Modified Ross procedure using a conduit with a synthetic valve

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Abstract

Objective: In the Ross procedure, a homograft conduit is commonly used in place of an autotransplanted pulmonary valve. Homograft availability may be a problem and has resulted in a search for alternatives. We performed a modified Ross procedure for right ventricular outflow tract reconstruction with a synthetic valved conduit as an alternative to homograft. Our early results of valvular and right ventricular function were evaluated in patients who used a conduit with a synthetic valve.

Methods: Subjects consisted of 11 patients, who ranged in age from 5 to 22 years (12.0 ± 4.9), and whose body weight ranged from 15.1 to 52.5 (34.3 ± 14.4) kg. Indications for surgery were aortic stenosis (n = 3), aortic stenosis and regurgitation (n = 4), and aortic regurgitation (n = 4). Right ventricular outflow tract reconstruction was performed using a hand-fashioned valved conduit prepared by sewing a 0.1 mm thick polytetrafluoroethylene sheet onto the luminal cavity of the 20–28 mm conduit. A conduit made with polytetrafluoroethylene was used in 8 patients, and a Dacron graft was used in 3 patients.

Results: There was no in-hospital or late mortality and angiocardiography at discharge revealed that all artificial valves remained active. The mean right atrial pressure and right ventricular end-diastolic pressure were not statistically different from preoperative values. The latest echocardiography (mean interval, 12.6 months) revealed that a mean pressure gradient across the synthetic valve was 11.4 ± 11.1 mmHg and none of the patients had moderate or severe regurgitation.

Conclusions: We demonstrated that a modified Ross procedure for right ventricular outflow tract reconstruction using a conduit with an appropriate synthetic valve is particularly effective in older children.

Keywords: Valvular function; Ross procedure; Right ventricular outflow tract reconstruction; Synthetic valved conduit; Polytetrafluoroethylene; Reoperation

1. Introduction

In the Ross procedure [1] the patient’s diseased aortic valve is replaced with his or her own pulmonary valve, which in turn requires right ventricular outflow tract reconstruction. The Ross procedure is characterized by excellent hemodynamics, potential growth of the autograft, and avoidance of antithrombotic therapy. Although the ideal conduit for right ventricular outflow tract reconstruction (RVOTR) is currently a pulmonary valve allograft [2], it is unavailable in many areas of the world. Constrains of availability of homografts have forced surgeons in many areas to search for alternatives to homografts [3]. Although many modification of Ross procedure has been reported, the best technique for an alternative to homografts is controversial.

In our hospital, we performed the Ross procedure using an expanded polytetrafluoroethylene (ePTFE) valve-equipped conduit. This modified procedure was indicated for patients with an aortic lesion in whom we were able to use conduits with a large diameter, which are less likely to require conduit replacement in the future. Our hypothesis is that an ePTFE valve-equipped conduit will lead to increased durability. The purpose of this study is to report our early operative results, postoperative valvular function, and right ventricular function using ePTFE valve-equipped conduits for RVOTR in the Ross procedure.

2. Patients and methods

2.1. Patients’ profile

In this study, between October 1998 and July 2000, we performed 690 operations for congenital heart disease in
the Department of Cardiovascular Surgery, Fukuoka Children’s Hospital. Eleven patients underwent a modified Ross procedure with an ePTFE valve-equipped conduit. In the same period, we limited the indication for the Ross procedure to older children who weighed over 15 kg, as they are less likely to require conduit replacement when they become an adult. This is an important consideration because pulmonary valve allografts are difficult to attain in Japan. The patients ranged in age from 5 to 22 years (12.0 ± 4.9) and ranged in weight from 15.1 to 52.5 kg (34.3 ± 14.4). Five patients had undergone seven previous operations: two one-stage repairs for an interrupted aortic arch and ventricular septal defect, two repairs for coarctation of the aorta (one end-to-end anastomosis, and one subclavian flap aortoplasty), and one each of the following: a release of left ventricular outflow tract obstruction, bypass grafting from the left subclavian artery to the descending aorta for recoarctation of the aorta, and ligation of persistent ductus arteriosus. Aortic stenosis (AS) was present in 3 patients, aortic stenosis and regurgitation (ASR) was present in 4 patients and aortic regurgitation (AR) was present in 4 patients. Informed consent by the patients was obtained preoperatively for the use of ePTFE valve-equipped conduits.

A bicuspid aortic valve was present in 7 patients; a tricuspid-valve was present in 3 patients; and a quadricuspid-valve was present in 1 patient (Table 1). Preoperative pressures are shown in Table 2. Subaortic stenosis was present in 2 patients. The preoperative aortic annulus diameter measured 10–24 mm (77.2–169.1% of normal), and the pulmonary annulus diameter was 12–27 mm (89.6–156.8% of normal).

2.2. Preparation of ePTFE valve-equipped conduit

First, a 0.1 mm thick ePTFE sheet was cut according to the circumference of the conduit used in the procedure with a margin of 1 or 2 mm to be sutured. The length of the ePTFE valve from the proximal to distal edges was the circumference/4. The width of one cusp was the circumference/3 to make the tricuspid valve. To make the ePTFE valve, the sheet was then folded and divided so that the inside part could be used as a cusp and the outside part could be fixed to the conduit. After making two central commissures of a folded ePTFE sheet using a 6-0 polypropylene running suture, the sheet was folded and a last commissure was made to fix the free edges using a 6-0 polypropylene running suture. At this point the ePTFE valve was completed. The proximal and distal edges of the ePTFE valve were sutured and then fixed with a 6-0 polypropylene running suture to the inner section of the conduit turned inside out. Fig. 1a shows a 22 mm hand-fashioned valved conduit. Fig. 1b shows a schema of the hand-fashioned valved conduit. The conduits were created with 4 different diameters; 20, 22, 24, and 28 mm, used in 2, 3, 5, and 1 patient(s), respectively. Conduits made of ePTFE were used in 8 patients and Dacron conduits were used in 3 patients.

2.3. Surgical procedures

The aortic root enlargement was performed in 5 patients (Konno + Nicks: 3, Konno: 1, Nicks: 1). The exposed myocardium of the ventricular septum where the pulmonary autograft was harvested and the conduit was applied was covered with autologous fresh pericardium to promote hemostasis and to secure the anastomosis [4]. RVOTR was performed using a hand-fashioned valved conduit prepared by sewing a 0.1 mm ePTFE sheet onto the inner section of the conduit turned inside out. Fig. 1a shows a 22 mm hand-fashioned valved conduit. Fig. 1b shows a schema of the hand-fashioned valved conduit. The conduits were created with 4 different diameters; 20, 22, 24, and 28 mm, used in 2, 3, 5, and 1 patient(s), respectively. Conduits made of ePTFE were used in 8 patients and Dacron conduits were used in 3 patients.

2.4. Statistical analysis

All data are expressed as mean ± standard deviation. Unrelated two group comparisons were done with an unpaired, 2-tailed t-test for means of normally distributed variables, and with a Wilcoxon rank sum tests for skewed
data. A $P$-value of less than 0.05 was considered significant. Statistical analysis was performed with Statview version 5.0J software.

3. Results

3.1. Mortality and morbidity

There was no in-hospital or late mortality and no reoperation was reported.

3.2. Postoperative course

After intensive care unit admission, dopamine was administered at a dose of $3.6\pm1.0$ (2–5) $\mu$g/kg per min and discontinued after $1.0\pm1.2$ (0–3) days. Intubation time was $9.9\pm5.4$ (2–14) h and the chest drainage was retained for $3.4\pm1.3$ (2–6) days. Patients stayed in the ICU for 1 day.

3.3. Valvular and right ventricular function

Angiocardiography that was performed at a postoperative time of 0.7 months revealed that the ePTFE valve was active in all patients (Fig. 2). None of the patients had moderate or severe pulmonary regurgitation (PR), and mild PR was found in 4 patients. Postoperative right ventricular systolic pressure was $34.4\pm6.3$ (23–43) mmHg, and pulmonary arterial systolic pressure was $25.2\pm7.9$ (12–37) mmHg. The pressure gradient across the ePTFE valve is shown in Fig. 3. The RAP and the RVEDP were not

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**Table 3**

<table>
<thead>
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<th>Surgical procedures</th>
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<tr>
<td>Conduit (size/mater)</td>
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<tr>
<td>20 mm/Dacron</td>
<td>2</td>
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<tr>
<td>22 mm/ePTFE</td>
<td>3</td>
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<tr>
<td>24 mm/ePTFE</td>
<td>5</td>
</tr>
<tr>
<td>28 mm/Dacron</td>
<td>1</td>
</tr>
<tr>
<td>Konno + Nick</td>
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<tr>
<td>Additional procedure</td>
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<td>Konno</td>
<td>1</td>
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<tr>
<td>Nick</td>
<td>1</td>
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<tr>
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<td>bypass time (min)</td>
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<td>Aortic clamp time</td>
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<td>(min)</td>
<td>153±29</td>
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Fig. 1. (a) Operative findings of the hand-fashioned valved conduit. ePTFE, expanded polytetrafluoroethylene. (b) schema of the hand-fashioned valved conduit. ePTFE, expanded polytetrafluoroethylene.

Fig. 2. Postoperative RVG. RVG, right ventricle graphy; ePTFE, expanded polytetrafluoroethylene.
The pressure gradient across the pulmonary autograft was 3.7 ± 4.8 (0–14) mmHg. Aortic regurgitation was identified in only 1 patient, and was mild. Echocardiography performed at a postoperative time of 12.6 ± 4.8 (6–21) months demonstrated that only 3 patients had mild PR (Fig. 5). The RV-PA pressure gradient is shown in Fig. 5. Postoperatively, blood clot formation was not found in the synthetic valve of these patients and there was no evidence of narrowing of the synthetic valved conduit by either a decreased effective orifice area or a decreased diameter.

4. Discussion

The Ross procedure [1] represents the surgical treatment of aortic stenosis or regurgitation by replacement of the diseased aortic valve with the patient’s own pulmonary valve. The replaced pulmonary autograft can grow with the patient and is advantageous over conventional surgical techniques, as anticoagulation is not required and the homograft maintains resistance to infection. However, the procedure requires RVOTR after harvest of the pulmonary autograft.

Homografts are commonly used to reconstruct right ventricular outflow tracts. It has previously been reported that homografts from PA provide better results than from aorta [5,6]. However, it has been demonstrated that homografts used in newborns or infants more frequently require further pulmonary valve replacement surgery later in life [7,8]. In addition, adult patients may develop an increased pressure gradient across homograft valves resulting from annular-valve narrowing [9]. Using homografts in infants may cause long-term calcification or homograft failure, which cannot be ignored.

Our department has developed a protocol for treatment of older children with aortic diseases. Our indication for the Ross procedure using synthetic grafts with a large diameters are patients who weigh over 15 kg, as they are less likely to required conduit replacement in the future. This is due to the difficulty of attaining pulmonary valve allografts in Japan. Other methods of RVOTR have been reported, including direct reconstruction with the patients’ tissues (anastomosis of the right ventricle with the pulmonary artery), bovine cervical vein grafts [3,10,11], swine pulmonary valve grafts [12], stentless xenografts [13] or grafts employing the patient’s own tissues [14]. Each of the methods has advantages and disadvantages. Acceptable long-term durability of the ePTFE monocusp was reported in tetralogy of Fallot [15] and excellent results were obtained in RV function due to reduced PR by using a synthetic conduit, in which an ePTFE valve was sewn. Our procedure conceptually has the following advantages: (1) pulmonary valve function can be maintained better in the early postoperative period, (2) restenosis and calcification of the synthetic valve does not progress since the valve is prepared with a thin 0.1 mm, less bio-reactive ePTFE sheet, (3) large conduit size prevents restenosis of conduits in the future, and (4) size discrepancy of the homograft is not present. On the other hand, disadvantages of this method are unavoidable implantation of the artificial material despite less bio-reactivity without self-growth and it is not applicable for patients that are light in weight.

The limitations of this study are the short follow-up time, the low number of operated patients, and it was not a randomized, controlled trial. Although we cannot conclude that this new modification of the Ross procedure is superior to other techniques, our procedure is effective in maintaining early postoperative pulmonary valve function in older children in whom large-diameter conduits are used. More cases need to be studied to evaluate long-term results.

In conclusion, we have obtained excellent early results through the development and application of a modified Ross procedure for RVOTR using a conduit equipped with an ePTFE valve. This procedure is particularly effective in older children requiring the Ross procedure.
References
