Should the ascending aorta be replaced more frequently in patients with bicuspid aortic valve disease?

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Objective: The optimal diameter at which replacement of the ascending aorta should be performed in patients with bicuspid aortic valve disease is not known.

Methods: We reviewed all patients with bicuspid aortic valves undergoing aortic valve replacement at our institution from 1979 through 1993 (n = 201). Patients undergoing concomitant replacement of the ascending aorta were excluded.

Results: Follow-up was obtained on 98% of patients and was 10.3 ± 3.8 (mean $\pm$ SD) years. The average patient age was 56 ± 15 years, and 76% were male. The ascending aorta was normal (<4.0 cm) in 115 (57%) patients, mildly dilated (4.0-4.4 cm) in 64 (32%) patients, and moderately dilated (4.5-4.9 cm) in 22 (11%) patients. All patients with bicuspid aortic valves with marked dilation (>5.0 cm) underwent replacement of the ascending aorta and were therefore excluded. Fifteen-year survival was 67%. During follow-up, 44 patients required reoperation, predominantly for aortic valve prosthesis failure. Twenty-two patients had long-term complications related to the ascending aorta: 18 required an operative procedure to replace the ascending aorta (for aortic aneurysm), 1 had aortic dissection, and 3 experienced sudden cardiac death. Fifteen-year freedom from ascending aorta-related complications was 86%, 81%, and 43% in patients with an aortic diameter of less than 4.0 cm, 4.0 to 4.4 cm, and 4.5 to 4.9 cm, respectively ($P < .001$).

Conclusions: Patients undergoing operations for bicuspid aortic valve disease should be considered for concomitant replacement of the ascending aorta if the diameter is 4.5 cm or greater.

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Aortic valve replacement is the therapy of choice for patients with symptomatic aortic valvular disease. Severe aortic valve disease is occasionally associated with dilation of the ascending aorta. Current recommendations call for surgical replacement of ascending aortic aneurysms if they exceed 5.5 cm in diameter or 5.0 cm in patients with Marfan syndrome.¹

Patients with bicuspid aortic valve disease are at increased risk of aneurysms of the ascending aorta, aortic dissections, and rupture. The increased risk might be due to hemodynamic factors or to a genetic predisposition.² The purpose of this study was to describe the risk of future aortic complications in patients undergoing aortic valve replacement for bicuspid disease and to determine the threshold diameter for which the ascending aorta should be replaced.

TABLE 1. Preoperative and intraoperative demographics for patients with bicuspid aortic valve disease undergoing aortic valve replacement from 1979 through 1993 (n = 201)

Variable	Prevalence*
Age (y)	56 ± 15
Body surface area (m ²)	1.85 ± 0.21
Male sex	76%
Hypertension	25%
LV ejection fraction <40%	19%
NYHA class III or IV	51%
Congestive heart failure	34%
Urgent timing	15%
Reoperation	3%
Endocarditis	6%
Diabetes mellitus	6%
Mitral valve surgery	8%
Tricuspid valve surgery	1%
Coronary bypass surgery	32%
Aortic crossclamp time (min)	66 ± 25
CPB time (min)	86 ± 29

LV, Left ventricular; NYHA, New York Heart Association; CPB, cardiopulmonary bypass.

*Continuous variables are expressed as means ± SD.

TABLE 2. Perioperative outcomes for patients with bicuspid aortic valve disease undergoing aortic valve replacement from 1979 through 1993 (n = 201)

Outcome	Prevalence*
Myocardial infarction	1%
Intra-aortic balloon pump	6%
Low cardiac output syndrome	15%
Stroke	1%
Hospital stay (d)	6.8 ± 6.8
Mortality	2.5%

*Continuous variables are expressed as means ± SD.

Methods

Ethics approval was granted by our institutional research ethics board. Our computerized database was examined to identify all patients undergoing aortic valve replacement for bicuspid aortic valve (BAV) disease. The vast majority of patients with BAV disease had one valve cusp that was attached to less than one half of the annulus and one cusp that was attached to more than one half of the annulus, with a raphe between the 2 fused leaflets. Rarely, patients with BAV disease had 2 equal-sized cusps with no raphe and coronary ostia that were 180° apart (true bicuspid disease).³

We included patients operated on by one surgeon (T.E.D.) to obtain consistent descriptions of pathologies of the aortic valve and ascending aorta. All patients with BAV disease undergoing aortic valve replacement with or without coronary bypass or other valvular procedures between 1979 and 1993 were included. Patients undergoing surgical intervention after 1993 were excluded to obtain adequate long-term follow up. Patients with BAV disease

TABLE 3. Causes of reoperation and death during long-term follow-up in patients undergoing aortic valve replacement for bicuspid disease

Outcome	n
Reoperation	
SVD	28
Aortic aneurysm	7
Endocarditis	3
Pannus formation	2
Aortic dissection	1
Mitral regurgitation	1
LVOT obstruction	1
Heart transplant	1
Total	44
Cardiac death	
Congestive heart failure	10
Myocardial infarction	8
Valve related	5
Sudden death	3
Noncardiac death	
Cancer	11
Renal failure	2
Pneumonia	2
COPD	1
Elderly age	1
Total death	43

SVD, Structural valve deterioration (includes 11 patients who underwent concomitant replacement of the ascending aorta); LVOT, left ventricular outflow tract; COPD, chronic obstructive pulmonary disease.

undergoing aortic root replacement (the Bentall procedure, n = 20) or supracoronary replacement of the ascending aorta (n = 21) were also excluded. A total of 201 patients were available for the final analysis.

Aortic valve replacement was performed with previously described techniques.^{4,5} All patients underwent cardiopulmonary bypass with mild-to-moderate systemic hypothermia. Antegrade crystalloid cardioplegia was used before 1989, and antegrade blood cardioplegia has been used since. The aortic annulus was enlarged in patients with a small annulus, according to previously described techniques.⁶

The ascending aorta was measured intraoperatively by means of direct measurement, transesophageal echocardiography, or both. All measurements referred to in this study are of the ascending aorta and not the aortic root. Operative reports for all patients were examined to determine the diameter of the ascending aorta during the aortic valve replacement surgery. The size of the ascending aorta was determined from precise intraoperative measurements in 78% of patients and by means of semiquantitative assessment in 22%. For those patients who did not have exact measurements recorded, we used the following guidelines. First, if the ascending aorta was reported as normal, it was recorded as having a diameter of less than 4 cm. Second, if the ascending aorta was reported as "mildly dilated," it was recorded as having a diameter of 4.0 to 4.4 cm. Third, if the ascending aorta was reported as "moderately dilated," it was recorded as having a diameter of 4.5 to 4.9 cm. Patients with ascending aortas that were "severely

TABLE 4. Comparison of variables that affect future aortic dilation in patients with normal ascending aorta diameters and those with mild or moderate dilation at the time of aortic valve replacement surgery

Variable	<4 cm (n = 115)	4.0–4.4 cm (n = 64)	4.5–4.9 cm (n = 22)	P value
Age (y)	55 ± 15	56 ± 15	61 ± 10	.2
Male sex	75%	72%	91%	.2
Hypertension	26%	23%	27%	.9
Aortic valve pathology				
Stenotic	64%	61%	64%	.7
Insufficiency	23%	19%	23%	
Mixed	12%	20%	14%	

dilated" (≥ 5 cm) underwent replacement of the aorta and therefore were not part of this study.

Follow-up was obtained by means of telephone and mail questionnaire of patients, family members, or both. Echocardiography reports were obtained from the patients' cardiologists and family physicians. Operative reports were obtained on all patients who required reoperation during follow-up.

Categorical variables are expressed as percentages, and continuous variables are expressed as means $\pm$ SD throughout the article. All statistical analyses were performed with the SAS system (SAS version 8.1, Cary, NC). Comparison of categorical variables was performed with χ^2 or Fisher exact tests, and continuous variables were analyzed with 1-way analysis of variance. Long-term survival and event-free survival were analyzed with the methods of Kaplan-Meier. Comparisons between groups were compared with the log-rank test.

Results

A total of 201 patients with BAV disease underwent aortic valve replacement during the study period. Aortic valve repair was not performed in any patients. Table 1 displays the preoperative and intraoperative demographics for the entire group.

Of the 201 patients with BAV disease, 63% had aortic stenosis, 22% had aortic regurgitation, and 15% had a mixed lesion. One patient had associated Marfan syndrome with a normal-sized ascending aorta.

The aortic valve was replaced with a stented tissue valve in 60% of patients, a stentless tissue valve in 18%, a mechanical valve in 12%, a pulmonary autograft in 7%, and a homograft in 3%. The labeled valve size was 19 in 1% of patients, 21 in 6%, 23 in 16%, 25 in 22%, 27 in 39%, and 29 in 16%.

Perioperative outcomes for the entire group of patients are listed in Table 2. The in-hospital mortality was 2.5% (5 patients).

Follow-up was obtained on 98% of patients. The mean ($\pm$ SD) length of follow up was 10.3 ± 3.8 years. A total of 43 (21%) patients died during follow-up. Ten- and fifteen-year survival was $81\% \pm 3\%$ and $67\% \pm 4\%$, respectively. Forty-four (22%) patients required reoperation during

follow-up. The causes of reoperation and death are summarized in Table 3.

At the time of initial aortic valve replacement surgery, the ascending aorta was normal sized (<4 cm) in 115 (57%) patients, mildly dilated (4.0–4.4 cm) in 64 (32%) patients, and moderately dilated (4.5–4.9 cm) in 22 (11%) patients. As stated previously, patients with ascending aortic diameters of 5 cm or more underwent replacement of the aorta and therefore were not included in this study. The 3 groups of patients were similar for those variables that are known to have an effect on future dilation of the ascending aorta: age, sex, hypertension, and valve pathology (Table 4).

Figure 1 displays the Kaplan-Meier survival curves for these 3 groups of patients. Patients with moderate dilation of the ascending aorta (4.5–4.9 cm) had worse long-term survival than the other 2 groups ($P = .004$, log-rank test).

Ascending aortic complications occurred in 22 patients during follow-up: 18 had an aneurysm requiring replacement of the ascending aorta, 1 had an aortic dissection requiring emergency surgical intervention, and 3 experienced sudden cardiac death. Of the 18 patients who had an ascending aortic aneurysm, 7 underwent isolated replacement of the aorta, and 11 underwent simultaneous aortic valve replacement for structural valve deterioration. The average size of the ascending aorta during replacement surgery was 58 ± 9 mm.

Figure 2 displays the Kaplan-Meier curves for freedom from ascending aortic complications according to the 3 groups of patients. Patients with an ascending aortic diameter of 4.5 cm or greater had a significantly increased risk of future aortic complications ($P < .001$).

Discussion

BAV disease is the most common congenital cardiac anomaly and is seen in 1% to 2% of the population.⁷ A large pathologic review by Sabet and colleagues³ revealed that BAV disease results in a stenotic lesion in three quarters of patients, insufficiency in 15%, and a mixed lesion in 10%, results that are similar to ours.

Figure 1. Kaplan-Meier survival curves for patients with BAV disease with an ascending aortic diameter of less than 4 cm, 4.0 to 4.4 cm, and 4.5 to 4.9 cm at the time of aortic valve-replacement surgery. Patients with moderate dilation of the aorta (4.5-4.9 cm) had significantly worse long-term survival.

Figure 2. Freedom from ascending aortic complications for patients with BAV disease. Patients with moderate dilation of the ascending aorta (4.5-4.9 cm) had a significantly increased risk of future aortic complications (aneurysm, dissection, or sudden death).

BAV disease is a well-recognized risk factor for aortic dilation, aneurysm formation, dissection, and rupture.^{8,9} The cause of ascending aortic dilation in such patients is unknown. A hemodynamic flow disturbance in the aorta beyond the stenotic valve is one possible cause of dilation because this mechanism is also observed in patients with stenotic tricuspid valves. The second possibility is a genetic predisposition to aortic dilation in patients with BAV disease. An increasing amount of data has been reported to support this latter cause.

Several investigators have found that patients with BAV disease, including those with a hemodynamically normal valve, have dilated aortic roots and ascending aortas compared with age- and sex-matched control subjects.¹⁰⁻¹² In

addition, there is a high correlation between coarctation of the aorta and BAV disease.^{2,9,10} The close association raises the possibility that such patients have congenitally increased fragility of the aortic media, which might in turn lead to dilation of the ascending aorta. Further evidence for a genetic component lies in the fact that BAV disease seems to follow an autosomal dominant inheritance pattern with reduced penetrance.^{13,14} Histologic studies have also confirmed that patients with BAV disease have abnormalities of the aortic media. Our group has previously demonstrated decreased fibrillin 1 content and increased matrix metalloproteinase 2 activity in the aortic media of patients with BAV disease when compared with levels seen in patients with tricuspid valves.¹⁵ In addition, we found increased severity of cystic medial necrosis, elastic fragmentation, and smooth muscle cell reorientation in patients with BAV disease.¹⁶ Bauer and coworkers¹⁷ also demonstrated that patients with BAV disease have thinner elastic lamellae of the aortic media and greater distances between elastic lamellae than patients with tricuspid aortic valves.

Given that patients with BAV disease have more abnormalities of the aortic media and are predisposed to ascending aortic dilation, we attempted to determine the optimal diameter for ascending aortic replacement during aortic valve surgery. We identified 201 patients with BAV disease who underwent aortic valve replacement between 10 and 25 years ago. Not surprisingly, patients with BAV disease were younger (mean age, 56 years) than most patients undergoing aortic valve replacement and were predominantly male. Because of their young age, long-term survival of patients with BAV disease was much higher (67% at 15 years) than survivals seen in most aortic valve-replacement series.

Patients were divided into 3 groups in our study, according to the size of the ascending aorta at the initial operation. We have traditionally used an aggressive approach to the ascending aorta in patients with BAV disease, with routine replacement if the aorta measures 5 cm or more in diameter. Therefore such patients were excluded from the current study.

The 3 groups of patients were similar for all preoperative characteristics, including age, sex, prevalence of hypertension, and aortic valve pathology—factors that affect future dilation of the aorta (Table 4). Despite these similarities, patients with moderate aortic dilation (4.5-4.9 cm) had a significantly increased risk of long-term aortic complications, including aneurysm, dissection, or sudden death (Figure 2). In addition, these patients had lower long-term survivals compared with patients with no or mild aortic dilation (Figure 1).

Our findings would suggest that the ascending aorta should be replaced in patients with BAV disease with an aortic diameter of 4.5 cm or more undergoing aortic valve surgery. Surgeons should therefore consider valve pathol-

ogy (ie, bicuspid vs tricuspid) when making their decision whether to replace the ascending aorta. Supportive evidence for this strategy can be found in a study by Russo and associates.¹⁸ These investigators compared long-term outcomes in patients with tricuspid versus bicuspid aortic valves undergoing valve replacement surgery. The incidences of late aortic dissection, sudden death, and cardiac-related death were significantly higher in patients with BAV disease. In addition, echocardiography of all long-term survivors revealed that the ascending aorta was significantly larger in patients with bicuspid valves than in patients with tricuspid valves (mean, 48 vs 37 mm).

Before recommending routine replacement of the ascending aorta in patients with BAV disease, we must first examine the surgical options. Operative strategies, in increasing order of complexity, consist of the following: (1) aortic valve replacement only (ie, leaving the ascending aorta intact), (2) reduction aortoplasty with or without reinforcement of the aorta, (3) replacing the supracoronary ascending aorta with a separate tube graft, and (4) replacing the entire aortic root and ascending aorta with reimplantation of the coronary ostia (ie, the Bentall procedure).^{19,20} The risk of long-term aortic complications for less complex procedures must be balanced against the increased perioperative risk associated with more complex procedures. Reduction aortoplasty is less technically demanding than tube graft replacement of the ascending aorta, but long-term results reveal a significant risk of recurrent dilation.^{20,21} We have therefore avoided this procedure. The operative mortality for Bentall procedures at our institution over the last 5 years is 3.9%. Although this risk is relatively small, it is significantly higher than that for isolated aortic valve replacement over the same time period (1.8%, $P = .01$).

Study Limitations

One limitation of our study is that the size of the ascending aorta during the initial aortic valve operation was assessed in a semiquantitative manner in 22% of patients, predominantly during earlier years of the study. It would have been preferable to obtain exact measurements of the ascending aorta and root at the time of the initial operation in these patients. The same surgeon, however, assessed all patients, and we therefore believe that our semiquantitative measurements were consistent.

Another limitation of our study is its retrospective design. Randomizing patients with BAV disease to receive aortic valve replacement plus or minus replacement of the ascending aorta would supply us with the definitive answer to our hypothesis, but this is unlikely to occur in the foreseeable future. We believe our study is the best available method of assessing this clinical issue at this time.

Summary

The current study demonstrates that patients with BAV disease with moderate dilation of the ascending aorta (4.5–4.9 cm) have a significantly higher risk of long-term aortic complications. Consideration should be given to replacing the ascending aorta if it is more than 4.5 cm in diameter in patients with BAV disease.

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Discussion

Dr Ludwig K. von Segesser (*Lausanne, Switzerland*). I congratulate Dr Borger and colleagues for this interesting report. The main issue here is what to do with borderline aortic dilatation, and a number of approaches have been proposed for this: let it be (we now know that some patients come back); aggressive replacement (at the cost of a higher risk); reduction aortoplasty (we have shown in the past that some patients come back, too); and reduction aortoplasty with external support, as reported by Francis Robicsek in the 1970s.

Dr Robicsek would use a Dacron graft for external support. In the old days, Ake Senning just went to the local department store, bought some nylon curtain, sterilized it, and used it. He probably even reused the part that was not used for the primary procedure. Nowadays, we use routinely a polyester net, as for hernia surgery, which might be an off-label use over here. I have a few questions.

Was there a difference between the 4.4- and 4.9-cm groups?

Dr Borger. In terms of long-term complications?

Dr von Segesser. Yes.

Dr Borger. What we did is we split the 2 patients into 2 groups because we were dealing with a relatively small number of patients, and therefore I cannot answer that question for you specifically. But I do know that the rate of aneurysm expansion is higher in patients with a larger aorta. Therefore intuitively I would say that, yes, there must be more long-term aortic complications in the 4.9-cm patients than in the 4.4-cm patients.

Dr von Segesser. Can you tell us something about wall quality and how this affects the operating strategy?

Dr Borger. These are patients from 1979 through 1993, and I think Dr David was pretty aggressive back then in his treatment of dilated aortas in bicuspid patients. However, I would say we are now even a little more aggressive in the treatment of this disease. If the aortic wall is very thin, even if it is not excessively dilated, we are currently more likely to replace it.

Dr von Segesser. Would you handle a dilated aorta in the same way as a dilated and very elongated aorta in which the heart is pushed into the left chest?

Dr Borger. We would make the decision to replace the aorta on the basis of its diameter only and not its length. The only alteration we make for a patient with a long aorta is that if we do replace it (on the basis of its diameter), then we make the replacement graft much shorter than the original aorta to try to get the heart back up into a more physiologic position.

Dr von Segesser. And my last question is whether there is a correlation between body size or surface area and aortic complications.

Dr Borger. No, there was not. We looked at that and were unable to find an association.

Dr von Segesser. So you think that, let us say, a 35-kg old woman with a 4-cm diameter should be addressed in the same way as a 2.5-m⁻² member of the National Hockey League?

Dr Borger. No, I do not, and I am going to give you a long answer to that question. We are not trying to say to all surgeons that 4.0 cm is the magic number and that you should replace the aorta in all patients with bicuspid valves with even mild aortic

dilation. What we are trying to say is that we should consider valve pathology (ie, tricuspid vs bicuspid disease) when making our decision whether to replace the aorta. Our data would suggest that we should lower our threshold for ascending aortic replacement in bicuspid patients. The surgeon has to consider many other factors, including patient age, comorbidities, type of valve prosthesis, and surgeon-specific results, when deciding whether to replace the aorta. An example would be a 30-year-old patient with bicuspid disease who has a 42-mm ascending aorta in whom you are going to insert a mechanical prosthesis because the patient wants to avoid future reoperations. I think 20 years ago it would have been unheard of to replace the ascending aorta in this patient. However, our data might suggest that you can do a full Bentall procedure in this patient to try to limit the risk of future reoperation or other complications of the aorta. Therefore the decision to replace the ascending aorta is patient specific and, to a certain extent, surgeon specific.

Dr Christophe Acar (*Paris, France*). Dr Borger, I enjoyed your presentation. Could you tell us what would be your recommendations concerning the diameter of the ascending aorta above the sinotubular junction? In patients with bicuspid aortic valve stenosis, oftentimes the root is not dilated, and the only portion to be enlarged is the supracoronary portion.

Dr Borger. That is a very good question, and we often see that pathology in patients with tricuspid aortic stenosis. We do not advocate a total root replacement in such patients but rather an aortic valve replacement with concomitant replacement of the supracoronary aorta. In patients with bicuspid aortic valves with dilation of the aorta above the sinotubular junction, I believe replacement of the supracoronary aorta is also the only operation that is required. However, if it is a very young patient receiving a mechanical valve and you are confident with the procedure, then a full Bentall procedure might be the appropriate solution for that patient.

Dr Acar. And a 4-cm diameter would be measured at which level, the level of the sinuses or the level of the ascending aorta above the sinotubular junction?

Dr Borger. Above the sinotubular junction, the ascending aorta.

Dr Acar. It would be 4 cm, the same.

Dr F. W. Mohr (*Leipzig, Germany*). Michael, I fully agree with the conclusions. What about patients with bicuspid disease in whom you've decided to replace the ascending aorta and also require coronary artery bypass surgery? How about proximal graft anastomosis in these cases? Do you completely avoid it? What is the strategy? Can you comment on that?

Dr Borger. Dr David is very good at imparting his knowledge on the other surgeons at our institution, and it is because of this that we try to avoid proximal vein graft anastomoses to the Dacron graft if the veins are of small caliber. Small-diameter vein grafts have an increased risk of intimal hyperplasia at the anastomotic site, probably in reaction to the Dacron. If the vein graft is of a large diameter, then we will proceed with the usual proximal anastomosis. The best option is to avoid proximal anastomoses altogether, which we will do if possible.

Dr Richard J. Shemin (*Boston, Mass*). This was a very nice paper. I am particularly interested in the patients requiring reoperation. Were any of these just for the primary indication of

structural valve deterioration and the patient happened to have an ascending aortic aneurysm, or was it the reoperation group determined by the ascending aortic pathology in addition to having structural valve deterioration? What is the true denominator?

Dr Borger. Of the 28 that were operated on for structural valve deterioration, 11 of them also had replacement of the ascending aorta because of an aortic aneurysm. These patients were therefore included in our composite outcome.

Dr Shemin. If you look back at this group, which is a significant number of the reoperations, if they did not have structural deterioration of the valve, would the aorta alone have been the indication for a reoperation?

Dr Borger. I cannot say definitely that the primary indication for reoperation was structural valve deterioration in patients who also underwent replacement of the aorta. But I can say that the ascending aorta was definitely aneurysmal in these patients and might have therefore been an indication for surgical intervention in and of itself. In addition, there were 7 patients who presented with ascending aortic aneurysms and normally functioning valve prostheses requiring isolated replacements of the aorta.

Dr Shemin. But you understand the implications of the question. The final thing regards bicuspid valves: What is your recommendation on the use of the Toronto valve in that subset of patients in which there is the potential for further aortic dilatation?

Dr Borger. I think that it would be acceptable to use the stentless Toronto valve if you perform some sort of reinforcement of the sinotubular junction to prevent future dilation or if you are using it in an elderly patient. I would not suggest the Toronto valve for a young patient with a bicuspid valve without some sort of reinforcement of the sinotubular junction.

Dr Bruce Lytle (*Cleveland, Ohio*). I have a question, but first I would like to make a comment. The idea that you are going to do a Bentall procedure with a mechanical prosthesis for a young man and he never is going to have to have another operation is a lovely thought, but experience thus far has not borne that out. The second thing is that you really have 4 catastrophic events that happened if you consider that all of the sudden deaths are related to an aortic complication. Therefore over 10 years that means that you have about a 0.2% per year risk of a catastrophe in these patients. It is good to avoid that, but that must mean, of course, that the incre-

mental risk of replacing the aorta also has to be extremely low. Would you agree?

Dr Borger. I agree with that completely and would like to reinforce what I previously stated. The take-home message from this presentation is not that all 4-cm aortas should be replaced in bicuspid patients. Rather, we would like surgeons to consider aortic valve pathology as one of the factors when deciding whether to replace the aorta in individual patients. We have been using an aggressive approach to the ascending aorta for several years at our institution. In some other institutions, the surgeons are much less aggressive, and an ascending aorta of 5.5 cm might be left alone. What I am trying to say is that you should probably re-evaluate this strategy in patients with bicuspid aortic valve disease. We are trying to lower the threshold a little in such patients.

At our hospital, the operative mortality rate for Bentall procedures is 3.9% over the last 5 years. Although this rate is quite acceptable, it is significantly higher than our mortality rate for aortic valve replacement, which is 1.8%. Therefore there is an absolute risk increase of 2% involved with a more aggressive approach to this disease.

Dr Lytle. Putting into your risk catastrophic events during a 10-year follow-up.

Dr Claudio Muneretto (*Brescia, Italy*). I enjoyed your paper. Of course the diameter of the aorta is a major concern in surgical decision making. But are there any other important concerns? For example, a positive family history for sudden death could be considered, and did you look at this risk factor in your analysis?

Dr Borger. We did not. I did not have that particular risk factor in our database. I can tell you that we had only 22 outcomes of interest, and we therefore did not feel justified in doing a Cox proportional hazard analysis on our data. But I also can tell you there was a paper from Russo and colleagues in Italy showing essentially the same results as ours. These investigators performed echocardiography on patients with tricuspid and bicuspid aortic valves 10 years after their operations, and the bicuspid patients had an average ascending aortic diameter of 48 mm versus 37 mm in the tricuspid patients. In addition, the bicuspid patients had more catastrophic complications, including aortic dissection and sudden death. Therefore there are some long-term implications to not replacing the aorta in bicuspid patients.