Original Article

Medium-term outcomes of bovine jugular valved conduits for right ventricular outflow tract reconstruction in children: a retrospective cohort study from China

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Background: Bovine jugular valved conduit (BJVC) has been reported as an optional material for right ventricular outflow tract (RVOT) reconstruction in patients with complex congenital heart disease (CHD). It showed comparable or even better performance than homograft. However, the durability of BJVC is still very poor in infants and children. Herein, we retrospectively analyzed and evaluated the mid-term results of RVOT reconstruction by using bovine jugular vein valved conduits (Balance BJVCs) in CHD patients, with a special focus on the functional status of the conduits.

Methods: Pediatric patients undergoing RVOT reconstruction using Balance BJVC in Guangzhou Women and Children's Medical Center from January 2018 to December 2020 were enrolled in this study. The demographic information, cardiac anatomical abnormalities, preoperative hemodynamic characteristics, surgical details, postoperative outcomes, and follow-up data of the patients were reviewed retrospectively.

Results: Ninety-four patients were enrolled in this study. The median age at implantation was 22 months (range, 2–168 months), the median weight was 10.8 kg (range, 3.8–40.0 kg); 34 children (36.2%) were younger than 1 year. The most common disease in these children was pulmonary atresia with ventricular septal defect (PA/VSD) (66/94, 70.2%). The patients were followed up for a median of 43.5 months (range, 6–60 months). Late mortality occurred in 4 (4.3%). Cumulatively, conduit dysfunction at different levels occurred in 31 (33%), conduit failure in 9 (9.6%), 6 patients underwent reoperation for conduit replacement, 5 (5.3%) developed infective endocarditis (IE) within 24 months (range, 12–36 months) after the surgery. Five-year survival rate is 95.7%. The free of conduit dysfunction rates at 1, 3, and 5 years was 91.4%, 68.5%, and 50.4%, respectively. In addition, the rates of patients who were free of conduit failure at 1, 3, and 5 years were 100%, 88.9%, and 88.9%, respectively.

Conclusions: Despite the high risk of BJVC dysfunction, approximately 90% of children are free from conduit failure at 5 years after conduit implantation through aggressive transcatheter intervention without increasing the incidence of IE. Thus, BJVC remains a useful alternative material for RVOT reconstruction in patients with complex CHD.

Keywords: Right ventricular outflow tract reconstruction; conduit dysfunction; conduit failure; infective endocarditis

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Introduction

Right ventricular outflow tract (RVOT) reconstruction remains a challenging technique in patients with complex congenital heart disease (CHD). The currently available materials for RVOT reconstruction have many shortcomings. For example, the pericardial tissue has no valve, which inevitably results in pulmonary regurgitation, whereas a single-valved patch is prone to failure. Patients with complex CHD typically have pulmonary hypertension and increased pulmonary vascular resistance; in these patients, the application of valved conduits is required for RVOT reconstruction. Cryopreserved pulmonary homografts were the earliest reconstruction material used in clinical settings. However, its clinical application has been plagued by restricted access and premature calcification, especially in neonates and small infants (1,2). The Contegra bovine jugular valved conduit (BJVC) (Medtronic, Minneapolis, MN, USA) was first used clinically in 1999, with satisfactory early- to mid-term results being reported; however, the risk of late conduit dysfunction and failure remained high (3-7). Patel *et al.* reported the freedom from BJVC explantation was 53% at 5 years and 15% at 10 years for infants (8). The mean time to conduit failure was 5.2 years in the infants subgroup and 5.8 years in the smallsized conduits (12–14 mm) subgroup (8). The highest rate of 10-year freedom from BJVC replacement was approximately 25% in young children (9,10). Although the results from different studies were not consistent, many studies revealed that BJVC has better performance than homograft in infants and young children (11,12). The latest multicenter study also demonstrated that the BJVC performed much better than homograft in infants (13). However, the BJVC has greater incidence of late endocarditis after being implanted, with a rate of 4.7% to 17.6% reported in previous studies (8,14-17). In recent years, handmade trileaflet valved ePTFE conduits for RVOT reconstruction have achieved satisfactory mid- and long-term results (18,19).

Given that the Contegra BJVC conduit is not available in China, Balance BJVC (Balance Medical Technology Co Ltd., Beijing, China) was approved by the National Medical Products Administration (NMPA) of China in 2016 and has been clinically applied. Our center has been using Balance BJVC as an alternative material for RVOT reconstruction since 2018. Herein, we retrospectively analyzed and evaluated the mid-term results of RVOT reconstruction using Balance BJVC in CHD patients in a single center, with a special focus on the functional status of the conduits in terms of conduit dysfunction and conduit failure. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-23-287/rc).

Highlight box

Key findings

- Approximately 90% of patients were free of bovine jugular vein conduit (BJVC) failure at 5 years after implantation due to aggressive transcatheter intervention.

What is known and what is new?

- Right ventricular outflow tract reconstruction with BJVC is associated with a high risk of conduit dysfunction or failure.
- Despite the high incidence of conduit dysfunction, the conduit failure rate at 5 years is low with aggressive transcatheter intervention. The incidence of infective endocarditis is low.

What is the implication, and what should now change?

- The available BJVC conduits can meet most of the clinical demand. Modification based on the currently available conduits, such as anti-calcification of glutaraldehyde-treated BJVC, non-glutaraldehyde crosslinking technology, tissue engineering technology, may help to further improve the long-term performance.

Methods

Patients

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This single-center retrospective study was approved by the Ethics Committee of Guangzhou Women and Children's Medical Center (No. 244A01), and informed consent was obtained from the guardians of the children. Pediatric patients undergoing RVOT reconstruction using Balance BJVC in Guangzhou Women and Children's Medical Center from January 2018 to December 2020 were enrolled in this study. Indications for conduit implantation included (I) pulmonary atresia or stenosis with or without pulmonary insufficiency and (II) right ventricular pressure greater than or equal to two-thirds of the systemic pressure. Adults older than 18 years were excluded from the study. Additionally, patients with RVOT reconstruction diameters longer than 18 mm were also excluded because hand-made trileaflet valved ePTFE conduits were used in these patients in our center.

Demographic information, cardiac anatomical abnormalities, preoperative hemodynamic characteristics,

surgical details, postoperative outcomes, and follow-up data were collected by reviewing medical records. Transthoracic continuous-wave Doppler echocardiography was used to measure peak transvalvular flow velocity to assess conduit stenosis. Moreover, the pulse color Doppler technique was used to measure the regurgitant jet to evaluate the degree of pulmonary regurgitation.

Definitions

Early death was defined as death in the hospital or within 30 days of discharge. All of the other events are considered late. Conduit dysfunction was defined as significant conduit stenosis, regurgitation, or endocarditis. Conduit stenosis was categorized into four types: (I) distal anastomotic stenosis, which involved stenosis of the left and/or right pulmonary artery opening, excluding stenosis of the right and left pulmonary artery trunks or branches; (II) supravalvular stenosis; (III) stenosis at the valve level; and (IV) proximal stenosis, which involved subvalvular and proximal anastomotic stenosis. Significant conduit stenosis was defined as a peak gradient greater than 50 mmHg across the conduit, and significant regurgitation was defined as moderate and above regurgitation observed on echocardiography (7). Infective endocarditis (IE) was diagnosed with reference to Duke's criteria (14). Once a diagnosis of IE was confirmed, if the patient was stable, adequate antibiotic therapy was administered for 6–8 weeks until blood cultures demonstrated negative results; subsequently, elective surgery was performed to replace the BJVC. If the patients had septic shock, unstable hemodynamics, or life-threatening valvular vegetation/conduit obstruction, the conduit was surgically replaced on an emergency basis. Conduit failure was defined as the need for surgical conduit replacement or transcatheter intervention, due to severe conduit stenosis (peak gradient ≥80 mmHg), or severe regurgitation (greater than grade 3+) (7,20). Conduit reinterventions included plasty, conduit replacement, or transcatheter interventional therapy but did not include reinterventions for stenosis of branch pulmonary arteries.

Conduit description and implantation technique

The Balance BJVC has an internal diameter of 12–17 mm and a length of 7–10 cm. Its lumen contains a natural triple-leaflet venous valve and sinus structures. Moreover, the outer layer of the conduit is covered with a polyester membrane to prevent conduit dilation and adhesion.

In all of the patients, extracorporeal circulation was established through median sternotomy and with upper and lower vena cava cannulation. A palliative right ventricle to pulmonary artery connection was performed under pulsatile extracorporeal circulation. For children undergoing anatomic correction, after moderate hypothermia (28–32 ℃) was achieved, 4 ℃ histidine-tryptophan-ketoglutarate (HTK) solution was perfused via the aortic root. After cardiac arrest, intracardiac or vascular malformations were repaired. For example, a unifocalization operation was performed to anastomose major aortopulmonary collateral arteries (MAPCAs) with the left/right pulmonary artery and to subsequently adequately enlarge them with bovine pericardium or autologous pericardium to relieve pulmonary artery stenosis. Subsequently, Balance BJVC was implanted. During the surgery, the selection of conduit diameter was based on the normal diameter corresponding to the age of the child (increased by 2–4 mm).

Prior to the implantation, the conduit was placed in sterile saline and rinsed sufficiently to remove the residual crosslinker. The valve-bearing conduit was trimmed to the specific length to avoid conduit twisting. Additionally, during anastomosis, the inner layer of the conduit was sutured while taking care to prevent purse-string contraction. Due to the fact that the conduit travels on the left sidewall of the heart, compression by the ascending aorta or sternum should be avoided. The proximal end of the conduit was directly trimmed at the windshield-like structure at the proximal anastomosis, thus avoiding the introduction of other implants. A vertical incision was created on the RVOT, with its length no longer than 1/3 of the long axis of the outflow tract. Efforts were made to avoid the anterior descending branch of the left coronary artery, and the conical branch of the right coronary artery was sacrificed (if necessary). The hypertrophic muscle bundle in the RVOT was removed. Moreover, on the first postoperative day, oral antiplatelet therapy with aspirin (5 mg/kg) was started and continued for six months.

Follow-up and reintervention

In the first year after surgery, transthoracic cardiac ultrasound and electrocardiography were performed at 1, 3, 6, and 12 months postoperatively. Afterwards, cardiac ultrasound was repeated every six months. The main observations included cardiac function, conduit function, and IE (if any). For children with conduit dysfunction, active

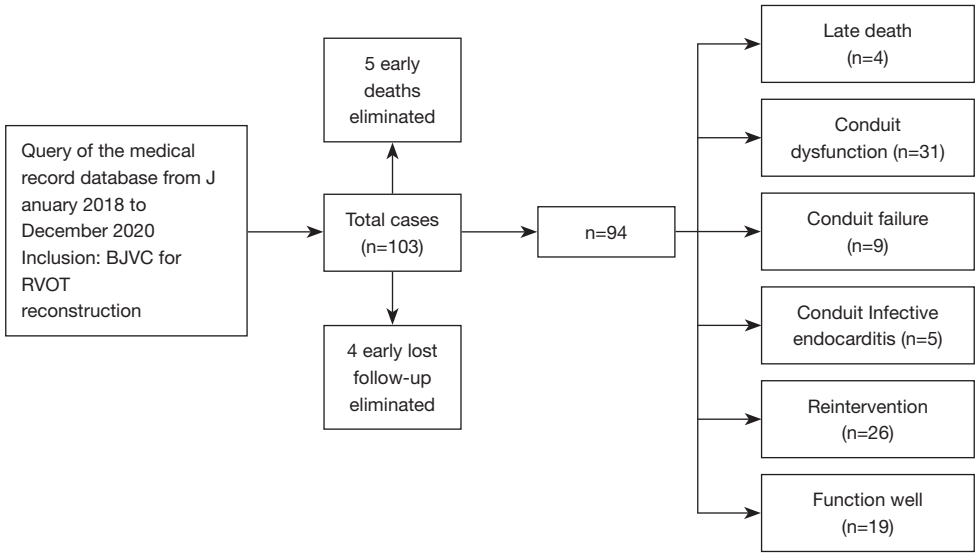

Figure 1 Research design map. BJVC, bovine jugular valved conduit; RVOT, right ventricular outflow tract.

cardiac catheterization and interventional therapy, including balloon dilation and stenting, were offered. For children with conduit failure, surgical replacement was recommended. The final clinical status of the children, including symptoms, exercise tolerance, and late death, was collected.

Statistical analysis

All of the continuous variables are expressed using the mean ± standard deviation or median (range), and categorical variables are expressed using frequencies. For subgroup analyses, the Student's *t*-test was used to compare parametric variables, and the chi-square test was used to compare nonparametric variables. The Kaplan-Meier method was used to estimate survival, and the differences in survival rates were compared by using the log-rank method. Additionally, to evaluate risk factors for BJVC failure, the univariate Cox regression analysis was performed; subsequently, variables with a P value of less than 0.1 were included in the multivariate Cox regression analysis by using forward stepwise regression based on maximum likelihood estimation (Forward: LR). A P value of less than 0.05 (two-sided) was considered to be statistically significant. All of the statistical analyses were performed by using the SPSS 22.0 software package.

Results

Patient demographics

A total of 103 children underwent RVOT reconstruction using Balance BJVC in our center from January 2018 to December 2020. Five children (4.9%) died early after surgery. Among them, four deaths were unrelated to the conduits (except for one child who died of conduit-related IE and septic shock early after surgery). In addition, 4 patients (3.9%) were lost to follow-up in the early postoperative period (<6 months), and they had normal conduit function at the last follow-up visit. All 9 children were excluded from this study, and 94 cases (91.3%) were entered into the final analysis (*Figure 1*).

The median age at Balance BJVC implantation was 22 months (range, 2–168 months), and the median weight was 10.8 kg (range, 3.8–40.0 kg). Thirty-four children (36.2%) were younger than 1 year. Moreover, the most common disease was pulmonary atresia with ventricular septal defect (PA/VSD) (66/94, 70.2%). Children were divided into two groups according to the size of the conduits: Group 1 (n=18, 19.1%) with conduits sized at 12–14 mm; and Group 2 (n=76, 80.9%) with conduits sized at 15–17 mm. The demographic and surgical data of these children are summarized in *Table 1*.

Table 1 Patient demographics and operative procedures

Demographic	Patients
Gender (M/F)	51/43
Median age at implant (month)	22 [2–168]
Age less than 12 months	34 (36.2)
Median weight (kg)	10.8 [3.8–40.0]
Main diagnosis, n (%)	
PA/VSD (type A)	3 (3.2)
PA/VSD/MAPCAs (type B)	55 (58.5)
PA/VSD/MAPCAs (type C)	8 (8.5)
Aortic stenosis	10 (10.6)
Mitral stenosis/regurgitation	5 (5.3)
ccTGA/VSD/PS	7 (7.4)
PTA	4 (4.3)
TOF	1 (1.1)
TGA/VSD/PS	1 (1.1)
Conduit diameter (mm)	
Group 1	
12	7 (7.4)
13	3 (3.2)
14	8 (8.5)
Group 2	
15	27 (28.7)
16	15 (16.0)
17	34 (36.2)
Operative procedures	
Intracardiac repair + RVOT reconstruction + MAPCAs Unifocalization	63 (67.0)
Ross-Konno	10 (10.6)
Intracardiac repair + RVOT reconstruction	8 (8.5)
Hemi-mustard + bidirectional Glenn shunt + Rastelli	7 (7.4)
Pulmonary autograft mitral valve replacement (Ross II procedure) + RVOT reconstruction	5 (5.3)
Nikaidoh procedure	1 (1.1)
Perioperative variables	
Aortic cross-clamp time (min)	74.5 [22–193]
Cardiopulmonary bypass time (min)	202 [33–657]
Ventilation time (hour)	71.5 [1–2,323]
ICU stay time (day)	6 [2–97]

Data are presented as median [range] or number (%). PA, pulmonary atresia; VSD, ventricular septal defect; MAPCAs, major aortopulmonary collateral arteries; ccTGA, congenitally corrected transposition of the great arteries; PTA, persistent truncus arterious; TOF, tetralogy of Fallot; PS, pulmonary stenosis; RVOT, right ventricular outflow tract; ICU, intensive care unit.

Late mortality

The patients were followed up for a median of 43.5 months (range, 6–60 months). Late mortality occurred in four patients (4.3%). Among these patients, the first is a 12-month-old female who was diagnosed with a complex mitral valve anomaly. She underwent the Ross-II procedure with RVOT reconstruction by using a 17-mm BJVC. During the course of the disease, there were symptoms of infection, and cardiac ultrasound prompted the presence of valvular vegetation in the conduit. Afterwards, a diagnosis of IE was made. After antimicrobial treatment, the clinical symptoms and vegetation disappeared. However, she died 24 months after surgery due to intracranial hemorrhage caused by trauma. The second case of late death was a 7-month-old male diagnosed with type A pulmonary atresia accompanied by ventricular septal defect. He underwent intracardiac defect repair and RVOT reconstruction with a 15-mm BJVC. This patient died six months after surgery due to pulmonary hemorrhage after balloon dilation for right pulmonary artery stenosis at another hospital. In the remaining two deaths, both children (a 10-month-old female and a 36-month-old male) had type B pulmonary atresia accompanied by ventricular septal defects and MAPCAs. They underwent complete unifocalization and intracardiac repair, along with RVOT reconstruction by using a 15-mm BJVC. The female patient was readmitted

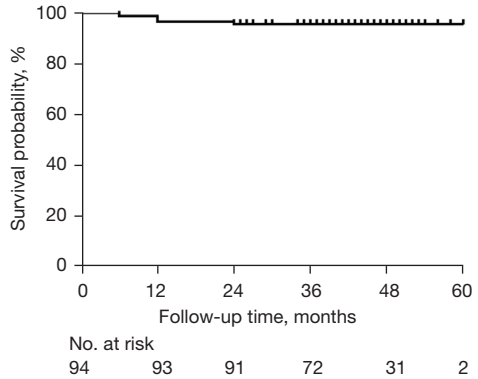

Figure 2 The Kaplan-Meier curves depict estimated survival for the entire cohort of 94 patients after BJVC insertion. BJVC, bovine jugular vein conduit.

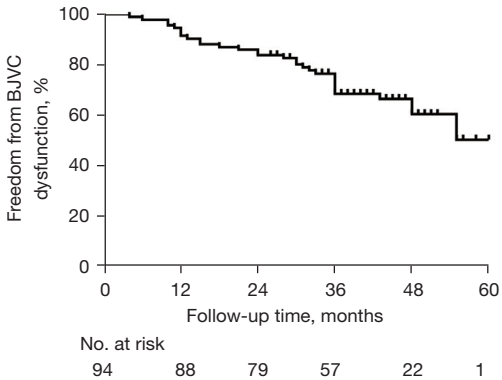

Figure 3 The Kaplan-Meier curves depict estimated freedom from BJVC dysfunction after operation. BJVC, bovine jugular vein conduit.

to our center for conduit IE at six months after surgery, and the valvular vegetations disappeared after antimicrobial treatment. The female patient died of unknown causes at home 12 months after surgery. The male patient died suddenly at home 14 months after surgery for unknown reasons. Kaplan-Meier analysis demonstrated a 5-year survival rate of 95.7% (95% CI: 91.6–99.8%) after conduit implantation (*Figure 2*).

Conduit dysfunction

During the follow-up, 31 patients (33.0%) in this cohort experienced conduit dysfunction at different levels of the conduit, mainly including distal anastomotic (i.e., left/right arterial opening) stenosis (n=19), supravalvular stenosis (n=5), stenosis at the valve level (n=7), subvalvular and proximal anastomotic stenosis (n=1), moderate or severe valve regurgitation (n=2), and IE (n=5). Kaplan-Meier analysis showed that the proportion of patients who were free of conduit dysfunction at 1, 3, and 5 years was 91.4% (95% CI: 85.7–97.1%), 68.5% (95% CI: 58.5–78.5%), and 50.4% (95% CI: 29.6–71.2%), respectively (*Figure 3*).

In Group 1, the proportions of patients who were free of conduit dysfunction at 1, 3, and 5 years were 88.9% (95% CI: 74.4–100%), 60.6% (95% CI: 37.9–83.3%), and 40.4% (95% CI: 13.0–67.8%), respectively; in Group 2, these proportions were 92.0% (95% CI: 85.9–98.1%), 70.5% (95% CI: 59.5–81.5%), and 51.0% (95% CI: 20.8–81.2%), respectively, thus demonstrating no significant difference from that in Group 1 (P=0.217; log-rank method). However, these proportions were 84.9% (95% CI: 72.7–97.1%), 57.8% (95% CI: 40.0–75.6%), and 19.3% (95% CI: 0–48.7%) at 1, 3, and 5 years in children who were operated on at an age younger than 1 year, respectively, which was significantly lower than the proportions [95.0% (95% CI: 89.5–100%), 74.4% (95% CI: 62.8–86.0%), and 71.7% (95% CI: 59.3–84.0%)] in those who were operated on at an age older than 1 year (P=0.01; log-rank method) (*Figure 4*).

Conduit failure

Conduit failure was detected in 9 children (9.6%), including significant stenosis of the distal anastomosis (n=1; the conduit was replaced 13 months after surgery), IE at the valve level 24–36 months after surgery (n=3), severe supravalvular stenosis (n=2), and significant calcified stenosis of the main conduit stem (n=3). Six children underwent surgical replacement, 1 child underwent balloon dilation, and 2 others are awaiting surgery. Kaplan-Meier analysis showed that the proportions of patients who were free of conduit failure at 1, 3, and 5 years were 100.0%, 88.9% (95% CI: 82.0–95.8%), and 88.9% (95% CI: 82.0–95.8%) (*Figure 5*), respectively. Multivariate Cox regression analysis showed that sex, age, and conduit diameter were not independent risk factors for conduit failure.

During the follow-up period, five children (5.3%) developed IE within 24 months (range, 12–36 months) after surgery. All five children had positive blood cultures, and echocardiograms demonstrated valvular vegetation. In two cases, the clinical symptoms and valvular vegetation disappeared after antimicrobial treatment, but the conduit dysfunction persisted. One of these two children died due to craniocerebral trauma, and the other child was in good clinical status. In the remaining three cases, the clinical

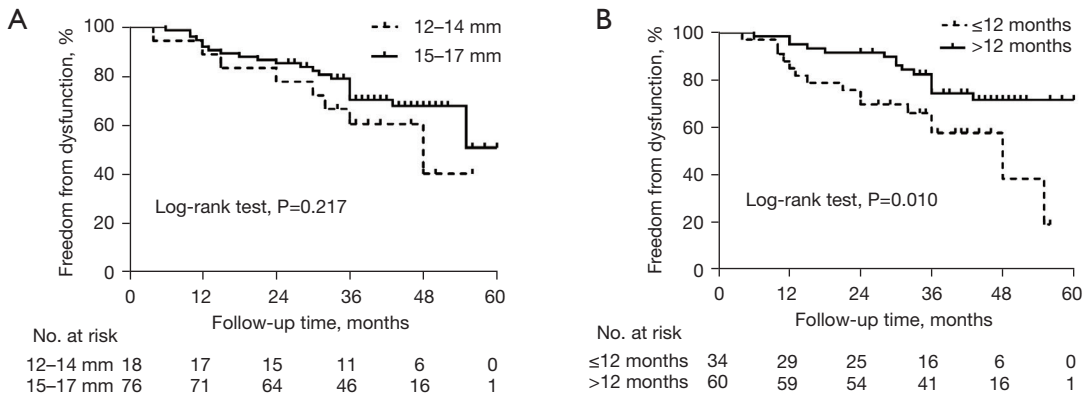

Figure 4 Kaplan-Meier curves of freedom from BJVC dysfunction stratified by (A) conduit diameter and (B) age at BJVC insertion. BJVC, bovine jugular vein conduit.

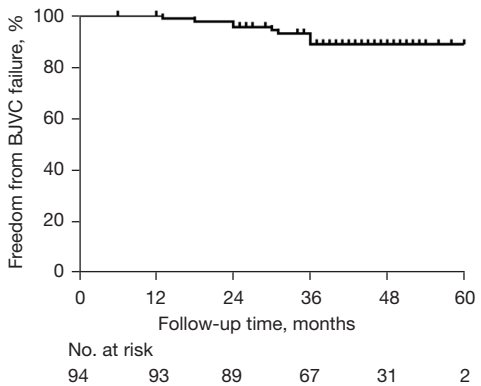

Figure 5 Kaplan-Meier curves of freedom from BJVC failure for the entire cohort. BJVC, bovine jugular vein conduit.

symptoms improved after antimicrobial treatment; however, the conduit failure persisted, and a second surgery was performed to replace the conduits.

A total of 28 reinterventions were performed in 26 children, including 5 reoperations, 21 balloon dilatations, and 2 pulmonary artery stent implantations. No deaths were noted in any of the reintervention cases.

All of the surviving children had good clinical status. They had no obvious clinical symptoms of right ventricular defects, and their activity tolerance was not obviously restricted.

Discussion

In this study, we retrospectively analyzed the mid-term results of RVOT reconstruction by using Balance BJVC in CHD patients, with a special focus on the functional status of the conduits. The results showed that despite the high incidence of conduit dysfunction, the risk of conduit failure remained low enough to meet clinical needs at 5 years after the procedure due to aggressive interventions. This result was similar to the findings reported in most previous studies literature (8,21).

Currently, the optimal material for RVOT reconstruction remains unclear. Patients with complex CHD typically have pulmonary hypertension and increased pulmonary vascular resistance, in whom the application of valved conduits is required for RVOT reconstruction. Compared with pulmonary homografts, BJVCs have numerous advantages, such as ready availability of different models, easy trimming and implantation, and prevention of twisting or compression. However, both pulmonary homograft and Contegra BJVC are not available at our center. Since 2018, Balance BJVC (sized 12–17 mm) has been used in our center. However, for patients with RVOT reconstruction diameters larger than 18 mm, hand-made trileaflet valved ePTFE conduits are used. As in most reports, we observed a high incidence of conduit dysfunction at 5 years after surgery, which was mainly manifested by stenosis of the distal anastomosis (61.3%, 19/31). Kaplan-Meier analysis showed that the proportions of patients who were free of conduit dysfunction at 1, 3, and 5 years were 91.4%, 68.5%, and 50.4%, respectively. Karamlou *et al.* found that the risk factors for conduit reintervention included: (I) PA arborization abnormalities, (II) younger age at implantation, and (III) smaller conduit Z score (22). In the present study, children who were operated on at an age younger than 1 year had a higher proportion of conduit dysfunction (36.2%, 34/94) and a higher proportion of type B/C PA/

VSD/MAPCAs (67.0%, 63/94). These patients often have poorly developed right and left pulmonary arteries, which need to be widened and reshaped with pericardial materials, along with the unifocalization of MAPCAs; finally, these arteries are anastomosed with the distal end of the BJVC, which results in a high risk of distal anastomotic stenosis. Other factors may include a mismatch between the conduit size and the distal pulmonary artery anastomosis, local immune/inflammatory responses, local pseudomembrane formation, thrombosis, and poor surgical anastomotic skill (21,23). Patel *et al.* found that the most common pathological changes in the conduits included fibrosis, calcification, and chronic inflammation; in contrast, local calcification in the valve leaflets was less common (8).

Conduit failure is the most significant concern in the clinical use of BJVC and often requires reoperation. Its risk factors are similar to those of conduit dysfunction. In our current study, conduit failure occurred in nine children, including significant calcific stenosis of the main conduit stem (n=3), stenosis due to IE at the valve level (n=3), severe supravalvular stenosis (n=2), and significant stenosis of the distal anastomosis (n=1). Kaplan-Meier analysis showed that the proportion of patients who were free of conduit failure at 5 years was 88.9%. This result was comparable to the findings in the previous literature (8,21). Active interventional therapies (such as balloon dilation) may help to prolong the lifespans of the conduits. In our center, balloon dilation is actively recommended for children with conduit dysfunction (e.g., the pressure peak gradient is >50 mmHg). Therefore, despite the high incidence of conduit dysfunction, the risk of conduit failure within 5 years is low, and the conduit can meet the clinical needs.

Evidence suggests that small conduits (12–14 mm) have a higher risk of dysfunction or failure (1,8,21). A similar trend was observed in the current study; specifically, the proportions of patients who were free of conduit dysfunction at 1, 3, and 5 years were 88.9%, 60.6%, and 40.4%, respectively, in Group 1 and 92.0%, 70.5%, and 51.0%, respectively, in Group 2. However, the difference between the two groups did not reach statistical significance (P=0.217) (*Figure 4*), which was possibly due to the lower use of small conduits (n=18) in our cohort. In our practice, we also minimize the use of conduits that are smaller than 14 mm, with the aim of prolonging the conduit lifespan. However, a recent study indicated that higher indexed Contegra BJVC size was an independent risk factor for conduit failure, with a freedom from conduit failure after 3 years of 78.4% (24). In a multicenter study, Marathe *et al.* found that BJVCs with diameters <15 mm (compared to pulmonary homografts or aortic homografts) had similar medium- and long-term performance (25). Therefore, conduits with larger diameters are not always better.

The age of the patients undergoing surgery is an important factor affecting the long-term function of conduits. Previous studies have shown that 84–90% of BJVCs were free from reintervention due to failure at 10 years after BJVC implantation (14,21,26-28). However, none of these studies stratified for age. A European Contegra multicenter study showed that the 5-year freedom from conduit explantation was 68% for those patients who underwent surgery at an age younger than 1 year, whereas this rate was 90% for those patients who had surgery at an age of 1–10 years (29). Patel *et al.* found that the 5-year freedom from conduit explantation was only 53% in those patients who received surgery under 1 year (8). Vitanova *et al.* reported that the 5-year freedom from conduit explantation was 59% in patients below 1 year of age (30). Our study also demonstrated that children who were operated on ≤12 months had a higher risk of conduit dysfunction. The reasons for this effect may include smaller conduit diameter, poorer distal pulmonary artery development, higher calcium and phosphorus metabolic rates, and faster growth and development in young children. The appropriate age for BJVC implantation needs to be further explored.

Late IE is a common complication associated with all RVOT reconstruction materials. Previous studies have shown that the incidence of IE ranges from 4.7–17.6% (8,14-17). Older age at surgery has been recognized as being a risk factor for IE in all conduits used for RVOT reconstruction (7). Mery *et al.* (14). evaluated three conduits, including pulmonary allografts, aortic homografts, BJVCs, and porcine heterografts, for RVOT reconstruction. BJVC was found to be associated with a significantly greater risk of late endocarditis but with lower reintervention rates compared with other valved conduits (14). In our current study, five children (5.3%) developed late IE. Among them, three children had to have their conduits surgically replaced; in the other two cases, the vegetations and clinical symptoms disappeared after antibacterial therapy, and the functional status of the conduits is still being investigated in the follow-up.

Notably, Zhang *et al.* reported a cohort of 53 Chinese pediatric patients underwent RVOT reconstruction with BJVC (15). Their study demonstrated a relatively high rate of endocarditis (17.6% at the median follow-up

of 25.3 months) and BJVC conduits failure (29.4% at 7 years). There are several important processing update with the conduits applied in this study, including non-glutaraldehyde fixed technique, anti-adhesion membrane. The results showed lower incidence of endocarditis (5.3%). Additionally, we would suggest and take more active action on transcatheter intervention after conduit dysfunction was diagnosed, so long as getting the family's consent. Therefore, the risk of conduits decay after 5 years implantation is comparatively low even though the patients in the cohort are younger (36.2% patients are younger than 12 months) and the incidence of conduits dysfunction is higher. We believe that the durability of the conduit will be further improved as more advanced processing techniques are adopted, such as non-glutaraldehyde crosslinking and anti-calcification treatment, even with the application of modern tissue engineering techniques.

Limitations

Our current study had some limitations: (I) it was limited by its single-center, retrospective design; (II) due to the fact that pulmonary homografts have rarely been used in China, we did not compare BJVC with pulmonary homografts; and (III) due to its small sample size and short follow-up duration, only the mid-term outcomes of the conduits were presented in this study.

Conclusions

Despite the high risk of BJVC dysfunction, approximately 90% of children are free from conduit failure at 5 years after conduit implantation through aggressive interventional therapy without increasing the incidence of IE. Thus, BJVC remains a useful alternative material for RVOT reconstruction in patients with complex CHD. Further close follow-up and exploration of the possible mechanisms of conduit dysfunction are warranted.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-23-287/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-23-287/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This single-center retrospective study was approved by the Ethics Committee of Guangzhou Women and Children's Medical Center (No. 244A01), and informed consent was obtained from the guardians of the children.

References

1. Yong MS, Yim D, d'Udekem Y, et al. Medium-term outcomes of bovine jugular vein graft and homograft conduits in children. ANZ J Surg 2015;85:381-5.
2. Patel PM, Herrmann JL, Rodefeld MD, et al. Bovine jugular vein conduit versus pulmonary homograft in the Ross operation. Cardiol Young 2020;30:323-7.
3. Bottio T, Vida VL, Stellin G, et al. Expected freedom from structural degeneration and patient outgrowth for the bovine jugular vein conduit: is it possible to calculate a safe rate for children?. Ann Thorac Surg 2003;76:2167-8.
4. Bottio T, Thiene G, Vida V, et al. The bovine jugular vein conduit for right ventricular outflow tract reconstruction: a feasible alternative to homograft conduits?. J Thorac Cardiovasc Surg 2004;127:1204-7.
5. Fiore AC, Brown JW, Turrentine MW, et al. A bovine

jugular vein conduit: a ten-year bi-institutional experience. Ann Thorac Surg 2011;92:183-90; discussion 190-2.
6. Kido T, Hoashi T, Kagisaki K, et al. Early clinical outcomes of right ventricular outflow tract reconstruction with small caliber bovine jugular vein conduit (Contegra(®)) in small children. J Artif Organs 2016;19:364-71.
7. Ugaki S, Rutledge J, Al Aklabi M, et al. An increased incidence of conduit endocarditis in patients receiving bovine jugular vein grafts compared to cryopreserved homograft for right ventricular outflow reconstruction. Ann Thorac Surg 2015;99:140-6.
8. Patel PM, Tan C, Srivastava N, et al. Bovine Jugular Vein Conduit: A Mid- to Long-Term Institutional Review. World J Pediatr Congenit Heart Surg 2018;9:489-95.
9. Falchetti A, Demanet H, Dessy H, et al. Contegra versus pulmonary homograft for right ventricular outflow tract reconstruction in newborns. Cardiol Young 2019;29:505-10.
10. Herrmann JL, Larson EE, Mastropietro CW, et al. Right Ventricular Outflow Tract Reconstruction in Infant Truncus Arteriosus: A 37-year Experience. Ann Thorac Surg 2020;110:630-7.
11. Hickey EJ, McCrindle BW, Blackstone EH, et al. Jugular venous valved conduit (Contegra) matches allograft performance in infant truncus arteriosus repair. Eur J Cardiothorac Surg 2008;33:890-8.
12. Poynter JA, Eghtesady P, McCrindle BW, et al. Association of pulmonary conduit type and size with durability in infants and young children. Ann Thorac Surg 2013;96:1695-701; discussion 1701-2.
13. Sandica E, Boethig D, Blanz U, et al. Bovine Jugular Veins versus Homografts in the Pulmonary Position: An Analysis across Two Centers and 711 Patients-Conventional Comparisons and Time Status Graphs as a New Approach. Thorac Cardiovasc Surg 2016;64:25-35.
14. Mery CM, Guzmán-Pruneda FA, De León LE, et al. Risk factors for development of endocarditis and reintervention in patients undergoing right ventricle to pulmonary artery valved conduit placement. J Thorac Cardiovasc Surg 2016;151:432-9, 441.e1-2.
15. Zhang HF, Chen G, Ye M, et al. Mid- to long-term outcomes of bovine jugular vein conduit implantation in Chinese children. J Thorac Dis 2017;9:1234-9.
16. Haas NA, Bach S, Vcasna R, et al. The risk of bacterial endocarditis after percutaneous and surgical biological pulmonary valve implantation. Int J Cardiol 2018;268:55-60.
17. Beckerman Z, De León LE, Zea-Vera R, et al. High incidence of late infective endocarditis in bovine jugular vein valved conduits. J Thorac Cardiovasc Surg 2018;156:728-734.e2.
18. Ando M, Takahashi Y. Ten-year experience with handmade trileaflet polytetrafluoroethylene valved conduit used for pulmonary reconstruction. J Thorac Cardiovasc Surg 2009;137:124-31.
19. Kasturi S, Prabhu S. Handmade trileaflet valved ePTFE right ventricle to pulmonary artery conduit - How do we do it?. Multimed Man Cardiothorac Surg. 2020;2020:10.1510/mmcts.2020.023
20. Kalfa D, Feier H, Loundou A, et al. Cryopreserved homograft in the Ross procedure: outcomes and prognostic factors. J Heart Valve Dis 2011;20:571-81.
21. Prior N, Alphonso N, Arnold P, et al. Bovine jugular vein valved conduit: up to 10 years follow-up. J Thorac Cardiovasc Surg 2011;141:983-7.
22. Karamlou T, Blackstone EH, Hawkins JA, et al. Can pulmonary conduit dysfunction and failure be reduced in infants and children less than age 2 years at initial implantation?. J Thorac Cardiovasc Surg 2006;132:829-38.
23. Corno AF, Mickaily-Huber ES. Comparative computational fluid dynamic study of two distal Contegra conduit anastomoses. Interact Cardiovasc Thorac Surg 2008;7:1-5.
24. Kim DH, Kwon YK, Choi ES, et al. Risk factors for early adverse outcomes after bovine jugular vein conduit implantation: influence of oversized conduit on the outcomes. Interact Cardiovasc Thorac Surg 2022;35:ivac197.
25. Marathe SP, Hussein N, Wallace FRO, et al. Comparison of homografts and bovine jugular vein conduits in the pulmonary position in patients <20 years of age. J Thorac Cardiovasc Surg 2022;164:752-762.e8.
26. Ruzmetov M, Shah JJ, Geiss DM, et al. Decellularized versus standard cryopreserved valve allografts for right ventricular outflow tract reconstruction: a single-institution comparison. J Thorac Cardiovasc Surg 2012;143:543-9.
27. Sarikouch S, Horke A, Tudorache I, et al. Decellularized fresh homografts for pulmonary valve replacement: a decade of clinical experience. Eur J Cardiothorac Surg 2016;50:281-90.
28. Sierra J, Christenson JT, Lahlaidi NH, et al. Right ventricular outflow tract reconstruction: what conduit to use? Homograft or Contegra?. Ann Thorac Surg 2007;84:606-11.
29. Breymann T, Blanz U, Wojtalik MA, et al. European Contegra multicentre study: 7-year results after 165 valved bovine jugular vein graft implantations. Thorac Cardiovasc

Surg 2009;57:257-69.
30. Vitanova K, Cleuziou J, Hörer J, et al. Which type of conduit to choose for right ventricular outflow tract reconstruction in patients below 1 year of age?†. Eur J Cardiothorac Surg 2014;46:961-6; discussion 966.

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