FIGURE 2. Computed tomography scan showing passage of outflow graft under the superior vena cava. SVC, Superior vena cava; OG, outflow graft; Ao, aorta; RA, right atrium; RPA, right pulmonary artery.

SVC, and roof of the left atrium, rendering compression of the SVC unlikely. As expected, we did not encounter SVC syndrome and the CT scan did not show any compression. At the time of VAD explant due to recovery or heart transplant, we propose to either remove the whole graft or leave a few millimeters of length behind the SVC if the adhesions prohibit its removal, thereby avoiding dissection and injury to adjoining structures like the right pulmonary artery, azygous vein, and SVC. Because the graft runs inside the pericardium, the phrenic nerve remains protected. The technique is simple, easy, and reproducible.

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Use of cryopreserved saphenous vein grafts in congenital heart surgery

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The use of saphenous vein grafts (SVGs) in congenital heart surgery was reported as early as 1984.¹ SVGs have several advantages, including a low incidence of thrombosis and infection and superior handling characteristics and hemostasis, with acceptable patency rates. A potential hemodynamic benefit of a competent valve also exists in cases in which SVGs are used as right ventricle to pulmonary artery (RV-PA) conduits.² We report our experience with cryopreserved SVGs as RV-PA conduits or modified Blalock-Taussig shunts (MBTSs) in neonates and infants.

TABLE 1. Patient characteristics and operative data

Variable	Study population (n = 36)
Patient	
Median age	0.21 mo (2-54 d)
Male gender	20 (55.6%)
Median weight (kg)	2.9 (2.1-5.9)
Functional classification	
Univentricular	24 (66.7%)
Biventricular	12 (33.3%)
Univentricular anomaly	
HLHS	8 (22.2%)
UVH + PS/PA	6 (16.7%)
Tricuspid atresia	4 (11.1%)
DILV/TGA	2 (5.6%)
PA/IVS	1 (2.8%)
Shunt endocarditis	1 (2.8%)
Biventricular anomaly	
TOF/PA	3 (8.3%)
PA/MAPCAs	3 (8.3%)
Truncus arteriosus	3 (8.3%)
TOF/AVSD	1 (2.8%)
PS, RV dysfunction, TR	1 (2.8%)
DORV	1 (2.8%)
Operative	
Procedure	
MBTS	25 (69.4%)
RV-PA conduit	8 (22.2%)
Central shunt	3 (8.3%)
Approach	
Median sternotomy	34 (94.4%)
Thoracotomy	2 (5.6%)
Redo cases	4 (11.1%)
Cardiopulmonary bypass	14 (38.9%)
Median graft size (mm)	
MBTS	4 (3.5-4)
RV-PA conduit	5 (5-7)
Central shunt	5 (4-5)

Data presented as median (range) or numbers (%). *HLHS*, Hypoplastic left heart syndrome; *UVH*, univentricular heart disease; *PS*, pulmonary stenosis; *PA*, pulmonary atresia; *DILV*, double inlet left ventricle; *TGA*, transposition of great arteries; *IVS*, intact ventricular septum; *TOF*, tetralogy of Fallot; *MAPCAs*, major aortopulmonary collateral arteries; *AVSD*, atrioventricular septal defect; *RV*, right ventricle; *TR*, tricuspid regurgitation; *DORV*, doublet outlet right ventricle; *MBTS*, modified Blalock-Taussig shunt; *RV-PA*, right ventricle to pulmonary artery.

PATIENTS AND METHODS

A single-center, retrospective review was conducted of neonates and infants undergoing palliation or correction of congenital heart disease with a cryopreserved SVG as a conduit or shunt between October 2003 and March 2011. The clinical, echocardiographic, and cardiac catheterization data were reviewed. The anticoagulation protocol entailed systemic heparinization with 100 U/kg, with no reversal. Outcomes included graft-related mortality and complications, including thrombosis, bleeding, infection, and significant stenosis, defined as greater than 50% diameter or requiring percutaneous or operative intervention. The institutional review board approved the present study.

RESULTS

A total of 36 patients were included in the study. Of these 36 patients, 11 (30.6%) were born prematurely and

TABLE 2. Outcomes

Outcome	Study population (n = 36)
Follow-up	
Median	6.3 mo
Range	2 d to 13.3 mo
Mortality	
All-cause mortality	
30-d	1 (2.8%)
In-hospital	4 (11.1%)
Interstage attrition	2 (5.6%)
Graft-related morbidity	
Thrombosis	3 (8.3%)
Intraoperative	2 (5.6%)
Late	1 (2.8%)
Banding for pulmonary overcirculation	2 (5.6%)
Stenosis	5 (13.9%)
RV-PA conduit	3 of 8 (37.5%)
MBTS	2 of 25 (8.0%)

Data presented as median and range or number (%). *RV-PA*, Right ventricle to pulmonary artery; *MBTS*, modified Blalock-Taussig shunt.

20 (55.6%) had a low birth weight; 34 (94.4%) were neonates in the first 3 days of life (Table 1). The median preoperative weight was 2.9 kg. Functionally, most (66.7%; n = 24) had univentricular hearts. The most common anomalies included hypoplastic left heart (22.2%; n = 8), univentricular heart disease with pulmonary stenosis or pulmonary atresia (16.7%; n = 6), and tricuspid atresia (11.1%; n = 4).

The patients in the present study underwent placement of a MBTS (69.4%; n = 25), RV-PA conduit (22.2%; n = 8), or central shunt (8.3%; n = 3; Table 1). Of the 25 MBTS patients, 17 (68.0%) had a low birth weight. The approach for most patients (94.4%; n = 34) was through a median sternotomy, with 2 (5.6%) undergoing thoracotomy. Two patients (5.6%) had required extracorporeal membrane oxygenation preoperatively. Four cases (11.1%) were reoperations. Cardiopulmonary bypass was used in 14 patients (38.9%).

The median follow-up was 6.3 months (range, 2 days to 13.3 months). Hospital mortality was 11.1% (4 patients), with 1 death occurring before and 4 beyond 30 days postoperatively. One patient with univentricular heart disease with pulmonary atresia experienced cardiac arrest on postoperative day 2 and died (30-day mortality, 2.8%; Table 2). An autopsy was declined by the parents. It is possible that the death could have been related to failure of the patient's shunt. An additional 3 patients died in-hospital: 1 of sepsis and malrotation on postoperative day 49 and 2 of right ventricular dysfunction on postoperative day 65 and 72. In the patients surviving to discharge, the interstage attrition was 6.3% (2 deaths). One patient died on postoperative day 45 of aspiration pneumonia. The second patient

had tricuspid atresia with a restrictive pattern, who presented in distress from an outside hospital and was given extracorporeal membrane oxygenation but died on postoperative day 110.

Intraoperative thrombosis was observed in 2 patients (5.6%) with isolated redo MBTS, both of whom underwent immediate placement of a new SVG shunt (Table 2). One patient (2.8%) developed thrombosis late after shunt placement in the setting of postoperative dehydration after Nissen fundoplication. Two patients (5.6%) required banding for pulmonary overcirculation, one of whom was of low birth weight.

Significant SVG stenosis developed in 5 patients (13.9%; Table 2), including 3 with RV-PA conduits (37.5% of RV-PA cases) that required stent placement. These stents were placed for proximal angulation of the conduit, distal stenosis, and diffuse stenosis (each, $n = 1$). Other cases of significant stenosis included a distal right MBTS stenosis that was augmented at the superior cavopulmonary anastomosis, and a left MBTS that was stenosed at the previous augmentation site of the left pulmonary artery.

DISCUSSION

We have appreciated several advantages to using SVGs in congenital heart surgery, and, in particular, in low-birth-weight neonates, who constituted most of our study population. From a technical aspect, SVGs are easier to handle and have superior hemostasis than synthetic grafts. Additionally, SVGs have lower thrombogenicity, an advantage even more relevant in these smaller grafts that are prone to thrombosis.³ In addition to a low thrombosis rate with SVGs, we have demonstrated a low rate of graft-related mortality. Finally, when used as an MBTS, SVGs were associated with a low rate of stenosis (8.0%) and did not require interstage intervention. Our finding of a lower rate of stenosis and intervention with MBTS versus RV-PA conduits was similar to the findings from a multicenter randomized trial that compared these shunt

types (including synthetic grafts) in the Norwood procedure.⁴

Despite these advantages, SVGs have a few drawbacks. In general, SVGs have limited availability and significant cost (each costs ~\$4000 vs \$1000 for synthetic grafts) and can have an unpredictable diameter. Pulmonary overcirculation requiring banding can occur owing to the small size of the children, the unpredictable diameter of the graft, and dilatation of the graft over time. We measure the inner diameter of the SVG with a Hegar dilator and judge the potential for overcirculation by the usual parameters, including diastolic blood pressure and oxygen saturation. In our experience, we noted a high rate of stenosis (37.5%) in cases in which SVGs were used as RV-PA conduits. This rate was greater than what has been reported in cases using synthetic RV-PA conduits.⁵ The reduced patency of SVGs as RV-PA conduits likely results from several factors, including the unpredictability of how the graft will lie and potential compression of the graft by nearby structures. A ringed synthetic conduit might, therefore, be a better option in this position. Given our data, we believe the best use for SVGs in congenital heart surgery are as MBTS in low-birth-weight neonates.

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