Long-Term Results After Reconstruction of the Left Ventricular Outflow Tract by Aortoventriculoplasty

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Background. **Aortoventriculoplasty is an established method of reconstruction of complex left ventricular outflow tract (LVOT) obstruction by insertion of a mechanical valve prosthesis after patch enlargement of the LVOT. Little data exist with respect to long-term outcome.**

Methods. **Between March 1991 and June 2001, 24 patients with a median age of 10.7 (range, 2.1 to 66) years underwent aortoventriculoplasty, which was performed as a primary procedure in 4 and as a secondary intervention in 20 patients. On follow-up, all patients were restudied with an actual prospective evaluation. Data were statistically analyzed using a paired *t* test.**

Results. **There was one early death from low cardiac output. Four patients had to be reoperated on for bleeding. All 23 postoperative survivors were followed up for 63 (range, 12 to 123) months. Aortic anulus size of 14 (7 to 19) mm could be significantly enlarged to a size of 24 (19 to 27) mm for insertion of a mechanical valve prosthesis ($p < 0.001$). Blood flow velocity across the LVOT significantly decreased to 1.8 (1.3 to 2.9) m/s (preoperative, 4.1 [2.7 to 5.8] m/s) ($p < 0.001$). There were no late deaths. One patient underwent late repair of a paraprosthetic leak. On follow-up, there was no hemorrhage related to anticoagulation observed, but there was one minor thromboembolic complication. Relief of LVOT obstruction and good function of the valve prostheses could be demonstrated in all patients.**

Conclusions. **Aortoventriculoplasty is an easily applicable, low-risk procedure for the effective relief of complex LVOT obstruction, and provides excellent long-term results.**

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Complex left ventricular outflow tract obstruction (LVOTO) consists of a combination of dysplastic aortic valve with hypoplastic aortic anulus and excessive "tunnel-like" muscular stenosis of the subvalvular region, mostly in combination with ventricular septum hypertrophy [1]. Initially, therapy focuses on the main level of obstruction using balloon valvoplasty, open commissurotomy, subvalvular muscle resection, or a combination of these methods. Nevertheless, there is a high incidence of recurrent obstruction, sometimes associated with aortic insufficiency caused by prior intervention, necessitating reintervention in the form of a more definitive surgical repair, such as an aortic valve replacement (AVR), in combination with relief of subvalvular stenosis [2–5].

Aortoventriculoplasty (AVP), known as the Konno procedure [6], is an established method of relief of complex LVOTO by insertion of an adequately sized mechanical valve prosthesis after patch enlargement of the aortic anulus and septum. Little data exist with respect to long-term outcome [7, 8]. We therefore analyzed our experience with this technique in a prospective follow-up study.

Patients and Methods

Between March 1991 and June 2000, 24 patients (17 male and 7 female) underwent AVP for complex LVOTO. Median age was 10.7 (range, 2.1 to 66) years (Fig 1). On operation, the median weight of the patients was 37.5 (range, 10.1 to 70.4) kg. Indication for AVP was hypoplastic aortic anulus with important stenosis and insufficiency, in combination with an excessive "tunnel-like" muscular obstruction of the subvalvular region. Two patients with AVR presented an outgrowth of their valve prosthesis. AVP was performed as a primary procedure in 4 patients. Twenty patients had one or more prior interventions on the aortic valve, with open aortic commissurotomy performed in all but 3 of these patients (Table 1). Concomitant surgical procedures included supracoronary ascending aorta replacement with a Dacron graft in 1 patient, aortic arch enlargement with a Dacron patch in 1 patient, and replacement of aortic valve and ascending aorta by means of a valved conduit in 1 patient. Replacement of aortic valve, ascending aorta, and aortic arch by means of a valved conduit in combination with coronary artery bypass grafting was per-

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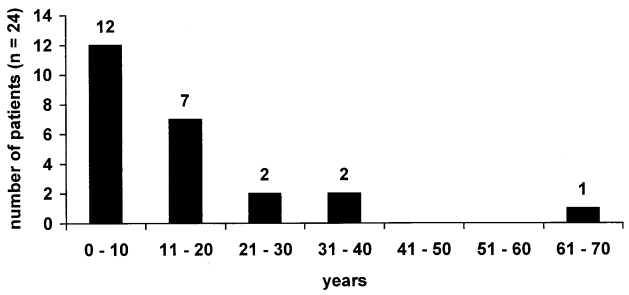

Fig 1. Distribution of age (years)

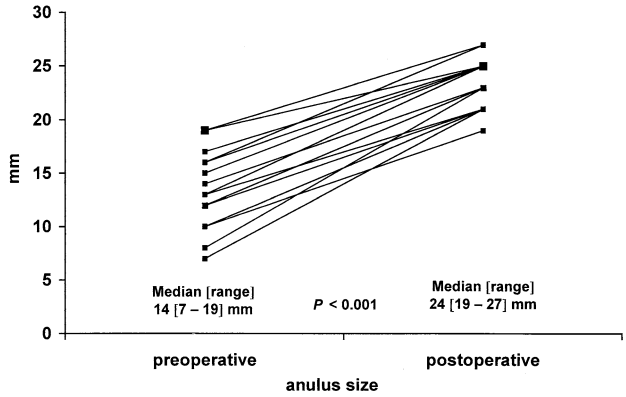

Fig 2. The change in aortic anulus size (inner diameter) between preoperative and postoperative status.

formed in 1 patient aged 66 years. Preoperative echocardiography revealed median blood flow velocity across LVOT of 4.8 (range, 2.7 to 5.8) m/s. Intraoperative measurements showed a median aortic anulus inner diameter of 14 (range, 7 to 19) mm (Fig 2).

AVP was performed through median sternotomy with standard cardiopulmonary bypass using bicaval cannulation, moderate hypothermia (24°C to 26°C), and antegrade extracellular cardioplegia. As described by Konno and associates [6], a vertical aortotomy was made and extended into the right ventricular outflow tract with a transverse incision respecting the pulmonary valve. The aortic anulus was incised on the left side of the right coronary artery ostium. This incision was then carried downward into the ventricular septum beyond any subvalvular stenosis. After excision of the dysplastic aortic valve, the enlargement of the ventricular septum was done with a tailored Dacron patch, prepared from a longitudinally incised vascular graft. This patch was sutured up to the level of the aortic anulus, and appropriate valve sizers were used to measure the enlarged anulus. A mechanical valve prosthesis (St. Jude Medical Inc, St. Paul, MN) was then inserted in orthotopic position, using interrupted pledged-enforced horizontal mattress sutures. After valve insertion, the Dacron patch was used for ascending aorta enlargement. Finally, a Gore-Tex patch was used for right ventricular outflow tract (RVOT) reconstruction.

Twenty-two of 23 patients were anticoagulated with phenprocoumon. One patient suffered from factor V and IX deficiency and did not require continuous oral anticoagulation. Parents and adult patients were trained in self-coagulation checking, keeping the international normalized ratio (INR) between 2.5 and 3.5.

All patients were regularly investigated by clinical examination and transthoracic echocardiography during postoperative course, with an actual prospective evaluation in September 2001. Patient data were analyzed retrospectively from hospital charts, including preoperative diagnosis, investigations, and operative reports, postoperative course, and follow-up. Data were statistically analyzed using a paired t test. A $p < 0.05$ was considered statistically significant. Data are presented as medians and ranges.

Results

There was one early postoperative death at the first postoperative day due to low cardiac output. This 16.9-year-old patient had four previous interventions: pulmonary artery banding for important ventricular septum defect (VSD) at the age of 4 months, debanding for spontaneous closure of the VSD in combination with pericard patch reconstruction of RVOT at the age of 3.1 years, open aortic valvotomy for valvular stenosis at the age of 6.3 years, and AVR with a Björk-Shiley prosthesis (19 mm) associated with posterior aortic root enlargement at the age of 10.2 years. The indication for AVP was LVOTO with dysfunction of the valve prosthesis due to

Table 1. Interventions Before Aortoventriculoplasty (n = 20/24)

First Intervention	Second Intervention	Third Intervention	Number of Patients
Open aortic commissurotomy			10
Myectomy			2
Open aortic commissurotomy	Recommissurotomy		2
Open aortic commissurotomy	Aortic valve reconstruction		2
Balloon valvoplasty	Open aortic commissurotomy		1
AVR	Aortic valve re-replacement		1
Open aortic commissurotomy	AVR + myectomy		1
Open aortic commissurotomy	Aortic valve reconstruction	AVR	1

AVR = aortic valve replacement.

misalignment. Concomitant procedures in this patient included replacement of ascending aorta and main pulmonary artery with a Dacron graft. Four patients had to be reoperated for bleeding, 1 of them with factor IX deficiency. Transient complete heart block occurred in 3 patients, necessitating transient cardiac pacing for 1 to 3 days in the intensive care unit.

The 23 survivors were followed up on a regular basis, and complete follow-up data were available on all patients with a median follow-up time of 63 (range, 12 to 123) months. There were no late deaths. There was no permanent complete heart block observed. There was one late repair of a paraprosthetic leak followed by tube resection of the ascending aorta because of supravalvular stenosis after cannulation in the same patient with the preoperative diagnosis of a hypoplastic ascending aorta. Anticoagulation-related hemorrhage was not observed. One minor thromboembolic complication in the form of sudden transitory partial blindness of the left eye occurred in a patient with a low INR at 1.7. On follow-up echocardiography, relief of LVOTO and good function of the valve prostheses could be demonstrated in all patients, and there was no evidence of paravalvular leak. Echocardiography (M-mode) revealed a significant reduction of posterior wall thickness from 10 (range, 5 to 16) mm preoperative to 8 (4 to 12) mm postoperative ($p = 0.032$). Actual postoperative Doppler examination showed significant decreased median blood flow velocity across LVOT of 1.8 (1.3 to 2.9) m/s compared with preoperative values (4.1 [2.7 to 5.8] m/s) ($p < 0.001$). There was one small residual VSD. Left ventricular systolic function, as determined by the ejection fraction (EF), was good (EF, 56% [49% to 66%]). All children and adults have resumed normal physical activity.

Comment

AVP, also known as the Konno procedure since initial descriptions of the technique in 1975 [6], has proven to be safe and effective in relieving complex LVOTO in a number of studies [7–14]. Consistent with previous studies, we have seen a very low mortality and morbidity rate after AVP, even when AVP was performed as reintervention [14], as was the case in 20 of our 24 patients. After relief of LVOTO by AVP, our surviving patients have resumed normal physical activity. Echocardiographic findings showed a significant decrease of blood flow velocity across the LVOT, and there was no evidence of recurrent obstruction.

In our study, there was only one reoperation related to the Konno procedure, due to a paraprosthetic leak. Freedom of reoperation is one of the most important advantages of AVP compared with other procedures, such as balloon valvoplasty or open aortic commissurotomy with or without subvalvular muscle resection. These therapeutic options are of palliative character, because there is an important number of recurrent stenoses of the LVOT, sometimes associated with important aortic insufficiency caused by previous intervention [2–5], necessitating a more definitive therapy by AVR in combination with effective enlargement of the LVOT.

In the presence of complex LVOTO, AVR alone will not sufficiently resolve the underlying problem, even when AVR is performed in combination with posterior aortic root enlargement, as described by Manouguian and Seybold-Epting [15]. Subaortic stenosis with long-segmented, "tunnel-like" obstruction requires an adequate enlargement of the subvalvular region, as provided by the Konno procedure and the Ross-Konno procedure [16]. The Konno procedure can be used to treat all levels of aortic stenosis. The small aortic anulus in congenital aortic stenosis, diffuse subaortic stenosis, and small ascending aorta may be corrected with this procedure. The technique provides enlargement of both the subaortic outflow tract and the aortic anulus to allow placement of an adequately sized valve prosthesis. In our study, aortic anulus size could almost be doubled by the Konno procedure. We found a significant increase of median aortic anulus inner diameter from preoperative 14 mm up to 24 mm postoperative. These findings are similar to those reported in other studies [6–14]. Even in infants and small children, AVR remains a good therapeutic option for definitive relief of LVOTO, providing the placement of an adequately sized mechanical valve prosthesis [17, 18]. In our report, the smallest aortic anulus size of 7 mm in a 2.3-year-old infant, weighing 10.1 kg, had been enlarged to 21 mm, which means a tripled inner diameter. The use of a large-sized valve prosthesis obviates the need for reoperation, an important benefit resulting in an enhanced quality of life. In our study group, none of the patients required reoperation for prosthetic valve dysfunction or poor hemodynamic performance of the valve prosthesis.

The most appropriate type of aortic valve prosthesis to be used in pediatric patients is still under discussion. Rapid degeneration and calcification is often seen in aortic xenografts used in young patients, leading to early valve dysfunction [19, 20]. Mechanical valves are known for excellent long-term function with low morbidity and mortality [19, 21], but warrant lifetime anticoagulation. In our report, we have seen no bleeding complications due to anticoagulation. There was only one minor thromboembolic event in a patient with a low INR at 1.7. All patients, or their parents, are trained in our institution to perform self-managed anticoagulation with phenprocoumon, with an INR aimed at 2.5 to 3.5.

The present study has several limitations: larger cohorts are needed, and assessment of exercise capacity would have been helpful to objectify postoperative functional status of our patients. Only M-mode measurement of left ventricular posterior wall thickness was used to assess changes in left ventricular hypertrophy after surgery. We did not use left ventricular mass index, the significance of which is discussed controversially in the literature [22, 23]. Cardiovascular magnetic resonance tomography, the gold standard for assessment of left ventricular mass, was not used in this series [24].

In summary, we conclude that AVP is an effective procedure for relief of complex left ventricular outflow

obstruction in infants and children, and also in adults. Large-sized valve prostheses may be inserted, representing a definitive therapy of aortic stenosis with no need for further reoperation. It can be performed at low risk with excellent functional and clinical long-term results.

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