Critical aortic stenosis in the neonate

A comparison of balloon valvuloplasty and transventricular dilation

The optimal treatment of critical aortic stenosis in the neonate and infant remains controversial. We compared transventricular dilation using normothermic cardiopulmonary bypass and percutaneous balloon aortic valvuloplasty with respect to early and late survival, relief of aortic stenosis, degree of aortic insufficiency, left ventricular function, and freedom from reintervention. Between July 1987 and July 1993, 30 neonates and infants underwent transventricular dilation or balloon aortic valvuloplasty for critical aortic stenosis. The patients in the transventricular dilation group ($n = 21$) ranged in age from 1 to 59 days (mean age 18.0 days $\pm$ 19.1 days) and the balloon aortic valvuloplasty group ($n = 9$) from 1 to 31 days (mean age 10.0 days $\pm$ 9.0 days). There were no significant differences in weight, body surface area, or aortic anulus diameter between the two groups ($p = 1.0$). Associated cardiovascular anomalies were more common in the transventricular dilation group (48%) than in the balloon aortic valvuloplasty group (11%). After intervention, the degree of residual aortic stenosis and insufficiency was equivalent in the two groups as assessed by postprocedural Doppler echocardiography. Ejection fraction improved within both groups (transventricular dilation 39% $\pm$ 20.2% versus 47% $\pm$ 22.0%; balloon aortic valvuloplasty 51% $\pm$ 16.1% versus 62% $\pm$ 8.4%), and there was no significant difference between groups. The left ventricular mass/volume ratio increased within both groups ($p < 0.05$) but with no significant difference between groups (transventricular dilation 1.4 $\pm$ 0.5 gm/ml versus 1.8 $\pm$ 0.6 gm/ml; balloon aortic valvuloplasty 1.1 $\pm$ 0.6 gm/ml versus 1.7 $\pm$ 0.4 gm/ml). Early mortality in the transventricular dilation group was 9.5% and in the balloon aortic valvuloplasty group, 11.1%. There was one late death in the transventricular dilation group. Four patients from the transventricular dilation group (19%) and two patients from the balloon aortic valvuloplasty group (22%) required reintervention for further relief of aortic stenosis. We conclude that both transventricular dilation and balloon aortic valvuloplasty provide adequate and equivalent relief of critical aortic stenosis. The treatment strategy adopted should depend on other factors, including associated cardiovascular anomalies, vascular access, preoperative condition, and the technical expertise available at each institution. (J THORAC CARDIOVASC SURG 1995;109:147-54)

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0022-5223/95 \$3.00 + 0 12/6/59963

Read at the Seventy-fourth Annual Meeting of The American
Association for Thoracic Surgery, New York, N.Y., April
24-27, 1994.

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The treatment of critical aortic stenosis in the neonate continues to carry a high mortality. With a few exceptions,¹ the reported hospital mortality has ranged from 22% to 58%.²⁻¹² The morphologic substrate in neonates with symptomatic aortic stenosis represents a wide spectrum of abnormalities and often includes patients with aortic annular hypoplasia, valvular dysplasia, hypoplasia of the left ventricle, mitral valve anomalies, and endocardial fibroelastosis. Treatment protocols and outcome analysis are, therefore, difficult to standardize and compare. A number of surgical techniques have been developed in an attempt to treat patients with congenital aortic stenosis. Direct exposure of the aortic valve has been the established treatment in the past. However, this procedure in the neonate is frequently unrewarding because the commissures are poorly defined and the anulus is small. Percutaneous balloon aortic valvuloplasty (BAV) is well established in older children and effectively reduces the severity of valvular stenosis¹³⁻¹⁸ with acceptable short-term and intermediate-term results.^{19, 20}

At the C. S. Mott Children's Hospital of the University of Michigan Medical Center, we²¹⁻²⁴ have taken an active role in applying transcatheter therapy for a number of congenital heart defects. However, the frequently unstable clinical condition of many of these neonates with critical aortic stenosis, as well as the problems encountered with femoral arterial access in small infants requiring relatively large angioplasty catheters, led us to adopt the operative approach of transventricular dilation (TVD) using cardiopulmonary bypass. This technique allows rapid stabilization of a hemodynamically compromised patient with circulatory support while avoiding the myocardial ischemia required to expose the aortic valve for open valvotomy. The development of smaller angioplasty catheters²⁵ and the introduction of the now preferred transumbilical artery approach have led us once again to examine the relative merits of both BAV and TVD. We therefore reviewed our recent experience with both procedures with respect to early and late survival, relief of aortic stenosis, degree of aortic insufficiency, left ventricular function, and freedom from reintervention.

Methods

Patient data. Between July 1987 and July 1993, 30 neonates and infants underwent TVD ($n = 21$) or BAV ($n = 9$) for critical aortic stenosis at C. S. Mott Children's Hospital, the University of Michigan Medical Center. All patients with biventricular hearts, as well as atrioventric-

Table I. Preoperative hemodynamics

	TVD	BAV*
Anulus (mm)	6.9 ± 1.8	7.5 ± 0.8
Gradient (mean)	33.8 ± 15.9	42.0 ± 15.7
LVEF (%)	39.0 ± 20.2	51.1 ± 16.1
LVEDV (ml/m ²)	82.1 ± 50.0	54.8 ± 24.3
Mass/volume (gm/ml)	1.4 ± 0.5	1.1 ± 0.2

TVD, Transventricular dilation; BAV, balloon aortic valvuloplasty; LVEF, left ventricular ejection fraction; LVEDV, left ventricular end-diastolic volume; mass/volume, left ventricular mass/volume.

* p = not significant compared with TVD.

Table II. Associated anomalies

	No. of patients
TVD ($n = 21$)	
Mitral stenosis	2
Ventricular septal defect	2
Patent ductus arteriosus	10
Coarctation of the aorta	5
Tetralogy of Fallot	1
BAV ($n = 9$)	
Patent ductus arteriosus	6

ular and ventriculoarterial concordance, were included for review. Patients with hypoplastic left heart syndrome, univentricular atrioventricular connection, common atrioventricular valve orifice, or truncus arteriosus were excluded from the study. The decision to perform TVD or BAV was predicated on the suitability of the umbilical arteries and often the preference of the referring physician. All measurements were made with Doppler echocardiography and reported as the mean value ± the standard deviation.

TVD. TVD was performed on 21 patients whose ages ranged from 1 to 59 days (mean 18.0 ± 19.1 days). Their weights ranged from 1.5 to 5.6 kg (mean 3.1 ± 1.0 kg). All patients were in moderate to severe congestive heart failure, 10 were receiving an infusion of prostaglandin E₁ to maintain patency of the ductus arteriosus, and 7 were in hemodynamically unstable condition. Patients were considered to be in unstable condition if they were persistently hypotensive or acidotic despite maximal support. Only eight of the patients underwent preoperative catheterization. Preoperative aortic anulus diameters ranged from 5.0 to 12.5 mm (mean 6.9 ± 1.8 mm). Peak instantaneous aortic valve gradients ranged from 16 to 98 mm Hg (mean 59.8 ± 25.2 mm Hg) and mean gradients varied from 12 to 53 mm Hg (mean 33.8 ± 15.9 mm Hg). Left ventricular ejection fraction ranged from 14% to 71% (mean 39.0% ± 20.2%), left ventricular end-diastolic volume from 14 to 192 ml/m² (mean 82.1 ± 50.0 ml/m²), and the mean left ventricular mass/volume ratio was 1.4 ± 0.3 gm/ml (Table I). Associated defects consisted of mitral stenosis in two patients, restrictive ventricular septal defect in two, patent ductus arteriosus in ten, coarctation in five, and tetralogy of Fallot in one patient (Table II).

In those patients without major associated anomalies requiring repair, TVD was performed with normothermic

Table III. Mortality

	Early		Late	
	No.	%	No.	%
TVD (<i>n</i> = 21)	2	9.5	1	5.3
BAV* (<i>n</i> = 9)	1	11.0	0	

**p* = Not significant.

cardiopulmonary bypass. In one patient, TVD was performed without bypass through a left thoracotomy during simultaneous coarctation repair. Cardiopulmonary bypass time ranged from 11 to 22 minutes with a mean of 14 minutes. No period of myocardial ischemia was necessary because the valve was not visualized. The heart was elevated and a pursestring suture placed in the left ventricular apex. Gradual dilation achieved with progressively larger dilators was then performed by passing the dilators through the left ventricular apex along the ventricular septum and across the aortic valve until they were palpated in the ascending aorta (Fig. 1). The optimal maximal dilator size was 1 mm larger than the preoperative echocardiographic measurement of the aortic anulus and ranged from 6 to 10 mm.

BAV. Nine patients underwent BAV. Their ages ranged from 1 to 31 days (mean 10.0 ± 9.0 days) and weights from 2.2 to 4.8 kg (mean 3.7 ± 0.7 kg). All of the patients were in congestive heart failure, although none were in hemodynamically unstable condition. Six of the patients were receiving prostaglandin E_1 to maintain ductal patency. One patient had undergone a previous open aortic valvotomy and had significant residual aortic stenosis. The aortic anulus diameters ranged from 6.5 to 7.9 mm (mean 7.5 ± 0.8 mm). Peak instantaneous aortic valve gradients ranged from 33 to 100 mm Hg (mean 68 ± 25.9 mm Hg) and the mean gradients ranged from 20 to 61 mm Hg (mean 42 ± 15.9 mm Hg). The left ventricular ejection fraction ranged from 36% to 81% (mean $51.1\% \pm 16.1\%$), and the left ventricular end-diastolic volume varied from 31.1 to 104 ml/m² (mean 54.8 ± 24.3 ml/m²). The mean left ventricular mass/volume ratio measured 1.1 ± 0.2 gm/ml (see Table I). Associated cardiovascular lesions included a patent ductus arteriosus in six patients and a variant of hypoplastic left heart syndrome, determined after treatment in one (see Table II).

The technique for BAV has been previously described in detail.²⁵ We prefer the transumbilical approach, when possible, using an arterial catheter in each umbilical artery and a venous catheter positioned across the foramen ovale into the left ventricle. This allows for simultaneous measurement of left ventricular and aortic pressures throughout the procedure. The balloon size is chosen to approximately equal the valve anulus diameter as estimated by echocardiography. After dilation, an aortogram is performed to evaluate the degree of aortic valve insufficiency.

Statistical evaluation. All data are reported as mean $\pm$ standard deviation. The two treatment groups were compared by the Student's *t* test for continuous data and the Fisher exact test for categorical data. A *p* value < 0.05 was required to indicate a significant result.

Fig. 1. Operative technique demonstrating antegrade TVD using blunt dilators through an apical pursestring suture.

Results

TVD group. There were two hospital deaths in the TVD group (9.5%, 70% confidence interval [CI]: 4.7% to 18.3%) (Table III). Both deaths resulted from low cardiac output. One patient was in extremely poor condition before the operation and the second was a patient with borderline left ventricular hypoplasia (volume about 25 ml/m²) whose ventricular function continued to deteriorate in the postoperative period. The one late death involved a child with multiple associated cardiovascular anomalies, including multiple ventricular septal defects, aortic coarctation, and pulmonary vein stenosis, who had undergone intraoperative pulmonary vein stenting. She died awaiting transplantation. The overall survival in the TVD group was 86%.

Among the remaining 19 patients, follow-up ranges from 6 to 94 months, with a mean follow-up of 56.5 ± 24.9 months. The residual peak instantaneous pressure gradient across the aortic valve ranged from 0 to 73 mm Hg (mean 29.1 ± 19.2 mm Hg). The residual mean pressure gradient varied from 3 to 43 mm Hg (mean 18.9 ± 10.9 mm Hg). The left ventricular end-diastolic volume ranged from 20 to 135 ml/m² (mean 73.6 ± 51.5 ml/m²). The left ventricular ejection fraction ranged from 12% to 77% (mean $47.7\% \pm 22.0\%$), as seen in Table IV. Five patients had no echocardiographic evidence of aortic insufficiency, ten patients had mild insufficiency, three had moderate insufficiency, and one patient had moderate to severe insufficiency that has

Table IV. Hemodynamic results

	TVD* (n = 19)	BAV*† (n = 8)
Gradient (mean)	18.9 ± 10.9	28.7 ± 10.9
LVEF (%)	47.7 ± 22.0	62.0 ± 8.4
Mass/volume (gm/ml)	1.8 ± 0.6	1.7 ± 0.4

Gradient and left ventricular ejection fraction were measured at hospital discharge. Left ventricular mass/volume ratio was measured at latest follow-up echocardiogram.

* $p < 0.05$ compared with preoperative value.

† p = not significant compared with TVD.

progressed over the course of 4 years (Table V). The left ventricular mass/volume ratio increased from 1.37 ± 0.34 gm/ml to 1.85 ± 0.19 gm/ml.

One patient, who underwent TVD followed by BAV, subsequently underwent a Norwood procedure because of poor left ventricular function. This was followed by staging to a successful Fontan procedure. Two patients from the initial TVD group required a subsequent BAV. The first underwent aortic valve replacement with a pulmonary autograft 6 years later for progressive aortic stenosis and insufficiency. The other patient had a residual coarctation that was successfully dilated concomitantly with the BAV. One additional patient required open valvotomy and resection for progressive subvalvular and valvular aortic stenosis 4 years after the initial procedure. The remaining 14 patients have required no additional procedures (Fig. 2).

BAV group. The BAV group consisted of nine patients. Ten procedures were performed in these patients. Seven of the dilations were done via a transumbilical approach. The remaining three procedures were accomplished via the femoral artery. One patient required a second valvuloplasty for persistent symptoms and a residual aortic valve pressure gradient of 95 mm Hg at 3 months of age (see Fig. 2). The one early death was due to low cardiac output and there have been no late deaths, for a mortality rate of 11.1% (70% CI 4.2% to 26.3%). The external iliac artery was injured during one of the transfemoral procedures, but without significant vascular compromise to the involved extremity.

Survivors have been observed for 12 to 56 months (mean 37.2 ± 15.2). The residual peak instantaneous pressure gradient across the aortic valve ranged from 25 to 60 mm Hg (mean 43.5 ± 15.6 mm Hg) and the residual mean pressure gradient varied from 17 to 45 mm Hg (mean 28.7 ± 10.9 mm Hg). Aortic insufficiency was absent in three patients, mild in three patients, moderate in one patient, and moderate to severe in one patient. Left ventricular

Table V. Postprocedural aortic insufficiency

	Grade				
	0	1+	2+	3+	4+
TVD (n = 19)	5	10	3	1	0
BAV (n = 8)	3	3	1	1	0

Results appear similar; however, because of the small numbers of patients in each group, no statement can be made concerning statistical significance.

ejection fraction increased from a mean of $51.1\% \pm 16.1\%$ to $62.0\% \pm 8.4\%$ and the left ventricular end-diastolic volume fell to 47.6 ± 21.2 ml/m². The left ventricular mass/volume ratio increased from 1.12 ± 0.2 to 1.74 ± 0.2 gm/ml at the most recent echocardiogram.

The two techniques studied had similar mortality rates (TVD 9.5% and BAV 11.1%). Both TVD and BAV were successful in relieving the anatomic left ventricular outflow tract obstruction as evidenced by the decline in the mean transvalvular gradients: TVD (mean 33.8 ± 15.9 mm Hg to 18.9 ± 10.9 mm Hg) and BAV (mean 42 ± 15.9 mm Hg to 28.7 ± 10.9 mm Hg). This represents a significant difference within each group but there is no significant difference between the treatment groups. This reduction in the mean gradient is especially encouraging when viewed in light of the improvement in left ventricular function. The left ventricular ejection fraction in the TVD group rose from a mean of $39\% \pm 20.2\%$ to $47\% \pm 22.0\%$, and in the BAV group it increased from a mean of $51\% \pm 16.1\%$ to $62\% \pm 8.4\%$. Because of the small number of patients in each group, the degree of aortic insufficiency could not be statistically evaluated but does appear to be similar in both treatment groups. Last, the need for reintervention is higher in the surgical group (TVD 22.2%) than in the catheterization group (BAV 12.5%); however, the follow-up in the surgical group is longer as well (TVD 56.5 ± 24.9 months, BAV 37.2 ± 15.2 months).

Discussion

Surgical therapy for critical aortic stenosis in neonates carries a significant perioperative mortality. A variety of different approaches have been proposed for the treatment of critical aortic stenosis in the neonate. These methods include open valvotomy with inflow occlusion or cardiopulmonary bypass,^{6-8,26} TVD with or without cardiopulmonary bypass,^{4,11,27-29} intraoperative BAV via the left ventricular apex,^{30,31} and percutaneous BAV.^{20,32,33} Neonates with critical aortic stenosis present a formidable

Fig. 2. Reintervention after TVD and BAV. *Valvotomy*, open valvotomy; *Ross procedure*, pulmonary autograft; *BAV/Coarc*, simultaneous BAV and dilation of recurrent aortic coarctation; *Norwood*, first-stage palliation of hypoplastic left heart syndrome; *AS*, aortic stenosis.

challenge because of the frequently associated unstable hemodynamic status, hypertrophied and irritable myocardium prone to ventricular arrhythmias, limited myocardial reserve, and the frequency of additional cardiac lesions such as left ventricular fibroelastosis, mitral stenosis, and left ventricular hypoplasia.

Although a few studies have reported good results with open aortic valvotomy,^{1, 34} in most series the mortality has remained high.³⁻¹² This may be because, in part, congenital aortic stenosis is a heterogeneous and complex disorder in which the aortic valvular and annular substrate may not be conducive to direct operative intervention. Aggressive attempts at valvotomy may lead to a high incidence of postoperative aortic insufficiency and further left ventricular failure. In addition, the need to subject the heart to an additional ischemic period during the procedure may result in a further deterioration of left ventricular function. Trinkle and associates¹¹ first described TVD as a simple and effective technique of closed aortic valvotomy in infants. All four patients survived the perioperative period with significant reduction in transvalvular gradients and minimal aortic insufficiency. Trinkle, Grover, and Arom²⁸ later reported continued benefit in the same group of patients at a follow-up period of 3 to 6 years. TVD using cardiopulmonary bypass provides reliable circulatory support, avoids myocardial ischemia, and allows for a conservative yet effective valvotomy with minimal aortic regurgitation. We believe that the antegrade technique tends to seek

the "true" orifice, making cusp perforation unlikely. The gradual dilation also promotes opening along naturally fused commissures. These mechanisms reduce the likelihood of significant aortic insufficiency. This approach optimizes prompt relief of the severe left ventricular pressure overload while minimizing left ventricular volume overload from valve regurgitation and myocardial injury from surgical ischemia. Similar to Trinkle's group, we have seen dramatic lasting improvement with the majority of patients being free from reintervention at a mean follow-up period of 53 months. As with all surgical procedures, this must be balanced against the infrequent yet possible complications of the procedure itself and the increased technical difficulty of subsequent operations should they be necessary.

On the other hand, transcatheter therapy avoids the need for general anesthesia, sternotomy, cardiopulmonary bypass, and an incision in the left ventricular apex. In the infant, BAV produces a decline in the transvalvular gradient by two possible mechanisms: stretching of valve tissue and rupture of commissural fusion. These are not unlike the mechanisms involved with closed TVD; however, the valvuloplasty is approached in retrograde fashion against the flow of blood and around the bend of the ascending aorta. This geometry may tend to direct the guidewire rightward into the noncoronary cusp. If cusp perforation occurs and is unrecognized, subsequent balloon dilation will create severe aortic insufficiency.³³ BAV in neonates with critical aortic

stenosis has been reported previously by a few centers with effective gradient reduction and acceptable degrees of aortic regurgitation.²⁰ The risks of BAV continue to include inadvertent unrecognized cusp perforation with resultant severe aortic insufficiency and femoral arterial injury. However, as previously reported by our group, the availability of smaller catheters has made the umbilical artery approach the procedure of choice in the neonate, preserving the femoral arteries for future catheterization should that become necessary.²⁵

Zeevi and associates⁶ compared BAV and open aortic valvotomy in an unselected group of 32 consecutive neonates with critical aortic stenosis. They found that the efficacy and mortality of surgical valvuloplasty and BAV were similar, but with a higher reoperation rate and mortality rate than we experienced using TVD. It is also clear from their work and that of multiple other groups that left ventricular size has a highly significant correlation with outcome in neonates with critical aortic stenosis, regardless of the procedure selected.³⁵⁻³⁷ Although the delineation of hypoplastic left heart syndrome from critical aortic stenosis can be difficult, we use certain criteria to select those patients best suited for single-ventricle type repairs. A mitral valve annulus of less than 8.0 mm, a left ventricular end-diastolic volume of less than 20 ml/m², an aortic valve annulus of less than 5.0 mm, a non-apex-forming left ventricle, and the presence of severe subaortic stenosis are all variables we believe place the patient into the hypoplastic left heart syndrome category. Patients with significant left ventricular hypoplasia are best treated with staged reconstruction leading to an eventual Fontan repair.

As can be inferred from the large range and standard deviation in the measurements of left ventricular end-diastolic volume and mass, as well as left ventricular ejection fraction, we are dealing with two different subsets of patients. One group of patients demonstrated relatively well-preserved ventricular function, small chamber sizes, and greatly hypertrophied left ventricles. The second group of patients was characterized by dilated left ventricular chambers and declining ventricular function. Because of the small numbers of patients in each category, we were unable to comment on any definite difference in outcome; however, these patients appear to represent a continuum progressing from left ventricular hypertrophy to chamber dilatation. This may be a result of continued left ventricular pressure overload and relative myocardial ischemia. Also, it is encouraging to see the normalization of

the mass/volume ratio in these infants after dilation. We surmise that relief of the left ventricular outflow obstruction without superimposing significant aortic insufficiency allows the left ventricular mass and/or volume to regress, improves the myocardial oxygen supply, and results in a more efficiently functioning left ventricle.

A limitation of this study is the potential for selection bias. The greater prevalence of associated anomalies and greater degree of hemodynamic instability in the TVD group indicate a population at greater risk. This may tend to obscure a potential benefit of TVD when compared with BAV.

Optimal treatment of critical neonatal aortic stenosis depends on prompt and accurate anatomic diagnosis and medical stabilization before intervention. Ventilation, inotropic support, and the treatment of acidosis before intervention are often beneficial. In particular, the administration of a prostaglandin infusion is extremely helpful in treating low cardiac output by allowing the right ventricle to perfuse the systemic circulation through the ductus arteriosus. Given the similar results of the two procedures as demonstrated in this report, the decision on the optimal procedure should rest on a variety of other factors, including vascular access, associated lesions necessitating surgical intervention, and institutional expertise. Currently, in stable neonates with patent umbilical arteries and no associated anomalies requiring repair, we prefer BAV. When umbilical artery access is not possible, we prefer to use TVD to preserve the femoral artery access for future percutaneous intervention. Alternatively, balloon dilation through the carotid artery has been used in some patients.³⁸ In the presence of coexisting cardiovascular conditions such as coarctation of the aorta, we prefer an operative approach to include TVD and concomitant repair of the associated lesion.

The debate over the optimal treatment of critical aortic stenosis in the neonate continues. We believe that TVD and BAV provide the best short-term and intermediate-term results to a problem that will likely require multiple interventions over the patient's lifetime.

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Discussion

Dr. Michel N. Ilbawi (*Oak Lawn, Ill.*). We differ in our approach to critical aortic stenosis. We invariably treat these patients with open extended valvuloplasty, which has a risk factor of less than 5% and good long-term outcome.

How do you explain, in your hands, the superiority of dilation over open valvotomy? How can a blind procedure better define the commissure than an open one?

Dr. Giovanni Stellin (*Padova, Italy*). It seems that the "nonpatency" of the umbilical artery is a limiting factor for you to perform aortic balloon dilation in neonates. In your institution, critical aortic stenosis in neonates has been managed, in the last 3 years, by balloon dilation utilizing the right carotid artery as arterial access, with no complications. I wonder if you have any experience with this approach, which seems to be very good, according to our cardiologists.

Obviously the carotid artery is not ligated at the end of the procedure. The patency of the artery is checked by two-dimensional echocardiography and Doppler studies before discharge. So far, we have not seen any occlusion or stenosis.

Dr. Ralph D. Siewers (*Pittsburgh, Pa.*). I would like to add to the comments of Dr. Stellin regarding the carotid artery approach to balloon dilation in critical aortic stenosis. Our cardiologists are happy with this approach and have had no trouble passing the balloon catheter so long as we extend the head, which tends to straighten the angle of the innominate artery. It gives them a very direct approach. We have been able to repair the carotid artery in each case with no complications. Our experience now numbers approximately 14 of these patients at the Children's Hospital of Pittsburgh. We agree that this does not give us the advantage of cardiopulmonary bypass resuscitation, but we have not needed mechanical support for resuscitation in these neonates.

Dr. Gerhard Ziemer (*Hannover, Germany*). This discussion shows that you are allowed to do anything to the stenotic aortic valve so long as you can come up with a mortality of no more than 10% accompanied by a low reoperation rate. We know that this is possible with each of the procedures mentioned. In Hannover we use several of these procedures and make a somewhat individual decision about what to do with a certain patient. For example, when we have a very sick baby at the Children's Hospital where no cardiopulmonary bypass option is given, we do not transport the patient to our unit, but

rather do an open valvotomy with inflow occlusion. Other patients are operated on with extracorporeal circulation. Older infants may undergo balloon-valve rupture performed by pediatric cardiologists.

Dr. John J. Lamberti (*San Diego, Calif.*). I cannot sit here and listen to this discussion without commenting on your remarks. You are espousing the standard teachings regarding aortic stenosis in infancy. I was also taught that the aortic valve cannot be approached directly in the infant. I now know that if you take the time to put the patient on bypass, use cardioplegia, and decrease pump flow for a few minutes, you can get a really good look at the valve. In 1988, at the meeting of this Association in Boston, Massachusetts, Dr. Messmer from Aachen, Germany, discussed a similar paper on neonatal aortic stenosis. Dr. Messmer pointed out that aortic valvotomy under direct vision in the neonate permits precise opening of the commissures, as well as trimming of obstructive lumps (excrescences) on the leaflets (*J THORAC CARDIOVASC SURG* 1990;99:683). Since that time we have used the technique in four patients with excellent early results.

I think your paper is an excellent report, but I am surprised that your group, which advocates early primary repair of tetralogy of Fallot, would put a patient on bypass and then not actually look at the valve. It is my belief that open techniques are appropriate for congenital aortic stenosis in the infant. One technical point: Although the aorta may be small, it takes only a few extra moments to place a patch of pericardium at the site of the aortotomy. I also recognize that we do not often have a chance to operate on these patients because the cardiologists try to do a balloon dilation whenever they can.

Dr. Miguel Sousa Uva (*Paris, France*). I agree with Dr. Ilbawi's comments. We too prefer to do an open valvotomy rather than a transventricular approach. We have used a transventricular dilation in the past but without cardiopulmonary bypass.

How many of these patients had left ventricular fibroelastosis and what was the mean aortic anulus diameter?

Dr. Mosca. As Dr. Robert Freedom pointed out in the October 1989 edition of *Circulation*, neonates with aortic stenosis have a complex substrate producing the restrictive aortic orifice. In addition to dysplastic aortic valve leaflets, there is marked annular hypoplasia and at times unrecognizable aortic valve commissures. Overall, the current literature shows a higher incidence of aortic regurgitation and restenosis with open valvotomy.

We believe that TVD is as safe as BAV and causes rupture of the stenotic valves along the fused commissures.

The mean aortic anulus diameter in the TVD group was 6.9 mm and in the BAV group, 7.5 mm. Also, the majority of our patients had changes of endocardial fibroelastosis.

The retrograde approach through the right carotid artery as reported by the group in Pittsburgh is also a viable option. As a retrograde approach it suffers from the occasional difficulties of catheterizing the eccentric and abnormal aortic orifice. The real danger of a retrograde approach is inadvertent cusp perforation leading to massive aortic insufficiency.

In conclusion, we believe TVD with cardiopulmonary bypass is the safest, most accurate, and most reproducible method available.