SURGERY FOR ACQUIRED CARDIOVASCULAR DISEASE

IMPACT OF SMALL PROSTHETIC VALVE SIZE ON OPERATIVE MORTALITY IN ELDERLY PATIENTS AFTER AORTIC VALVE REPLACEMENT FOR AORTIC STENOSIS: DOES GENDER MATTER?

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Objective: Ideal management of the elderly patient with a small aortic root remains controversial. This retrospective analysis was performed to determine whether small prosthetic valve size is related to outcome in patients 70 years of age or older undergoing aortic valve replacement for aortic stenosis. **Methods:** Between December 1991 and July 1998, 366 patients 70 years of age or older (median age 77 years, range 73-81 years, 49% male) underwent isolated aortic valve replacement or aortic valve replacement with coronary bypass grafting with standard Carpentier-Edwards bovine pericardial valves (Baxter Healthcare Corp, Edwards Division, Santa Ana, Calif) (n = 277; 76%) or St Jude Medical mechanical valves (St Jude Medical, Inc, St Paul, Minn) (n = 89; 24%). Propensity scoring and multivariable regression models were used to evaluate the risks associated with implantation of 19-mm valves. **Results:** Operative mortality was 16.7% (17/102) in patients who received 19-mm valves and 3% (8/264) among those receiving ≥ 21 -mm valves ($P \leq .0005$). The univariable odds ratio for operative death for 19-mm versus ≥ 21 -mm valves was 6.4 (95% CI 2.7, 15.4; $P \leq .0005$). In the final multivariable model, receipt of a 19-mm valve alone was not a statistically significant predictor of operative death (odds ratio 2.1; 95% CI 0.7, 6.4; $P = .21$). However, the combination of male sex and 19-mm valve resulted in a significant risk of operative death (4/9 patients; odds ratio 17.5; 95% CI 2.2, 139; $P = .007$). Use of a 19-mm valve was not related to late death in either the univariable (hazard ratio 1.0; 95% CI 0.5, 2.0; $P = .95$) or the multivariable analysis (hazard ratio 0.7; 95% CI 0.3, 1.8; $P = .51$). **Conclusions:** Implantation of a standard 19-mm aortic valve in elderly men with aortic stenosis may be associated with an increased risk of operative mortality. A higher performance valve and/or a root enlargement procedure should be considered in men with a measured 19-mm annulus. (J Thorac Cardiovasc Surg 1999;118:815-22)

Optimal surgical management of aortic valve disease in the elderly patient with a small aortic root remains controversial. Aortic valve replacement (AVR)

with a small prosthetic valve is technically straightforward and commonly performed, but it may result in a patient-prosthetic mismatch resulting in a high residual

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outflow gradient, the significance of which remains the subject of controversy.¹⁻¹¹ Use of stentless valves or homografts results in lower residual postoperative gradients, but implant procedures are technically more demanding, leading to increased total ischemic time.^{10,12-14} Annular enlargement allows for insertion of a larger aortic prosthesis, but it too may introduce increased surgical risks.^{15,16} For the past several years our practice at Brigham and Women's Hospital has been to size the anulus and insert a standard 19-mm valve prosthesis when indicated, without annular enlargement. To clarify the clinical influence of inserting a 19-mm valve in elderly patients, we have examined our operative and long-term outcomes after AVR for aortic stenosis with or without concomitant coronary artery bypass grafting (CABG). Since gender may play a role in operative mortality,^{17,18} we evaluated our surgical outcomes in that context.

Patients and methods

Patients. Baseline risk factors and subsequent outcome were collected in 366 patients with aortic stenosis who were 70 years of age or older undergoing isolated AVR (n = 139; 38%) or AVR combined with CABG (n = 227; 62%) at Brigham and Women's Hospital between December 1991 and July 1998. The median age of patients was 77 years (interquartile range [IQR] 73 to 81 years) and 49% were male. All patients underwent preoperative cardiac catheterization and echocardiography. Isolated aortic stenosis was identified in 306 patients (84%), and 60 patients (16%) had combined aortic stenosis and insufficiency. Aortic stenosis was categorized as severe in 278 patients (76%), moderate in 77 patients (21%), and mild in 11 patients (3%). AVR prosthesis size (19-25 mm) and type (Carpentier-Edwards bovine pericardial valve [Baxter Healthcare Corp, Edwards Division, Santa Ana, Calif] or St Jude Medical valve [St Jude Medical, Inc, St Paul, Minn]) were left to the discretion of the operating surgeon. AVR was performed with the use of standard cardiopulmonary bypass with moderate hemodilution (hematocrit value 20%-25%). Multidose intermittent cold blood or crystalloid potassium cardioplegic solution was given through the aortic root or directly into the coronary ostia. Antegrade/retrograde delivery was also routinely used. Topical hypothermia was used to maintain myocardial cooling. A vent was used routinely to decompress the left ventricle and achieve a bloodless field. Careful debridement of the aortic anulus with copious irrigation with cold (4°C) saline solution was performed to remove all calcific debris to prevent embolization. A Carpentier-Edwards bovine pericardial valve was used in 277 patients and a St Jude Medical mechanical valve in 89 patients. One hundred two patients received 19-mm valves (85% pericardial valves) and 264 patients received larger ones (72% pericardial valves). Operative mortality and morbidity were carefully documented, and all patients surviving to discharge underwent long-term follow-up.

Patient characteristics were defined as follows. *Body sur-*

face area (BSA) is body morphometric analysis indexing weights and heights. *Diabetes mellitus* indicates a history of diabetes, regardless of duration of disease or need for antidiabetic agents. *Renal failure* is defined as a documented fasting serum creatinine level of 2.0 mg/dL. *Stroke* refers to a central neurologic deficit that is unresolved at the time of primary hospital discharge. *COPD* is defined as the need for pharmacologic therapy for chronic pulmonary compromise or as a forced expiratory volume in 1 second of less than 75% of predicted value. *Ejection fraction* is defined either by the catheterization report or cardiac echocardiogram. *Myocardial infarction* is defined either as the appearance of a new Q wave in 2 or more contiguous leads on the electrocardiogram or as clinical, angiographic, electrocardiographic, and/or laboratory isoenzyme evidence of myocardial necrosis if the electrocardiogram shows no new Q waves. *Congestive heart failure* has to fulfill at least 3 of the following criteria: presence of dyspnea, râles thought to represent pulmonary congestion, peripheral edema, cardiomegaly on chest x-ray film, and chest x-ray film compatible with interstitial edema. *Reoperation* includes patients who had any prior cardiac operations. *Nonelective* status describes an operation that is required during the same admission because of instability. *Severe aortic stenosis* designates all cases reported as "severe" by either preoperative catheterization or cardiac echocardiography. *CABG* denotes patients whose AVR operation was combined with concomitant CABG. *Ischemic time (crossclamp time)* is the total number of minutes the aorta is completely crossclamped during bypass. *Operative death* includes all deaths that occurred within 30 days of the AVR operation or death that occurred within the same admission. *Cardiac cause of death* includes the inability to wean from cardiopulmonary bypass, low cardiac output incompatible with life, life-threatening cardiac arrhythmia, and postoperative hemorrhage. *Multiorgan system failure* indicates compromised function of 2 or more major organ systems. *Gastrointestinal etiology* includes episodes of severe gastrointestinal hemorrhage or intestinal ischemia. *Adult respiratory distress syndrome* includes all patients with documented ARDS by clinical examination with or without a chest radiograph. *Pneumonia* describes positive sputum, blood, pleural fluid, empyema fluid, transtracheal fluid, or transthoracic fluid cultures consistent with the diagnosis and clinical findings of pneumonia or chest x-ray evidence of pulmonary infiltrates. *Sepsis* is defined as an active infection with positive blood culture. *Atrial fibrillation* indicates multiple atrial foci that discharge without a single uniform atrial depolarization documented by either monitor or electrocardiogram. *Bleeding* includes all patients who required surgical exploration, either in the operating room or in the intensive care unit, for postoperative continued hemorrhage. *Ventilatory support* is the number of postoperative days during which the patients required ventilatory support, which include days in which they are dependent at night or for periods during the day, but does not include oxygen support with a face mask. *Intensive care unit stay* refers to the number of days in the intensive care unit before the patient is moved to the step-down unit.

Table I. Demographics, risk factors, and operative characteristics of patients receiving 19-mm and ≥ 21 -mm valves

	Valve size		P value*
	19 mm [n = 102]	≥ 21 mm [n = 264]	
Demographics			
Female	91 (93)	35 (93)	$\leq .0005$
Age in years, median (IQR)	79 (76-83)	76 (73-79)	$\leq .0005$
BSA in m ² , median (IQR)	1.62 (1.55-1.79)	1.87 (1.75-2.00)	$\leq .0005$
Risk factors			
Diabetes mellitus	25 (26)	21 (56)	.23
Renal failure	10 (10)	11 (28)	.50
Hypertension	51 (52)	55 (145)	.29
Stroke	9 (9)	13 (34)	.19
COPD	10 (10)	14 (37)	.18
% EF, median (IQR)	60 (45-65)	55 (40-65)	.02
MI	23 (23)	20 (53)	.35
CHF	50 (51)	63 (166)	.02
Reoperation	8 (8)	16 (42)	.03
Nonelective procedure	25 (25)	18 (47)	.10
Severe AS	76 (74)	77 (198)	.45
Operative details			
CABG	65 (66)	61 (161)	.30
Crossclamp time in min, median (IQR)	85 (67-106)	83 (69-106)	.87
Carpentier-Edwards valve	85 (87)	72 (190)	.10
Summary risk			
Propensity score, median (IQR)	0.48 (0.28-0.69)	0.13 (0.06-0.28)	$\leq .0005$
Outcome			
Operative mortality	16.7 (17)	3.0 (8)	$\leq .0005$

Numbers presented are column percents (n) or medians (interquartile range). *IQR*, Interquartile (25th-75th) range; *BSA*, body surface area; *COPD*, chronic obstructive pulmonary disease; *EF*, ejection fraction; *MI*, myocardial infarction; *CHF*, congestive heart failure; *AS*, aortic stenosis; *CABG*, coronary artery bypass grafting.

*Column percents compared with Fisher's exact test and medians compared with the Wilcoxon rank-sum test.

Statistical analysis. This is an observational study and patients were not randomly assigned to receive valves of a particular size; valve size was the surgeon's choice. Thus we evaluated the relationships between patient characteristics and size of the implanted valve so that we might control for the differences between the group receiving 19-mm valves and the group receiving ≥ 21 -mm valves with a propensity score.^{19,20} Univariable evaluations were made with Fisher's exact test and the Wilcoxon rank-sum test. Characteristics considered in calculating the propensity score were age, BSA, diabetes, renal failure, hypertension, stroke, chronic obstructive pulmonary disease, ejection fraction, previous myocardial infarction, congestive heart failure, reoperation, nonelective procedure, presence of severe aortic stenosis, and concomitant CABG and Carpentier-Edwards valve. These risk factors were entered into a logistic regression model to predict receipt of a 19-mm valve. A parsimonious model was developed, interactions among variables in that model were examined, and finally risk factors not in the parsimonious model were added back to account, as much as possible, for all differences between the 2 groups. The propensity score, then, is the probability of receiving a 19-mm valve predicted by this final model. Patient sex was not used to calculate the propensity score because we wanted to evaluate the relationships between sex, valve size, and mortality. Multivariable

logistic regression and multivariable proportional hazards regression were used to predict operative mortality and morbidity risk and hazard of late death, respectively, associated with small valve, patient sex, and the interaction between small valve and sex while controlling for patient differences via the propensity score. We performed multivariable logistic regression analyses, again using propensity scores, to predict operative mortality in strata of sex and valve size. We repeated our final multivariable logistic analysis 1000 times on samples of the same size as the total sample drawn randomly from the total sample (bootstrapping) to get a more conservative estimate of the effect of our interaction term. Statistical analyses were performed with the use of Stata version 6 software (Stata Corporation, College Station, Tex).

Results

Small valve. Patients receiving small valves were more likely to be female (91% vs 35%), older (median age 79 vs 76 years), and smaller (median BSA 1.62 vs 1.87) than those receiving larger valves (Table I). They were also more likely to have diabetes, to be undergoing AVR as a nonelective procedure, and to be receiving a Carpentier-Edwards valve. On the other hand, these patients were less likely to have had a stroke, to

Table II. Demographics, risk factors, and operative characteristics of operative deaths and survivors

	Operative death		P value*
	Yes [n = 25]	No [n = 341]	
Demographics			
Female	72 (18)	49 (168)	.02
Age in years, median (IQR)	82 (77-83)	77 (93-80)	.002
BSA in m ² , median (IQR)	1.69 (1.57-1.80)	1.82 (1.67-1.98)	.008
Risk factors			
Diabetes mellitus	40 (10)	21 (72)	.03
Renal failure	20 (5)	10 (33)	.10
Hypertension	60 (15)	53 (182)	.33
Stroke	16 (4)	11 (39)	.34
COPD	16 (4)	13 (43)	.40
% EF, median (IQR)	60 (45-68)	58 (42-65)	.68
MI	36 (9)	20 (67)	.05
CHF	68 (17)	59 (200)	.24
Reoperation	20 (5)	13 (45)	.25
Nonelective procedure	40 (10)	18 (62)	.01
Severe AS	78 (18)	76 (254)	.53
Operative details			
CABG	68 (17)	62 (210)	.34
Crossclamp time in min, median (IQR)	85 (72-103)	84 (67-106)	.77
Carpentier-Edwards valve	72 (18)	76 (259)	.41
Summary risk			
Propensity score, median (IQR)	0.51 (0.22-0.64)	0.18 (0.08-0.43)	≤.0005
Valve size			
19 mm	68 (17)	25 (85)	.001

Numbers presented are column percents (n) or medians (interquartile range). *IQR*, Interquartile (25th-75th) range; *BSA*, body surface area; *COPD*, chronic obstructive pulmonary disease; *EF*, ejection fraction; *MI*, myocardial infarction; *CHF*, congestive heart failure; *AS*, aortic stenosis; *CABG*, coronary artery bypass grafting.

Table III. Etiology of operative death categorized by valve size

Cause of death	19 mm	≥21 mm
Cardiac	8 women, 3 men	3 women, 3 men
Stroke	1 woman, 1 man	1 woman
Multorgan system failure	2 women	
Gastrointestinal	2 women	1 woman

have congestive heart failure, chronic obstructive pulmonary disease, or a low ejection fraction, or to be undergoing a reoperation. The final propensity score model included age, BSA, diabetes, hypertension, stroke, chronic obstructive pulmonary disease, ejection fraction, congestive heart failure, reoperation, non-elective procedure, and concomitant CABG and Carpentier-Edwards valve. The area under the receiver operating characteristic curve for this model was 0.83. When the propensity score was divided into quintiles, the propensity score for those receiving small valves was nearly identical to that of patients receiving larger valves within each quintile.

Women had significantly higher propensity scores for

receiving small valves than men among the small valve group (women: 0.53, IQR 0.33-0.70; men: 0.22, IQR 0.10-0.22; $P = .01$). The same was true among those receiving larger valves (women: 0.28, IQR 0.13-0.48; men: 0.10, IQR 0.05-0.18; $P \leq .0005$). In both groups, men had significantly larger BSAs. Median BSA for female patients ($n = 186$) was 1.69 m² (IQR 1.56-1.80 m²) and for male patients ($n = 180$), 1.93 m² (IQR 1.82-2.04 m²). Interestingly, 39 patients (38%) with a measured annular size appropriate for a size 19-mm prosthetic valve had a BSA of 1.7 m² or more. Specifically, of all women who received a 19-mm valve, 34% (32/93 patients) had a BSA of 1.7 m² or more. Among male patients who received a 19-mm valve, 78% (7/9 patients) had a BSA of 1.7 m² or more.

Operative mortality. Operative death was significantly more likely in women (72% vs 49%; $P = .02$), in older patients (median age 82 vs 77 years; $P = .002$), and in smaller patients (median BSA 1.69 vs 1.82 m²; $P = .008$) (Table II). Risk factors for operative mortality included diabetes mellitus, history of previous myocardial infarction, and urgent/emergency status. Patients receiving a 19-mm aortic valve prosthesis were also at significantly increased risk for operative mortality; 68%

Table IV. Odds ratio (95% CI for operative mortality)

Model	Population	Variables in the model	OR (95% CI)	P value
1	All patients (n = 366)	19-mm valve	5.1 (1.6, 16)	.006
		Female sex	0.6 (0.2, 2.2)	.47
		Propensity score	5.3 (0.7, 39)	.10
2	All patients (n = 366)	19-mm valve	2.1 (0.7, 6.4)	.21
		Female sex	2.2 (0.5, 10.2)	.30
		Male sex + 19-mm valve	17.5 (2.2, 139)	.007
		Propensity score	5.9 (0.8, 43)	.08
3	All 19-mm valves (n = 102)	Male sex	6.5 (1.4, 31)	.02
		Propensity score	4.4 (0.3, 62)	.27
4	All ≥ 21-mm valves (n = 264)	Male sex	0.3 (0.1, 1.9)	.23
		Propensity score	0.7 (0.3, 16)	.83
5	All women (n = 186)	19-mm valve	1.9 (0.6, 6.0)	.30
		Propensity score	9.7 (0.7, 134)	.09
6	All men (n = 180)	19-mm valve	42 (4.8, 384)	.001
		Propensity score	1.4 (0, 1277)	.95
7	All patients (n = 366)	19-mm valve	1.2 (0.3, 4.4)	.81
		Female sex	1.9 (0.4, 9.7)	.46
		Male sex + 19-mm valve	12.2 (1.2, 122)	.03
		Propensity score	8.7 (0.7, 104)	.09
		BSA < 1.7 m ²	3.4 (0.7, 17.5)	.14
		BSA ≥ 1.7 m ² + 19-mm valve	3.1 (0.4, 23)	.26

OR, Odds ratio; CI, confidence interval; BSA, body surface area.

of operative deaths occurred in patients receiving 19-mm valves, whereas 25% of survivors received a 19-mm valve ($P = .001$). The most common cause of death was cardiac in origin in both groups (Table III).

The first multivariable model predicting operative death (Table IV, model 1) showed that those receiving a small valve were at increased risk of operative death (odds ratio [OR] 5.1; 95% CI 1.6, 16; $P = .006$). Contrary to expectations, though, women were at slightly reduced risk. We constructed Table V to evaluate the relationship between sex, valve size, and operative mortality. The overall mortality was higher in women than in men (10% vs 4%; $P = .02$). Of more significance, although the difference in operative mortality in women who received a 19-mm valve was significantly higher than in women who received a larger valve (14% vs 5%; $P = .04$), the difference was even more dramatic in male patients who received a 19-mm valve versus a ≥21-mm valve (44% vs 2%; $P \leq .0005$). Thus we added a sex–valve size interaction term in our final multivariable analysis model (Table IV, model 2). In this model, men who received a 19-mm valve were at very high risk of operative mortality (OR 17.5; 95% CI 2.2, 139; $P = .007$). Female sex and small valve also conferred risk of operative mortality, although not to a statistically significant degree. A likelihood ratio test comparing model 2 with model 1 showed that the interaction term in model 2 added significant information ($\chi^2 = 7.2$; $df = 1$; $P = .007$). The goodness-of-fit χ^2 (df

Table V. Percent of patients who died (n deaths/n at risk) in strata of valve size and sex

	All patients, % (n deaths/ n at risk)	Valve size		P value
		19 mm, % (n deaths/ n at risk)	≥21 mm, % (n deaths/ n at risk)	
Female	10 (18/186)	14 (13/93)	5 (5/93)	.04
Male	4 (7/180)	44 (4/9)	2 (3/171)	≤.0005
P value	.02			

= 8) yielded a P value of .40. In diagnostic plots, the men receiving small valves had fairly high leverage but were not among the observations with large Hosmer-Lemeshow $\Delta \chi^2$ influence or Δ -D influence statistics.²¹

However, because the interaction term is fit to 9 subjects and because the confidence interval around the estimate is so large, we were concerned about the robustness of the finding of significantly increased risk. Consequently, we fit additional multivariable logistic models in strata of valve size and sex (Table IV, models 3-6). Each model was fit with a propensity score derived in its stratum. The number of events and patients is much smaller in the strata, such that confidence intervals are considerably larger, but men are at a 6.5-fold increased risk of operative mortality among patients receiving 19-mm valves (model 3), and among men, those receiving 19-mm valves are at a 42-fold risk

Table VI. Odds ratio (95% CI) for operative morbidity for receipt of 19-mm valve; all models included a propensity score

Morbidity	No. of events	OR (95% CI)	P value
Stroke	25	1.2 (0.4, 3.3)	.78
Renal failure	19	1.4 (0.4, 4.4)	.62
ARDS	3	0.4 (0, 5.9)	.46
Pneumonia	22	1.2 (0.4, 3.8)	.80
Sepsis	11	1.9 (0.4, 9.1)	.43
Atrial fibrillation	150	1.1 (0.6, 2.0)	.75
Bleeding	31	1.7 (0.6, 5.1)	.34
Ventilatory support ≥ 24 h	96	0.9 (0.5, 1.9)	.86
ICU stay ≥ 72 h	98	1.8 (0.99, 3.5)	.05
Hospital stay ≥ 10 d	105	0.8 (0.4, 1.6)	.52

OR, Odds ratio; CI, confidence interval; ARDS, adult respiratory distress syndrome; ICU, intensive care unit.

of operative mortality (model 6). In addition, the median odds ratio for the interaction term in model 2 calculated from the bootstrapping procedure was 18.5. The odds ratio at the 5th percentile was 2.4, indicating that 95% of the time the odds for operative death for men receiving a 19-mm valve in this sample is 2.4 or greater.

We remained concerned that the male–small valve interaction reflected valve mismatch. We fit a final model that included terms for BSA less than 1.7 m² and interaction between small valve and BSA of 1.7 m² or more to see whether these would displace the male–small valve term (Table IV, model 7). Men receiving small valves continued to be at significantly increased risk of operative death (OR 12.2; 95% CI 1.2, 122; $P = .03$). Both BSA terms had odds ratios of about 3. Although it did not reach statistical significance, there is the suggestion that valve mismatch may confer additional risk of operative death. However, this model really stretches the data; confidence intervals are large. In diagnostic plots, the men receiving small valves, however, had leverage similar to that in the earlier model, and the Hosmer-Lemeshow $\Delta \chi^2$ influence and Δ -D influence statistics for other observations that were large before were still larger.

Morbidity. Postoperative morbidity was evaluated in all patients (Table VI), and models included the propensity score. Patients who received a 19-mm prosthetic valve were at increased risk of prolonged intensive care unit stay (≥72 hours) (OR 1.8; 95% CI 0.99, 3.4; $P = .05$). A small valve did not appear to confer risk of any other morbidity, although a number of morbidities, particularly adult respiratory distress syndrome and sepsis, occurred infrequently.

Late death. All 341 patients who survived to dis-

charge were observed in the postoperative period, with a median follow-up time of 24 months (80% of these patients have been contacted within the past 6 months). Survival at 24 months after the operation was 90% ± 4% ($n = 50$) in patients who received 19-mm valves and 91% ± 2% ($n = 131$) in patients who received ≥21-mm valves. Survival at 48 months after the operation was 85% ± 5% ($n = 20$) in patients who received 19-mm valves and 81% ± 4% ($n = 43$) in patients who received ≥21-mm valves. In the univariable proportional hazards model, 19-mm valve was not related to late death (hazard ratio 1.0; 95% CI 0.5, 2.0; $P = .95$). In the multivariable model that included a propensity score, there continued to be no difference in hazard of death between patients receiving 19-mm valves and those receiving ≥21-mm valves (hazard ratio 0.7; 95% CI 0.3, 1.8; $P = .51$).

Discussion

Optimal surgical management of aortic valve stenosis in elderly patients with a small aortic root remains highly controversial. In the past, small aortic valve prostheses were believed to have poor hemodynamic performance and were therefore used sparingly.^{22,23} Aortic root enlargement was popularized as a means to allow implantation of larger prosthetic valves, thus minimizing the risk of significant patient-prosthesis mismatch.^{15,16,22} When newer generation prosthetic valves with better performance became available in small sizes, many groups, including our own, chose to implant them in patients.^{5,9,24-27}

No randomized studies have been done to answer the question whether a patient with a small aortic anulus is better treated by insertion of a 19-mm prosthetic valve or by root enlargement with insertion of a larger valve. Several recent studies have attempted to clarify the consequences of inserting a small prosthetic aortic valve. Unfortunately, many of these studies have included patients undergoing valve replacement for aortic insufficiency or patients undergoing concomitant mitral valve replacement,^{5,28} which complicates comparisons of reported outcomes.²⁹ We limited our study to elderly patients with stenotic aortic disease with or without coronary artery disease in an attempt to identify a homogeneous cohort.

We were surprised to identify a significant increase in operative mortality among patients receiving a size 19-mm prosthetic valve. The selective impact of 19-mm valve insertion on operative mortality was elucidated only after we identified the subgroup at risk: elderly male patients with a measured 19-mm anulus. Medalion and associates⁵ recently published their experience with insertion of small aortic valves in octo-

genarians and noted patients receiving 19-mm valves exhibited a trend toward a higher operative mortality, but they did not specifically address differences related to sex. The factors responsible for the poor outcome in our male subgroup remain unclear. Certainly size mismatch may have been an important variable given 7 of 9 men who received a 19-mm prosthesis had a BSA of 1.7 m² or more. It should be noted that women with a BSA of 1.7 m² or more who received a 19-mm valve were not at increased risk for mortality. It is also possible that the poor outcome observed in men did not result directly from the hemodynamic consequence of 19-mm valve insertion. The presence of a small anulus may be a marker for other undefined risk factors that may in a collective manner adversely affect outcome in men more than women. It is known, for example, that there are differences related to sex in left ventricular adaptation to aortic stenosis, and in general abnormal myocardial architecture and ventricular dysfunction are more commonly observed in men.³⁰ Furthermore, Morris and associates⁴ demonstrated a positive independent effect of female sex on recovery of left ventricular ejection fraction after AVR. Recently, Cohen and colleagues³¹ have also reported that male sex has a negative impact on late survival after bioprosthetic AVR. Our subgroup of men receiving 19-mm valves is too small to enable us to draw specific conclusions, but our observation of increased operative mortality warrants further investigation.

Although data regarding postoperative prosthetic transvalvular gradients and calculated effective valve orifice areas vary widely, the consensus is that patients surviving insertion of a small prosthetic valve are left with a fixed degree of left ventricular outflow tract obstruction. As a result, the regression of left ventricular hypertrophy is slower than in recipients of larger valves.^{1,2,11} The impact of persistent prosthetic outflow obstruction on late survival is controversial and has been previously addressed by several investigators. Kratz and associates³ reported that patients with a BSA of more than 1.9 m² who received a 19-mm St Jude Medical aortic valve were more likely to experience late sudden death. He and colleagues²⁴ noted that patient-prosthesis size mismatch (≤ 21 -mm size prosthetic valve with BSA > 1.7) in the setting of concomitant CABG was a negative determinant for long-term survival. In contrast, Sawant and associates^{8,9} found no correlation between insertion of a 19-mm St Jude Medical valve and BSA with late mortality. Similarly, Medalion and coworkers⁵ found that long-term survival was unaffected by the combination of 19-mm prosthetic valve and BSA more than 1.7 m². We did not observe a higher late mortality in our patients receiving 19-mm

prostheses regardless of BSA, but our follow-up remains relatively short.

Our findings have caused us to think carefully about our use of standard 19-mm aortic prostheses in elderly men. Although the number of patients in this subgroup is extremely small (9/366 patients), it is hard to ignore their poor outcome. It would appear that a higher performance valve, such as a homograft or stentless valve, and/or root enlargement procedure should be considered in men with a measured 19-mm anulus. Ongoing trials with higher performance valves in elderly patients may identify other subgroups that would benefit from similar management.

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Discussion

Dr Donald B. Doty (*Salt Lake City, Utah*). Dr Adams and his associates at the Brigham and Women's Hospital in Boston have presented data that attempt to answer the ongoing controversy of whether a small prosthetic valve, 19 mm in diameter, should be implanted in adult patients. We have already heard from the Cleveland Clinic that a 19-mm valve is fine and that mismatch between prosthetic size and body size makes no difference in short- or long-term patient survival.

What seems to have caught Dr Adams' attention is an excessively high operative mortality of 16.7% when a 19-mm prosthesis was used to replace the stenotic aortic valve. This is 5 times higher than the 3% mortality when larger valves were used. The rate was 14% in women and even worse when a 19-mm valve was used in men: 4 of 9, or 44%, died. The authors conclude that insertion of a 19-mm prosthesis carries a substantial risk of death, especially in men, but also in women, and advised aortic root enlargement or perhaps the use of a stentless prosthesis.

I agree with this conclusion and would extend it a few more steps. We are presently using stentless porcine valve prostheses in nearly all patients over the age of 70 years because of superior hemodynamic performance. In situations in which mechanical prostheses are indicated, we do not use 19-mm valves at all and only use 21-mm prostheses in patients who have a BSA less than 1.5 m² and who are sedentary. This is standard textbook policy.

In the original abstract, I noted that operative mortality was doubled in the 21-mm valves. Dr Adams, would you comment on how 21-mm valves should be used in practice?

Dr Adams. Thank you, Dr Doty. On the basis of our data, I would implant a 21-mm valve without hesitation, except perhaps in an extremely large patient. We did find a doubling of operative mortality with univariable analysis of 21-mm valves, but we later combined 21-mm and larger valves because there was little difference in their operative outcome once multiple variables were taken into account.

We are not ready to join you in abandoning the use of 19-mm valves, but we will be using fewer of them in elderly men. In general, stentless valve or root enlargement procedures are more tedious, and I think we will continue to perform the simplest operation possible in most patients. I believe the "standard" textbook policy" you referred to may need to be revised. Ongoing randomized studies comparing stentless and stented valves, particularly in the smaller valve size groups, should clarify optimal patient/valve matching.