CARDIOVASCULAR

Reduction Ascending Aortoplasty: Midterm Follow-Up and Predictors of Redilatation

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Background. **Reduction ascending aortoplasty is an alternative procedure to the replacement of the ascending aorta in case of ascending aorta aneurysm without aortic root involvement. This study was designed to evaluate the midterm follow-up of aortoplasty and to determine predictors of redilatation.**

Methods. **From January 1, 1998, to April 30, 2005, 68 patients with dilatation of the ascending aorta underwent unsupported reduction aortoplasty in combination with other cardiac procedures. All patients underwent associated surgical procedures. Sixty patients (88.2%) underwent associated aortic valve replacement. Cumulative follow-up time was 191.4 patient-years and was 100% complete. Median follow-up time was 2.5 years, and mean follow-up time was 2.9 ± 1.7 years (range, 0.4 to 6.3 years).**

Results. **The overall perioperative mortality rate was 1.5%. Overall survival estimates at 3 and 6 years were 93.3% ± 4.5% and 89.3% ± 5.9%, respectively. The actuarial freedom from cardiac-related death at 3 and 6 years was 100% and 95.7% ± 4.3%, respectively. Ascending aorta redilatation occurred in 5 patients (7.5%). The actuarial freedom from redilatation at 3 and 6 years was 97.7% ± 2.3% and 79.8% ± 8.4%, respectively. The actuarial freedom from reoperation at 3 and 6 years was 100% and 86.3% ± 7.5%, respectively. Only preoperative diameter was a significant predictor of redilatation using multivariate stepwise logistic regression analysis.**

Conclusions. **Unsupported reduction aortoplasty is a safe and effective technique with low mortality, low morbidity, and rare late complications for selected chronic aneurysm of the ascending aorta with diameter less than 55 mm.**

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A variety of different surgical techniques are currently available for the treatment of ascending aortic aneurysm. The choice of the appropriate technique requires careful consideration of many factors, such as aneurysm morphology, the associated dilatation of the annulus or sinuses, the presence of aortic valve disease, and surgical risks [1].

When the dilatation involves only the ascending aorta, the most frequently performed procedure is the ascending aorta replacement, which is associated with eventual aortic valve replacement if there is concomitant valve disease. This procedure offers good results [2], but still entails significant risk, with both perioperative mortality and morbidity varying up to 10% [3–6].

Reduction ascending aortoplasty (RAA) is an alternative to the ascending aorta replacement in patients with an ascending aortic aneurysm without aortic root involvement [7]. It is a feasible technique that presents various advantages, such as being a less radical procedure than Dacron graft replacement, a shorter cross-clamp time, and less bleeding. Moreover, lower rates of mortality and morbidity have been reported with RAA than with alternative procedures [8, 9].

However, as a result of a reported high aneurysm recurrence rate, RAA is considered a controversial surgical option that is generally limited to select patients in whom high perioperative risks necessitate shorter cross-clamp time [10]. Reduction ascending aortoplasty is traditionally indicated in older patients with nondissecting borderline ascending aortic aneurysm and nondilated aortic root, especially during operation for other cardiac disease [1, 11, 12].

Different types of RAA are described and can be supplemented with circumferential external reinforcement using synthetic materials [6]. In our institute, we performed the procedure described by Robicsek and coworkers [6, 7] without external reinforcement. This study was designed to evaluate the midterm follow-up of unsupported RAA and to determine predictors of redilatation.

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Table 1. Preoperative Characteristics

Characteristic	Number or Mean ± SD	Percentage or Range
Age (y)	61.9 ± 12.3	22–78
Sex		
Male	41	60.3%
Female	27	39.7%
NYHA functional classification		
Class I	5	7.3%
Class II	42	61.8%
Class III	21	30.9%
Electrocardiogram		
Sinus rhythm	66	97.1%
Atrial fibrillation	2	2.9%
Left ventricular ejection function	0.589 ± 0.095	0.360–0.744
>0.50	59	86.8%
0.40–0.50	7	10.3%
<0.40	2	2.9%
Aortic valve lesion	60	88.2%
Stenosis	21	30.9%
Insufficiency	23	33.8%
Mixed	6	8.8%
Bicuspid valve	10	14.7%
Previous AVR	3	4.4%
Coronary artery disease	11	16.1%
One-vessel	5	7.3%
Two-vessel	5	7.3%
Three-vessel	1	1.5%
Mitral valve disease	6	8.8%
Stenosis	3	4.4%
Insufficiency	3	4.4%

AVR = aortic valve replacement; NYHA = New York Heart Association; SD = standard deviation.

Material and Methods

From January 1, 1998, to April 30, 2005, 68 patients with ascending aortic dilatation underwent reduction aortoplasty alone or in combination with other cardiac procedures. Data were collected prospectively and patients were followed up at regular (6 months) intervals. This study had the approval of our institutional ethics committee, and written informed consent was obtained from every patient by the senior investigator in accordance with institutional guidelines.

Aortoplasty was performed when patients presented with moderate ascending aorta dilatation, with aortic diameters between 40 and 50 mm for younger patients and aortic diameters of up to 60 mm for older patients or in patients for whom it was believed that reducing cross-clamp and perfusion times would be beneficial owing to coexisting diseases. In the event of aortic diameters greater than 60 mm, aortoplasty was considered only when operative risk was very high.

Clinical variables are detailed in Table 1. The mean age was 61.9 ± 12.3 years (median, 64.5 years; range, 22 to 78 years). Forty-one patients were male (60.3%), and 92.7% of patients were in New York Heart Association functional class II or III.

We performed a preoperative echocardiography and a computed tomographic scan of the chest to evaluate the diameter of the ascending aorta in all patients. Aneurysm diameter was measured at the level of bifurcation of the pulmonary artery. The mean preoperative aortic diameter was 50.9 ± 7.0 mm (range, 39 to 70 mm). None of the patients had Marfan syndrome or other genetic disorders, as aortoplasty is contraindicated in such patients. Aortic dilatation was fusiform in all patients and localized to the ascending aorta without involving the aortic root or arch.

Aortic valve disease was present in 60 patients (88.2%). The valvular pathologic diagnosis was aortic stenosis in 21 patients (30.9%), aortic insufficiency in 23 patients (33.8%), and mixed lesion in 6 patients (8.8%). Ten patients (14.7%) had diseased bicuspid aortic valve. Three patients (4.4%) had previously undergone aortic valve replacement with mechanical valves. No patient had aortic root dilatation. All but 2 patients had good ventricular function. 59 patients (86.8%) had left ventricular ejection fraction greater than 0.50, 7 patients (10.3%) had left ventricular ejection fraction between 0.40 and 0.50, 2 patients (2.9%) had left ventricular ejection fraction less than 0.40. Cardiac catheterizations and coronary angiographies were performed in all patients 40 years or older. There was significant coronary artery disease in 11 cases (16.1%).

All patients underwent associated surgical procedures. Sixty patients (88.2%) underwent associated aortic valve replacement, whereas other concomitant procedures included coronary artery bypass grafting in 11 patients (16.1%), mitral valve replacement in 3 (4.4%), and mitral valve repair in 3 (4.4%).

Surgical Technique

Median sternotomy, cardiopulmonary bypass, moderate hypothermia (30°C), and aortic cross-clamping were used in all patients. The aortic cannula was placed in the proximal transverse aortic arch in all but 3 patients. A right femoral arterial cannula was used in patients with previous aortic valve replacement. Cardiac arrest was obtained by an initial bolus of anterograde cold crystalloid cardioplegic solution (only in patients with aortic valve stenosis), followed by a bolus of retrograde cold crystalloid cardioplegic solution and maintained by retrograde cardioplegia repeated at 20-minute intervals, with additional topical cooling. The aortic incision was extended from the noncoronary sinus following an upper left line along the aortic axis to the aortic arch bend just proximal to the aortic cross-clamp.

Reduction aortoplasty consisted of direct resection of an oval portion of the anterior aortic wall to bring the diameter of the ascending aorta down to normal. The expected supraaortic ridge was computed with Roman's formula [13]. Once the ideal aortic diameter was reached, we established a tail about 3 cm of circumference per 1 cm of diameter to reduce, given that the circumference is

Table 2. Operative and Perioperative Details

Variable	Number or Mean ± SD	Percentage or Range
Aortic cross-clamp time (min)	68.2 ± 8.1	32–79
Cardiopulmonary bypass time (min)	77.3 ± 13.2	42–94
Associated aortic valve replacement	60	88.2%
Biologic prosthesis	35	51.4%
Mechanical prosthesis	25	36.8%
Associated CABG	11	16.1%
One graft	5	7.3%
Two grafts	5	7.3%
Three grafts	1	1.5%
Number of distal anastomosis	1.6 ± 0.7	1–3
Associated mitral valve replacement	3	4.4%
Associated mitral valve repair	3	4.4%
Postoperative bleeding (mL)	335 ± 135	119–438
Postoperative complications	1	1.5%
Acute aortic arch dissection	1	1.5%
ICU stay (days)	2.07 ± 0.59	1–5
Postoperative stay (days)	7.5 ± 1.9	5–15
Total in-hospital stay (days)	13.7 ± 4.5	5–29

CABG = coronary artery bypass grafting; ICU = intensive care unit; SD = standard deviation.

$2\pi r$ (r = radius; $\pi = 3.14$). The aortotomy was then closed in two layers using 4-0 suture [9]. The aortoplasty was not additionally supported by wrapping the ascending aorta with a prosthetic graft.

All the associated cardiac procedures were performed after the incision of the aorta and before the aortoplasty. The mean aortic cross-clamp time was 68.2 ± 8.1 minutes, and the mean duration of cardiopulmonary bypass was 77.3 ± 13.2 minutes. Table 2 summarizes the surgical operations and operative data. Intraoperative transesophageal echocardiography was performed on every patient before and after reduction aortoplasty.

Patient Follow-Up

Data were obtained by means of direct visits and telephone interviews. Transthoracic echocardiography or computed tomographic scan of the chest was performed preoperatively, at discharge, at 3 months, at 1 year, and annually thereafter. Follow-up of survivors was last collected between May 15 and May 28, 2005. Cumulative follow-up time was 191.4 patient-years and was 100% complete. Median follow-up time was 2.5 years, and mean follow-up time was 2.9 ± 1.7 years (range, 0.4 to 6.3 years).

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation. Discrete variables were expressed as numbers and proportions. Actuarial life table estimates were constructed using the Kaplan–Meier method. Repeated-measures analysis of variance was used to detect any significant changes in mean ascending aortic diameter with time. If statistically significant, Student's paired *t* test was then performed, with Bonferroni's method used to correct for multiple comparisons.

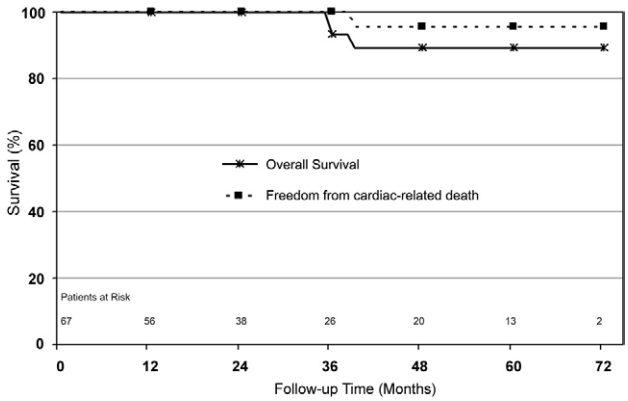

*Fig 1. The actuarial freedom from death (solid line, *) and the actuarial freedom from cardiac-related death (dashed line, ■).*

Significant predictors of redilatation were investigated by examining the association between various variables and redilatation in univariate analysis, followed by a stepwise logistic regression analysis on factors demonstrated to be significant in univariate analysis. For univariate and multivariate analysis, only patients with a follow-up greater than 12 months (58 patients) were included, as dilatation generally does not occur in the first months after surgery. A *p* value of less than 0.05 was considered statistically significant. Statistical analyses were performed using SPSS 13.0 software (SPSS, Inc, Chicago, IL).

Results

Postoperative and Perioperative Mortality and Morbidity

There was one in-hospital death. The cause of death was acute anterograde dissection of the aortic arch that oc-

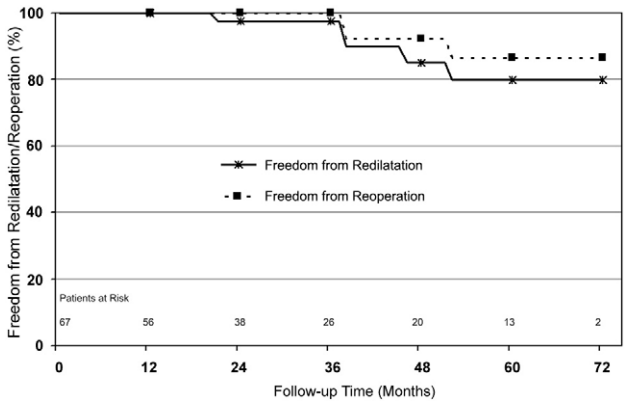

*Fig 2. The actuarial freedom from redilatation (solid line, *) and the actuarial freedom from reoperation (dashed line, ■).*

Table 3. Changes in Mean Ascending Aorta Diameters[a]

Diameter	Preoperative	Postoperative	3 months	1 year	2 years	3 years	4 years	5 years
Total[b]	50.9 ± 7.0	36.4 ± 5.2[c]	36.2 ± 4.9[c]	36.5 ± 5.3[c]	36.7 ± 9.3[c]	39.5 ± 7.6[c]	37.0 ± 5.6[c]	39.3 ± 4.2[c]

[a] Values are in millimeters (mean ± standard deviation). [b] $p < 0.001$ by repeated-measures analysis of variance. [c] $p < 0.05$ versus preoperative.

curred 5 days after surgery. The overall perioperative (30-day) mortality rate was 1.5%. No other patient experienced significant postoperative complications. The total perioperative morbidity rate was 1.5%.

Long-Term Survival

There were 3 late deaths at the time of follow-up. Overall survival estimates at 3 and 6 years were 93.3% ± 4.5% and 89.3% ± 5.9%, respectively (Fig 1). The mean age at death was 76.1 ±70 years.

There was one cardiac-related death, with stroke as the cause of death. The actuarial freedom from cardiac-related death at 3 and 6 years was 100% and 95.7% ± 4.3%, respectively (Fig 1). There were 2 noncardiac deaths, attributed to lung cancer and prostate cancer. The actuarial freedom from noncardiac death at 3 and 6 years was 93.3% ± 4.5% and 93.3% ± 4.5%, respectively.

Ascending Aortic Redilatation and Reoperation

Ascending aorta redilatation occurred in 5 patients (7.5%) after 21, 38, 38, 46, and 52 months. The actuarial freedom from redilatation at 3 and 6 years was 97.7% ± 2.3% and 79.8% ± 8.4%, respectively (Fig 2). The mean diameter of the redilated aorta was 50.8 ± 4.6 mm. All patients who experienced redilatation had a preoperative original diameter greater than 55 mm (56, 56, 58, 64, and 70 mm). Original dilatation was associated with aortic stenosis in 2 patients, aortic insufficiency in 2, and bicuspid valve in 1.

Three patients underwent ascending aortic replacement with Dacron graft. All 3 patients survived reoperation uneventfully. In the other 2 cases, it was decided not to proceed because of the stability of the ascending aorta dilatation and patients' advanced age. The actuarial freedom from reoperation at 3 and 6 years was 100% and 86.3% ± 7.5%, respectively (Fig 2).

The ascending aorta diameters are summarized in Table 3. As shown, the mean diameter decreased significantly after surgery without further changes.

Predictors of Redilatation

Table 4 outlines variables that were evaluated for their impact on redilatation using univariate analysis. The only significant risk factor adversely affecting redilatation was preoperative diameter. Although not significant, the p value for postoperative ascending aorta diameter was near to significance ($p = 0.074$) and was included in the multivariate analysis.

Only preoperative diameter was a significant predictor of redilatation using multivariate stepwise logistic regression analysis (Table 5).

The preoperative ascending aortic diameter was dichotomized using different cut-off values (45, 50, 55, or 60 mm) to determine which is the first to be an independent risk factor for redilatation in a logistic regression model. A preoperative diameter greater than 55 mm was found to be a predictor of redilatation ($p = 0.304$ for 45 mm; $p = 0.148$ for 50 mm; $p = 0.009$ for 55 mm; $p = 0.023$ for 60 mm). The odds ratio was 18.5 for preoperative aortic diameter greater than 55 mm.

Comment

Reduction ascending aortoplasty is a procedure for the treatment of ascending aortic aneurysm, and a viable alternative to radical ascending aortic replacement. It is generally indicated in patients with a borderline dilated aorta in which a decreased aortic cross-clamping time is advantageous [14]. Reduction ascending aortoplasty is effective in decreasing the aortic diameter with short cross-clamp times and low rates of mortality and morbidity [8, 9]. In our series, only 1 patient experienced a serious perioperative complication, dissection of the aortic arch, which led to death. All other patients experienced an uncomplicated postoperative course. The good perioperative outcomes of RAA contrasts with that of total ascending aortic replacement, which still remains a challenge, as reported by Robicsek and colleagues [6]. Ascending aortic replacement entails higher rates of perioperative mortality and morbidity [3, 4, 15–17], but could reflect differing situations and patient characteristics. Aortoplasty is not indicated in all patients who require an ascending aortic replacement, as patients with type A aortic dissection, Marfan syndrome, and cystic medial necrosis are generally contraindicated. However, reduction aortoplasty is generally performed in older patients with high perioperative risks and with other associated cardiac procedures.

The major concern about reduction aortoplasty is the long-term follow-up, with specific regard to survival and rate of redilatation. We pointed out an overall survival estimate at 6 years of 89.3% ± 5.9% and a freedom from

Table 4. Univariate Analysis of Variables Affecting Redilatation

Variable	p Value
Age	0.756
Sex	0.639
Aortic disease	0.227
Previous aortic valve replacement	0.759
Bicuspid valve	0.584
Preoperative ascending aorta diameter	0.001
Postoperative ascending aorta diameter	0.074

Table 5. Factors Affecting Redilatation Using Multivariate Stepwise Logistic Regression

Variable	OR	95% CI	*p* Value	SEM
Preoperative aortic diameter	1.29	1.01–1.63	0.038	0.122

CI = confidence interval; OR = odds ratio; SE = standard error of the mean.

cardiac-related death at 6 years of 95.7% ± 4.3%. Only 1 patient at 6 years' follow-up died of cardiac reasons whose cause of death was not related to reduction aortoplasty, as stroke was related to aortic valve replacement. These results are similar to those presented in other studies [8–10]. Bauer and associates [9] reported a survival at 5 years of 94%. They also reported freedom from aortoplasty-related mortalities, supporting the claim that reduction aortoplasty procedure does not affect midterm and long-term survival [8, 9].

Literature review regarding the occurrence of redilatation after RAA shows conflicting results, with rates varying from 0% to 25% [8–10, 18]. The absence of external reinforcement is claimed to be responsible for these differences, but direct comparison among studies is difficult owing to lack of homogeneous groups. Arsan and colleagues [8] reported concomitant aortic valve replacement in 35.5% of patients, without specifying the type of valve disease, whereas 88.9% of patients underwent combined aortic valve replacement in our group and 94.8% in the report of Bauer and associates [9]. In our study, the leading valvular disease was insufficiency (42.6%), whereas Bauer and coworkers [9] reported 22.6% of insufficiency and 47.8% of stenosis. Again, Muller and colleagues [10] reported that all redilatation occurred in patients with Marfan syndrome whereas other authors considered Marfan syndrome to be a contraindication to RAA [6, 8, 9]. We found an actuarial freedom from redilatation at 6 years of 79.8% ± 8.4%. Five patients had redilatation of the ascending aorta (7.5%). This result is similar to those of Bauer and colleagues [9] and Kamada and associates [18].

There is a general agreement that patients with ascending aortic aneurysm greater than 60 mm should not undergo reduction aortoplasty [6]. Univariate and multivariate analysis of our data confirmed that preoperative diameter is the main factor to be considered before performing RAA, as it is the only independent risk factor for redilatation. The risk of redilatation increased significantly for preoperative diameter greater than 55 mm ($p = 0.001$), with an odds ratio of 18.5. All patients who exhibited redilatation had a preoperative diameter greater than 55 mm. We agree with Kamada and coworkers [18] and advise that a diameter of 55 mm should be considered the cut-off.

Another important factor to avoid redilatation after RAA is the postoperative ascending aortic diameter. In our study, it was not identified as an independent risk factor for redilatation, even given a difference of postoperative diameter among patients who experienced redilatation and who did not approach significance ($p = 0.078$). This could reflect a dependent correlation between preoperative and postoperative diameters, as patients with greater preoperative diameter had greater postoperative diameter. Although not significant in our study, the postoperative diameter still remains an important concern, and it should be less than 35 mm to avoid redilatation [9].

No other risk factors were identified, including aortic valve insufficiency, which is reported to be a risk factor for redilatation after unsupported RAA [6]. However, an aortic prosthesis was implanted in all cases, which can favorably influence the outcomes by stabilizing the aortic orifice and facilitating proximal anchoring.

Limitations of the Study

This study is prospective by nature, but is not randomized. Aortoplasty was performed in a selected subgroup of patients with aneurysm of the ascending aorta. Information was not collected regarding aortic wall histology, and was not correlated to redilation. Moreover, long-term follow-up is needed to evaluate whether patients with a preoperative diameter less than 55 mm also can redilate, particularly with respect to this young group.

Conclusions

In our group, unsupported RAA resulted in a safe and effective technique with low mortality, low morbidity, and few late complications for selected chronic aneurysm of the ascending aorta with diameter less than 55 mm. It can represent an alternative to the replacement of the ascending aorta in selected patients with moderate dilatation. A diameter greater than 55 mm is an independent risk factor for redilatation, and it should be considered a contraindication to this procedure and may be considered an indication to the Dacron graft support.

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