Reoperative aortic root and transverse arch procedures: A comparison with contemporaneous primary operations

Christian D. Etz, MD,[a] Konstadinos A. Plestis, MD,[a] Tobias M. Homann, MD,[a] Carol A. Bodian, DrPH,[b] Gabriele Di Luozzo, MD,[a] David Spielvogel, MD,[a] and Randall B. Griepp, MD[a]

Supplemental material is available online.

Objectives: Long-term survival and risk factors affecting outcome after reoperative root/ascending aorta and transverse arch procedures have not been clearly described.

Methods: Two hundred patients (138 male patients; age, 60 ± 15 years) underwent reoperative root/ascending aorta (n = 100) or transverse arch (n = 100) procedures at our institution from January 1998 to December 2004 and were compared with 480 consecutive contemporaneous patients with primary procedures (323 male patients; age, 62 ± 16 years; 335 proximal aorta and 145 transverse arch procedures).

Results: Reoperative proximal aorta procedures had a higher hospital mortality (7%) than primary root/ascending aorta procedures (3%), but there was a less dramatic difference in operative mortality after primary and reoperative arch procedures (9% vs 10%). Separate multivariable analyses of root/ascending aorta procedures and arch procedures revealed chronic obstructive pulmonary disease and age to be significant risk factors for death after either procedure. In addition, an ejection fraction of less than 30% posed a significant risk for proximal aortic surgery, and diabetes and nonelective operations predicted poorer outcome after arch operations. For survivors of root/ascending aorta operations, there was no significant difference in long-term outcome between reoperations and primary procedures, with both restoring longevity to expected levels for an age- and sex-matched normal population. Patients undergoing arch operations, however, continued to have a poorer long-term outlook than their normal peers.

Conclusions: In this series, reoperations in the transverse arch carry the same risk as primary arch procedures, but a higher operative mortality is seen with reoperative than with primary root/ascending aorta procedures. The long-term outlook is better for patients undergoing root/ascending operations than for patients undergoing aortic arch operations, with no difference in the longevity of patients undergoing primary procedures versus reoperations.

Operations on the aortic root/ascending aorta and aortic arch are not uncommon in patients who have had, often many years earlier, other types of cardiac or aortic operations.[1-8] This study was undertaken to assess the risk factors associated with these reoperations and to determine their long-term outcomes.

Preliminary analysis of the patients who had reoperative surgery involving the proximal aorta showed significant differences in preoperative profile from patients

From the Departments of Cardiothoracic Surgery[a] and Anesthesiology,[b] Mount Sinai School of Medicine, New York, NY.

Read at the Eighty-sixth Annual Meeting of The American Association for Thoracic Surgery, Philadelphia, Pa, April 29–May 3, 2006.

Address for reprints: Christian D. Etz, MD, Mount Sinai School of Medicine, Department of Cardiothoracic Surgery, One Gustave L. Levy Place, PO Box: 1028, New York, NY 10029 (E-mail: christian.etz@mountsinai.org).

J Thorac Cardiovasc Surg 2008;136:860-7

0022-5223/$34.00

doi:10.1016/j.jtcvs.2007.11.071

Abbreviations and Acronyms

COPD = chronic obstructive pulmonary disease
HCA = hypothermic circulatory arrest
SCP = selective cerebral perfusion
SMR = standardized mortality ratio

whose reoperations involved the aortic arch. It was therefore decided that the patients who had aortic root/ascending aorta reoperations should be analyzed separately from those whose reoperations involved the aortic arch.

To analyze not only the immediate results of the reoperations but also their long-term sequelae, we reviewed our results in patients who had undergone either aortic root/ascending aorta or aortic arch surgery as a primary operation during the same interval as the patients undergoing reoperations. This allowed us more accurately to determine long-term survival after aortic root/ascending aorta and aortic arch surgery, to assess risk factors for adverse outcomes for each operative group, and to try to determine whether reoperation has a significant effect on long-term outcome.

Because patients undergoing aortic operations are usually somewhat elderly and have significant comorbidities, we have elected to place the emphasis on outcome compared with an age- and sex-matched general population. Thus in addition to describing operative mortality and complications according to standard surgical definitions, we also describe survival at 1 year and after 1 year compared with that of an age- and sex-matched New York State population.

Materials and Methods

A review of the institutional database disclosed 680 patients who underwent aortic root or transverse arch replacement from January 1998 to December 2004. A previous cardiac or aortic operation had been performed in 200 patients; 480 patients underwent primary procedures within this period. The institutional review board approved this research, and additional patient consent was not required.

Patient Demographics

Patients undergoing reoperations. Two hundred patients (146 male patients; age, 60.2 ± 15.1 years) underwent aortic reoperations at our institution (January 1998–December 2004) after 1 or more previous cardioaortic procedures. Table 1 summarizes the clinical characteristics of the patients undergoing reoperations. Most of the patients undergoing reoperations had undergone 1 previous operation, but 29 had 2 previous procedures, 9 had 3 previous procedures, and 1 each had 4, 5, and 6 previous heart procedures. Patients with multiple previous operations often had congenital heart defects that involved heart valves or the transverse arch. Because our institution is a referral center for aneurysm surgery, the patients reported herein might not reflect the prevalence of different kinds of aortic pathology in the community at large.

The principal indication for reoperative surgery was chronic aortic dissection in 69 patients, degenerative aneurysm in 54 and atherosclerotic aneurysm in 30 patients, aortic valve dysfunction in 37 patients, endocarditis in 12 patients, and acute dissection in 4 patients. In patients undergoing primary procedures, in contrast, there were fewer patients with chronic dissection (7.5% vs 35%), infection (2% vs 6%), and false aneurysms (0% vs 6%).

Primary procedures. Four hundred eighty patients who had undergone aortic procedures as primary operations during the same interval as the reoperations (January 1998–December 2004) were also reviewed: 335 patients who had primary aortic root/ascending aorta procedures and 145 who had transverse arch procedures. Three hundred twenty-three were male, and the mean age was 62.4 ± 15.9 years. The patients who had primary procedures were well matched with those who had reoperations with regard to a history of hypertension, coronary artery disease, chronic obstructive pulmonary disease (COPD), and diabetes, sex, urgency of operation, and ejection fraction, but differed in having a significantly higher incidence of aortic dilatation and a higher mean age than the patients undergoing reoperations.

Previous procedures in patients undergoing reoperations. In accordance with our hypothesis that patients with root/ascending aorta and arch aneurysms differ, it should be noted, as detailed in Table 1 and Figure 1, that previous aortic valve surgery had been carried out in 50% of patients undergoing reoperative root procedures, whereas previous surgical intervention on the aorta had

TABLE 1. Clinical profile of patients undergoing reoperative root/ascending aorta (n = 100) and arch (n = 100) procedures

Demographics	Roots	Arches
No. of patients	100	100
Mean age, y (± SD)	58.8 (± 15.6)	61.7 (± 14.6)
Age >60 y	54	55
Male sex	79	67
Number of previous operations (median [range])	1 (1–6)	1 (1–5)
Aortic valve replacement/repair	50	14
CABG with or without valve (other than aortic)	16	13
Aortic root replacement ± arch	23	58
Other	11	15
Timing of operation		
Elective	80	83
Urgent	9	10
Emergency	11	7
Risk factors		
Left ventricular EF ≤30%	6	4
History of hypertension	43	62
Coronary artery disease	25	25
Smoking	13	21
Diabetes	3	2
COPD	3	5

Values are presented as percentages or mean numbers as shown. *SD*, Standard deviation; *EF*, ejection fraction; *COPD*, chronic obstructive pulmonary disease.

ACD

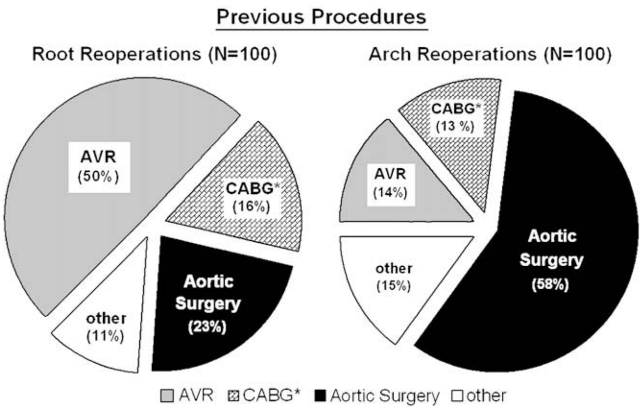

Figure 1. Aortic root (n = 100) and arch reoperations (n = 100): previous procedures. *AVR*, Aortic valve replacement/repair; *CABG, CABG with or without valve (other than aortic); *Aortic Surgery*, aortic root replacement ± arch/descending aorta with cardiopulmonary bypass; *other*, (congenital) cardiac surgery with use of cardiopulmonary bypass.**

preceded reoperation in 58% of patients with arch aneurysms. As noted in Table 2, a higher proportion of patients undergoing arch operations had chronic dissections and atherosclerotic aneurysms, whereas patients undergoing root operations were more likely to have had infections, aortic regurgitation, and degenerative aneurysms.

TABLE 2. Intraoperative data for reoperative root/ascending aorta and arch procedures

Variable	Roots	Arches
Etiology		
Infective endocarditis/mediastinitis*	9	3
Pseudoaneurysm	5	5
Aortitis (Takayasu)	1	1
Chronic dissection (A/B)	22	47
Acute type A dissection	3	1
Degenerative	37	17
Atherosclerosis	10	20
Other†	13	6
Intraoperative findings		
Clot or atheroma	6	10
Aortic dilatation	51	55
Aortic regurgitation	26	13
CPB		
Axillary cannulation	58	64
CPB time (mean ± SD; min)	252.4 ± 68.1	242.6 ± 76.4
SCP used: mean duration (+/− 50; min)	1	66 (65 +/− 30)

CPB, cardiopulmonary bypass; *SD*, standard deviation; *SCP*, selective cerebral perfusion. *Endocarditis = infected Bentall and mediastinitis. †Other = traumatic, sinus of Valsalva aneurysm, and coarctation.

The intervals between the first operation and the reoperation were less dramatically different for patients undergoing root and arch operations than the distribution of previous operations (Figs E1 and E2). The median interval, in years, to root/ascending aorta reoperation was 11.1 (interquartile range, 5.1–17.7) after previous aortic valve replacement, 8.2 (interquartile range, 5.2–9.0) after previous aortic surgery, 6.3 years (interquartile range, 3.4–8.8 yrs) after previous coronary artery bypass grafting, and 18.4 years (interquartile range, 7.0–26.7 yrs) after miscellaneous other cardioaortic surgery. The median interval to arch reoperation was 12.4 years (interquartile range, 4.6–16.5 yrs) after previous aortic valve replacement, 7.0 years (interquartile range, 3.0–9.7 yrs) after previous aortic surgery, 3.3 years (interquartile range, 1.0–9.5 yrs) after previous coronary artery bypass grafting, and 6.0 years (interquartile range, 4.0–7.6 yrs) after miscellaneous other cardioaortic operations.

Surgical Technique

Cannulation and myocardial protection. Arterial cannulation was carried out either through the femoral artery (n = 44, 22%), the ascending aorta (n = 33, 16%), or, increasingly more recently, the right axillary artery (n = 123, 62%). Venous cannulation was usually through a 2-stage catheter in the right atrium, but in some patients undergoing arch operations in whom the heart was not fully exposed, the right atrium was accessed through a wire-directed catheter placed in the right atrium through the femoral vein. Myocardial protection was provided with cold antegrade blood cardioplegia and systemic perfusion at 20°C and, in patients with severe coronary disease, retrograde blood cardioplegia. Cardioplegia was administered every 20 to 30 minutes during periods of myocardial ischemia.

Hypothermic circulatory arrest. Hypothermic circulatory arrest (HCA) was brought about by means of surface (cooling blanket) and perfusion cooling. If HCA was anticipated early in the procedure, the patient was cooled during the initial period of cardiopulmonary bypass. A minimum of 30 minutes of cooling was used. In some patients in whom HCA was instituted later in the operative procedure, the patient was maintained at a perfusion temperature of 20°C until about 15 minutes before HCA, after which the blood temperature was decreased to 10°C. Adequate cerebral cooling was ensured in all cases by a jugular venous saturation of greater than 95% and an esophageal temperature of 12°C to 15°C. In all patients in whom more than 20 minutes of HCA was anticipated or selective cerebral perfusion (SCP) was used, the head was packed circumferentially in ice.

Perfusion warming was carried out at the end of the procedure, with the gradient between the esophageal and blood temperatures maintained at less than 10°C. Warming was maintained until the esophageal temperature reached 35°C and the bladder temperature was greater than 32°C. Downward drift, however, resulted in most patients leaving the operating room with esophageal and bladder temperatures of 32°C. Warming was usually accomplished in 1 hour of perfusion; during the last 15 or 20 minutes, partial bypass was frequently used to take advantage of improved warming with pulsatile perfusion.

SCP. Perfusion of all 3 head vessels was achieved during SCP. In the early portion of this series, SCP was provided by suturing an island of arch tissue to a beveled 16- to 18-mm Hemashield graft and providing inflow either through the graft or through the right axillary artery. Once the use of the trifurcation graft was introduced for arch repair, SCP was delivered by providing inflow to the trifurcation graft through the right axillary artery.[9] SCP was carried out at a blood temperature of 15°C to 20°C and flow sufficient to maintain a pressure of 50 to 60 mm Hg. This usually required a flow of 800 to 1200 mL/min. The average duration of SCP was 65 ± 30 minutes and ranged from 18 to 143 minutes.

Aortic root replacement. A button Bentall procedure was used in 81 patients; a valvuloplasty or valve-sparing procedure was used in 9 patients; a Cabrol procedure was used in 7 patients, and a classic Bentall procedure was carried out in 3 patients. In 31 patients a biologic valve was used.

Aortic arch replacement. Arch replacement was carried out by suturing the head vessels to a beveled graft in 61 patients; a trifurcation graft was used in 39 patients. The rationale for the use of a trifurcation graft and results with this technique have recently been reported elsewhere.[9] Thirty-nine patients had a portion of the ascending aorta (n = 27) or the entire aortic root (n = 12) replaced in conjunction with their arch reoperation.

Anastomotic technique. Proximal anchoring of the Bentall grafts was accomplished with interrupted pledgeted sutures. Coronary button anastomoses were reinforced with small strips of Teflon felt. All graft-to-aorta anastomoses were performed with a sandwich technique, placing the aortic wall between the vascular graft and an external band of Teflon felt.[10] All graft material was albumin-impregnated woven Dacron.

Follow-up

Patients were followed by the referring cardiologist and contacted periodically by our research personnel. Annual computed tomographic scans were scheduled in all patients and attained in 61%. Postoperative events were compiled and analyzed according to the "Guidelines for reporting morbidity and mortality after cardiac valvular operations" and our institutional check list.[11] For this study, the follow-up was closed on September 21, 2005. The duration of follow-up among survivors ranged from 0.8 to 7.7 years (median, 3.8 years).

Statistical Methods

Data were entered in Excel spreadsheets and transferred to a SAS file for data description and analysis. Patient and disease characteristics are described as percentages, and groups were compared with χ^2 tests. Aortic root/ascending aorta and arch procedures were considered separately in the statistical analyses. Kaplan–Meier life tables were calculated to describe the survival experience after root and arch primary procedures and reoperations.

Factors influencing survival were initially explored by means of separate univariate and multivariate analyses for primary procedures and for reoperations, each considering factors related to operative or long-term death, in which operative death was defined as death within 30 days after the procedure or death before discharge if beyond 30 days.

Primary procedures and reoperations were combined for the ultimate analysis of factors associated with survival, where follow-up time started on the day of the procedure and terminated at the time of death (whether in the hospital or thereafter), or September 21, 2005. For these analyses, main effects were selected by using the stepwise procedure of the Cox model. Findings from the separate exploratory analyses were then used to guide further testing for interaction effects between primary procedures and reoperations and for changes in the influence of factors with increasing time after the procedure. These analyses controlled for possible subtle sex effects by retaining it as a factor in all the models. Other factors with *P* values of less than .10 were retained in the multivariate results.

Logistic regression analysis was used to compare groups with regard to operative mortality rates while controlling for age and sex. Comparisons of overall survival experiences were based on standardized mortality ratios (SMRs; ie, observed numbers of deaths relative to the numbers that would be expected based on New York State population death rates for comparable ages, sexes, and follow-up times) and tested with a Poisson model. These SMRs were separated into 2 periods: survival in the first postoperative year, and long-term survival. The 1-year period was chosen to more accurately assess the real mortality and morbidity of the operation because standard accounts of operative mortality might not include patients discharged from the acute care hospital into rehabilitation facilities or other institutions who never fully recover from the operation.

The risk factors considered for analysis were as follows: age, sex, history of hypertension, insulin-dependent diabetes mellitus, COPD, left ventricular ejection fraction, coronary artery disease, number of previous procedures, type of previous procedures (reoperation group), presence of clot or atheroma, urgency of the procedure, concomitant procedures, concomitant coronary artery bypass grafting, and axillary artery cannulation.

Results

Operative Mortality and Causes of Death

In the group undergoing reoperations, the overall operative mortality (Table 3), conventionally defined as death in the hospital or within 30 days postoperatively, was 9% (n = 17). This crude mortality (which does not take into account differences even of age and sex between the groups) did not differ significantly between root/ascending aorta (n = 7, 7%) and arch (n = 10, 10%) procedures (*P* = .45). In contrast, among primary procedures, conventional early mortality was higher for arch (n = 13, 9.0%) than for root/ascending aorta (n = 10, 3.0%) procedures (*P* = .005).

Myocardial failure was the most frequent cause of death in all but primary arch operations, in which bowel infarction and stroke were each more common. The causes of death in both primary operations and reoperations are outlined in Table E1.

Postoperative Complications

As might have been anticipated, complications tended to occur in a slightly higher percentage of reoperations than in

TABLE 3. Operative mortality

	Primary operation	Reoperation	Primary operation vs reoperation
Root/ascending aorta replacement	10/335 = 3.0%	7/100 = 7.0%	*P* = .07
Arch replacement	13/145 = 9.0%	10/100 = 10.0%	*P* = .97

ACD

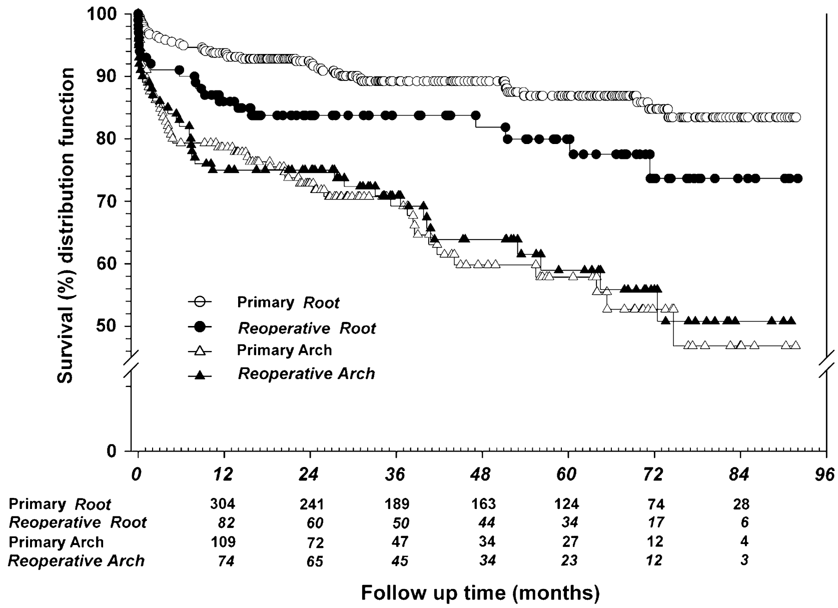

Figure 2. Survival after reoperative aortic root (*filled circles*, n = 100) and transverse arch (*filled triangles*, n = 100) procedures versus primary aortic root (*open circles*, n = 335) and transverse arch (*open triangles*, n = 145) procedures. Numbers beneath the graph indicate patients remaining at risk in each category.

primary procedures. Postoperative complications occurred in 21 (21%) patients after root/ascending aorta reoperations compared with 57 (17%) patients after primary root procedures ($P = .36$); length of hospital stay was similar for reoperations of the aortic root (8 vs 8 days, $P = .20$). Infection was the only complication that occurred significantly more often in proximal aorta reoperations than during initial operations.

Thirty-one (31%) patients experienced a complicated postoperative course after arch reoperations compared with 38 (26%) after primary arch procedures ($P = .41$); none of the complications in patients undergoing arch procedures was significantly more prevalent among patients undergoing reoperations. Median hospital stay was not significantly longer in reoperations of the aortic arch (12 vs 11 days, $P = .43$).

Overall Mortality

Long-term survival after aortic surgery was different for root/ascending aorta and arch operations, as seen in Figure 2. Survival in patients with aortic root operations seems to undergo relatively little attrition after the immediate postoperative period, whereas there is a steady decrease in survival after arch procedures.

Because each patient group has a different set of risk factors, however, they should each ideally be evaluated in relation to an age- and sex-matched general population, especially to assess long-term outcome. We have therefore considered root/ascending aorta and arch operations separately, comparing each with suitable control populations in terms of 1-year and late mortality.

Proximal Aortic Root/Ascending Aorta Operations: Primary Operations and Reoperations

Multivariate analysis of all deaths after replacement of the aortic root/ascending aorta, whether primary operations or reoperations, identified COPD and age as highly significant risk factors (Table 4). An ejection fraction of less than 30% also had a significant adverse effect on survival. The positive influence of axillary cannulation was of borderline significance, as was the adverse effect of reoperation ($P = .08$). Numerous other potential risk factors (a list is included in the Methods section) were tested but not found to be significant.

Early mortality was analyzed with a cutoff of 1 year because we believe that the usual definition of operative mortality can be distorted as a consequence of discharge of patients

TABLE 4. Root/ascending aorta operations: Primary operations (n = 335) and reoperations (n = 100)

Multivariate determinants of all deaths		
Variable	Hazard ratio	*P* value
Male sex	0.78	.41
COPD	4.5	.006
Age	1.06/y	<.0001
EF <0.30	2.1	.05
Axillary Cannulation	0.60	.06
Reoperation vs primary operation:		
Within 1 y	2.3	.02
Beyond 1 y	0.9	1.0

COPD, Chronic obstructive pulmonary disease; *EF*, ejection fraction.

TABLE 5. Standardized mortality ratios for root/ascending aorta operations: Primary operations (n = 335) and reoperations (n = 100)

	SMRs (observed/expected)	
	Operation to 1 y (early mortality)	1 y to last follow-up (late mortality)
Primary operation	21/3.1 = 6.8 $P < .0001$	19/25.0 = 0.8 $P = .23$
Reoperation	14/1.2 = 11.7 $P < .001$	6/8.9 = 0.7 $P = .33$
SMR primary operation vs SMR reoperation	$P = .04$	$P = .87$

SMR, Standardized mortality ratio.

with residual postoperative problems. We used a normal age- and sex-matched population to provide expected deaths, assuming that factors associated with increased operative risk are also present in a general population. There was a significant excess of observed versus expected deaths during the first year both among patients having primary procedures and reoperations on the proximal aorta (6.8 and 11.7, respectively), and the difference between them reached significance ($P = .04$, Table 5); this is likely the effect of a higher operative mortality in the reoperation group. Late mortality, after 1 year, was less than the expected rate in the healthy population, with ratios of 0.7 to 0.8 both for patients undergoing primary procedures and those having reoperations on the proximal aorta, with no significant difference between them.

Primary Arch Replacements and Reoperations on the Aortic Arch

Multivariate analysis identified diabetes as a highly significant risk factor for mortality after arch surgery, whether a primary operation or a reoperation. Nonelective operations and COPD were also significant risk factors for mortality after arch replacement (Table 6). Age was of borderline significance. Reoperation ($P = .4$) had no significant effect on overall mortality after arch operations nor were any of the other possible risk factors previously outlined found to be significant.

Although operative mortality according to standard definitions was very similar between arch replacement as a primary or subsequent procedure, excess mortality during the first year was higher after reoperations than in patients undergoing primary arch surgery when calculated by using SMRs ($P = .04$, Table 7). Late mortality, after 1 year, was 1.6 to 1.8 times that of the general population, suggesting continuing increased vulnerability of patients undergoing arch operations to an earlier death than their peers (in contrast to patients after proximal aorta operations), but the trajectory of long-term survival did not differ in patients who had primary arch operations from those who underwent reoperations (Figure 2).

TABLE 6. Arch replacements: Primary operations (n = 145) and reoperations (n = 100)

Multivariate determinants of all deaths		
Variable	Hazard ratio	*P* value
Male sex	0.78	.27
COPD	2.2	.03
Age	1.02/y	.06
Diabetes	3.3	.007
Elective	0.56	.03
Reoperation vs primary operation		
Within 1 y	1.6	.12
Beyond 1 y	0.78	.82

COPD, Chronic obstructive pulmonary disease.

ACD

Discussion

Proximal Aortic Surgery

For the aortic root and ascending aorta, early mortality differs between primary and reoperative operations. Crude hospital mortality statistics reveal risks of 3% for primary operations versus 7% for reoperations, and a 2-fold excess mortality is seen during the first year after surgical intervention in reoperations when compared with primary operations. After 1 year, however, survival is equal in the 2 groups and is equivalent to that of age- and sex-matched control subjects drawn from the general population.

It seems an inescapable conclusion that surgical replacement of the aortic root/ascending aorta leads to a major improvement in survival over a population of patients with aortic root/ascending aorta aneurysms not undergoing an operation. In fact, operations for proximal aortic disease appear to be curative. For patients undergoing reoperations, the increased early mortality prevents them from enjoying overall longevity fully equivalent to the general population, but their survival after 1 year does become the same as that of their age- and sex-matched peers.

TABLE 7. Standardized mortality ratios for arch replacements: Primary operations (n = 145) and reoperations (n = 100)

	SMRs (observed/expected)	
	Operation to 1 y (early mortality)	1 y to last follow-up (late mortality)
Primary operations	31/2.2 = 14.0 $P < .0001$	20/14.3 = 1.8 $P = .01$
Reoperations	25/1.0 = 25.0 $P < .0001$	11/6.7 = 1.6 $P = .10$
SMR primary operation vs SMR reoperation	$P = .04$	$P = .83$

SMR, Standardized mortality ratio.

These observations suggest that we should encourage operative approaches that minimize the necessity for reoperative rather than primary aortic root/ascending aorta procedures. This includes planning for elective composite replacement of the modestly dilated aorta when an operation for coexisting conditions is required, as well as for elective operations in asymptomatic patients with moderate ascending aortic dilatation before impending rupture requires emergency treatment.

The increased mortality after reoperations in the aortic root/ascending aorta compared with primary procedures might reflect the presence of more patients with aortic root infections in the reoperative group: such patients are known to have a high operative mortality and an enhanced risk of recurrent infection. The high proportion of patients with chronic dissection in the group undergoing reoperations, as well as the inclusion of some patients with extensive false aneurysms, might also contribute to the higher risk of early death in proximal aorta reoperations. The excellent long-term prognosis after surgical intervention and the knowledge that reoperation on the proximal aorta carries a significantly higher risk than primary proximal aortic surgery argue for aggressive use of aortic root/ascending aorta replacement in cases of aortic valve dysfunction with borderline ascending aortic dilatation.

The finding that a low ejection fraction is a risk factor in root/ascending aorta reoperations is in accordance with the finding in previous studies that mortality in reoperations on the aortic root is higher in patients in New York Heart Association class III or IV.[1,12] These reoperations require lengthy dissection and can be poorly tolerated if there is suboptimal myocardial protection intraoperatively, which is likely in patients who have concomitant aortic regurgitation. Postoperative mortality is likely to be especially high in patients in whom the myocardium is already compromised before surgical intervention.

In our series we have not seen many patients who required reoperations because of extensive destruction of the aortic root, as reported in other studies. This probably reflects a very low incidence of patients treated with gelatin resorcinol formol glue, which has been identified as the culprit in some series of reoperations prompted by problems at the aortic root.[13,14] In our practice, distal anastomoses are reinforced with Teflon felt, and distal suture line dehiscence and false aneurysms are therefore also uncommon.[10]

Arch Aneurysms

For patients with arch aneurysms, although crude operative mortality does not differ between primary and reoperative replacement, analysis of 1-year mortality compared with that seen in age- and sex-matched New York State population suggests significantly poorer 1-year survival for patients undergoing reoperations. After the first year, patients undergoing primary and reoperative arch procedures have an equivalent survival, but their late mortality is still significantly higher than that of a healthy population ($P = .01$ for primary operations and $P = .10$ for reoperations).

Overall mortality after arch replacement is 3 to 4 times that of a general population, reflecting both early and late deaths and driving home the point that patients with arch disease are not cured by arch resection. Although we believe that postoperative survival is undoubtedly better than in unoperated patients with significant arch aneurysms, the extent of enhanced survival after the operation is unknown. Moreover, because cardiovascular deaths, including from downstream aneurysmal disease, contribute to late mortality, continuing postoperative surveillance is extremely important after arch replacement. Avoidance of reoperation is not as critical as in the proximal aorta because the difference between the risk of primary and reoperative arch operations is small, and it cannot be anticipated that the patient will return to a normal life expectancy, even after successful arch replacement.

Given the evidence from this study, extensive arch resection during initial aneurysm surgery, especially under emergency circumstances in a center without special expertise in aortic surgery, would not seem to be justified. Under emergency circumstances, a more limited operation is more likely to be carried out safely, and arch operations can subsequently be undertaken electively without marked additional risk. The multivariate risk factors identified in this study are a reminder that even under elective circumstances, arch surgery is especially hazardous in the elderly patient with chronic lung disease and diabetes.

Axillary Cannulation

Axillary cannulation was an independent protective factor for long-term survival after aortic root/ascending aorta reoperations, and univariate analysis indicates that axillary artery cannulation might provide some advantage for 30-day survival in aortic reoperations as a whole ($P = .10$). The axillary artery provides an excellent route for SCP, which is almost invariably used for arch surgery.[9,10,14,15] Axillary artery cannulation can be especially valuable in reoperations by diminishing the risk of re-entry into a previously operated chest by allowing rapid initiation of cardiopulmonary bypass. Axillary cannulation also arguably reduces the risk of embolization in patients who have a high risk of stroke because of underlying atherosclerosis.

Comparison of Patients With Root/Proximal Aorta and Arch Aneurysms

For patients with proximal aortic disease, operative and 1-year mortality are higher for reoperations than for primary operations, but after 1 year, survival is equivalent to an age- and sex-matched population. For patients undergoing arch resections, operative mortality for primary and reoperative procedures are equivalent, although 1-year mortality is slightly higher after reoperation. After 1 year, in contrast to those undergoing proximal resections, patients undergoing arch resection continue to exhibit excess mortality compared with age- and sex-matched control subjects. Whether this difference in long-term outcome for patients undergoing root/ascending aorta resections and patients undergoing arch procedures reflects a fundamental difference in the biology of the disease or a different distribution of risk factors cannot be answered by our results and analysis. Nonetheless, it seems reasonable to say to a patient contemplating an operation of the aortic root/ascending aorta that a successful procedure is curative, as assessed by survival equivalent to a general population. For the patient facing an arch resection, however, although we believe that survival is superior to that of an unoperated patient with the same arch lesion, a successful operation does not ensure return to a normal survival expectation.

Conclusions

Early mortality in patients with resections of aneurysms of the aortic root/ascending aorta is higher after reoperations than after primary procedures. After 1 year, however, patients with both primary and reoperative proximal aortic surgery can anticipate longevity equivalent to that of their age- and sex-matched peers. In contrast, reoperations and primary operations for aortic arch aneurysms have a similar early mortality. Long-term outcome, however, shows ongoing excess mortality in patients with arch aneurysm repairs compared with that seen in age- and sex-matched control subjects.

References

1. Dougenis D, Daily BB, Kouchoukos NT. Reoperations on the aortic root and ascending aorta. *Ann Thorac Surg*. 1997;64:986-92.
2. David TE, Feindel CM, Ivanov J, Armstrong S. Aortic root replacement in patients with previous heart surgery. *J Card Surg*. 2004;19:325-8.
3. Dossche KM, Tan ME, Schepens MA, Morshuis WJ, de la Riviere AB. Twenty-four year experience with reoperations after ascending aortic or aortic root replacement. *Eur J Cardiothorac Surg*. 1999;16:607-12.
4. Hahn C, Tam SK, Vlahakes GJ, Hilgenberg AD, Akins CW, Buckley MJ. Repeat aortic root replacement. *Ann Thorac Surg*. 1998; 66:88-91.
5. Raanani E, David TE, Dellgren G, Armstrong S, Ivanov J, Feindel CM. Redo aortic root replacement: experience with 31 patients. *Ann Thorac Surg*. 2001;71:1460-3.
6. Schepens MA, Dossche KM, Morshuis WJ. Reoperations on the ascending aorta and aortic root: pitfalls and results in 134 patients. *Ann Thorac Surg*. 1999;68:1676-80.
7. Kirsch EW, Radu NC, Mekontso-Dessap A, Hillion ML, Loisance D. Aortic root replacement after previous surgical intervention on the aortic valve, aortic root, or ascending aorta. *J Thorac Cardiovasc Surg*. 2006; 131:601-8.
8. Ito M, Kazui T, Tamia Y, Morishitia K, Tanaka T, Komatsu K, et al. Redo composite valve graft replacement. *J Card Surg*. 2001;16: 240-5.
9. Spielvogel D, Etz CD, Silovitz D, Lansman SL, Griepp RB. Aortic arch replacement with a trifurcated graft. *Ann Thorac Surg*. 2007;83(suppl): S791-5; discussion S824-31.
10. Strauch JT, Spielvogel D, Lansman SL, Lauten AL, Bodian C, Griepp RB. Long-term integrity of Teflon felt-supported suture lines in aortic surgery. *Ann Thorac Surg*. 2005;79:796-800.
11. Edmunds LH Jr, Clark RE, Cohn LH, Grunkemeier GL, Miller DC, Weisel RD. Guidelines for reporting morbidity and mortality after cardiac valvular operations. *Eur J Cardiothorac Surg*. 1996;10: 812-6.
12. Szeto WY, Bavaria JE, Bowen FW, Geirsson A, Cornelius K, Hargrove WC, et al. Reoperative aortic root replacement in patients with previous aortic surgery. *Ann Thorac Surg*. 2007;84:1592-9.
13. Kazui T, Washiyama N, Bashar AH, Terada H, Suzuki K, Yamashita K, et al. Role of biologic glue repair of proximal aortic dissection in the development of early and midterm redissection of the aortic root. *Ann Thorac Surg*. 2001;72:509-14.
14. Sakurada T, Kikuchi Y, Hirano T, Yatsuyanagi E, Kusajima K, Suzuki M, et al. [Re-dissection of aortic root without gelatin-resorcin-formalin (GRF) glue effect one year after aortic repair]. *Kyobu Geka*. 2003;56:211-5.
15. Strauch JT, Spielvogel D, Lauten A, Lansman SL, McMurtry K, Bodian CA, et al. Axillary artery cannulation: routine use in ascending aorta and aortic arch replacement. *Ann Thorac Surg*. 2004;78: 103-8.

ACD

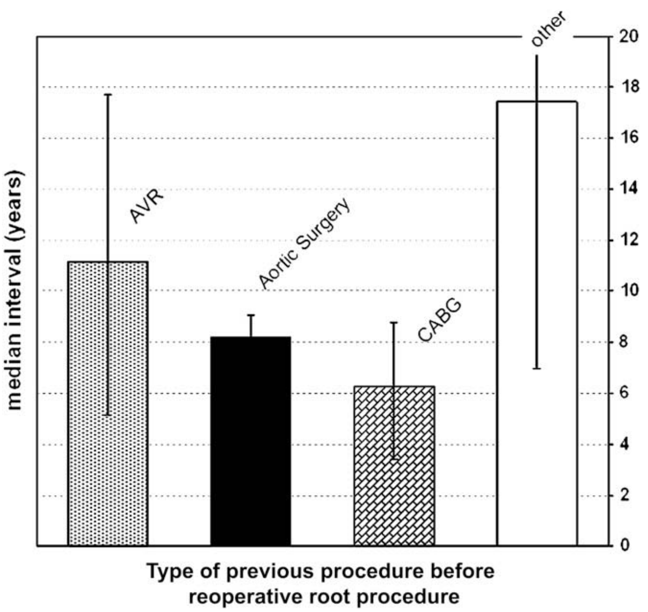

Figure E1. Interval between aortic root reoperation and the most recent previous procedure. Medians and interquartile ranges (in years) are shown as follows. Aortic valve replacement/repair *(AVR)*, 11.1 (interquartile range, 5.1–17.7); aortic surgery, 8.2 (interquartile range, 5.2–9.0); coronary artery bypass grafting *(CABG)*, 6.3 (interquartile range, 3.4–8.8); other, 18.4 (interquartile range, 7.0–26.7).

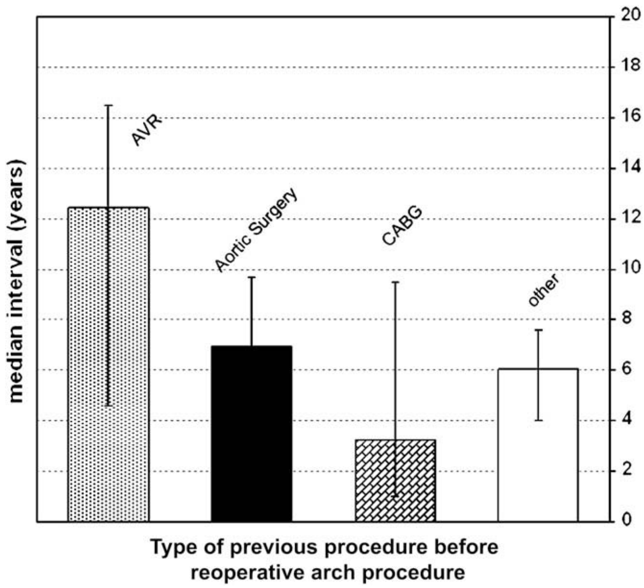

Figure E2. Interval between arch reoperation and the most recent previous procedure. Medians and interquartile ranges (in years) are shown as follows: aortic valve replacement/repair *(AVR)*, 12.4 (interquartile range, 4.6–16.5); aortic surgery, 7.0 (interquartile range, 3.0–9.7); coronary artery bypass grafting *(CABG)*, 3.3 (interquartile range, 1.0–9.5); other 6.0 (interquartile range, 4.0–7.6).

ACD

TABLE E1. Causes of hospital death

Cause of death	Roots		Arches	
	Reoperation (n = 100)	Primary operation (n = 335)	Reoperation (n = 100)	Primary operation (n = 145)
Myocardial failure	4 (4%)	5 (1.5%)	5 (5%)	2 (1.4%)
Bleeding	1 (1%)	1 (0.3%)	1 (1%)	1* (0.7%)
Sepsis	1 (1%)	2 (0.6%)	1 (1%)	–
Stroke	–	1 (0.3%)	2 (2%)	4 (2.8%)
Respiratory failure	–	–	–	1 (0.7%)
Bowel infarction	1 (1%)	1 (0.3%)	–	4 (2.8%)†
Multiorgan failure	–	–	1 (1%)	1 (0.7%)
Total mortality	7 (7%)	10 (3%)	10 (10%)	13 (9%)

*Aorta-related rupture. †Thromboembolic bowel infarction identified in 1 patient. The majority of cardiac complications were biventricular pump failures, with 1 instance of right heart failure.