Results of aortic valve–sparing operations

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Objective: To review the late results of valve-sparing operations in patients with aortic root aneurysm and in those with ascending aortic aneurysm and aortic insufficiency.

Methods: From May 1988 to June 2000, 120 patients with aortic root aneurysm and 68 with ascending aortic aneurysm and aortic insufficiency underwent aortic valve–sparing operations. Patients with aortic root aneurysm were younger, were predominantly male, and had less severe aortic insufficiency than patients with ascending aortic aneurysm, who were older and often had aneurysm of the transverse arch. Forty-eight patients with aortic root aneurysm had the Marfan syndrome. The prevalence of aortic dissection was similar in both groups. Reconstruction of the aortic root was performed by reimplanation of the aortic valve in 64 patients and by remodeling of the aortic root in 56. Patients with ascending aortic aneurysm and aortic insufficiency were treated by replacement of the ascending aorta with reduction in the diameter of the sinotubular junction. Approximately two thirds of the latter patients also required replacement of the transverse aortic arch. The mean follow-up was 35 ± 31 months for patients with aortic root aneurysm and 26 ± 23 months for those with ascending aortic aneurysm.

Results: There were 2 operative and 5 late deaths in patients with aortic root aneurysm and 1 operative and 9 late deaths in patients with ascending aortic aneurysm. The 5-year survival for patients with aortic root aneurysm was 88% ± 4% and for patients with ascending aortic aneurysm, 68% ± 12% ($P = .01$). Severe aortic insufficiency developed in 2 patients, and they required aortic valve reoperation. The 5-year freedom from aortic valve reoperation was 99% ± 1% for patients with aortic root aneurysm and 97% ± 4% for those with ascending aortic aneurysm. Seven patients had moderate aortic insufficiency at the latest echocardiographic study. The 5-year freedom from severe or moderate aortic insufficiency was 90% ± 4% in patients who had aortic root aneurysm and 98% ± 2% in those who had ascending aortic aneurysm.

Conclusions: Aortic valve–sparing operations have provided excellent clinical outcomes and few valve-related complications. The function of the reconstructed aortic root remains unchanged in most patients during the first 5 years of follow-up.

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Aortic insufficiency may develop in patients with ascending aortic aneurysm because of dilation of the sinotubular junction, and the aortic cusps may remain normal. Inasmuch as the sinuses of Valsalva are minimally dilated, simple reduction in the diameter of the sinotubular junction restores aortic valve competence in these patients.[1,2] Patients with aortic root aneurysm have dilated sinuses of Valsalva. Isolated dilation of the sinuses of Valsalva does not cause aortic insufficiency.[3,4] As the sinotubular junction and/or the aortic anulus dilate, aortic insufficiency ensues.[3,4] If the aortic cusps remain normal or minimally stretched, an aortic valve–sparing operation is feasible.[1,2] Aortic valve–sparing operations in patients with aortic root aneurysms are more complex than in those with ascending aortic aneurysm because they may involve reduction in the diameter of the aortic anulus if they have annuloaortic ectasia, creation of neoaortic sinuses, adjustment of the sinotubular junction, and reimplantation of the coronary arteries.[1,2,4-7]

We have performed aortic valve–sparing operations since 1988 in our institution and the results have been most gratifying. This report describes the clinical outcomes of these operations in patients with aortic root and/or ascending aortic aneurysms.

Patients and Methods

From May 1988 to June 2000, 188 patients underwent aortic valve–sparing operations at Toronto General Hospital. All patients with aortic root aneurysm were included in this study. Patients with ascending aortic aneurysm and aortic insufficiency (AI) were also included. Patients with ascending aortic aneurysm and a normally functioning aortic valve were excluded. Forty-eight patients had the Marfan syndrome according to the Gent criteria.[8]

On the basis of intraoperative transesophageal echocardiography[9] and surgical findings, 120 patients had aortic root aneurysm with various degrees of AI and 68 patients had primary aneurysm of the ascending aorta with secondary dilation of the sinotubular junction, normal aortic anulus, and moderate or severe AI. Patients with aortic root aneurysm had an aortic valve–sparing operation by means of "reimplantion of the aortic valve" or "remodeling of the aortic root" as previously described by us.[1,2] Table 1 shows the clinical data on patients with aortic root aneurysm according to the operative technique used for repair and in patients with ascending aortic aneurysms.

Operative Procedures

The selection of the operative procedure was based on the location of the aneurysm and the pathophysiology of AI. Patients with ascending aortic aneurysm with normal aortic anulus, aortic cusps, and sinuses of Valsalva but dilated sinotubular junction and AI had replacement of the ascending aorta with reduction in the diameter of the sinotubular junction.[1,2,4] This was accomplished by suturing a tubular Dacron graft right at the level of the sinotubular junction. The diameter of the graft was equal to or slightly smaller than the average length of the free margins of the aortic cusps. This procedure was performed in 68 patients. Eleven of them also required replacement of the noncoronary aortic sinus and/or of the right coronary aortic sinus because of acute or chronic dissection of the sinus wall.

Patients with aortic root aneurysm had either reimplantation of the aortic valve into a tubular Dacron graft (64 patients) or remodeling of the aortic root with a tailored graft to create three neoaortic sinuses (56 patients). The choice of one or the other procedure was entirely the surgeon's personal preference. Patients who had reimplantion of the aortic valve or remodeling of the aortic root had similar abnormalities and clinical profiles in this study. Patients with annuloaortic ectasia had either reimplantation of the aortic valve or remodeling of the aortic root combined with an aortic annuloplasty.[2] The coronary arteries were reimplanted into their respective neoaortic sinuses.

Thirteen patients who had aortic root aneurysm and 5 who had ascending aortic aneurysm had prolapse of one aortic cusp. Cusp prolapse was corrected by shortening of the free margin either by central plication or by weaving a double layer of a fine suture of expanded polytetrafluoroethylene all along the free margin.[10]

Table 2 summarizes the operative data.

Follow-up

Patients were contacted at yearly intervals. No patient was lost to follow-up. The mean follow-up for all patients was 36 ± 28 months (range 0-134 months). The mean follow-up was 35 ± 31 months for patients with aortic root aneurysm and 26 ± 23 months for those with ascending aortic aneurysm ($P = .03$). Every patient had an echocardiographic study at the last follow-up contact, and most patients have had annual studies.

Statistical Analysis

All data analyses were performed with SAS 6.12 for Windows (SAS Institute, Inc, Cary, NC). Subgroup comparisons were made with the use of unpaired t tests for continuous variables and the χ^2 or Fisher exact test for categorical variables. Kaplan-Meier analysis was used for the evaluation of time-related variables; subgroup comparisons were made by means of the log-rank test.

Results

There were 3 operative deaths: 2 due to myocardial infarction and 1 due to pneumonia after hospital discharge. Table 2 shows the operative mortality and morbidity in each subgroup of patients. Re-exploration of the mediastinum for bleeding or pericardial tamponade was needed in 17 patients (9%). Seven patients had a perioperative stroke (4 recovered completely and 3 were left with residual deficits). Four patients had a myocardial infarction and 2 of them died. The second patient in this series had reimplantation of the aortic valve without intraoperative echocardiography and was found to have severe AI on the first postoperative day. He underwent successful replacement of the aortic root with a valved conduit. There was no other serious postoperative complication.

Fourteen patients died during the follow-up: 5 in the aortic root aneurysm group and 9 in the ascending aortic

TABLE 1. Clinical profile of patients with aortic root and ascending aortic aneurysms

	Aortic root aneurysm			
	Reimplantation	Remodeling	Ascending aortic aneurysm	*P* value*
No. of patients	64	56	68	
Mean age ± SD	44 ± 14	49 ± 17	64 ± 12	.001
Sex				
Male	49 (77)	44 (79)	38 (56)	
Female	15 (23)	12 (21)	30 (44)	.008
Body surface area (m^2)	2.00 ± 0.36	2.02 ± 0.28	1.87 ± 0.26	.004
NYHA functional class				
I	30 (47)	26 (46)	14 (21)	
II	15 (23)	14 (25)	25 (37)	
III	7 (11)	7 (12)	15 (22)	
IV	12 (19)	9 (16)	14 (21)	.032
Type A aortic dissection				
Acute	9 (14)	3 (5)	7 (10)	
Chronic	3 (5)	7 (12)	6 (9)	.4
Marfan syndrome	29 (45)	19 (35)	0	.001
Previous operations				
RAA	3 (5)	7 (12)	0	
Ross	1 (2)	0	0	.021
Left ventricular ejection fraction				
≥60%	38 (59)	31 (55)	19 (28)	
40%-59%	20 (31)	21 (37)	37 (54)	
21%-39%	6 (9)	2 (4)	10 (15)	
≤20%	0	2 (4)	2 (3)	.004
Coronary artery disease	7 (11)	8 (14)	17 (25)	.09
Aortic arch aneurysm	2 (3)	3 (5)	43 (63)	.001
Mega-aorta syndrome	0	2 (3)	22 (32)	.001
Mitral insufficiency	5 (2)	3 (5)	4 (6)	.8
Annuloaortic ectasia	52 (81)	15 (28)	0	.001
Bicuspid aortic valve	1 (2)	1 (2)	6 (9)	.06
Diameter of aneurysm (mm)	54 ± 11	53 ± 10	61 ± 11	.03
Aortic insufficiency				
None/trace (1+)	10 (16)	8 (14)	0	
Mild (2+)	27 (42)	26 (46)	0	
Moderate (3+)	20 (31)	16 (29)	31 (46)	
Severe (4+)	7 (11)	6 (11)	37 (54)	.001

**P* values are for differences between the three groups of patients. In the subgroups reimplantation and remodeling, only age and annuloaortic ectasia were statistically different. Percentages are shown in parentheses. *SD,* Standard deviation; *NYHA,* New York Heart Association; *RAA,* replacement of the ascending aorta; *Ross,* aortic root replacement with pulmonary autograft.

aneurysm group. The causes of death in the aortic root aneurysm group were aortic dissection in 2, sudden death in 1, and noncardiovascular in 2. The causes of death in the ascending aortic aneurysm group were aortic dissection in 1, myocardial infarction in 3, stroke in 1, and noncardiovascular in 4. The 5-year survival for patients with aortic root aneurysm was 88% ± 4%, and for patients with ascending aortic aneurysm it was 68% ± 12% ($P = .01$), as shown in Figure 1. The late survival in patients with aortic root aneurysm was better than in patients with ascending aortic aneurysm, but the latter patients were older and had more extensive vascular disease, renal failure and hypertension. Table 3 shows the 5-year survival in various subgroups of patients.

In 1 patient with a bicuspid aortic valve who had cusp repair and replacement of the ascending aorta with reduction of the sinotubular junction, severe AI developed 2 years postoperatively. He underwent successful aortic root replacement. Thus, only 2 patients have required aortic root reoperation because of recurrent severe AI. There were no other reoperations in the aortic root of any patient from either group. The 5-year freedom from aortic root reoperation was 99% ± 1% in patients with aortic root aneurysm and 97% ± 2% in those with ascending aortic aneurysm (Figure 2).

TABLE 2. Operative data

	Aortic root aneurysm			
	Reimplantation	Remodeling	Ascending aortic aneurysm	*P* value
No. of patients	64	56	68	
Aortic annuloplasty*	64 (100)	13 (23)*	0	.001
Adjustment of STJ	64 (100)	56 (100)	68 (100)	1.0
Repair of cusp prolapse	7 (11)	6 (11)	5 (7)	.7
Replacement of transverse arch	2 (3)	3 (5)	43 (63)	.001
Mitral valve surgery				
Repair	6 (10)	3 (5)	2 (3)	
Replacement	0	0	2 (3)	.2
Coronary artery bypass	8 (12)	9 (16)	17 (25)	.16
Repair of abdominal aortic aneurysm	1	0	0	.4
Aortic crossclamping time (min)	115 ± 28	102 ± 25	71 ± 26	.001
Cardiopulmonary bypass (min)	143 ± 36	127 ± 36	101 ± 35	.001
Operative complications				
Death	1	1	1	1.0
Re-exploration for bleeding	4 (6)	7 (12)	6 (9)	.5
Stroke	1†	2†	4 (6)	.4
Myocardial infarction	1	1	2	.4
Aortic root replacement	1	0	0	.4

Percentages are shown in parentheses.
*Patients with annuloaortic ectasia.
†Patients with acute type A aortic dissection.

In addition to 2 patients who required aortic root reoperation for severe AI, 7 patients had moderate AI at the most recent echocardiographic study. The remaining patients had mild, trace, or no AI. The 7 patients with moderate AI were asymptomatic and had normal left ventricular size and function. Of these patients, 3 had reimplantation of the aortic valve and 4 had remodeling of the aortic root. The 5-year freedom from severe or moderate AI was 90% ± 4% in patients with aortic root aneurysm and 98% ± 2% in those who had ascending aortic aneurysm.

Five patients required further aortic surgery in the transverse arch or descending thoracic aorta because of expansion of the false lumen of a dissecting aneurysm or as the second-stage treatment for mega-aorta syndrome. One patient with the Marfan syndrome who required replacement of the entire aorta became paraplegic. The other patients did well.

Seven thromboembolic events occurred: 2 strokes (1 fatal) and 5 transient ischemic attacks (TIAs). Both strokes and 2 TIAs occurred in patients who had ascending aortic aneurysm. Patients who had reimplantation of the aortic valve had 2 TIAs and those who had remodeling had 1 TIA. Two of these 3 events occurred in patients who had also had mitral valve repair for advanced myxomatous disease of the mitral valve. The 5-year freedom from thromboembolic events was 95% ± 3% in patients who had aortic root aneurysm and 86% ± 8% in those who had ascending aortic aneurysm.

Discussion

This study examined the outcomes of aortic valve–sparing operations in two distinct pathologic entities: ascending aortic aneurysm with AI and aortic root aneurysm. AI may develop in patients with primary aneurysm of the ascending aorta because of dilation of the sinotubular junction with outward displacement of the aortic valve commissures.[1,2,4,6] These patients frequently have normal or minimally diseased aortic valve cusps. Replacement of the ascending aorta with a graft of a predetermined diameter is all that is required to correct the AI. The graft is sutured right at the sinotubular junction and the three commissures must be spaced according to the size of the aortic cusps. Thus, if the three cusps have similar sizes, the commissures should be equidistantly spaced along the suture line. However, if one cusp is larger that the other (eg, the noncoronary cusp is larger than the right and left cusps), the commissures of the larger cusp should be spaced further apart than the other two commissures. The diameter of the sinotubular junction should not exceed the average length of the free margins of the aortic cusps.[2,4] We use the average length of the free margins of the three cusps to select the size of graft to adjust the diameter of the sinotubular junction. If the estimated diameter of the sinotubular junction is less than 26 mm in an adult patient, we use a graft of 26 mm or larger and reduce the end of the graft that is going to be anastomosed to the aortic root to avoid an increase in left ventricular afterload. This is particularly important in large patients

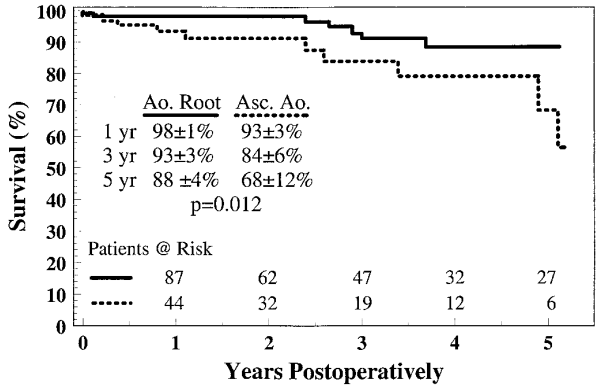

Figure 1. Survival in patients with aortic root and ascending aortic aneurysms.

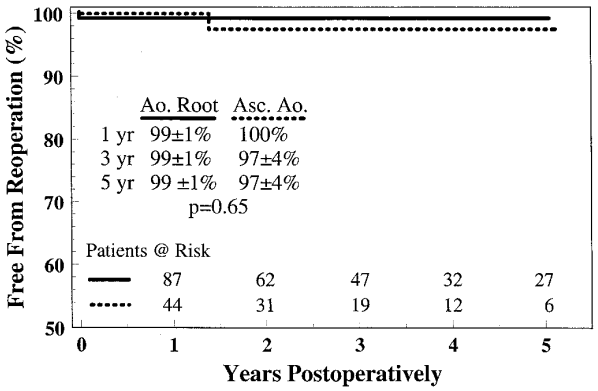

Figure 2. Freedom from aortic root reoperation.

ACD

who also require replacement of the transverse arch by the elephant trunk technique.

The noncoronary aortic sinus and, less often, the right coronary sinus may be damaged by acute or chronic aortic dissections and should be replaced with a tailored Dacron graft in patients with primary aneurysm of the ascending aorta.[1,2] This was done in 11 of 68 patients with ascending aortic aneurysm in this series.

Patients with aneurysm of the ascending aorta and AI due to dilated sinotubular junction are usually in their sixth or seventh decades of life. Advanced age was one of the reasons the late survival of our patients with ascending aortic aneurysm and AI was not as good as in patients who had aortic root aneurysm. In addition, they also had more extensive vascular disease, such as aneurysm of the transverse arch and/or entire thoracic and abdominal aorta, coronary artery disease, renal failure, and other systemic diseases.

Patients with aortic root aneurysms often have normal or minimally stretched aortic cusps when they are referred for surgery. Isolated dilation of the sinuses of Valsalva does not cause AI.[3] However, as the aortic sinuses dilate, the sinotubular junction and/or the aortic anulus may also dilate and cause AI.[4] As the root dilates, the increased mechanical stress may damage the aortic cusps. They become thinner and overstretched, and stress fenestrations appear along their commissural areas. These changes are uncommon when the root measures less than 50 mm in diameter, and they are common when the diameter exceeds 60 mm.[11] Patients with aortic root aneurysms often have the Marfan syndrome or its forma frusta. They are usually in their third or fourth decades of life when they require surgical intervention.

We have used two basic types of aortic valve–sparing operations to treat aortic root aneurysm: reimplantation of the aortic valve and remodeling of the aortic root.[1,2] Early in our experience we used the reimplantation technique. The main drawback of this operative procedure is that it places

TABLE 3. Kaplan-Meier estimates of survival in various subgroups of patients

Subgroup	Survival at 5 years	*P* value
Reimplantation	94% ± 4%	
Remodeling	83% ± 7%	.06
Marfan syndrome	100% ± 5%	
No Marfan syndrome	68% ± 6%	.001
Aortic arch aneurysm	56% ± 13%	
No aortic arch aneurysm	91% ± 4%	.0001
Aortic dissection	84% ± 8%	
No aortic dissection	82% ± 5%	.9

the aortic cusps inside a cylindrical structure without aortic sinuses, with potential increase in the mechanical stress on the aortic cusps.[5,12] In an attempt to correct this problem we switched to the remodeling technique. We added an aortic annuloplasty to the remodeling procedure in patients with annuloaortic ectasia.[2] Schafers and colleagues[13] found similar clinical and echocardiographic outcomes with these 2 operative procedures. Our results are similar with both operations. However, after 12 years of experience with both procedures, we prefer the reimplantation technique for the following reasons. Most patients with aortic root aneurysm have some degree of annuloaortic ectasia. We believe that an aortic annuloplasty is important to prevent further dilation of the aortic anulus with resulting late AI. Although a separate annuloplasty can be performed during the remodeling procedure, it is already incorporated into the reimplantation technique. In a report by Yacoub and coworkers,[14] who used the remodeling technique without annuloplasty in 158 patients, the freedom from aortic root replacement was 89% at 10 years, and moderate AI was documented in one third of the patients postoperatively. In our series, the patients with the longest follow-up had the technique of reimplanta-

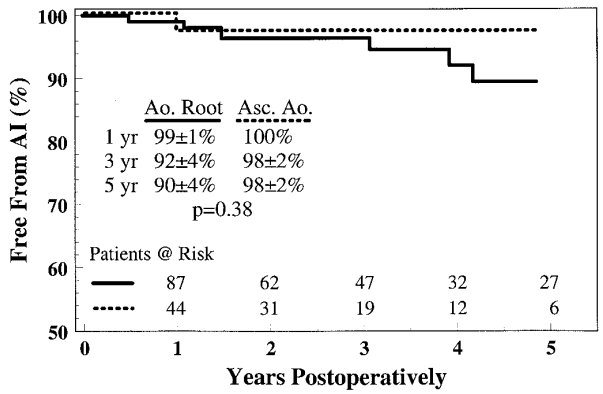

Figure 3. Freedom from 3+ or 4+ AI.

tion of the aortic valve, and the freedom from aortic valve reoperation was 99% at 5 years. The freedom from moderate or severe AI was 90% at 5 years. We believe the difference in outcomes is due to the fact that all our patients with annuloaortic ectasia had the reimplantation technique or remodeling with an aortic annuloplasty.

A recent study on finite element analysis of the aortic root by Grande-Allen and colleagues[12] suggested that placement of the aortic valve inside a cylindrical structure such as the reimplantation technique is associated with increased stress on the aortic cusps. Although that study may have some limitations because of its design,[15] it is probably true that the sinuses of Valsalva are important to minimize stress on the aortic cusps. However, it is possible to create neoaortic sinuses with either procedure—remodeling or reimplantation. To create neosinuses with the remodeling procedure, all that is required is to tailor the graft in such way that the area of the fabric contained within two commissures is larger than that anatomic area.[2] With the reimplantation technique, neosinuses are created by using a tubular Dacron graft 2 to 4 mm larger in diameter than needed; after the valve is reimplanted, the spaces between the commissures are plicated to reduce the diameter of the sinotubular junction to the desired one. This maneuver creates neoaortic sinuses that bulge like the normal ones.[15]

The reimplantation technique is particularly useful in patients with aortic root aneurysm and acute type A aortic dissection because it is extremely hemostatic in comparison with other techniques. Of 12 patients with acute type A aortic dissection and aortic root aneurysm, the reimplantation technique was used in 9 patients and remodeling in 3. Aortic dissection had no effect on late survival, but the number of patients with acute type A dissection was small in this series.

The late results of aortic valve–sparing operations have been exceptionally good in patients with the Marfan syndrome.[11,16] None of the 48 patients with the Marfan syndrome in our series have required aortic valve reoperation during the first decade of follow-up, and only 1 patient has moderate AI, which has been present since the operation and has not changed over the years. More important, the 5-year survival in patients with the Marfan syndrome was 100%. We believe the outcomes of valve-sparing operations are better than those of aortic root replacement in patients with the Marfan syndrome.[11] Because of these excellent results, we now recommend surgery in patients with the Marfan syndrome when the diameter of the aortic sinuses reaches 50 mm and echocardiography suggests normal aortic cusps. We believe that it is important to operate on these patients before permanent damage to the aortic cusps occurs. As a general rule, the probability of a valve-sparing operation decreases as the diameter of the aortic root increases.

Aortic cusp prolapse resulting from elongation of its free margin may contribute to the AI in patients with aortic root aneurysm, as well as in those with ascending aortic aneurysm. When only one cusp is prolapsing because of excessive dilation of its aortic sinus, we have shortened its free margin by central plication or by reinforcement and shortening with a double layer of a 6-0 expanded polytetrafluoroethylene suture.[10] The right and the noncoronary cusps have been the ones more often affected. Although we have added this procedure in only 18 patients during the past 5 years, the midterm results have shown no more AI in this small subgroup than in those with normal cusps. The addition of cusp repair has allowed us to expand the indication for valve-sparing operations.

We documented 2 strokes and 5 TIAs in our patients during the follow-up. Both strokes occurred in elderly patients with extensive vascular disease, but 3 TIAs occurred in relatively young patients with aortic root aneurysm, although 2 of them had also had mitral valve repair for myxomatous disease of the mitral valve. Since this analysis, we now recommend that all patients receive an antiplatelet drug such as aspirin.

In conclusion, the late results of aortic valve–sparing operations have been excellent, and they justify the recommendation of earlier surgery in patients with aortic root aneurysm in whom there is evidence of progressive dilation and echocardiographically normal aortic cusps.

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Discussion

Sir Magdi Yacoub *(London, England).* Dr David, this is a superb series comprising a relatively large number of patients followed up for up to 11 years, with a mean of 3 years. It includes patients with aortic wall disease with either potential or actual aortic valve dysfunction who required or actually underwent a valve-sparing operation. The end points looked at were survival, valve function, and incidence of other complications.

You have shown that the results are good or excellent in terms of survival, particularly in the Marfan group, and that aortic valve function is stable. You have compared the techniques, but I will limit myself to the techniques dealing with the aortic root rather than the ascending aorta. In the manuscript, you express a preference for the tube technique rather than the remodeling technique.

I have a few questions and one comment. What is the percentage of patients who underwent replacement? This series represents what percentage of the total number of patients who required operations on the aortic root? How often was it feasible to perform this operation?

With regard to the indications for operation in patients with Marfan syndrome, you mentioned the dimension of 5 cm, but did you take into account the rate of progression, the presence of intramural hemorrhages, family history of rupture, or pregnancy? What do you do about root aneurysms in patients with the Marfan syndrome who are pregnant?

My next point has to do with dissection. You mentioned that 34 patients had dissection. Was that acute or chronic dissection? Acute dissection can have major implications for survival and complications that are not related to the techniques but to the preferral complications. In our series we have found that acute as well as chronic dissection does influence the long-term results. Therefore, in chronic dissections, although there was no early mortality, the late mortality was significantly different from that of the rest of the group. How do you explain the fact that, in your series, dissection did not affect the longer term or even the early results? I would appreciate a clarification.

In terms of calculating actuarial survival, how many patients were at risk beyond 5 years to allow for statements with regard to actuarial incidence of something beyond 5 years? What was the method of calculating the amount of regurgitation echocardiographically?

My final comment has to do with technique. As you know, we have treated more than 200 patients who underwent the remodeling operation, starting in 1978, with a follow-up period ranging up to 22 years and with a mean approaching 10 years. We have used the technique with or without splinting of the aortic root either internally or externally. More recently, we have been using internal splinting by internodal or intertrigonal compression or plication.

In a collaborative study that was conducted between our group and that of Hans Seivers in Lubeck, Germany, which was published in *Circulation* in November 1999, we showed that the distensibility of the aortic root, as well as the instantaneous movements, closing and opening characteristics of the cusps, were quite different in the tube technique than in the remodeling technique. The remodeling tended to reproduce the control group of normal individuals. We think that could have implications on coronary flow, left ventricular function, and durability of the valve. What are your views about that?

Dr David. Thank you, Sir Magdi. Those are a lot of topics to cover. I will try to be brief but cover them all.

First, we are so happy with the outcomes of the patients with Marfan syndrome that we have become much more aggressive in Toronto; to be quite honest, my cardiologists are more aggressive than I am. At the slightest sign of enlargement of the aortic root in a patient with Marfan syndrome, I have a patient in my office to discuss the aortic valve–sparing operation. Indeed, if a woman is planning to have a family, we are even more aggressive and operate earlier, because the composition of the arterial wall changes during pregnancy.

If the patient has a family history of dissecting aneurysm, we tend to replace almost normal roots. In those patients we are a bit more aggressive and replace the transverse arch as well, suturing the graft all the way to the ligamentum arteriosum. Our cutoff point now is 50 mm in the Marfan syndrome. We have done this in 48 patients with all the stigmata of Marfan and no deaths; they have no events afterward. Why not recommend an early operation?

In the dissecting aneurysm group, we had 34 patients, about half with acute type A and half with chronic dissections. Most of those with chronic dissection had had the repair elsewhere. The surgeon had replaced the ascending aorta only, and the patients were referred to us because of progressive dilatation of the root. In those patients we repaired the aortic root, preserving the aortic valve.

I do not know why survival after dissection is so high in our patients. Perhaps it is because of the next issue you brought up. We have only 42 patients at risk beyond 5 years. Of those 42, only 4 had a dissecting aneurysm. Perhaps it is a matter of sample size; if we observed them longer, we might see that dissecting aneurysm was a predictor of poor outcome later. We could not find any pre-

dictors of mortality except age and extent of disease, such as megaaorta syndrome.

AI was quantitated only by transthoracic echocardiography. Dr Gary Webb, a cardiologist interested in Marfan syndrome, was kind enough to care for all our patients and establish a network for the international patients, so the cardiologists continued sending him the transthoracic echocardiograms. We are basically looking at ventricular function and quantitate the aortic insufficiency at 1, 2, 3, and 4+. Therefore, all the analyses of AI were done by transthoracic Doppler echocardiography.

With regard to technique, in 1991 I reported on aortic valve reimplantation before this society. Karen Kunzelman, a biomedical engineer who became interested in this topic, said, "You know, it's a mistake what you are doing. You are abolishing the sinus of Valsalva. We have to create the sinus of Valsalva to minimize the mechanical stresses on the cusps." I started to find ways to preserve the sinus of Valsalva, and, coincidentally, I found out what Mr Yacoub had done 10 years earlier, scalloping our graft to create the sinus of Valsalva. The taller the incision on the graft is made, the more sinus is created. So the sinus of Valsalva issue resolved.

The problem is that the remodeling effected in the operating room is not permanent. I had a perfectly competent aortic valve whose roots had dilated again 1 year later. I added aortic annuloplasty to prevent dilatation, and nothing happened. We had no change in geometry after reimplantation, and that is the reason I favor reimplantation over remodeling. Whatever I do in the operating room will persist over the next 20 years, because I shape the graft. The shortcoming is the lack of a sinus of Valsalva, but that can be resolved very simply. Take a graft larger than the patient needs, do some puckering above the sinotubular junction, create new sinuses, and that solves the problem.

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