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Contemporary Results for Proximal Aortic Replacement in North America

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Abstract

Objectives—To characterize operative outcomes for ascending aorta and arch replacement on a national scale and develop risk models for mortality and major morbidity.

Background—Contemporary outcomes for ascending aorta and arch replacement in North America are unknown.

Methods—We queried the Society of Thoracic Surgeons Database for patients undergoing ascending aorta (+/− root) +/− arch replacement from 2004 to 2009. The database captured 45,894 cases, including 12,702 root, 22,048 supracoronary ascending alone, 6,786 ascending+arch, and 4,358 root+arch. Baseline characteristics and clinical outcomes were analyzed. A parsimonious multivariable logistic regression model was constructed to predict risks of mortality and major morbidity.

Results—Operative mortality was 3.4% for elective and 15.4% for non-elective cases. A risk model for operative mortality [c-index 0.81] revealed a risk-adjusted odds ratio (OR) for death following emergent vs. elective operation of 5.9 [95% confidence interval (CI) 5.3, 6.6]. Among elective patients, end stage renal disease and re-operative status were the strongest predictors of mortality (adjusted OR 4.0 [95% CI 2.6, 6.4] and 2.3 [95% CI 1.9, 2.7] respectively, $p<0.0001$).

Conclusions—Current outcomes for ascending aorta and arch replacement in North America are excellent for elective repair; however, results deteriorate for non-elective status, suggesting that increased screening and/or lowering thresholds for elective intervention could potentially improve outcomes. The predictive models presented may serve clinicians in counseling patients.

Keywords

aortic disease; aortic surgery outcomes; aortic aneurysm and dissection

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Despite development of improved operative techniques and circulatory adjuncts, existing published data suggests that ascending aortic and arch repairs retain significant morbidity and mortality (3). However, the best clinical studies suffer important limitations including single-institution reporting, small sample sizes, and reporting of operative techniques no longer commonly in use. As such, the objectives of this study are: (1) to report the characteristics and outcomes of patients undergoing ascending aortic and arch replacement in a large contemporaneous North American cohort; and (2) to determine the predictors of mortality and major morbidity for these patients.

Methods

Data Source

The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) currently houses data from over 950 participants, representing greater than 90% of the cardiac surgery centers in the United States. Clinical sites enter data using uniform definitions (available at: http://www.sts.org/doc/8428) and certified software systems, with data storage and analysis performed at the Duke Clinical Research Institute (Durham, NC). The quality of the data has been rigorously assessed by comparison with independent national and regional datasets (4). The present study was approved by the Access and Publications Committee of the STS Workforce for National Databases as well as by the Duke University institutional review board.

Patient Population

The study population consists of all patients with aortic pathology requiring repair of the ascending aorta (+/− root) +/− arch reported to the STS ACSD between 2004 and 2009. Patients undergoing descending thoracic or thoracoabdominal aortic replacement were not included in the analysis. The STS ACSD first began distinguishing aortic replacement location (ascending, arch, descending, and thoracoabdominal) in 2004, with implementation of STS case report form version 2.52. The current analysis was based primarily on case report form version 2.52.

Data Collection and Definitions

Those variables previously identified in the peer-reviewed literature as potential predictors of outcome in aortic surgery were included as candidate variables for the analysis, as well as all variables from existing STS 30-day operative mortality and morbidity risk models (5,6). Data regarding maximal aortic diameter, use of circulatory arrest or adjunctive cerebral perfusion, connective tissue disorders, coagulation, liver disease, and specifics of intraoperative neuromonitoring were not available for study.

The primary outcome variable was operative mortality, defined as death from any cause either in-hospital or within 30 days of the index thoracic aortic operation. Preoperative shock was defined as systolic blood pressure < 80 mmHg or cardiac index < 1.8 despite maximal treatment. Stroke was defined as persistent neurologic deficit lasting >72 hours; renal failure was defined as a doubling of the serum creatinine and an absolute value >2.0; prolonged ventilation was defined as mechanical ventilation > 24 hours postoperatively. The secondary outcome variable was the composite endpoint of operative mortality and major morbidity, where major morbidity was defined using the standard STS database composite of stroke, renal failure, prolonged ventilation, deep sternal wound infection, and reoperation. Further details regarding STS ACSD data definitions are available online (7).

Statistical Analysis

Baseline patient characteristics and outcomes were summarized by the percentage distribution for categorical variables and medians and 25th, 75th percentiles for continuous variables. Missing data were rare (<0.5% for all variables). Missing values of BMI were imputed to gender-specific median values. Missing values of ejection fraction were imputed to gender-specific median values for patients with congestive heart failure, otherwise were imputed to 50%. Missing values of the remaining risk factors and various outcomes were defaulted to their most common value.

Logistic regression modeling was used to estimate the risk of the individual outcome as a function of patient variables. Models were created for the overall study cohort in addition to the subset of elective patients. Generalized Estimating Equations (GEE) methodology was used to fit the models (8). C statistics were calculated and compared for the full model and reduced model. For either mortality or major morbidity and mortality, a reduced model was able to explain approximately 99% of the variation in the predicted log odds as estimated by the full model. Full and reduced models were fit again in the overall population to obtain the risk adjusted odds ratios (ORs) for predictors.

Results

Centers Performing Proximal Aortic Replacement

In 2004, the first year the STS ACSD began recording the location for aortic replacement, 285 North American centers reported 2,121 proximal (ascending +/− arch) aortic replacements. By 2008, 806 participating centers reported 11,033 cases. Figure 1A shows the proximal aortic cases captured per year in the STS ACSD, both as the raw number of cases reported and as a percentage of total STS ACSD cases each year. Figure 1B displays, for each year of study, the proportion of STS ACSD centers performing proximal aortic replacement and the median number of cases reported per center performing the procedure. While the proportion of centers performing proximal aortic replacement increased each year, the number of proximal aortic replacements per center remained relatively constant from 2005 to 2009 (approximately 12 cases per center).

Patient and Operative Characteristics

Table 1 displays patient demographics for the overall proximal aortic replacement cohort stratified by location of aortic replacement. As a whole, patients undergoing supracoronary ascending aortic replacement +/− arch were older with more comorbid conditions 59% of cases were elective, 20% urgent, and 20% emergent. The most common indications reported for an urgent procedure were anatomical considerations (30%), aortic dissection (25%), and valve dysfunction (24%). For emergent cases, dissection was the indication 94% of the time. Supracoronary ascending +/− arch procedures were most common in the non-elective setting with >50% of ascending + arch cases being non-elective. The addition of arch replacement to ascending aortic or root replacement increased cross clamp and operative times modestly.

Clinical Outcomes

Figure 2 displays operative mortality stratified by case status. Table 2 shows univariate outcomes for the overall proximal aortic population, stratified by location of aortic repair and elective versus non-elective case status. Overall operative mortality was 8.3%, including 3.4% for elective and 15.4% for non-elective cases. Mortality was highest for non-elective supracoronary ascending + arch replacement at 17.6%. Nonfatal adverse outcomes included stroke or coma in 6.6%, renal failure in 8.3%, perioperative MI in 2.4%, prolonged ventilation in 27.8%, and deep sternal wound infection in 0.6%. Similar to mortality, stroke rate was highest for cases involving replacement of the supracoronary ascending aorta and arch (Table 2). Reoperation for bleeding occurred in 7.4% and reoperation for any cause in 14.2%. Postoperative length of stay > 14 days was reported for 15.7% of patients.

Predictive Models

Table 3 displays results of a subset of the predictors in the reduced model for operative mortality following proximal aortic replacement. The c-index of the reduced predictive model was 0.8176 (compared to 0.8179 for the full model). The risk-adjusted odds ratio (OR) for death following emergent vs. elective operation was 5.9 [95% confidence interval (CI) 5.3, 6.6; p<0.0001]. Adjusted OR for urgent versus elective operation was 2.0 (95% CI 1.8, 2.3; p<0.0001). Concomitant CABG (adjusted OR 2.1) and concomitant mitral valve procedure (adjusted OR 1.6) each conferred significantly higher risk of death. Adjusted OR for mortality with arch involvement was 1.2 (95% CI 1.1, 1.4; p=0.0002). However, the adjusted OR for root involvement was 1.0 (95% CI 0.9, 1.1; p=0.72) in the full model and this variable did not remain in the reduced model.

Table 4 displays results of the multivariable model for major morbidity or mortality. The c-index of the reduced predictive model was 0.7816 (compared to 0.7827 for the full model). Results of the predictive model for major morbidity or mortality were similar to those in the operative mortality model. Table 5 displays the predictors of operative mortality among patients having an elective operation. The c-index was 0.77 for the reduced model compared to 0.78 for the full model. The reduced model could explain approximately 96% of the variation in the predicted log odds as estimated by the full model. Among elective patients, end stage renal disease (preoperative dialysis) was the strongest predictor of mortality with adjusted OR 4.0 (95% CI 2.6, 6.4; p<0.0001). In patients undergoing reoperation (including any redo sternotomy), adjusted OR for mortality was 2.3 (95% CI 1.9, 2.7; p<0.0001). Predictors of major morbidity and mortality among elective patients are presented in Table 6. The reduced model (c-index 0.71) was able to explain 98% of the variation in the log odds as estimated by the full model. Results of the predictive model for major morbidity or mortality in the elective setting were again similar to those in the operative mortality model.

Discussion

The present study provides a broad overview of the current practice and outcomes for proximal aortic replacement in North America. The 45,894 patients captured in the STS ACSD between 2004 and 2009 represent the largest contemporaneous cohort of proximal aortic replacement reported to date. During the study period, an increasing number of these procedures were reported to the database each year, while the median number of cases performed annually at any given center remained few (approximately 11 to 12 cases per year). The observed elective operative mortality of 3.4% is excellent; however, results markedly deteriorate for non-elective status and the observed overall operative mortality of 8.3% and overall stroke rate of 6.6% indicates room for continued improvement. The multivariable models predicting operative mortality and major morbidity confirm the critical prognostic importance of procedure status: adjusted OR 5.9 and adjusted OR 2.0 for operative death with emergent and urgent operation, respectively, versus elective cases. Arch involvement was associated with increased risk of mortality and major morbidity; however, involvement of the aortic root was not. Despite being technically less challenging than root replacement, adverse outcomes appeared more common after supracoronary ascending (+/− arch) replacement in both the elective and non-elective settings, likely secondary to the older age and greater comorbidities of these patients. Among the subset of elective patients, severe renal dysfunction, reoperation status, severe chronic lung disease, and concomitant procedures are the strongest predictors of operative mortality and major morbidity.

While the morbidity and mortality of thoracic aortic repair remains high relative to other surgical procedures, patient outcomes have improved in each of the past 3 decades due in part to advances in operative approaches, perioperative care, and increased surveillance (3,9–14). Single-institutional studies from tertiary aortic surgery referral centers have reported in-hospital mortality ranging from 3 to 8%, 30-day mortality 5 to 10%, stroke 3 to 6%, and renal failure 2 to 10% (14–19). The findings of the present study indicate comparable results among STS ACSD participating centers.

Although an increasing number of proximal aortic replacement cases were reported to the STS ACSD during each year of study, the median number of cases per participant doing at least one case has risen only slightly, with the 2008 average being only 12 cases per participating center. A recent study analyzing the effects of institutional volumes on operative outcomes for aortic root replacement in North America using the STS ACSD found a clear, inverse association between hospital procedure volume and postoperative mortality which appeared most pronounced among centers performing fewer than 30 to 40 elective aortic root procedures per year (20). Recent data from 2,218 CABG patients, however, has found that outcomes did not vary significantly based on volume but instead were correlated with compliance with National Quality Forum process measures (21). This suggests an opportunity for further systems analysis aimed at optimizing quality of care for patients requiring proximal aortic replacement by examining the role of volume and other processes of care in thoracic aortic surgery.

The risk models presented herein may assist clinicians in risk stratification and patient counseling when planning proximal aortic replacement. Urgent/emergent procedure status, reoperation, chronic renal failure, and pulmonary disease have each been associated with adverse outcomes in smaller observational studies of ascending and aortic arch repair (3,17,19) and are corroborated by the results of the present analysis. Performance of concurrent CABG or mitral valve procedure was shown to increase postoperative risk for mortality and major morbidity among the overall study cohort (Tables 3 & 4) as well as the subset of elective patients (Tables 5 & 6). In addition, concomitant arch replacement was associated with an increased risk for adverse outcomes in all models but root replacement was not. For the clinician counseling patients prior to an elective proximal aortic replacement procedure, the predictive models based on data for greater than 27,000 elective patients provide a guide to estimating the increased risk of perioperative death and major morbidity in the setting of renal disease, lung disease, heart failure, and other comorbidities.

The current STS ACSD study presents a first look at outcomes for repair of acute Type A aortic dissection in North America. 94% of the 9,289 emergent cases were due to acute aortic dissection and mortality in this cohort was 21.5%, which is very similar to the approximately 25% 30-day mortality for patients treated surgically in reports from the International Registry of Acute Aortic Dissection (22). The current cohort represents the largest report of emergent Type A dissection repairs to date and, unfortunately, highlights that results with surgical treatment of this disease appear to have improved little over the past 20+ years (23). However, prior work has suggested that outcomes for repair of acute type A dissection appear highly influenced by the arena of care (24), and operative mortality rates below 10% have been achieved at experienced high-volume aortic centers (25,26). Consequently, these findings should remind those involved in the treatment of aortic disease of the need for continued improvement in the management of this challenging patient population, and efforts to standardize or centralize care of acute type A dissection patients may be warranted.

The most common indication for replacement of the ascending aorta and/or arch is thoracic aortic aneurysm (17,27). Current ACC/AHA/AATS/STS guidelines recommend evaluation for elective repair in asymptomatic patients with an ascending (Class I recommendation) or arch (Class IIa) diameter of 5.5 cm and prompt evaluation for surgical intervention in patients with symptomatic aneurysms (Class I) (28). These current joint U.S. society guideline size criteria recommendations are based on previous observations that the risk of a serious adverse event (rupture, dissection, death) exceeds the risk of elective operation when the maximum aortic diameter exceeds 5.5 to 6.0 cm (29–31). This recommendation is contingent upon the assumption that the risk of operation is approximately 5% (32). We show herein that the current elective operative mortality is actually only 3.5% across the U.S. and Canada suggesting that current diameter thresholds may need to be reconsidered.

To this point, in a 2007 report from IRAD, nearly 60% of acute type A dissection patients had ascending aortic diameters ≥ 5.5 cm at the time of dissection, and approximately 40% had diameters ≤ 5.0 cm (33). If we assume that these dissections result in emergent operations, the mortality for those cases, based on the present report, is 21.5%. With an overall elective mortality of only 3.5% for proximal aortic replacement (adjusted OR 5.9 for operative mortality with emergent vs. elective cases), the question arises as to whether we are waiting too long to intervene. Given the large denominator of patients with ascending aortic diameters between 4 and 5 cm, however, it is likely not feasible to simply recommend lowering diameter thresholds as a means of improving overall outcomes via diminishing the number of urgent/emergent procedures (34). Rather, a more practical approach would be increased screening and improved medical therapy for patients at risk for aortic aneurysm and/or dissection (10,35). Continual broadening of clinical awareness of thoracic aortic aneurysms and dissections and the methods of diagnosis should be expected to reduce the need for urgent or emergent operation and therefore reduce associated procedural morbidity and mortality.

Limitations

The clinical registry studied was observational and the results of our analyses represent hypothesis generation. Although the data source represents a significant majority of US cardiac surgical centers and includes the most recent reported results, data were limited to those reported through the STS ACSD and did not reliably distinguish underlying aortic pathologynecessitating proximal aortic replacement. We expect future studies to focus on specific pathologies with implementation of the new STS ACSD case report form version 2.73 which will differentiate aneurysm, dissection, trauma, and other aortic disease processes (7).

Further, details of the specific operative procedure performed, for example proximal arch versus total arch, are limited in the data analyzed. However, given the only modest increase in operative and aortic cross-clamp times observed in cases in which concomitant arch replacement was performed (Table 1), we would predict that the majority of arch procedures reported herein represent proximal or hemi-arch replacement. The updated STS ACSD case report form (version 2.73) instituted in July 2011 captures this information and is expected to allow further study in the future once several years' worth of data has been collected.[7] Data were also lacking regarding details of potentially important variations in aortic replacement technique including aortic diameter, connective tissue disorder diagnosis, degree of hypothermia, cerebral perfusion, and use of neurologic monitoring. Finally, all STS ACSD outcomes data are voluntarily self-reported without external adjudication of adverse events or universal auditing, which opens the possibility of under-reporting event rates.

Conclusions

Proximal aortic replacement is increasingly being performed in North America. Current outcomes for ascending aorta and arch replacement are excellent for elective repair; however, results are much less favorable for patients requiring non-elective procedures. This suggests increased screening of at-risk populations as well as lowering aortic diameter thresholds triggering elective intervention could potentially improve outcomes by reducing the fraction of operative procedures performed in non-elective circumstances. The predictive models presented may serve clinicians in developing risk stratification strategies when they counsel patients.

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Abbreviations and Acronyms

STS	Society of Thoracic Surgeons
NCSD	National Cardiac Surgery Database
HR	hazard ratio
OR	odds ratio
CI	confidence interval
BMI	body mass index
MI	myocardial infarction
CABG	coronary artery bypass grafting

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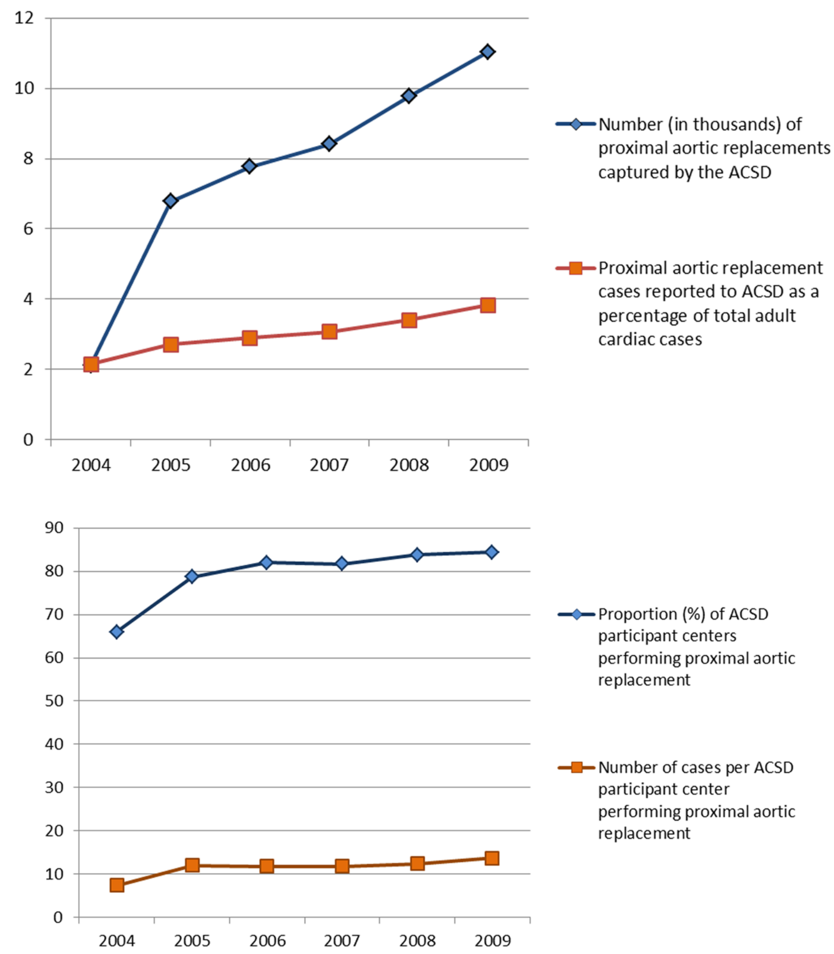

Figure 1.

Proximal aortic replacements among Society of Thoracic Surgeons Adult Cardiac Surgery Database (STS ACSD) participants by year 2004 to 2009. **A,** Total number of proximal aortic cases captured per year in the STS ACSD and proximal aortic cases as a percentage of total adult cardiac surgery cases reported to the ACSD each year. **B,** Proportion of ACSD participant centers reporting proximal aortic procedures and mean number of cases per reporting center.

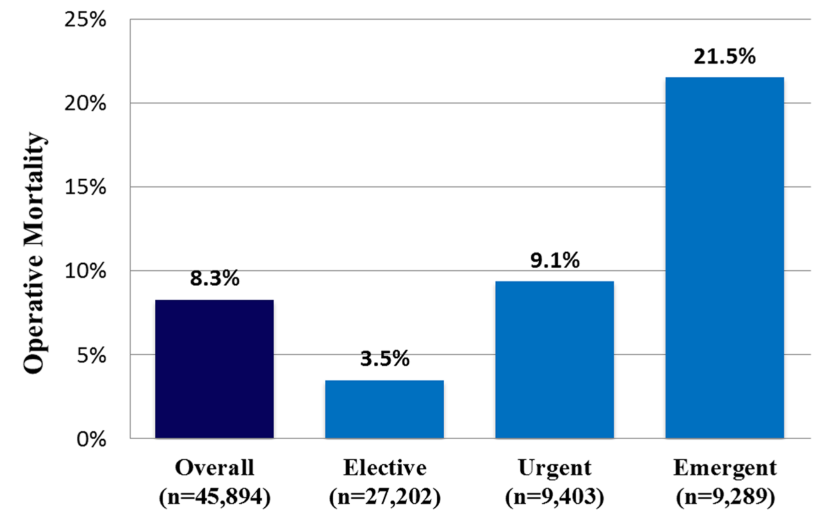

Figure 2.
Operative mortality (in hospital or 30 day) categorized by procedure status

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Table 1

Patient and operative characteristics*

	Proximal Aortic Replacement				
Variable	**Overall (n=45894)**	**Root (n=12702)**	**Ascending alone (n= 22048)**	**Ascending + arch (n= 6786)**	**Root +arch (n= 4358)**
Age	62 (52,72)	58 (48,69)	64 (54,73)	65 (54,74)	60 (49,70)
Female	32.09	24.85	34.30	39.95	29.78
Race					
Caucasian	85.19	87.34	84.85	81.27	86.78
Black	7.61	6.04	7.61	10.86	7.11
Asian	2.00	1.49	2.14	2.58	1.88
Native American	0.15	0.15	0.15	0.15	0.16
Demographic region					
Midwest	33.90	35.73	32.20	34.00	37.06
Northeast	20.22	17.62	18.08	26.32	29.07
South	27.10	26.29	30.25	23.90	18.52
West	18.78	20.37	19.46	15.78	15.35
Body Mass Index	28 (24,31)	28 (25,31)	28 (25,32)	27 (24,31)	27 (24,31)
Hypertension	72.41	66.01	74.74	78.79	69.32
Current or recent smoker Median (25^{th}–75^{th} percentile)	21.10	19.34	21.48	24.42	19.14
Hypercholesterolemia	49.19	47.43	51.10	48.17	46.21
Chronic lung disease	17.77	16.16	18.54	19.16	16.38
Renal function stages					
GFR ≥90	23.30	27.20	21.84	20.76	23.29
GFR 60–89	51.81	52.50	51.76	48.84	54.64
GFR 30–59	22.04	17.98	23.34	26.92	19.69
GFR ≤29	1.65	1.32	1.79	2.08	1.24
Dialysis	1.20	0.99	1.27	1.40	1.15
Immunosuppressive treatment	2.77	2.31	2.70	3.51	3.33
Diabetes mellitus	12	10	13	11	9
Peripheral vascular disease	19.36	16.74	19.34	23.74	20.24
Cerebrovascular disease	11.28	8.88	11.74	14.44	11.06

Variable	Overall (n=45894)	Proximal Aortic Replacement			
		Root (n=12702)	Ascending alone (n= 22048)	Ascending + arch (n= 6786)	Root +arch (n= 4358)
History of myocardial infarction	11.43	9.23	13.35	11.11	8.65
History of congestive heart failure	20.01	22.40	19.58	15.38	22.44
Any previous cardiovascular surgery	16.69	16.11	15.67	19.19	19.62
Previous CABG	5.38	3.92	6.30	5.78	4.31
Previous valve procedure	10.28	10.97	9.36	10.36	12.76
Preoperative cardiogenic shock	3.91	2.50	4.21	5.94	3.30
Procedure status					
Elective	59.22	70.11	55.53	47.27	64.80
Urgent	20.46	19.03	21.69	20.07	18.95
Emergent	19.19	10.16	21.55	30.78	15.53
Salvage	1.08	0.66	1.17	1.83	0.71
Urgent reason					
Anatomy	29.52	23.71	33.43	30.54	22.15
Aortic Dissection	24.74	14.36	22.56	47.36	30.51
Valve Dysfunction	23.53	38.68	20.13	8.00	24.46
CHF	11.44	15.60	10.01	5.73	16.95
Emergent reason					
Aortic Dissection	93.87	89.54	93.92	96.17	94.68
Shock	2.1	2.8	2.0	1.5	2.5
Valve Dysfunction	1.39	4.65	0.86	0.53	1.48
Concomitant CABG	25.94	24.50	28.83	21.19	22.85
Concomitant mitral valve procedure	7.2	5.0	9.4	6.3	4.8
Concomitant arrhythmia correction	4.97	5.53	5.45	3.04	3.85
Operation time (hours)	5.2 (4.1,6.6)	5.2 (4.2,6.7)	4.8 (3.7,6.1)	5.7 (4.6,7.1)	6.2 (4.9,7.7)
Cross clamp time (minutes)	111 (79,152)	131 (101,170)	95 (67,129)	102 (70,141)	154 (118,197)

* Categorical data are given as percentages. Continuous data are given as medians (25th, 75th percentiles).

CABG=coronary artery bypass grafting.

Table 2

Unadjusted event rates

	Proximal Aortic Replacement				
Outcome	**Overall (n=45894)**	**Root (n= 12702)**	**Ascending alone (n= 22048)**	**Ascending + arch (n= 6786)**	**Root + arch (n= 4358)**
Operative mortality (in- hospital or 30-day)	8.28	6.01	8.67	11.67	7.62
Elective	3.36	2.72	3.41	5.05	3.29
Non-elective	15.42	13.74	15.25	17.62	15.58
Stroke > 72 hours or coma > 24 hours	6.62	3.92	6.88	11.03	6.29
Elective	3.17	2.24	3.24	5.33	3.36
Non-elective	9.84	6.91	9.83	13.09	9.58
Renal failure	8.31	6.27	8.45	11.54	8.56
Elective	4.41	3.91	4.22	6.07	4.96
Non-elective	14.00	11.84	13.75	16.45	15.19
Dialysis	3.86	2.83	3.81	5.92	3.88
Elective	1.68	1.36	1.57	2.83	1.91
Non-elective	7.02	6.28	6.63	8.70	7.50
Perioperative MI	2.39	1.96	2.53	3.27	2.80
Elective	2.48	2.47	2.01	3.89	2.94
Non-elective	2.26	2.66	1.90	2.71	2.54
Pneumonia	6.65	4.48	6.82	9.80	7.25
Elective	4.12	3.04	4.06	6.45	5.10
Non-elective	10.34	7.86	10.26	12.81	11.21
Deep sternal wound infection	0.58	0.60	0.48	0.75	0.48
Elective	0.45	0.36	0.52	0.59	0.28
Non-elective	0.76	0.76	0.69	0.90	0.85
Reoperation for bleeding	7.39	7.13	7.16	8.27	7.89
Elective	5.68	5.70	5.34	6.23	6.41
Non-elective	9.88	10.50	9.44	10.10	10.63
Any reoperation	14.22	12.73	13.81	17.89	14.96
Elective	10.09	9.56	9.47	12.71	11.44
Non-elective	20.24	20.17	19.23	22.55	21.45
Prolonged ventilation > 24 hours	27.81	20.22	27.99	40.44	29.39

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		Proximal Aortic Replacement			
Outcome	**Overall (n=45894)**	**Root (n= 12702)**	**Ascending alone (n= 22048)**	**Ascending + arch (n= 6786)**	**Root + arch (n= 4358)**
Elective	16.23	12.79	15.49	25.97	19.23
Non-elective	44.66	37.66	43.63	53.43	48.11
Postoperative length of stay > 14 days	15.73	16.12	11.23	22.90	15.72
Elective	9.31	7.05	9.28	14.82	10.27
Non-elective	25.08	21.07	24.68	30.15	25.75

MI=myocardial infarction.

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Table 3

Selected predictors of operative mortality among all patients

Variable	Adjusted OR (95% CI)	P value
Status: emergent vs. elective	5.91 (5.31, 6.58)	<0.0001
Preoperative shock	2.01 (1.74, 2.31)	<0.0001
Status: urgent vs. elective	2.01 (1.78, 2.27)	<0.0001
Concomitant CABG	2.14 (1.87, 2.46)	<0.0001
Concomitant mitral valve procedure	1.63 (1.36, 1.96)	<0.0001
Any reoperation	1.63 (1.43, 1.86)	<0.0001
Cerebrovascular disease	1.43 (1.28, 1.59)	<0.0001
Chronic kidney disease stage 3 or greater (GFR <60)	1.43 (1.32, 1.56)	<0.0001
Moderate or severe chronic lung disease	1.36 (1.20, 1.54)	<0.0001
Arch involvement	1.23 (1.10, 1.37)	0.0002

CABG=coronary artery bypass grafting; GFR=glomerular filtration rate.

Table 4

Selected predictors of major morbidity and mortality among all patients

Variable	Adjusted OR (95% CI)	P value
Status: emergent vs. elective	6.72 (6.25, 7.22)	<0.0001
Preoperative shock	2.00 (1.71, 2.34)	<0.0001
Status: urgent vs. elective	1.81 (1.69, 1.93)	<0.0001
Myocardial infarction within 6	1.78 (1.26, 2.51)	0.0011
Severe chronic lung disease	1.72 (1.48, 1.99)	<0.0001
Any reoperation	1.62 (1.48, 1.78)	<0.0001
Concomitant CABG	1.59 (1.47, 1.72)	<0.0001
Chronic kidney disease stage 3 or greater (GFR <60)	1.55 (1.45, 1.66)	<0.0001
Concomitant mitral valve procedure	1.54 (1.36,1.73)	<0.0001
Arch involvement	1.45 (1.31, 1.62)	<0.0001
Cerebrovascular disease	1.37 (1.27,1.47)	<0.0001

CABG=coronary artery bypass grafting; GFR=glomerular filtration rate.

Table 5

Selected predictors of operative mortality among elective patients

Variable	Adjusted OR (95% CI)	P value
Preoperative dialysis	4.04 (2.56, 6.37)	<0.0001
Any reoperation	2.29 (1.93, 2.70)	<0.0001
Concomitant CABG	1.99 (1.70, 2.32)	<0.0001
Moderate or severe chronic lung disease	1.85 (1.52, 2.25)	<0.0001
Congestive heart failure, NYHA class IV	1.74 (1.28, 2.38)	0.0005
Concomitant mitral valve procedure	1.69 (1.34, 2.14)	<0.0001
Female vs. male	1.57 (1.36, 1.83)	<0.0001
Immunosuppressive treatment	1.55 (1.10, 2.17)	<0.0113
Age > 70 years (5 year increment)	1.44 (1.33, 1.56)	<0.0001
Preoperative atrial fibrillation	1.32 (1.12, 1.56)	0.0011

CABG=coronary artery bypass grafting; GFR=glomerular filtration rate; NYHA=New York Heart Association.

Table 6

Selected predictors of major morbidity and mortality for elective patients

Variable	Adjusted OR (95% CI)	P value
Chronic kidney disease stage 4 or greater (GFR <30)	2.68 (2.18, 3.30)	<0.0001
Severe chronic lung disease	2.05 (1.71, 2.47)	<0.0001
Any reoperation	1.88 (1.71, 2.07)	<0.0001
Concomitant mitral valve procedure	1.75 (1.52, 2.01)	<0.0001
Congestive heart failure, NYHA class IV	1.57 (1.25, 1.97)	<0.0001
Concomitant CABG	1.55 (1.44, 1.67)	<0.0001
Aortic arch aneurysm	1.50 (1.31, 1.72)	<0.0001
Race: Black vs. White	1.50 (1.29, 1.74)	<0.0001
History of myocardial infarction	1.32 (1.14, 1.54)	<0.0001
Age > 70 years (5 year increment)	1.31 (1.24, 1.39)	<0.0001

CABG=coronary artery bypass grafting; GFR=glomerular filtration rate; NYHA=New York Heart Association.