AORTOVENTRICULOPLASTY WITH THE PULMONARY AUTOGRAFT: THE "ROSS-KONNO" PROCEDURE

Background: For patients with complex left ventricular outflow tract obstruction, including hypoplastic aortic anulus with or without severe diffuse subaortic stenosis, various aortoventriculoplasty procedures (e.g., Konno procedure and its modifications; extended aortic allograft root replacement) are important management options. In younger patients, however, reoperation for valve replacement is inevitably required, and anticoagulation issues pose additional problems. The pulmonary autograft provides a promising option for aortic valve replacement as part of the aortoventriculoplasty procedure in children. Long-term follow up shows that the pulmonary autograft functions well as the systemic arterial (neoaortic) valve and that valve growth occurs.

Methods: Between July 1993 and May 1995, 11 patients 4 days to 17 years old (median 12 months) underwent aortoventriculoplasty with pulmonary autograft (Ross-Konno procedure). The diagnoses were aortic stenosis with or without subaortic stenosis ($n = 8$), Shone complex ($n = 2$), and interrupted aortic arch with subaortic stenosis ($n = 1$). On average, 1.9 previous interventions had been performed per patient, including a previous Konno procedure in one patient. The aortic root was replaced with a pulmonary autograft valve. The left ventricular outflow tract was enlarged with a Dacron polyester fabric patch in two patients, with an allograft aortic patch in two patients and a right ventricular infundibular free wall muscular extension harvested in continuity with the autograft in seven patients. **Results:** Intraoperative transesophageal echocardiographic assessment revealed mild aortic insufficiency in one patient. One patient had a residual left ventricular outflow tract gradient of 15 mm Hg. Significant complications were cardiac tamponade from bleeding ($n = 1$) and complete heart block necessitating a permanent pacemaker ($n = 1$). Follow-up ranged from 2 weeks to 16 months. To date, there have been no late deaths or reoperations. Follow-up echocardiography revealed mild autograft insufficiency in one patient and a 16 mm Hg residual left ventricular outflow tract gradient in one patient. **Conclusions:** Initial experience suggests that aortoventriculoplasty with the pulmonary autograft is an excellent alternative for young patients with complex left ventricular outflow tract obstruction. Because the pulmonary autograft has been shown to grow after implantation, reoperation on the left ventricular outflow tract is likely to be avoided. (J THORAC CARDIOVASC SURG 1996;111:158-67)

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Congenital aortic stenosis in infants and children is sometimes complicated by hypoplastic anulus or diffuse subaortic stenosis.¹ These cases are typi-

cally managed conservatively through infancy and childhood by repeated valvotomy or balloon dilation, often with significant residual obstruction or insufficiency that persists until the time of more

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Table I. Diagnoses and previous procedures

Patient	Age	Diagnoses	Previous procedures		Indication for operation	Interval
			Surgical	Catheter		
1	4.4 yr	Congenital AS; secondary AI	Two valvotomies	One BAV	Progressive AI, residual AS	4.3 yr
2	16.6 yr	IAA, VSD, subAS	IAA repair + PAB; VSD closure + PAB resection + myectomy; Konno procedure	None	SubAS, prosthetic valve obstruction	10 yr
3	17.3 yr	Shone complex	Two COA repairs; resection of supramitral ring	None	Severe valvular and subvalvular AS	NA
4	22 days	Congenital AS, parachute MV, moderate MR, ASD; secondary AI	None	One BAV	Acute AI, residual AS	1 day
5	7.5 yr	Congenital AS and subAS, COA (Shone complex)	Two COA repairs; one resection of sub AS	None	Recurrent subAS and valvular AS	5 yr
6	12 mo	Congenital AS and subAS, COA	One COA repair	None	Severe AS and subAS	NA
7	3.5 mo	Congenital AS; secondary AI	None	One BAV	Progressive AI, residual AS, LV ejection fraction 25%	3 mo
8	4.2 mo	Congenital AS and subAS; secondary AI	None	Two BAVs	Severe subAS, residual AS, moderate AI	4 mo
9	4 days	Congenital AS, hypoplastic LV*; LV endocardial fibroelastosis, LV to LAS coronary fistula	None	One BAV	Duct dependent†	1 day
10	9 days	Congenital AS, hypoplastic LV‡; LV endocardial fibroelastosis	None	One BAV	Duct dependent,‡ primary repair	2 days
11	1.3 yr	Congenital AS; secondary AI	One surgical valvotomy	None	Progressive AI, residual AS	1.2 yr

Interval indicates the duration between last intervention for LVOT obstruction and the procedure described in this article. AS, Aortic stenosis; AI, aortic insufficiency; BAV, balloon aortic valvotomy; IAA, interrupted aortic arch; VSD, ventricular septal defect; PAB, pulmonary artery band; COA, coarctation of aorta; MV, mitral valve; MR, mitral regurgitation; ASD, atrial septal defect; LV, left ventricle; LAD, left anterior descending coronary artery.

*Left ventricular volume 12 to 16 ml/m².

†Attempted balloon valvotomy was unsuccessful.

‡Left ventricular volume 14 to 16 ml/m².

definitive surgical repair.^{2,3} Aortic valve replacement with concomitant enlargement of the subaortic left ventricular outflow tract (LVOT) and the aortic annulus^{4,5} is often required at this time. The problems of prosthetic aortic valve replacement in children are numerous. The most important of these are the limitations imposed by available prosthetic valve sizes, which often delay the timing of the “corrective” surgical procedure in very young children, and the need for reoperation for valve replacement in growing children because the prosthesis has no growth potential. One alternative has been the use of small aortic valve allografts.⁶ Major questions exist, however, regarding even short-term and mid-term durability of these valves in children. In addition, the lack of growth potential remains a recurrent problem. Another alternative, the pulmonary autograft,⁷ has proven long-term durability and growth potential in the LVOT.⁸⁻¹⁰ We have used the pulmonary autograft for the management of complex LVOT tract in the pediatric population, includ-

ing neonates. In this report, our experiences in aortoventriculoplasty (technique and results) with the pulmonary autograft are discussed.

Patients and methods

Patients. Between July 1993 and May 1995, 35 patients underwent aortic valve replacement with the pulmonary autograft. Of these, 15 patients required simultaneous operation for enlargement of the LVOT. Myectomy alone was performed in four patients. A Konno type of enlargement of the LVOT was performed in 11 patients; this group forms the focus of this report.

The median age of these 11 patients was 12 months (range 4 days to 17 years). Six of these patients were younger than 1 year; five of these were younger than 6 months, including three neonates. The median weight for the whole group was 7.7 kg (range 3.7 to 64 kg).

Diagnosis and morphology. Diagnosis was established in all patients by cardiac catheterization and echocardiography. The details are summarized in Table I. The aortic valve was bicuspid in nine patients and unicuspid in one patient. One patient who originally had a bicuspid valve had undergone a previous Konno procedure with a 21 mm Björk-Shiley mechanical valve (Shiley, Inc., Irvine, Calif.).

Fig. 1. Angiogram of a 3½-month-old infant who underwent a balloon aortic valvotomy. Significant residual stenosis and progressive aortic insufficiency resulted in severe left ventricular dysfunction. *Top frame* shows the diastolic appearance of the dilated left ventricle with thickened bicuspid aortic valve. *Bottom frame* shows the systolic appearance of the poorly contracting left ventricle.

The aortic anulus was hypoplastic in all patients (median diameter 10 mm, range 4 to 21 mm), and there was diffuse subaortic stenosis in five patients.

Previous interventions. Either previous operation or catheter intervention was performed in all patients (Table I). On average, 1.9 interventions were performed per patient. Of these, 13 interventions were directed at the LVOT. Two infants had severe progressive left ventricular dysfunction and dilatation (Fig. 1) after a suboptimal result of balloon valvotomy, and one other infant had severe hypertrophic cardiomyopathy with long-segment subaortic stenosis (Fig. 2). Two neonates had severe acute aortic valve insufficiency after balloon valvotomy.

Surgical technique. Standard neonatal and pediatric techniques of cardiopulmonary bypass, including bicaval cannulation, moderate hypothermia, and cardioplegia, were used. After initiation of cardiopulmonary bypass, the

pulmonary autograft was harvested along with an extension of infundibular free wall muscle attached to it (Fig. 3, A). After aortic crossclamping and cardioplegia administration, the aorta was transected at the level of the sinotubular junction. The coronary arteries were explanted with large coronary buttons comprising almost the entire wall of the sinus of Valsalva. The remaining aortic root tissue was then excised along with the aortic valve up to the native anulus (Fig. 3, B). The interventricular septum was incised to the left of the right coronary artery in a fashion similar to that used in the Konno procedure (Fig. 3, C). If only anular enlargement was necessary, the septal incision was limited, extending to about 5 to 10 mm into the septum. In patients with long-segment subaortic stenosis, the septal incision was extended beyond the obstruction. Additional ventricular myectomy was performed if deemed necessary ($n = 5$). The pulmonary autograft was seated with the infundibular muscle extension fitting into the Konno incision in the interventricular septum. The autograft was then sutured to the native aortic anulus with a continuous Maxon suture (Davis & Geck Div., American Cyanamid Co., Wayne, N.J.) starting at the posterior midpoint (Fig. 3, D). This is then continued onto the infundibular muscle extension, which is sutured to the interventricular septal incision and reinforced with nonabsorbable, interrupted, pledgeted mattress sutures (in four patients, a Dacron polyester fabric/allograft aortic patch was used to enlarge the subaortic LVOT). The coronary ostia, with their entire sinus of Valsalva buttons, are then anastomosed to the appropriate sinuses of the autograft with a continuous 7-0 Maxon suture. The proximal neo-aorta is sutured to the ascending aorta with a continuous Maxon suture. The right ventricular outflow tract is reconstructed with an allograft valved conduit (Fig. 3, E). The allograft is sutured directly to the right ventricular infundibular muscle without the use of any additional patching material. The patient is separated from bypass in the usual manner, and transesophageal echocardiography is performed. Pulmonary autograft revision was not necessary in any patient. Additional procedures performed and the type and size of allograft used for right ventricular outflow tract reconstruction are listed in Table II. The chest was left open in three neonates and was closed on the second or third postoperative day without any complications.

Follow-up. Follow-up was complete in all patients as of May 1995. The data were obtained by direct physician and patient contact in all cases and included clinical status and progress, medications, and echocardiographic data.

Results

Perioperative course. One patient had cardiac tamponade as a result of bleeding and required reexploration. One patient had complete heart block and received a permanent pacemaker. Delayed closure of the sternum was performed uneventfully in three patients. One patient required reoperation. There were no other significant complications.

Fig. 2. Angiogram of a 4.2-month-old infant who had a suboptimal result from balloon aortic valvotomy in the neonatal period. Systolic frame shows severely hypertrophied left ventricle with long-segment subaortic obstruction.

Early mortality. There were no intraoperative deaths. One patient died 2 weeks after operation of a hypoplastic left ventricle (Fig. 4) with severe endocardial fibroelastosis. At birth, this patient had functional aortic atresia. With resuscitation and inotropic support, minimal forward flow across the aortic valve was detected. The non-apex forming left ventricle was estimated by echocardiography to have a volume of 12 to 16 mL/m² and a mitral valve diameter of 8 mm. There was also marked endocardial fibroelastosis and a left ventricle-left anterior descending coronary artery fistula. Cardiac catheterization revealed a systolic left ventricular pressure of 180 mm Hg. The ascending aorta, aortic arch, and isthmus were mildly hypoplastic, with no discrete obstruction. When the patient was 3 days old, an attempted balloon dilation was unsuccessful. When he was 4 days old, he underwent an uncomplicated Ross-Konno procedure. Left ventricular ejection fraction increased dramatically, from close to zero before operation to 60% after operation without LVOT gradient. Cardiac output appeared to be adequate (good diuresis and mixed venous saturation of 60%) during the first 3 days, while the patient was paralyzed, and delayed sternal closure was

performed without event. With removal of paralysis and attempts to wean the patient from the ventilator, however, it became clear that the cardiac output was fixed as a result of endocardial fibroelastosis and a small left ventricular cavity. After 10 days of medical management with various pharmacologic means, no progress was made. Echocardiography revealed neither residual outflow tract gradient nor autograft valve insufficiency. The patient ultimately died of a ventricular-assist device complication after reoperation to resect the left ventricular endocardial fibroelastosis.

Resource utilization. In 10 of 11 early survivors, the median duration of ventilation was 1.5 days (range 1 to 12 days) and intensive care unit stay had a median duration of 4 days (range 2 to 14 days). Discharge from the hospital occurred a median of 9 days (range 5 to 23 days) after operation.

Postsurgical echocardiographic evaluation. Transesophageal echocardiography in the operating room after operation revealed good ventricular function in eight patients and mild dysfunction in three patients. The neo-aortic valve (autograft) was fully competent in 10 patients and was mildly regurgitant in one patient. A residual gradient of 15 mm Hg

Fig. 3. Technique of Ross-Konno procedure. **A**, The *dashed lines* indicate the lines of incision along which the autograft pulmonary valve is harvested, the ascending aorta (*Ao*) is transected, and coronary buttons are developed. *RPA*, Right pulmonary artery; *LPA*, left pulmonary artery; *MPA*, main pulmonary artery; *APV*, pulmonary autograft; *RC*, right coronary button. **B**, The pulmonary autograft is harvested. Large coronary buttons are developed and diseased aortic valve is excised up to the anulus. The *dashed line* indicates the site of the septal incision for ventriculoplasty. *LC*, Left coronary button; *IMPatch*, infundibular free wall muscle flap used for aortoventriculoplasty; *AAnn*, aortic anulus; *IVS*, interventricular septum; *K*, site of septal incision. **C**, Pulmonary autograft is seated with the suture line starting posteriorly and continuing along the anulus onto the interventricular septum. **D**, Pulmonary autograft in place with reimplanted coronary artery buttons. **E**, allograft conduit (*AC*) sutured directly to the right ventricle without the use of additional patch material.

across the LVOT was present in one patient who also required extensive left ventricular myectomy. The echocardiogram performed at discharge showed mild autograft insufficiency in one patient, no gradients across the LVOT, no residual ventric-

ular septal defects, and improvement in ventricular function in three patients who showed mild dysfunction after bypass. No significant allograft insufficiency was noted in any patient. Of the two patients with parachute mitral valve, mild to moderate mitral

valve insufficiency was present in one and mild stenosis was present in the other.

Follow-up. The follow-up for the 10 patients who survived to leave the hospital ranged from 2 weeks to 16 months, with a median duration of 8.5 months. There have been no late deaths and no reinterventions. Only one patient is receiving afterload-reducing medication. All patients are free of symptoms. Follow-up echocardiography was performed in eight patients at a median of 3.5 months (range 1.5 to 8 months) after operation. The results are summarized in Table III. Dilatation of the autograft (neo-aortic) root was not noted in any of the patients. Left ventricular function was good in all patients. One patient had mild recurrent coarctation of the aorta, with a gradient of 16 mm Hg. The previous findings were unchanged in the two patients with parachute mitral valve.

Discussion

LVOT obstruction complicated by hypoplastic annulus or diffuse subaortic stenosis is difficult to manage in neonates and small infants. Standard approaches are palliative and include balloon or surgical valvotomy, both of which often leave substantial residual stenosis or insufficiency.² Many of these patients eventually require an annular enlargement procedure or aortoventriculoplasty.^{4,5} Postponing these procedures until the patient is much older, with the hope of placing an adult size prosthesis, is a common practice.^{2,3} Substantial left ventricular dysfunction as a result of the long-standing obstruction or insufficiency of the aortic valve, however, is an important concern when this approach is taken. In addition there are other drawbacks to aortoventriculoplasty with a prosthetic valve. Mechanical valves generally warrant the long-term use of anticoagulants. Bioprosthetic valves have a high rate of degeneration and calcification necessitating replacements. Prosthetic valves may also result in thromboembolism and hemolysis and are associated with anticoagulation-related issues. Both types of prosthetic valve also require replacement in young children because of patient-prosthesis mismatch related to patient growth. Efforts to insert larger prostheses in younger children can result in compression of the right coronary artery, sometimes with fatal consequences.

An alternative is early extended aortic root replacement with allograft valved conduits.⁶ Anticoagulation, thromboembolic, and hemolytic complications can thereby be avoided. Rapid degeneration of

Table II. Additional procedures and allograft features

Patient	Procedures	Allograft
1	None	21 mm P
2	Explant B-J valve; closure of residual VSD	22 mm A
3	LV myectomy; plication of ventricular septal aneurysm	24 mm P
4*	ASD closure; PDA ligation; exploration of mitral valve	14 mm P
5	LV myectomy	21 mm A
6†	ASD closure; resection of subaortic fibrous stenosis and LV myectomy	18 mm P
7†	ASD closure	15 mm P
8†	LV myectomy	15 mm P
9*	None‡	13 mm A
10*	Resection of endocardial fibroelastosis; LV myectomy	12 mm A
11	None	18 mm P

P, Pulmonary; B-J, Björk-Shiley; VSD, ventricular septal defect; A, aortic; LV, left ventricular; ASD, atrial septal defect; PDA, patent ductus arteriosus.

*Neonate.

†Infant.

‡Resection of fibrotic left ventricular endocardium and myectomy were performed 2 weeks after the initial Ross-Konno procedure.

allografts is a serious drawback, however, especially in infants and younger children. Therefore, the pulmonary autograft seems to be the ideal valve for aortic valve replacement in the pediatric population.¹¹ Several reports document the growth of these valves in older children, with excellent midterm results.^{8-10, 12-14}

Adaptation of the pulmonary autograft for aortoventriculoplasty incorporates the principles of aortic root replacement¹⁵ and aortoventriculoplasty.^{4,5} This procedure is similar to extended aortic root replacement with allograft.⁶ In seven patients, we have used an infundibular muscle extension to enlarge the LVOT. In patients with a very long septal incision, however, a separate patch is preferred. Right ventricular function was not compromised in any of the patients in whom the contiguous infundibular free wall flap was used. No additional patching material was required when reconstructing the right ventricular outflow tract with allograft valved conduit. The conduit was directly sutured to the right ventricle in all cases.

At our institution, all aortic valve replacements with autograft are performed as a root replacement. In patients requiring annular and subannular enlargement of the LVOT, especially with the operation described in this article, root replacement technique is ideal. In addition, other techniques of autograft implantation are not feasible in neonates

Fig. 4. Angiogram of a 3-day-old patient. Note the severely hypertrophied hypoplastic left ventricle. The calculated (by echo) left ventricular end-diastolic volume was 12 to 16 ml/m².

Table III. Results of follow-up echocardiography (n = 8)

Lesion	Autograft valve (neo-aortic)	RVOT allograft
Valvular insufficiency		
None	7 patients	4 patients
Mild	1 patient	3 patients
Moderate/severe	None	1 patient/none
Valvular stenosis		
None	8 patients	5 patients
Mild*	None	3 patients
Moderate/severe	None	None
Subvalvular stenosis	1 patient†	—

RVOT, Right ventricular outflow tract.

* <20 mm Hg.

† Infant, 16 mm Hg.

and infants with hypoplastic LVOT. With the technique of root replacement, efforts are made to reconstruct the sinotubular junction. Clearly, this would not be a normal sinotubular junction. Nonetheless, medium-term results with root replacement technique in children appear to be excellent.^{9,10} The significance of mild dilatation of the autograft (neo-aortic) anulus is currently unclear.^{9,10} Increasing experience and long-term follow-up are necessary to

clearly identify the advantages of various techniques of autograft implantation, especially in neonates, infants, and young children.

The encouraging short-term and midterm results achieved in our experience suggest that the management approach to small patients (especially neonates and infants) with critical aortic stenosis should be reassessed. In certain cases, balloon or surgical valvotomy achieves a “viable” patient with substantial residual and progressive left ventricular hypertrophy or dilation often accompanied by dysfunction. This point is dramatically made by two of our young infants who underwent initial balloon valvotomy. Both returned 3 to 4 months later with failure to thrive, substantial residual lesions, and progressive left ventricular dysfunction. These patients probably would not have survived long-term. Similarly, the practice of conservatively managing patients with aortic stenosis into the teen years because they are “compensated,” despite residual lesions, should be reassessed if left ventricular function is to be maximally preserved. Finally, the Ross-Konno procedure offers a two-ventricle alternative to the Norwood procedure for a select subgroup of patients with borderline hypoplastic left heart syndrome. The one death in this series was that of one

such patient in whom we attempted a two-ventricle repair. We speculate that resection of the endocardial fibroelastosis at the time of aortoventriculoplasty might have been beneficial. In a subsequent patient with similar morphologic characteristics (Table I, patient 10), a successful two-ventricle repair was achieved with a Ross-Konno procedure and simultaneous extensive endocardial resection. Successful two-ventricle repairs in other selected patients with borderline hypoplastic left heart syndrome will certainly be possible with this approach.

One drawback of this approach is that reoperations are necessary to replace the small right ventricular allograft conduits that are used in neonates, infants, and younger children. Replacement of right ventricular outflow tract conduits can be achieved with very low mortality and morbidity,^{16, 17} however, and we believe that this disadvantage is outweighed by the early normalization of left ventricular dynamics.

In summary, the pulmonary autograft can be modified for use in aortoventriculoplasty procedures for the management of complex LVOT obstruction, even in neonates and infants, with excellent short-term and midterm results. A number of practical and theoretic advantages have been discussed; however, long-term follow-up is necessary to completely define the timing of and indications for this procedure.

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Discussion

Dr. Jan M. Quaegebeur (*New York, N.Y.*). I find it ironic to have to comment because it is like commenting on our own experience. We were given the opportunity last year to present to the Association our experience with the Ross operation in children. We described exactly what you have described today, that the Konno modification of the Ross procedure is a useful method in children with LVOT obstruction.

I would like to comment on the infant operations in your experience. We have performed the Ross operation on seven infants. Most of them had critical aortic stenosis at birth and one child had interrupted aortic arch. As a result of palliative and interventional cardiologic procedures, aortic incompetence was present immediately before the Ross operation.

We have performed the operation exactly as you have described. One question that I have for you is that many patients have complicated additional risk factors, such as the fibroelastosis seen in one of your patients. Ventilatory dependency, inotropic support, pulmonary hypertension, and bronchopulmonary dysplasia were frequently present

in our patients. I would like you to comment on the presence of those risk factors in your experience.

One problem that we have seen with the Ross-Konno operation, usually in small infants, is that there is a discrepancy between the size of the pulmonary anulus and the size of the aortic anulus; in many patients the pulmonary anulus is twice the size of the aortic anulus. This has a technical consequence in reimplantation of the right coronary artery, which comes in an unnatural position. I would like you to comment on how you solved the problem of reimplantation of the right coronary artery.

Dr. Reddy. We are aware of your excellent work with the Ross procedures in children. In response to your question regarding the risk factors in neonates and infants, two neonates and one infant were supported with mechanical ventilation and inotropic and afterload-reducing agents. Severe acute and progressive left ventricular failure developed in all three. Hypertrophic obstructive cardiomyopathy developed in one infant. Two neonates in addition had severe left ventricular endocardial fibrosis. Many of these patients with complex LVOT obstruction have associated problems such as those you have pointed out. If we could accurately predict which valves are likely to have a poor result from balloon or surgical valvotomy, these patients could undergo a primary Ross-Konno procedure, minimizing the number of risk factors seen in this group of patients.

Regarding your second question, I agree that there is invariably a discrepancy between the aortic and the pulmonary anulus, and this is often substantial. So far we have not had a problem with reimplantation of the right coronary artery. I talked specifically about this issue with Dr. Hanley, who as you know has performed most of these procedures. We generally try to harvest the infundibular muscle extension in such a way that we do not have to rotate the autograft too much for proper alignment with the Konno incision in the ventricular septum. We rotate the autograft root slightly in the clockwise direction so that the right posterior sinus of the pulmonary valve becomes the noncoronary sinus, the anterior sinus of the pulmonary valve becomes the right coronary sinus, and the left posterior pulmonary sinus becomes the left coronary sinus. I agree, however, that it may sometimes be technically difficult.

Dr. Willem Daenen (Leuven, Belgium). In Leuven, we started with this new operation in June 1991. Since then, 14 patients have undergone this procedure. This experience was presented at the third Ross Colloquium, preceding this meeting.

Nine patients underwent this operation for very severe tunnel subaortic stenosis. All these operations were secondary operations; five patients had undergone two previous interventions. The preoperative mean gradient was 80 mm Hg. It was possible to increase the minimal diameter of the LVOT from 50% to 103% of normal.

We also used the concept of this operation in five patients with an outgrown small aortic valvular prosthesis. It was possible to increase the valve size by two or three sizes.

I have two concerns. First, we always used a Dacron polyester fabric or a xenopericardial patch because we were concerned about the viability of the right ventricular

muscle patch. Second, when you use a large infundibular patch, you end up with a large gap in the right ventricular outflow tract, which is already enlarged at the septal site. Did you have problems closing that gap?

Dr. Reddy. I had the opportunity to listen to your talk in the Ross Colloquium, and I think your concerns are valid. But if the right ventricular infundibular muscle wall is going to be an issue, I think it will probably dilate or blow up in the first few days after operation. By intraoperative, early postoperative, and short-term follow-up echocardiography, the infundibular septal muscle extension seems to function very well in the LVOT. If there is reason to be concerned on long-term follow-up, we will definitely report it.

Regarding your question about a large defect in the right ventricular free wall, if annular enlargement is required you do not need to take a large piece of the right ventricular free wall. Only for cases with long-segment tunnel subaortic stenosis do you need to take a slightly larger piece of infundibular free wall muscle. There are certainly cases where a separate patch is preferable. As you can see from the figures, however, we directly sew the homograft to the right ventricular defect without the use of additional patching material. So far we have not had any problems related to right ventricular dysfunction in the early postoperative period. These patients were extubated at a median of 1.5 days and were discharged from the hospital at a median of 9 days after operation.

Dr. Giovanni Stellin (Padova, Italy). According to the drawings you are showed, in harvesting your pulmonary autograft you obtain a flap of tissue from the muscle of the right ventricular outflow tract to enlarge your LVOT. I wonder whether instead of weakening your right ventricular outflow tract you could not better apply a little patch to your autograft.

Dr. Reddy. We have used a homograft patch in two patients, but it is technically much easier to take a small piece of infundibular muscle in continuity with the pulmonary autograft. This infundibular free wall muscle can easily be appropriately trimmed to patch the Konno incision in many cases. This is a technical advantage of taking a contiguous piece of infundibular free wall, which provides a natural fit appropriate to the autograft valve size. So far we have not encountered any right ventricular problems; however, we will continue to follow these patients closely.

Dr. Serafin Y. DeLeon (Maywood, Ill.). I just have a question. I noticed in one of your slides and also Dr. Daenen's that you perform the Ross-Konno procedure for a simple LVOT obstruction when you could do a modified Konno procedure preserving the aortic valve. I have done close to 17 modified Konno procedures with no deaths. Provided the aortic valve is all right, you can enlarge the LVOT. I have added a modification to the Ross procedure that I think will make the procedure more attractive. In some patients, the aortic valve looks good, and you hate to just discard it. I have harvested the aortic valve in five patients, one with congenital aortic insufficiency and four with rheumatic aortic insufficiency. The aortic valve can be harvested intact because the commissures are higher and can then be implanted as a pulmonary valve. All of our patients did very well. The pulmonary valve, although it

may be incompetent on the aortic side, works well on the pulmonary side because of low diastolic pressure. In the long run, I believe that this could make the Ross procedure a potentially curative operation in some patients with aortic valve disease. The leaflet itself gets its nutrients directly from the blood and just like the pulmonary autograft, lasting for almost 25 years now on the left side and remaining viable with minimal degeneration.

Dr. Reddy. I think we are dealing with a different population. All of our patients had severely dysplastic valves, and many of them had undergone previous procedures, including a Konno procedure with a Björk-Shiley valve in one patient. The neonates and infants with progressive left ventricular dysfunction had aortic valves with torn leaflets and severe

dysplasia, and typically had an aortic anulus in the 4 to 7 mm range. I do not think that these are suited for implantation in the right ventricular outflow tract. I agree, however, that there will be selected cases in which it is possible to salvage the diseased aortic valves and implant them in the right ventricular outflow tract.

Regarding the valve-sparing modification of the Konno procedure, I had the opportunity to see some of these procedures when Dr. Jonas was performing them at the children's hospital. This procedure is appropriate for a completely different group of patients than we have shown here; however, the valve-sparing Konno modification definitely has a place in the management of LVOT obstruction.

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