Long-term outcomes of survival and freedom from reoperation on the aortic root or valve after surgery for acute ascending aorta dissection

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Objective: Limited long-term outcome data are available on survival and the need for aortic root or valve reoperation after surgery for acute ascending aorta dissection. We report our 42-year experience.

Methods: We reviewed the records of 269 patients who had undergone surgery for acute ascending aorta dissection from July 1969 to June 2011. The mean age at surgery was 62.1 ± 15.2 years, and 181 were men (67.3%). The distal operation was limited to hemiarch replacement. The proximal aortic operation groups included a composite valve conduit in 66 patients (24.5%), aortic root repair in 112 (41.6%), and isolated supracoronary ascending aorta replacement in 91 (33.8%).

Results: Operative morbidity occurred in 224 patients (83.3%) and mortality in 44 (16.4%), with similar rates among the groups ($P = .894$ and $P = .466$, respectively). The mean follow-up was 9.7 ± 7.5 years. The Kaplan-Meier survival estimate at 10 and 20 years was $65.5\% \pm 3.6\%$ and $28.7\% \pm 4.3\%$, respectively, and was similar among the groups ($P = .227$). Reoperation on the aortic root or valve occurred in 20 patients (8.9%) at a median of 6.8 years (range, 0.2-20.3). The freedom from reoperation rate at 10 and 20 years was $91.5\% \pm 2.3\%$ and $79.3\% \pm 6.1\%$, respectively, with no difference among the groups ($P = .605$).

Conclusions: Operative morbidity and mortality rates are significant after repair of acute ascending aorta dissection. Aortic root surgery can be performed without an apparent increase in the prevalence of operative morbidity or mortality; however, patients remain at risk of subsequent aortic root or valve surgery. (J Thorac Cardiovasc Surg 2014;148:2117-22)

See related commentary on pages 2123-4.

Surgery for acute ascending aorta dissection may result in significant morbidity and mortality rates.¹ The main goals of surgery are to prevent death of the patient from aortic rupture, to correct malperfusion and restore blood flow in the true aortic lumen, and to correct aortic valvular regurgitation. Achieving these goals requires varying degrees of operation on the aortic root, the long-term outcomes of which have not been extensively studied. To address this issue, we reviewed our single-center, 42-year experience in the management of acute ascending aortic dissection. We report the outcomes of long-term survival and freedom from subsequent aortic root or valve surgery stratified by magnitude of the aortic root operation.

METHODS

The institutional review board approved the present study, and all the patients or their families gave informed consent. We reviewed the records of all patients who had undergone surgery for acute ascending aorta dissection from July 1969 to June 2011 at Mayo Clinic (Rochester, Minn). We identified 400 patients, and eliminated 131 who had ≥ 1 of the following: previous cardiac surgery ($n = 79$), aortic arch replacement ($n = 13$), iatrogenic aortic dissection ($n = 27$), insufficient data ($n = 8$), or primary repair of the ascending aorta ($n = 8$).

We reviewed the medical records of 269 patients and collected data related to patient characteristics, surgery, and follow-up. All patients had undergone replacement of the supracoronary ascending aorta with a polyester graft. The distal extent of the operation was limited to a hemiarch replacement. We recorded the postoperative complications as defined using the Society of Thoracic Surgeons criteria and acute kidney injury as defined by the Acute Kidney Injury Network criteria.²

For the purposes of the present study, we divided the patients into 3 groups according to the type of procedure performed on the aortic root. The operations included composite valve conduit placement in 66 patients (24.5%), aortic root repair (eg, aortic valve commissure suspension, reconstruction or replacement of a sinus of Valsalva) in 112 patients (41.6%), and isolated supracoronary ascending aorta replacement in 91 patients (33.8%). The primary endpoint of the study was survival, with a secondary endpoint of freedom from reoperation on the aortic root or valve.

We report the categorical data as numbers and frequencies and continuous data as the mean $\pm$ standard deviation and median and range. Many of the study variables occurred with low numbers and did not lend themselves to reliable statistical analysis. Recognizing this limitation, where appropriate, we analyzed the categorical data using the Fisher exact test or chi-square test and continuous data using the nonparametric rank sum test.

We had follow-up data for all the patients and performed logistic regression analysis to determine the univariate and multivariate predictors of outcome. We constructed survival and freedom from reoperation curves

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TABLE 1. Patient characteristics

Variable	Composite valve conduit group (n = 66)	Root repair group (n = 112)	Isolated supracoronary ascending aorta replacement (n = 91)
Continuous			
Age (y)			
Mean $\pm$ SD	53.4 $\pm$ 16.6	64.7 $\pm$ 13.74	65.2 $\pm$ 13.5
Median	54.7	65.9	67.7
Range	17.9-88.9	18.6-88.2	23.7-89.3
Body surface area (m ²)			
Mean $\pm$ SD	2.0 $\pm$ 0.2	1.9 $\pm$ 0.3	1.9 $\pm$ 0.3
Median	2.0	2.0	1.9
Range	1.5-2.8	1.3-2.8	1.4-2.5
Creatinine (mg/dL)			
Mean $\pm$ SD	1.1 $\pm$ 0.4	1.5 $\pm$ 1.7	1.3 $\pm$ 1.0
Median	1.1	1.2	1.1
Range	0.5-2.5	0.5-14.6	0.6-9.9
Categorical			
Male sex	49 (74.2)	79 (70.5)	53 (58.2)
Diabetes (oral agent or insulin)	1 (1.5)	5 (4.4)	0
Hypertension	27 (40.9)	73 (65.2)	70 (76.9)
Chronic lung disease (moderate or severe)	2 (3.0)	4 (3.5)	2 (2.2)
Peripheral vascular disease	8 (12.1)	13 (11.6)	11 (12.1)
Cerebrovascular disease	7 (10.6)	10 (8.9)	7 (7.7)
Connective tissue disorder	4 (6.1)	1 (0.9)	3 (3.3)
NYHA functional class (III or IV)	32 (48.5)	28 (24.8)	25 (27.5)
Cardiogenic shock	4 (6.1)	14 (12.4)	7 (7.7)
Cardiopulmonary resuscitation	0	7 (6.2)	2 (2.2)
Aortic valve stenosis (moderate or severe)	3 (4.5)	1 (0.9)	3 (3.3)
Aortic valve regurgitation (moderate or severe)	59 (89.4)	57 (50.4)	11 (12.1)

Data presented as n (%), unless otherwise noted. SD, Standard deviation; NYHA, New York Heart Association.

using Kaplan-Meier estimates and compared the curves using the log-rank test. All statistical tests were 2-sided.

The demographic data of the 269 patients included a mean age of 62.1 $\pm$ 15.2 years (median, 64.9; range, 17.9-89.3), male sex in 181 patients (67.3%), and the presence of hypertension in 170 (63.2%). Moderate or severe aortic valve regurgitation was present in 127 patients (47.7%) and was more common in patients who had undergone composite valve conduit placement (59 patients, 90.8%) or root repair (57 patients, 51.4%) than in those who had undergone isolated supracoronary artery aorta replacement (11 patients, 12.2%; $P < .001$). The patient characteristics stratified by group assignment are listed in Table 1.

RESULTS

An open distal aortic anastomosis was done in 166 patients (61.7%) and included hemiarch replacement in 123 patients (45.7%). Aortic valve replacement was performed in 81 patients (30.1%) and included 66 patients (100%) in the composite valve conduit group, 4 (4.9%) in the root repair group, and 11 (12.1%) in the isolated supracoronary ascending aorta replacement group. The valve replacement was mechanical in 63 patients (77.8%), biologic in 16 (19.8%), and a homograft in 2 (2.5%). In the composite valve conduit group, the replacement was mechanical in 53 patients (80.3%), biologic in 11 (16.7%; 10 were porcine stentless conduits), and a homograft in 2 (3.0%).

Aortic valve repair included aortic valve commissural suspension in 86 patients (76.8%) in the root repair group

and 0 patients in the isolated supracoronary ascending aorta replacement group. Aortic valve-sparing procedures were done in 6 patients (5.4%) in the root repair group: reimplantation in 4 and remodeling in 2. The operative data, including each group's operative time, cardiopulmonary bypass time, aortic crossclamp time, and circulatory arrest time, are listed in Table 2.

Concomitant operative procedures were done in 66 patients (24.4%). These procedures included coronary artery bypass grafting in 44 patients, vascular procedures in 12, and other procedures in 10 patients. The other procedures included repair of the pulmonary artery in 4, mitral or tricuspid valve procedure in 3, septal myectomy in 1, closure of a patent foramen ovale in 1, and thymectomy in 1.

All patients received a red blood cell transfusion. The transfusion included 14 $\pm$ 10 units (median, 11; range, 2-56) of packed red blood cells in the composite valve conduit group, 13 $\pm$ 8 units (median, 11; range, 3-45) in the root repair group, and 13 $\pm$ 12 units (median, 9.5; range, 3-87) in the isolated supracoronary ascending aorta replacement group. No significant difference was found in the red blood cell transfusion amount among the groups ($P = .293$). Furthermore, no difference was found in the transfusion amount of fresh frozen plasma ($P = .056$), cryoprecipitate ($P = .054$), or platelets ($P = .098$).

TABLE 2. Operative procedure data

Variable	Composite valve conduit group (n = 66)	Root repair group (n = 112)	Isolated supracoronary ascending aorta replacement group (n = 91)
Continuous			
Operative time (min)			
Mean ± SD	359.4 ± 101.5	327.9 ± 81.6	306.8 ± 99.0
Median	337.5	320	279.5
Range	210-623	177-562	170-680
Cardiopulmonary bypass time (min)			
Mean ± SD	178.0 ± 59.5	150.4 ± 53.9	139.6 ± 58.0
Median	161.5	144.5	135
Range	89-354	55-458	40-348
Aortic crossclamp time (min)			
Mean ± SD	114.2 ± 33.5	81.0 ± 34.5	81.4 ± 40.1
Median	107	76.5	73
Range	58-234	8-215	13-212
Circulatory arrest time (min)			
Mean ± SD	27.7 ± 10.2	26.4 ± 12.0	28.3 ± 11.4
Median	25.5	25	27
Range	14-62	2-76	4-56
Categorical			
Simple ascending aorta replacement	41 (62.1)	43 (38.4)	62 (68.1)
Hemiarch replacement	25 (37.9)	69 (61.6)	29 (31.9)
Open distal aortic anastomosis	29 (43.9)	91 (81.35)	46 (50.6)
Aortic valve replacement	66 (100)	4 (3.6)	11 (12.1)
Concomitant cardiac operation	17 (25.8)	27 (24.1)	23 (25.3)

Data presented as n (%), unless otherwise noted. *SD*, Standard deviation.

Operative morbidity occurred in 224 patients (83.3%), including 54 (81.8%) in the composite valve group, 93 (83.0%) in the root repair group, and 77 (84.6%) in the isolated supracoronary ascending aorta replacement group ($P = .895$; Table 3). The degree of aortic regurgitation at presentation ($P = .328$) and the type of operative procedure ($P = .895$) were not predictive of any complication.

The specific operative complications were pulmonary related in 128 patients (47.9%), renal related in 118

(44.2%), and neurology related in 58 patients (21.6%). No differences were found among the groups with respect to the prevalence of pulmonary-related ($P = .313$) or renal-related ($P = .101$) complications. Stroke occurred in 4 patients (6.3%) in the composite valve conduit group, 12 (10.7%) in the root repair group, and 5 (5.7%) in the isolated ascending aorta replacement group, with no significant differences among the groups ($P = .361$).

TABLE 3. Thirty-day or in-hospital outcome data

Variable	Composite valve conduit group (n = 66)	Root repair group (n = 112)	Isolated supracoronary ascending aorta replacement group (n = 91)
Complication (any)	54 (81.8)	93 (83.0)	77 (84.6)
Reoperation for bleeding	9 (13.6)	6 (5.5)	7 (7.8)
Delayed sternal closure	3 (4.6)	1 (0.9)	1 (1.1)
Myocardial infarction	1 (1.5)	2 (1.8)	0
Neurologic complication	13 (19.7)	24 (21.4)	21 (23.1)
Stroke	4 (6.3)	12 (10.7)	5 (5.7)
Pulmonary complication	27 (41.5)	59 (52.7)	42 (46.7)
Intubation >24 h	27 (41.5)	57 (50.9)	41 (45.6)
Renal complication	24 (36.9)	58 (51.8)	36 (40.0)
Stratified by AKIN classification			
Stage 1	19 (29.2)	40 (35.7)	24 (26.7)
Stage 2	1 (1.5)	7 (6.3)	9 (10.0)
Stage 3	4 (6.2)	11 (9.8)	3 (3.3)
Mortality (30-d or in-hospital)	9 (13.6)	22 (19.6)	13 (14.3)

Data presented as n (%). *AKIN*, Acute Kidney Injury Network.

Survival Plot

FIGURE 1. Kaplan-Meier estimate survival curve.

Operative mortality (30-day or in-hospital) occurred in 44 patients (16.4%; Table 3). No differences were found in the mortality rates among the groups ($P = .466$). Furthermore, the operative mortality rates did not differ by decade of operation: 1969 to 1979, 4 of 22 (18.2%); 1980 to 1989, 12 of 68 (17.7%); 1990 to 1999, 8 of 60 (13.3%); and, 2000 to 2011, 20 of 119 (16.8%; $P = .907$). We analyzed the patient characteristics by the decade of surgery and identified a significant increase in the median age from the first (50.8 years; range, 18.6-77.5) to the last (67.2 years; range, 21.8-88.9) decade ($P = .004$).

The follow-up data were complete for all patients who survived surgery. The average follow-up period was 9.7 ± 7.5 years (median, 7.7; range, 0.12-35.0). No difference was found in the follow-up duration among the groups ($P = .128$). At the last follow-up visit, 114 patients (42.2%) were alive, including 27 (40.9%) in the composite valve group, 57 (50.9%) in the root repair group, and 30 (33.0%) in the isolated supracoronary ascending aorta replacement group.

The survival rate for all patients at 10 and 20 years was $54.8\% \pm 3.4\%$ and $24.0\% \pm 3.7\%$, respectively (Figure 1). No difference was found in survival among the groups ($P = .227$). However, the patients with dissection had a significant reduction in survival compared with age- and gender-matched controls ($P < .001$). The significant predictors of late mortality are reported in Table 4. The degree of aortic valve regurgitation at presentation was not predictive of late mortality ($P = .145$).

Reoperation on the aortic root or valve occurred in 20 (8.9%) of 225 patients who had survived the original operation. The median interval to reoperation was 6.8 years (range, 0.2-20.3). Reoperations occurred in 6 patients (10.5%) in the composite valve conduit group, 8 (8.9%) in the root repair group (none in the remodeling or reimplantation group), and 6 (7.7%) in the isolated supracoronary replacement group ($P = .828$). The

TABLE 4. Predictors of late mortality

Predictors of late mortality	HR	95% CI	P value
Univariate			
Aortic valve stenosis (moderate or severe)	4.64	1.4-11.2	.016
Chronic lung disease	2.61	0.91-5.83	.070
Cerebrovascular disease	1.99	1.06-3.43	.033
Stroke	1.34	0.54-2.98	.544
Atrial fibrillation	1.06	0.63-1.70	.810
Age at surgery	1.04	1.02-1.05	<.001
Aortic valve regurgitation (moderate or severe)	0.76	0.52-1.10	.147
Multivariate			
Aortic valve stenosis	2.27	0.67-5.81	.170
Stroke	1.84	0.96-3.22	.064
Age at surgery	1.03	1.02-1.05	<.001

HR, Hazard ratio; CI, confidence interval.

indications for reoperation included aortic root dilation or valve regurgitation in 14 patients (70%), pseudoaneurysm in 3 (15%), aortic valve infective endocarditis in 2 (10%), and paravalvular regurgitation in 1 (5%). Reoperations included a composite valve conduit in 14 patients (70%), aortic valve replacement in 4 (20%), and root operation in 2 (10%).

Freedom from reoperation on the aortic root or valve at 10 and 20 years was $91.5\% \pm 2.3\%$ and $79.3\% \pm 6.1\%$, respectively (Figure 2). Freedom from reoperation on the aortic root at 10 and 20 years was $93.4\% \pm 2.1\%$ and $83.3\% \pm 5.8\%$, respectively. The freedom from reoperation on the aortic valve at 10 and 20 years was $92.3\% \pm 2.2\%$ and $81.8\% \pm 5.9\%$, respectively. No differences were found among the groups with respect to freedom from reoperation on the root or valve ($P = .605$), root ($P = .144$), or valve ($P = .711$). We identified no factors that were predictive of reoperation on the aortic root or valve.

Survival Plot

FIGURE 2. Kaplan-Meier estimate for freedom from reoperation on the aortic root or valve.

Repeat operation on the distal aorta or arch was required in 6 patients (2.7%). The characteristics of the original operation in this group included closed distal anastomosis (ie, with aortic crossclamp in place) in 5 patients and open hemiarch anastomosis in 1 patient. Also, 3 patients were in the composite valve group, 2 in the isolated supracoronary group, and 1 in the root repair group. Freedom from reoperation on the distal aorta or arch at 10 and 20 years was $97.2\% \pm 1.3\%$.

DISCUSSION

We report our 42-year experience with the operative management of the aortic root in 269 patients treated with primary sternotomy and surgery for acute ascending aorta dissection. The overall operative mortality in our series remained relatively constant at about 16% during the encompassing 4 decades. We found that aggressive aortic root surgery does not affect the outcomes with respect to operative morbidity or mortality or long-term survival or reoperation on the aortic root or valve. Finally, patients undergoing surgery for acute ascending aorta dissection experienced reduced survival compared with age- and gender-matched controls.

The choice of operation in the management of acute ascending aorta dissection depends on many factors (eg, root aneurysm, Marfan syndrome, dysfunctional aortic valve). In the absence of these factors, it is unclear how extensive should be the magnitude of the aortic root operation. For instance, Halstead and colleagues³ have recommended an aggressive policy of composite valve conduit placement in patients with acute ascending aorta dissection, whereas Lai and colleagues⁴ have recommended a more conservative procedure. Thus, difficulties exist in determining the best practice.

It is difficult to assess the magnitude of surgery by constructing groups of patients with similar preoperative characteristics, because many factors determine the aggressiveness or magnitude of the operation. For example, a patient who presents with acute ascending aorta dissection, root dilation, and severe bicuspid aortic valve stenosis will most likely undergo a different operation than a patient who presents with isolated nondilated acute ascending aorta dissection and a competent, nonstenotic aortic valve.

Recognizing the inherent differences in patient characteristics, several investigators believe it is reasonable to study patients according to the type of operation performed. The foundation of this supposition has been that the outcome of the operation will be most directly related to preventing aorta rupture, correcting malperfusion and establishing blood flow in the true aorta lumen, and establishing a reasonably competent aortic valve, not necessarily on the specific technique used to achieve the outcome. This philosophy has been previously espoused by the groups from Stanford, Yale, and Virginia.⁴⁻⁶

Our study has provided long-term outcome data supporting the premise, “the best operation is the one that has been customized to each individual patient,” as so eloquently stated by Lai and colleagues⁴ from the Stanford group. Survival will mostly be affected by patient-related factors, such as was shown by our univariate and multivariate analyses. Additional support comes from Ro and colleagues,⁷ who noted that the maximal aortic root diameter at the initial presentation was the only significant predictor of postoperative aortic regurgitation and aortic root dilatation, and Rylski and colleagues,⁸ who reported that dissection of all 3 aortic sinuses was the only predictor of reoperation.

Our study group had demographic data representative of most series of patients undergoing surgery for acute ascending aortic dissection. These included a mean age of 62 years and male gender for 67% of the patients. These data are similar to those reported by Dell'Aquila and colleagues⁹ (319 patients; age, 63 years; 68% men), Geirsson and colleagues¹⁰ (221 patients; age, 62 years; 66% men), Rylski and colleagues⁸ (97 patients; age, 61 years; 67% men), and others.^{4,11,12} With these data, we believe that a comparison of our outcomes with those from previous reports was reasonable.

We found no difference in the 30-day or in-hospital mortality rates in the patients undergoing composite valve conduit placement (14%), root repair (19%), or isolated supracoronary ascending aorta replacement (14%; $P = .485$). These outcomes were similar to those recently reported by Montalvo and colleagues,¹³ who noted an operative mortality of 7% in patients who had undergone an aortic root operation and 11% in patients who had not (P value reported as not significant, but a numeric value was not given). Similar results have been reported by Halstead and colleagues³ in 2005, Lai and colleagues⁴ in 2003, and Moon and colleagues¹² in 2001.

Other investigators, however, have reported worse operative mortality with more aggressive root surgery, most notably Geirsson and colleagues¹⁰ from the University of Pennsylvania group. They noted an operative mortality rate of 23% in patients after composite root replacement and 8% in patients who underwent surgery without a root operation ($P = .004$). They were unable to provide an explanation for the significant difference in mortality rates.¹⁰ They suggested that root replacement might be a marker for more severe dissection and its associated increased operative time.¹⁰ However, no consensus has yet been reached on this issue.

We have demonstrated no difference in long-term survival in our patients, whether they had undergone composite valve conduit placement, root repair, or isolated supracoronary ascending aorta replacement ($P = .098$). These data are corroborated by Geirsson and colleagues,¹⁰ who also noted no difference in long-term survival (mean follow-up, 49.1 months) after aortic valve suspension compared

with patients who underwent composite root replacement ($P = .478$); and Halstead and colleagues,³ who reported no difference in survival between patients who had undergone received interposition graft replacement of the ascending aorta (mean follow-up, 56.4 months) or composite graft replacement (mean follow-up, 65.8 months; $P = .48$). Other investigators have reported similar results.^{4,11,12}

We noted no difference in the freedom from reoperation on the aortic root or valve among the composite valve conduit, root repair, or isolated supracoronary ascending aorta replacement groups. A similar, but somewhat controversial, outcome has been reported by Halstead and colleagues.³ They stated, "There was a clear trend toward a lower proximal reoperation rate after composite root replacement." However, the level of significance was $P = .08$. We disagree with their assessment and believe that a P value of .08 does not represent a significant difference. Other groups have supported our conclusion, including studies from The Netherlands,¹¹ the University of Pennsylvania,¹⁰ Stanford University,⁴ and Washington University.¹²

We noted no improvement in operative mortality with time, for which we have several potential explanations. When we analyzed the 4 decade groups comparing patient characteristics, the only difference with significance was patient age. We found that the median patient age in each group had increased significantly from the first to the last decade by almost 20 years. Furthermore, our center is a referral center, and some of our patients come by ambulance from distant communities. The effect of the transport time delay was unknown, and it could have negatively affected our outcomes. Finally, although one would expect decline in mortality over time, a level of operative mortality associated with repair of acute ascending aorta dissection might be present that we just cannot improve on.

The most important limitation in our study was surgeon bias in the choice of operation as that played out during the 42-year study period. It was impossible to match patients according to preoperative characteristics, because those characteristics are what most likely determine the aggressiveness of the surgeon and the magnitude of the operation. As an example, we reported a limited experience with valve-sparing techniques (ie, 6 patients) and have not included those techniques as a part of our routine practice for patients with acute ascending aorta dissection. A bias was present in the choice of operation that could not be controlled for with reasonable certainty. Finally, it is possible that some repeat operations were performed at other facilities without our knowledge. This would have resulted in an underreport of the repeat operation prevalence.

However, such a bias would theoretically have applied to all 3 operative study cohorts.

CONCLUSIONS

Acute ascending aorta dissection is a challenging condition to treat, and the associated operative morbidity and mortality is significant. Most factors that affect the operative outcomes are patient related. Understanding that relationship, surgeons must be cautious not to over- or undertreat these patients. The key will be to customize the operation to the individual patient (ie, let the pathologic findings dictate the operative procedure). To the best of our knowledge, durable 20-year outcomes can result. Regardless of the repair type, patients undergoing surgery for acute ascending aorta dissection will experience reduced survival compared with age- and gender-matched controls.

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