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Techniques of Proximal Root Reconstruction and Outcomes Following Repair of Acute Type A Aortic Dissection

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Abstract

***Background*: The goal of this study was to compare the early and late outcomes of different techniques of proximal root reconstruction during the repair of acute Type A aortic dissection, including aortic valve (AV) resuspension, aortic valve replacement (AVR), and a root replacement procedure.**

***Methods*: All patients who underwent acute Type A aortic dissection repair between January 2000 and October 2010 at four academic institutions were compiled from each institution's Society of Thoracic Surgeons Database. This included 189 patients who underwent a concomitant aortic valve (AV) procedure; 111, 21, and 57 patients underwent AV resuspension, AVR, and the Bentall procedure, respectively. The median age of patients undergoing a root replacement procedure was significantly younger than the other two groups. Early clinical outcomes and 10-year actuarial survival rates were compared. Trends in outcomes and surgical techniques throughout the duration of the study were also analyzed.**

***Results*: The operative mortality rates were 17%, 29%, and 18%, for AV resuspension, AVR, and root replacement, respectively. Operative mortality (p = 0.459) was comparable between groups. Hemorrhage related re-exploration did not differ significantly between groups (p = 0.182); however, root replacement procedures tended to have decreased rates of bleeding when compared to AVR (p = 0.067). The 10-year actuarial survival rates for the AV resuspension, Bentall, and AVR groups were 72%, 56%, and 36%, respectively (log-rank p = 0.035).**

***Conclusions*: The 10-year actuarial survival was significantly lower in those receiving AVR compared to those receiving root replacement procedures or AV resuspension. Operative mortality was comparable between the three groups.**

Key Words

Aorta • Aortic aneurysm • Aortic root • Aortic valve

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Introduction

Acute Type A aortic dissection is a rare and catastrophic condition with a high mortality rate [1-4]. The incidence is estimated to be between 2.9 and 4.7 per 100,000 persons per year [5, 6]. The incidence of thoracic aortic dissection and the percentage of patients undergoing operative treatment may be increasing [7]. Emergent surgery is recommended after the diagnosis of Type A aortic dissection as the mortality rate increases considerably during the first 48 hours, approaching 60% with conservative treatment alone [8, 9]. Midterm survival is higher in patients with thoracic aortic dissection who receive surgical intervention rather than medical treatment [6]. Medical therapy including volume management, anti-impulse and blood pressure control, and pain alleviation are frequently employed in patients with a history of stroke, comorbid conditions, and late presentation [10]. The aortic valve and root are frequently involved in the dissection, with as many as 40% of patients presenting with moderate or severe aortic regurgitation [11].

The three most common surgical techniques for proximal aortic root reconstruction during repair of acute Type A dissection include: aortic valve (AV) resuspension if the aortic valve and the sinuses are structurally normal, an aortic valve replacement (AVR) with a mechanical or tissue prosthesis if the valve is abnormal but the sinuses are normal, or a root replacement with a mechanical or tissue valve conduit if both the valve and sinuses are abnormal due to preexisting dilatation or extension of the intimal tear proximally to the level of the valve [9, 12]. The objectives of our study were to evaluate the effect of the three proximal aortic root reconstruction techniques on early outcomes and late survival following acute Type A aortic dissection repair.

Materials and Methods

Patients

All patients who underwent aortic dissection repair between January 2000 and October 2010 at Beth Israel Deaconess Medical Center (*n* = 41), Carolinas Medical Center (*n* = 54), Missouri Baptist Medical Center (*n* = 21), and Meijer Heart and Vascular Institute (*n* = 73) were compiled from each institution's Society of Thoracic Surgeons (STS) National Database. A total of 189 patients who underwent surgical repair for acute Type A aortic dissections with a concomitant AV procedure were included (111 patients who had an AV resuspension, 21 with an AVR, and 57 who underwent a root replacement). Patients who required only supracoronary graft placement without any intervention of the AV or aortic root were excluded (*n* = 62). Approval from the Institutional Review Boards of each center was obtained prior to this analysis. Consistent with the 1996 Health Insurance Portability and Accountability Act (HIPAA) regulations, patient confidentiality was maintained at all times.

CT angiography (CTA) or transesophageal echocardiography (TEE) was utilized to make the preoperative diagnosis of aortic dissection, which was later confirmed intraoperatively. Dedicated data-coordinating personnel prospectively generated a database containing demographic and procedural data, as well as preoperative outcomes. Late survival data was attained from the Social Security Death Index (http://www.genealogybank.com/gbnk/ssdi/). Follow-up was 97% complete.

Definitions

The definitions used in this study were attained from the STS National Database, which is available online at http://www.sts.org/national-database. Acute Type A dissection was defined as any dissection of the ascending aorta with presentation within two weeks of symptoms. Diabetes was defined as a history of diabetes mellitus of any duration regardless of the need for antidiabetic medications. Cerebrovascular accident was defined as a history of central neurological deficit persisting for more than 24 hours. Chronic lung disease was defined as emphysema, chronic bronchitis, or pulmonary disease. Prolonged ventilation was defined as pulmonary insufficiency requiring ventilator support for more than 24 hours. Hemodynamic instability was defined as the presence of cardiac tamponade, shock, acute congestive heart failure, myocardial ischemia and/or infarction, or hypotension with a systolic blood pressure less than 80 mm Hg. Operative mortality includes all deaths occurring during the hospitalization in which the operation was performed and those deaths occurring after hospital discharge within 30 days of the procedure.

Operative Technique

TEE was used intraoperatively to confirm the diagnosis of Type A aortic dissection. Following a median sternotomy, cardiopulmonary bypass (CPB) was initiated with venous cannulation of the right atrium and arterial cannulation of the femoral or right axillary artery, based on surgeon's preference. To ensure myocardial protection, antegrade cold blood cardioplegia was administered via the ostia of the coronary arteries or retrograde through the coronary sinus. A vent was then placed in the left ventricle through the right superior pulmonary vein. Once a mean bladder temperature between 15 and 18°C was attained, the aortic clamp was removed, and the aortic arch was inspected. Distal aortic anastomosis was then performed, and antegrade aortic perfusion was initiated. The creation of distal anastomosis using an open distal anastomosis and hemiarch technique versus creation of the distal anastomosis with a clamp on was based on the surgeon's preference. If the aortic valve and sinuses were normal, resuspension of the aortic valve by placing three polypropylene pledgeted sutures at the three valve commisures was performed along with replacement of the ascending aorta with a straight tube graft. If the aortic valve was structurally abnormal but the sinuses were normal, AVR with mechanical or tissue prosthesis and supracoronary aortic grafting were employed. If the aortic valve and sinuses were abnormal from dilation (more than 5 cm) or extension of the intimal tear to the valve, aortic root replacement (modified Bentall operation) with a tissue or mechanical valved conduit was used. Polytetrafluoroethylene strips were used to reinforce the proximal and distal anastomoses. In some patients, biological glue (BioGlue® surgical adhesive, Cryolife, Kennesaw, GA, USA) was used to better reapproximate the dissected layers.

Data Analysis

Univariate comparisons of preoperative, operative, and postoperative variables were preformed between groups of patients undergoing AV resuspension ($n = 111$), AVR ($n = 21$), and Bentall ($n = 57$) procedures. Continuous variables were tested using the analysis of variance (ANOVA) test for association, while categorical variables were assessed by the chi-square or Fisher exact test as appropriate according to the data distribution. Tukey posthoc analysis was performed for variables with statistically significant differences. Kaplan–Meier univariate unadjusted survival estimates were calculated and compared for all three aortic valve procedures using a log-rank test. A multivariable, stepwise, forward logistic regression analysis was conducted to determine independent predictors of operative mortality. The criterion for variable entry into the logistic model was a univariate probability level of $p < 0.1$. The quality of fit of the logistic model was tested with the Hosmer–Lemeshow goodness-of-fit test. $p < 0.05$ was considered significant. All analyses were performed using SPSS Statistics Version 21 (IBM Corp., Armonk, NY, USA).

Results

Preoperative Characteristics

Preoperative characteristics are summarized in Table 1. Tukey posthoc analysis indicated that patients undergoing root replacement procedures were significantly younger than those receiving an AVR ($p = 0.027$), while the age difference between patients with root replacement procedures and those with valve resuspension was not statistically significant ($p = 0.192$).

Operative Characteristics

Operative patient characteristics of those receiving AV resuspension, AVR, or root replacement procedures for acute Type A aortic dissection repair are presented in Table 2. Median CPB time differed by valve procedure ($p < 0.001$) and was longest in root replacement procedures followed by AVR and AV resuspension (246, 203, and 163 min, respectively). Posthoc analysis indicated a significantly longer duration of CPB in root replacement procedures compared to AV resuspension ($p < 0.001$) or AVR ($p = 0.027$), while CPB duration was comparable between the AV resuspension and AVR groups ($p = 0.392$). Arterial cannulation strategies varied between groups with increased axillary arterial cannulation in root replacement procedures and increased femoral access in AV resuspension ($p = 0.006$). BioGlue® was more frequently utilized in patients who underwent AVR compared to resuspension or the Bentall procedure ($p = 0.026$). Circulatory arrest time ($p = 0.739$) and retrograde ($p = 0.598$) and antegrade cerebral perfusion ($p = 0.351$) were not significantly different between the three groups. Patients who did not have antegrade or retrograde cerebral perfusion were repaired using profound hypothermic arrest only ($n = 118$). More patients who had AVR or root replacement underwent an open distal anastomotic technique compared to those who had resuspension ($p = 0.028$).

Postoperative Characteristics

Postoperative patient characteristics are displayed in Table 3. An increased incidence of cardiac arrest was observed in those patients receiving AVR compared to the other two groups ($p = 0.029$). Hemorrhage-related re-exploration did not differ significantly between groups ($p = 0.182$). Root replacement procedures had a lower rate of hemorrhage-related re-exploration compared to AVR; however, the differences were not statistically significant ($p = 0.067$). Operative mortality ($p = 0.459$) and hospital length of stay ($p = 0.617$) were comparable between groups. The operative mortality rates were 17%, 29%, and 18%,for AV resuspension, AVR, and root replacement, respectively.

Multivariate Analysis

In multivariable logistic regression analysis, hemodynamic instability (odds ratio (OR) = 1.9, 95% confidence interval (CI) = 0.03-0.75, $p = 0.021$) and CPB time >200 min (OR = 1.92, 95% CI = 0.04-0.54, $p = 0.004$) emerged as independent predictors of operative mortality.

Table 1. Preoperative patient characteristics.

Variable[a]	Resuspension (*n* = 111)	AVR (*n* = 21)	Bentall (*n* = 57)	*p*
Age, years	60 (20-82)	65 (39-84)	56 (19-80)	0.028
Female	31 (28%)	6 (29%)	18 (32%)	0.884
Diabetes	9 (8%)	0 (0%)	3 (5%)	0.347
Hypertension	92 (83%)	17 (81%)	41 (72%)	0.247
EF	55 (27-73)	55 (15-65)	55 (35-65)	0.118
COPD	8 (7%)	4 (21%)	3 (5%)	0.099
Creatinine	1.20 (0.50-12.5)	1.10 (0.70-2.20)	1.05 (0.60-2.60)	0.284
Hemodynamic instability	17 (17%)	2 (10%)	4 (7%)	0.180
Arrhythmias	11 (10%)	6 (29%)	7 (12%)	0.062
History of CVA	9 (8%)	2 (10%)	4 (7%)	0.930
EF <40	6 (11%)	4 (24%)	1 (3%)	0.086

[a] Continuous data are shown as median (range) and categorical data are shown as *n* (%).
AVR = aortic valve replacement; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; EF = ejection fraction.

Table 2. Operative patient characteristics.

Variable[a]	Resuspension (*n* = 111)	AVR (*n* = 21)	Bentall (*n* = 57)	*p*
CPB time >200 min	33 (30%)	10 (50%)	40 (70%)	<0.001
CPB time, min	163 (31-391)	203 (100-267)	246 (100-684)	<0.001
Circulatory arrest time, min	1.5 (0-90)	13.5 (0-30)	18 (0-62)	0.739
Distal anastomotic technique				
Distal with cross-clamp	43 (39%)	2 (10%)	17 (30%)	0.028
Open distal	71 (64%)	19 (90%)	40 (70%)	
Hemiarch technique	58 (52%)	14 (67%)	24 (42%)	0.140
Total arch replacement	9 (8%)	1 (5%)	8 (14%)	0.340
Arterial cannulation				0.006
Axillary	45 (41%)	6 (29%)	29 (51%)	-
Femoral	66 (59%)	15 (71%)	28 (49%)	-
Retrograde cerebral perfusion	12 (11%)	2 (10%)	9 (16%)	0.598
Antegrade cerebral perfusion	24 (22%)	6 (29%)	18 (32%)	0.351
BioGlue®/felt strip				0.026
BioGlue®	56 (56%)	16 (76%)	24 (54%)	-
Felt strip	26 (26%)	2 (10%)	11 (20%)	-
Both	8 (8%)	0 (0%)	7 (13%)	-

[a] Continuous data are shown as median (range) and categorical data are shown as *n* (%).
AVR = aortic valve replacement; CPB = cardiopulmonary bypass.

Survival Analysis

Unadjusted Kaplan–Meier survival estimates are shown in Figure 1. Patients undergoing AV resuspension, AVR, and the Bentall procedure, had median follow up time of 2,229 days (range 1-4802), 1,836 days (range 1-4,001), and 2,190 days (range 1-4,132), respectively ($p = 0.148$). The actuarial 10-year survival rates for AV resuspension, root replacement, and AVR were 72%, 56%, and 36%, respectively (Figure 1, log-rank $p = 0.035$), and the corresponding actuarial 5-year survival rates were 75%, 68%, and 60%. The increased 10-year survival of patients undergoing AV resuspension compared to AVR was statistically significant (p = 0.011), but the differences comparing the AVR and root replacement and AV resuspension groups were not (p = 0.171 and p = 0.220, respectively). There was an increase in the proportion of patients receiving AVR from 2000 to 2010 (Figure 2).

Discussion

Our study is among the first to compare postoperative outcomes and 10-year survival rates for patients undergoing AVR, AV resuspension, or root replacement procedures during acute Type A aortic dissection repair. Notably, we observed a decreased 10-year survival rate in patients undergoing AVR.

Preoperative Characteristics and Morbidity

Patients receiving root replacement procedures were significantly younger than those undergoing AVR. We theorize that due to the more extensive dissection in younger patients causing significant root destruction, root replacement is more frequently required in this population. Patients who underwent AVR tended to be older and have increased incidences of chronic obstructive pulmonary disease, arrhythmias, and low ejection fraction; thus, their expected survival was lower compared to the resuspension and root replacement groups. More elderly patients likely had preexisting valve pathology and comorbidities prior to thoracic aortic dissection that may have influenced the higher rate of AVR and worse outcomes.

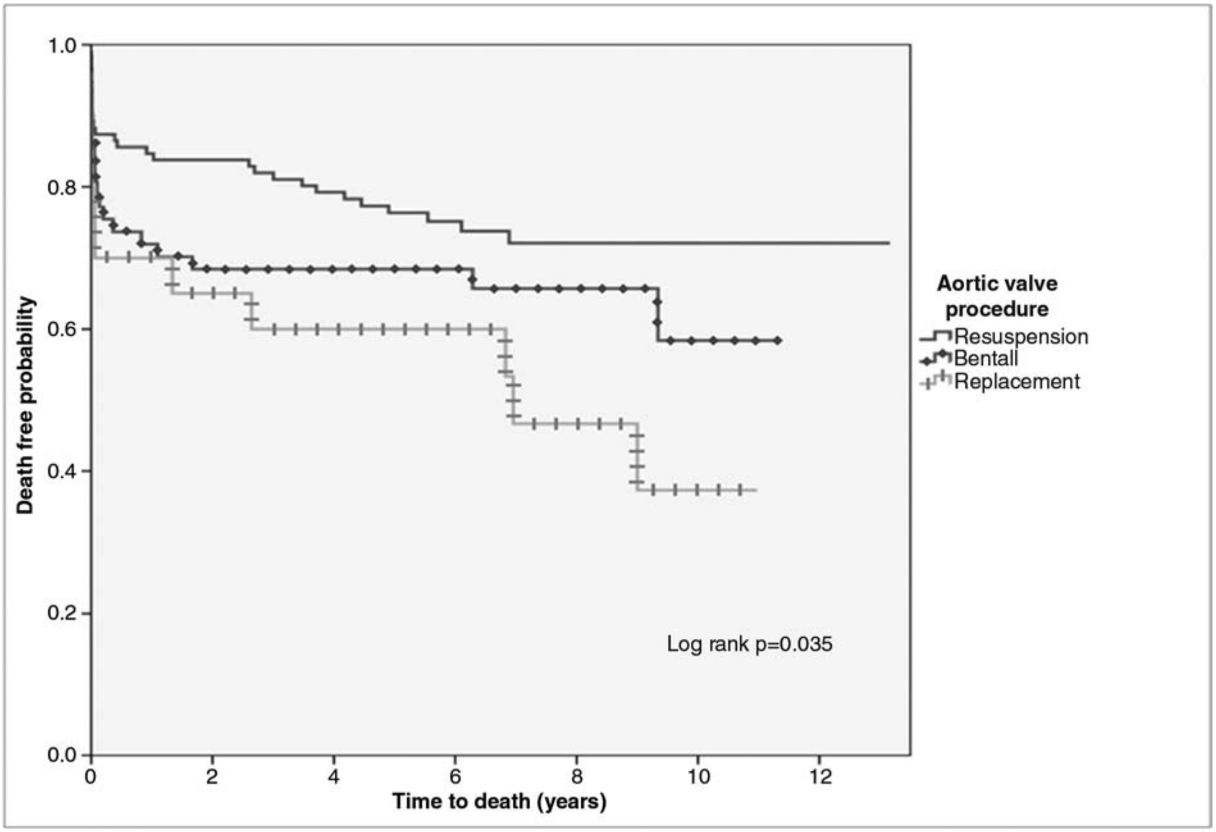
Operative Mortality

Surgical repair of Type A aortic dissection has traditionally carried a high rate of mortality. Our total operative mortality was 19%, which can be further divided into 17%, 29%, and 18% for AV resuspension, AVR, and root replacement procedure, respectively. These differences in operative mortality were not statistically

Table 3. Postoperative patient characteristics.

Variable[a]	Resuspension (n = 111)	AVR (n = 111)	Bentall (n = 57)	p
Deep sternal wound infection	1 (1%)	0 (0%)	2 (3.7%)	0.361
Prolonged ventilation	52 (49%)	5 (26%)	29 (54%)	0.115
Acute renal failure	24 (22%)	4 (21%)	12 (22%)	0.991
Hemodialysis	9 (9%)	1 (6%)	6 (13%)	0.627
Hemorrhage-related re-exploration	22 (21%)	7 (37%)	8 (16%)	0.182
Cardiac arrest	7 (7%)	5 (26%)	6 (11%)	0.029
Stroke	22 (21%)	3 (16%)	9 (17%)	0.783
Atrial fibrillation	30 (28%)	5 (26%)	12 (22%)	0.730
Length of stay, days	12 (0-70)	12 (0-45)	10 (0-99)	0.617
Operative mortality	19 (17%)	6 (29%)	10 (18%)	0.459

[a] Continuous data are shown as median (range) and categorical data are shown as *n* (%).
AVR = aortic valve replacement.



Number at risk	1 year	2 years	3 years	4 years	5 years	10 years
Resuspension (n=111)	94 (84%)	93 (82%)	89 (79%)	83 (76%)	67 (75%)	10 (72%)
Bentall (n=57)	41 (68%)	39 (68%)	38 (68%)	32 (68%)	31 (68%)	9 (56%)
Replacement (n=21)	14 (65%)	13 (60%)	12 (60%)	11 (60%)	10 (60%)	3 (36%)

Figure 1. Unadjusted Kaplan–Meier survival estimates comparing types of aortic root reconstruction.

significant; however, the trend toward a higher mortality for patients undergoing AVR might be related to their advanced age and higher number of medical comorbidities. The mortality rates reported in this study are comparable to those recently described in the literature. Klodell et al. [13] reported an operative mortality of 17% in a cohort of 190 patients who underwent surgery for acute Type A aortic dissection between 1998 and 2010. In another study, Subramanian et al. [14] calculated an operative mortality of 23% for 208 patients with acute Type A aortic dissections who underwent surgical repair of the aortic root between 1995 and 2010, as well as an operative mortality of 27% for those who received a similarly modified Bentall procedure. Lai et al. [15] reported an operative mortality of 16% in 123 patients with Type A aortic dissection with associated aortic regurgitation between 1967 and 1999. Conversely, a low operative mortality of 10% was reported by Bavaria et al. [1] in a population of 163 patients who underwent surgical treatment for acute Type A aortic dissection, of which 83% underwent aortic root repair. Other studies have published operative mortality figures between 14 and 26% in the setting of acute Type A aortic dissection [4, 6, 7, 16-18]. The average mortality decreased from 24% during the first period of the study (years 2000-2005) to 12% during the second half, indicating a continuous improvement in preoperative, operative, and postoperative care. Similarly, the postoperative rate of cardiac arrest was halved from 12% in the first study period to 6% during the second study period. The relatively high postoperative stroke rate may be due to the high rate of patients who presented with hemodynamic instability.

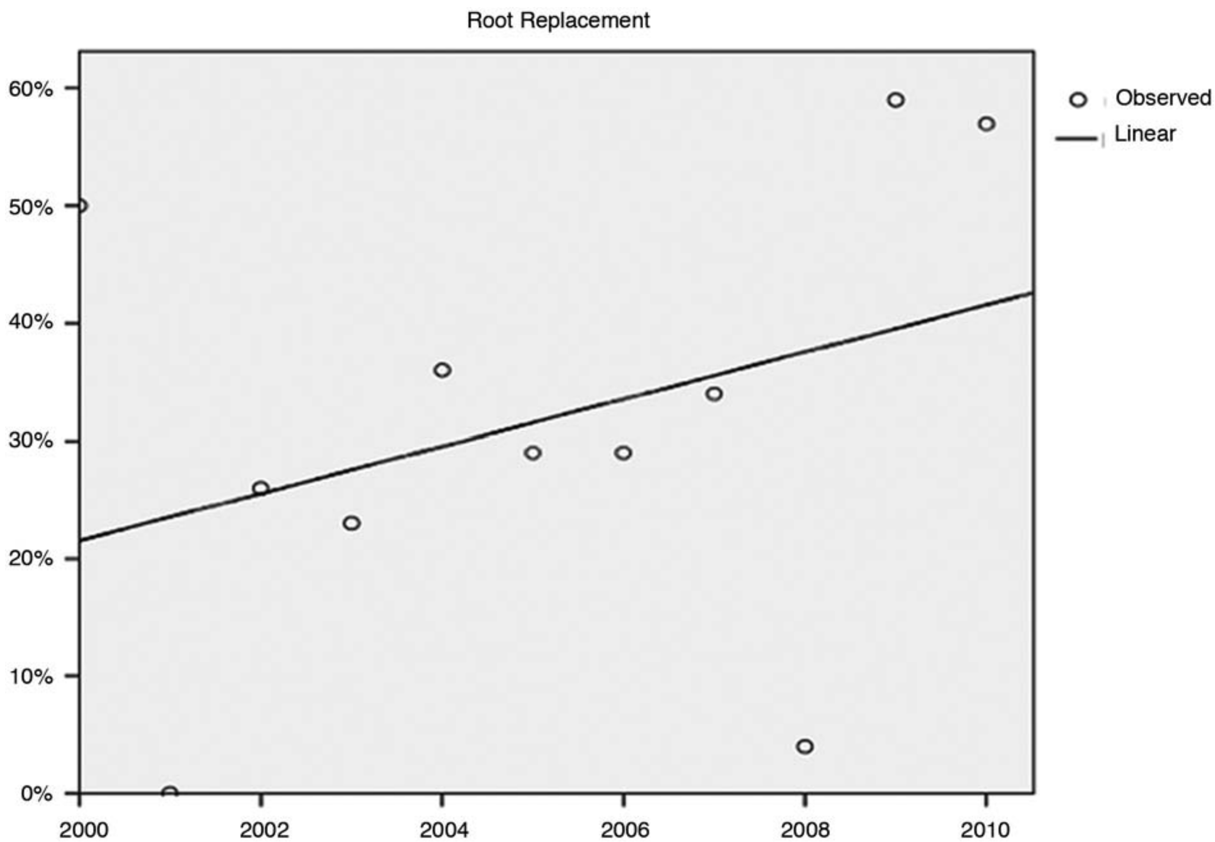


Figure 2. Trends in root replacement procedures (Bentall procedure), over time in patients who underwent acute Type A aortic dissection repair.

Actuarial 10-Year Survival and Trends Over Time

Survival analyses yielded statistically significant differences between valve procedures, with higher survival rates in patients receiving AV resuspension than those undergoing AVR or Bentall procedures. The survival rates for AV resuspension and root replacement procedures were slightly higher than those reported in other studies, however, survival for AVR was lower. Sabik et al. [19] reported a noticeably decreased survival in patients with root replacement and increased survival of those receiving AVR in a cohort of 208 patients undergoing operations for both acute and chronic ascending aortic dissection between 1978 and 1995. This contradicts with our findings, possibly because the Cleveland Clinic study included both acute and chronic dissections, while our study focused on acute Type A aortic dissections. Consistent with our results, Lai et al. [15] found that there was no significant difference in long-term overall survival rates among these three surgical techniques; however, midterm survival (4-6 years) tended to be lower for those patients receiving AVR, which is again in accordance with our findings. Over time, we noticed an increased rate of root replacements in patients with Type A aortic dissection, which can be partially explained by the accumulated surgical experience that allowed more surgeons to perform root replacement in the face of extensive involvement or destruction of the aortic root instead of attempting a root repair as was often done in the early years of the study. In our series, prolonged cardiopulmonary bypass was found to be an independent predictor of mortality regardless of the aortic valve procedure. Although more time consuming, root replacement is required in patients with destroyed roots and results in better outcomes compared to aortic valve replacement that leaves diseased aortic tissue that may result in bleeding or other complications. The higher incidence of cardiac arrest in patients with aortic valve replacement may be related to complications from the proximal diseased root, such as bleeding from the reconstructed aortic root or extension of the dissection into the coronary arteries.

Key Findings

This study is among a few reports in literature evaluating the outcomes of the three main surgical techniques for proximal root reconstruction. Operative mortality was found to be comparable between the three groups in our study. Improved late survival of patients undergoing valve resuspension compared to AVR, as well as comparable survival to those who received Bentall procedures may encourage repair of the native aortic valve when technically feasible. An increasing trend was observed in the proportion of patients receiving root replacement over time. Comorbidities, presentation (with hemodynamic instability), and a prolonged CPB time tend to be the best predictors of surgical outcomes. Early recognition and careful management of aortic dissections remain a top priority for optimizing patient outcomes. The median age of patients undergoing a root replacement was significantly younger than the other two groups, likely due to more extensive involvement or destruction of the aortic root or earlier onset and more extensive pathology in young patients with connective tissue disorders. A history of Marfan syndrome or other connective tissue disorders was not included as a preoperative variable in this study.

Study Limitations

The inherent limitations of a retrospective multi-institution study affected our analysis. The findings are limited by evolution of the operation, accumulation of surgical experience, and support techniques across the years. Aortic valve-sparing root replacement (the David procedure) has recently become more popular in the setting of Type A aortic dissection, especially in young and otherwise healthy patients. However, aortic valve-sparing root replacement was not performed in this patient population due to surgeons' preference in the emergent setting of Type A aortic dissection. Potential bias could have been introduced by the fact that nine surgeons from four different institutions contributed to this database. Topics beyond the scope of our study included further investigation regarding the causes of late mortality, reoperations on the remaining dissected aorta, and the fate of the false lumen. Although data from multiple institutions was included, the small sample size is another limitation that did not allow risk-adjusted multivariate analysis and provide better insight into late survival. Future reports evaluating the late outcomes of acute Type A aortic dissection are warranted.

Conclusions

In our multi-institutional retrospective review of patients undergoing surgical repair of acute Type A aortic dissection, 10-year survival was significantly decreased in those receiving AVR compared to those receiving root replacement procedures or AV resuspension. The overall operative mortality trended downward throughout the study.

Conflict of Interest

The authors have no conflict of interest relevant to this publication.

Comment on this Article or Ask a Question

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