operative strategy, perfusion techniques, neuroprotective and blood conservation strategies.

2.3.1. Operative approach

All the operations were performed through a median sternotomy incision. Where improved access was required for extensive reconstructions of the distal aortic arch and/or the proximal descending aorta, a lateral T-extension into the left fourth intercostal space was used.

2.3.2. Perfusion techniques

Cardiopulmonary bypass was established through cannulation of the distal ascending aorta or proximal aortic arch. In the presence of aortic dissection or extensive aneurysm formation the common femoral artery was used. Venous drainage generally was provided by a two-stage cannula but where retrograde cerebral perfusion was used or planned for, bicaval cannulation was used. The left ventricle was vented through the right superior pulmonary vein in the majority of cases.

Myocardial protection was predominantly by a combination of intermittent antegrade and retrograde cold blood cardioplegia. Where circulatory arrest was not required, aortic cross-clamping with moderate systemic hypothermia to 28–32 °C was used. Where deep hypothermic circulatory arrest was required the target cooling temperature was 18 °C. Where there was concern about malperfusion the ascending aorta was not cross-clamped, cooling proceeded and the distal surgery was performed first.

As an adjunct to profound hypothermia, retrograde cerebral perfusion was used via the SVC cannula after the technique of Ueda et al. [10] between 1993 and 1997.
From 1997 to 2001 profound hypothermia alone was used. Since 2001, selective antegrade cerebral perfusion was used after the technique of Kazui et al. [11].

During the rewarming period where femoral cannulation was used this was maintained until bypass was discontinued at the completion of rewarming. Since 2000, reperfusion via the side arm of an Ante Flo graft (Sulzer Vasutek Inc.) has increasingly been used particularly in acute dissection to avoid malperfusion syndromes.

2.3.3. Surgical techniques

In aortic dissection the operation was adapted to the clinical findings. For the distal aorta an open distal anastomosis was used for dissections extending beyond the ascending aorta. In general an attempt was made to resect the intimal tear. Where this was in the ascending aorta this was replaced to the level of the innominate artery. Spiral tears extending along the under-surface of the arch were treated with a bevelled distal anastomosis (hemi-arch replacement). With tears within the aortic arch complete aortic arch replacement was performed.

In the dissected aorta the proximal and distal aorta was reinforced with Teflon strips. In the early period the aortic wall was reconstructed with GRF® (Microval) biological glue but more recently Bioglue (Cryolife Europa Ltd) has been used exclusively.

Where composite aortic root replacement was required the open technique described by Kouchoukos [12] was used exclusively, utilising the implantation of coronary buttons.

Valve replacement devices were with mechanical valve conduits (St Jude Medical, Carbomedics) or biological replacements (Shellhigh porcine pericardial stentless valve graft).

2.3.4. Anaesthetic techniques

Fentanyl 20–35 µg/kg and pancuronium 0.15 µg/kg was used in all cases along with isoflurane or propofol pre-bypass. Propofol 3 mg/kg per h infusion was used during the bypass routinely. Where deep hypothermic circulatory arrest was required either propofol 3 mg/kg per h infusion or thiopentone 25–30 mg/kg was used depending on individual preference latterly, trans-oesophageal echocardiography was used routinely to assess the valve competence. Use of ice packs for cerebral protection during deep hypothermic circulatory arrest again depended on individual preference.

2.3.5. Blood conservation

Aprotinin was used in the vast majority of cases. Where circulatory arrest was used, particular care was taken with the monitoring of anticoagulation. Cell savers were widely used. Other blood products were administered as appropriate and guided by thromboelastography since 1998.

2.4. Statistical analysis

Propensity scores, which estimate the probability of being operated on by the high volume surgeon, were used to take account of the imbalance in the distribution of prognostic factors between the two groups. The propensity scores were estimated using multiple logistic regression. All known characteristics of the study cohort were included in the regression model.

When estimating propensity scores missing values were imputed. For categorical variables the most prevalent category was assumed and for continuous variables the median value was used. When comparing outcomes, patients with missing data were omitted.

Baseline characteristics were compared using the chi-squared or Fisher’s exact test (categorical variables) or the Wilcoxon rank sum test (continuous variables). Quintiles of propensity score and the interaction between propensity score quintile and group (where statistically significant at the 5% level) were included as covariates when comparing baseline characteristics after adjustment.

Analyses comparing outcomes after surgery were adjusted for propensity score quintile, era of surgery, and surgical risk/complexity (see Table 4 for details). Interactions between variables were not examined. Outcomes with fewer than 10 events were not subjected to statistical analysis.

Binary variables were compared using logistic regression and model adequacy was assessed using the Hosmer–Lemeshow goodness-of-fit test. Time to event variables were analysed using Cox proportional hazards regression. Patients for whom the event had not occurred were treated as censored observations. Post-operative survival was censored at 3 years. The proportional hazards assumption was assessed and where untenable separate effects were fitted for two epochs of time. The two epochs were chosen to represent clinically meaningful periods of follow-up (see Table 4 for details). All analyses were carried out using Stata® (Stata Corporation, College Station, Texas, USA).

Results are reported as effect sizes with 95% confidence intervals, calculated using robust standard errors, and clustered by surgeon. No correction has been made for multiple comparisons, but our interpretation of the findings takes into account both the consistency and magnitude of the associations, as well as their statistical significance.

3. Results

3.1. Baseline characteristics

Baseline characteristics were broadly similar across the two groups (Table 1). The only significant differences were in age distribution and percentage of emergency cases. The higher volume surgeon operated on a significantly older population, whereas the lower volume group carried out
a significantly higher number of emergency procedures. The difference in percentage of emergency cases was expected as these patients are operated on by the surgeon on-call on a rotational basis. After adjustment for propensity scores no statistically significant differences between the groups were detected, indicating that the propensity model had successfully served to remove the imbalance in distribution of these prognostic factors.

### 3.2. Operative details

Details of the surgical procedure and operative details are summarised in Table 2. The higher volume surgeon carried out the majority of arch replacements. Similar numbers of patients had combined CABG and/or mitral valve procedures in the two groups. Use of circulatory arrest was more common amongst patients operated on by the higher volume surgeon. Cross-clamp and by-pass times were similar.

### 3.3. In-hospital outcomes

There were 37 in-hospital deaths (12.5%), 14 in the higher volume group (Table 3). After adjustment for baseline differences, era and surgical risk/complexity, the overall risk of in-hospital death was lower in the higher volume group, but not significantly so (odds ratio 0.84; 95% CI 0.51–1.39; Table 4). However, for the subset of

### Table 1

**Baseline characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Higher volume surgeon (n = 130)</th>
<th>Lower volume surgeons (n = 166)</th>
<th>(P)-value*</th>
<th>(P)-value after adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>64 (52–72)</td>
<td>60 (47–68)</td>
<td>0.01b</td>
<td>0.89</td>
</tr>
<tr>
<td>Male patient</td>
<td>92</td>
<td>117</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td>Parsonnet score</td>
<td>18 (11–30)</td>
<td>20 (10–25)</td>
<td>0.51b</td>
<td>0.92</td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>19</td>
<td>24</td>
<td>0.97</td>
<td>0.89</td>
</tr>
<tr>
<td>Hypertension</td>
<td>63</td>
<td>87</td>
<td>0.50</td>
<td>0.95</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>18</td>
<td>27</td>
<td>0.57</td>
<td>0.96</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>16</td>
<td>12</td>
<td>0.14</td>
<td>0.56</td>
</tr>
<tr>
<td>Emergency procedure</td>
<td>52</td>
<td>86</td>
<td>0.04</td>
<td>0.84</td>
</tr>
<tr>
<td>Repeat operation</td>
<td>14</td>
<td>15</td>
<td>0.62</td>
<td>0.94</td>
</tr>
<tr>
<td>Endocarditic</td>
<td>3</td>
<td>6</td>
<td>0.74c</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Data are reported as number and percentage or median and interquartile range.

* Data are compared using a \(x^2\)-test, unless indicated otherwise.

b Wilcoxon rank sum test.

c Fisher’s exact test.

### Table 2

**Surgical procedure**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Higher volume surgeon (n = 130)</th>
<th>Lower volume surgeons (n = 166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch replacement</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Composite root replacement</td>
<td>62</td>
<td>77</td>
</tr>
<tr>
<td>Interposition graft</td>
<td>61</td>
<td>89</td>
</tr>
<tr>
<td>(\geq) Valve suspended</td>
<td>33</td>
<td>54</td>
</tr>
<tr>
<td>With valve replaced</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Associated procedure(s)</td>
<td>29a</td>
<td>22</td>
</tr>
<tr>
<td>Coronary artery bypass graft</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>Mitral valve surgery</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Circulatory arrest</td>
<td>82</td>
<td>64</td>
</tr>
<tr>
<td>Circulatory arrest time</td>
<td>35 (26–43)</td>
<td>31 (26–41)</td>
</tr>
<tr>
<td>Bypass time</td>
<td>160 (139–188)</td>
<td>161 (124–200)</td>
</tr>
<tr>
<td>Cross-clamp time</td>
<td>101 (79–123)</td>
<td>93 (69–123)</td>
</tr>
</tbody>
</table>

Data are reported as number and percentage or median and interquartile range.

a One patient had both associated procedures.
elective patients the risk was significantly low in the high volume group (odds ratio 0.33, 95% CI 0.15–0.71, Table 4). In the emergency group no differences were found. Re-operation rates for bleeding, the incidence of neurological complications and length of post-operative stay were also similar in the two groups. The ‘risk’ of renal complications was significantly lower at approximately one-fifth of the risk in the other group (odds ratio 0.22, 95% CI 0.10–0.48).

3.4. Mid-term outcome

The median follow-up of survivors was 2.75 years in the higher volume group and 3 years in the other group. There were 60 deaths in total over the 3 years, 50% occurred within 11 days of surgery. The overall risk of death was significantly lower for patients in the higher volume group (hazard ratio 0.67, 95% CI 0.51–0.88), which equates to an almost 50% increased mortality risk in the group of lower volume operators.

4. Discussion

This study examined the early and mid-term outcomes for patients undergoing surgery of the ascending aorta ± aortic arch over an 11-year period in a single centre. Particular attention was paid to the relationship between outcome and caseload, with a single higher volume surgeon and a group of six lower volume surgeons. The main findings of the study were that after adjustments for case mix there was no significant difference with respect to overall early mortality between higher and lower volume surgeons. There was, however, significantly lower morbidity associated with the higher volume surgeon with a lower incidence of renal failure. There was a significantly enhanced mid-term survival in the higher volume group.
which was evident both in the elective and emergency groups.

Like many European countries, in the United Kingdom, there is no formal arrangement for the organisation of surgery of the thoracic aorta. Some centres have developed expertise and as a consequence attract a higher volume of cases [7]. With a high proportion of emergency cases (47%) in our series and the majority of these aortic dissections with a high early attrition rate not only must comprehensive emergency cover be provided but also transfer of such patients to distant specialist centres may well be inappropriate. In our own centre, individual consultant surgeons dealt with emergency cover on a rotational basis but one surgeon over the 11-year period undertook a much greater proportion of the workload. If we examine the results in our centre, overall they compare favourably with the UK National Adult Cardiac Surgical Database report, which reported an in-hospital mortality rate of 17% for surgery of the ascending aorta/arch (98 deaths in 575 procedures) in 2000–2001 [13]. The overall mortality of 12.6% in our series over 11 years is similar to one of the more prestigious centres internationally who quote a 12.1% in hospital mortality rate [14]. We can be confident that outcomes in our centre were comparable to national and international standards.

While no studies have been done to examine the volume–outcome relationship in the specific context of surgery of the ascending aorta/arch, numerous studies have examined this relationship in other areas of surgical care. Luft and colleagues [15] first examined the volume–outcome hypothesis in 1979 and concluded that for operations like CABG, hospitals performing more than 200 procedures annually had lower mortality than those performing fewer than 200 procedures annually (3.4 vs. 5.7%). This has been referred to as the ‘threshold volume’. In 1991, Hannan et al. [16] used risk-adjusted clinical data to examine the volume–outcome relationship and suggested that while surgeon volume was significantly related to mortality, hospital volume was only marginally related to mortality ($P = 0.04$). It was also found that high volume surgeons in high volume hospitals achieved the best results.

Contrary to these studies, the data from the Veterans Affair hospitals, which examined the volume–outcome relationship in context of eight common non-cardiac procedures, showed no relationship between volume and 30-day mortality nor was there a volume threshold [17]. Clark [18] when examining the volume–outcome relationship for CABG showed a weak to very weak inverse correlation between volume and mortality, which achieved clinical significance only for groups performing less than 100 procedures per year. Other studies have shown that no association between hospital CABG volume and in-hospital mortality [19,20].

Shahian and Normand in their recent review on volume–outcome relationship have highlighted the controversial aspects of the studies examining the volume–outcome hypothesis. The differing data sources, wide variation in risk-adjustment among studies, cross-sectional nature of most studies, the different models of statistical analysis used in different studies are some of the concerns raised by the authors. The definition of low volume or threshold volume is also quite variable. Moreover they raise the conceptual question that while some technical proficiency is necessary for good outcome, high quality results are often achieved by low to moderate volume providers and also high volume does not guarantee high quality.

The relationship between caseload and outcome is a complex one with respect to cardiac surgery. Relationships between caseload and outcome have been accepted for paediatric cardiac surgery [4,5] and higher volume transplant centres [6] but to our knowledge this relationship has not been examined in relation to surgery of the thoracic aorta.

In our centre we did not demonstrate such a relationship with early mortality after adjusting for case mix. Nevertheless, at mid-term follow-up there was a definite improvement in survival, which again persisted after adjustment for case mix. The late causes of death, whether they were related to aortic complications or other cardiovascular causes have not been established. We may speculate that a higher volume surgeon would more effectively conserve valves, replace more valves with biological substitutes reducing the risk from warfarin anticoagulation and be more willing to carry out more extensive aortic reconstructions, reducing the risk of late aortic complications and hence achieve better outcome.

The deficiencies in our study are that the overall cohort of patients is a small one of 296 procedures. Indeed with respect to the higher volume surgeon it might be argued that 130 procedures is not a high enough volume to qualify for this description. There was undoubtedly ‘leakage’ in the both series of cases and expertise but this did not occur in a recognised and consistent manner. On occasion the higher volume surgeon did perform cases originally referred to one of the other surgeons. In addition, the higher volume surgeon did on a few occasions assist the lower volume surgeons with more complicated cases. This did not happen in a systematic way. In addition the higher volume surgeon did not perform the highest aortic caseload for each of the 11 years of study. Finally, and which is the most difficult to define, it is possible that institutional factors which relate to case selection, anaesthesia and perfusion techniques and intensive care skills are a more important determinant of outcome than individual surgical skill. Indeed for areas like paediatric cardiac surgery and cardiac organ transplantations comparisons have tended to be between institutions [5,6] rather than between individual surgeons. Further comparison in this area between higher volume and lower volume institutions would clearly be of interest.

Overall, we have satisfied ourselves that the early mortality of the patients was not compromised by
the organisational strategy that we consistently adopted over an 11-year period. The lower morbidity and better long-term survival in the higher volume surgeon’s caseload does support a role for some concentration of expertise. Further work to establish the reasons for the difference in late outcome and a broader comparison between higher and lower volume centres would be of value.

Acknowledgements

We would like to thank Mr J.A. Hutter, Mr F. Ciulli, Mr M.J. Underwood, Mr J.P. Dhasmana, and Mr J. Wisheart, for contributing to this study by operating on the patients. We also acknowledge the contribution of our anesthetic colleagues and the nursing staff for management of these patients.

References


Appendix A. Conference discussion

Dr A. Graffigna (Trento, Italy): You pointed out the differences between high and low volume centers, but may these differences be due to the fact that the high volume centers have better services in terms of like diagnosticians and lower times from pain to surgery?

Mr Narayan: I think you have somehow misunderstood my presentation. I was telling you about a higher volume surgeon and lower volume surgeon(s) in a single institution. We are not comparing a high volume center and a low volume center.

Dr P. Mortensen (Odense, Denmark): Some of the differences in your starting data was that the low volume surgeons had more acute cases. Is that an impact of your midterm results that the high volume surgeons had a better outcome, that it was not emergency cases he did?

Mr Narayan: Not exactly, because we have subanalyzed the data, and we found that the same difference stays true for both elective and emergency cases.

Dr S. Karuker (Turkey): I would like to know, what was the reason of late deaths actually in the low volume surgeon group?

Mr Narayan: We do not have all the information about the deaths. Some of them were obviously related to cardiac causes, but unfortunately we don’t have the data at the moment.