Options for Prosthetic Pulmonary Valve Replacement

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This article reviews current data on various prostheses utilized for pulmonary valve replacement. Durability data is reviewed and risk factors for deterioration are examined. Finally, the choice of prosthesis should be tailored to the specific clinical scenario based on existing data regarding durability and risk factors.

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Introduction

Prosthetic valves and conduits are utilized as a part of complete repair for numerous congenital cardiac defects. The most common diagnoses necessitating primary valved conduit placement in infancy include tetralogy of Fallot, pulmonary atresia – with intact ventricular septum or ventricular septal defect, truncus arteriosus, transposition of the great vessels with ventricular septal defect (as part of Rastelli procedure), interrupted aortic arch with diminutive ascending aorta (as part of Yasui-type repair), and severe congenital aortic stenosis (as part of Ross procedure). Implantation of stented bioprosthetic valve without conduit is indicated for patients with pulmonary regurgitation who have undergone previous right ventricular outflow tract reconstruction (RVOT) as a component of management of congenital heart defects. The indications for valve replacement in these patients have evolved over the past decade, with a trend toward earlier replacement to prevent the deleterious effects of long-standing pulmonary regurgitation on right ventricular function, dilation, and tricuspid regurgitation. The options for conduit and valve replacement include synthetic-, homograft-, and xenograft-based prostheses. Unfortunately, none of the currently available conduits are ideal, and each is associated with specific advantages and disadvantages.

Homografts

Cryopreserved aortic and pulmonary homografts may be used for RVOT reconstruction. The advantages of homografts include availability in a wide range of sizes and favorable handling characteristics during implantation. bifurcating pulmonary grafts or aortic branch vessels can be directly anastomosed to branch pulmonary arteries in the absence of adequate central pulmonary arteries. Major disadvantages include limited supply of the smaller sizes necessary for neonatal repair, the limited shelf life of each homograft (approximately 2 years), and high cost. Modification of an homograft by excision of one leaflet and creation of a smaller “bicuspid” homograft allows the use of larger-sized homografts in smaller patients when appropriate-sized smaller homografts are unavailable.

Freedom from reintervention rates reported in the literature range widely, from 30% to over 80% at 10 years. Smaller conduit size (or younger age at operation) has been consistently shown in multiple series to be a risk factor for homograft conduit failure. Freedom from reoperation at 10 years is <50% for homografts of <19 mm diameter. Other factors that have less consistently been shown to increase the risk of failure include use of aortic homografts, residual branch pulmonary artery stenosis, ABO mismatch, and non-Ross operation (particularly operation for truncus arteriosus). The reason for the discrepancy in durability between Ross and non-Ross patients is unclear, but may be related to orthotopic position of the conduit in the former; it is placed more anteriorly in Rastelli, Yasui, and truncus repairs, which may predispose to compression from the sternum. Several studies have shown superiority of pulmonary homografts over aortic homografts in patients with normal pulmonary artery pressures. However, pseudoaneurysm and fusiform conduit dilation are more common with pulmonary homografts when implanted into patients with elevated pulmonary artery pressures.

Xenograft Conduits

The most commonly used conduits include bovine jugular vein grafts, porcine pulmonary valved conduit (Shelhigh
Advantages of the synthetic valved conduits include excellent short-term outcomes in this cohort of patients.26

Young age at implantation is risk factor for reintervention and distal conduit stenosis.23 In patients with elevated right-ventricular pressures or pulmonary hypertension, the Contegra conduit has been associated with graft dilation and decreased durability, raising concerns for its use in these patients.21,23,24

Options for prosthetic pulmonary valve replacement

Several options exist for pulmonary valve replacement in patients beyond infancy. Implantation within native RVOT with or without pulmonary artery augmentation is the most common technique of implantation following transannular repair of tetralogy of Fallot. Placement within synthetic conduit (described above) may be necessary for replacement of calcified or foreshortened conduits.

Mechanical Valves

Despite the theoretical advantages of long-term durability of mechanical valves, concerns regarding risks of long-term anticoagulation and valve thrombosis, despite adequate anticoagulation, have limited extensive use of these prostheses. Risk of thrombosis may be higher in patients with right-ventricular dysfunction.30 Several small series have reported acceptable durability of the mechanical prosthesis in the pulmonary position, with mode of failure being growth of fibrosis rather than mechanical failure or thrombosis events.31,32 Use of mechanical valves may be justified in patients requiring anticoagulation for other reasons, in patients likely to be compliant with long-term anticoagulation, and those in whom risk of reoperation is deemed to be unusually high.

Bioprosthetic Valves

Stented bioprosthetic valves have been designed and FDA-approved for use in the aortic position, but have been implanted extensively in the pulmonary position. The most commonly utilized xenograft valves are the porcine and bovine pericardial valves. Data from performance in the aortic position suggests that bovine pericardial valves are more durable than porcine valves, but this difference has not been demonstrated in the pulmonary position.33,34 Calcification is the mode of failure of bioprosthetic valves in the aortic position, and several manufacturers have developed anticalcification treatment processes to limit this complication. In a retrospective review of 229 pulmonary valve implantations at Children’s Hospital Boston, no differences in freedom from structural valve deterioration could be found between several bioprosthetic valve types at short-term follow-up, with freedom from reintervention of approximately 94% at 5 years.
Considerations for Choice of Prosthesis

For the neonate or infant undergoing valved conduit placement, homografts and bovine jugular vein grafts are the only options. Factors to consider include anticipated pulmonary artery pressures and nature of concomitant operation. In neonates and infants with normal pulmonary artery pressures, several studies have shown superior durability of pulmonary homografts compared with aortic homografts and bovine jugular vein grafts. Yet other studies have demonstrated similar freedom from reintervention between bovine jugular vein graft and homografts. However, these studies group pulmonary and aortic homografts together for this analysis, which prevents comparison of bovine jugular vein graft to pulmonary homograft. If reoperation is planned within a short time interval as a part of staged repair strategy, implantation of a low-cost but less durable conduit may be acceptable. In the presence of elevated pulmonary pressures, pulmonary homografts and bovine jugular vein grafts are at an increased risk of pseudoaneurysm formation, and thus aortic homografts are preferred. When the central pulmonary arteries are absent or hypoplastic, use of a bifurcating pulmonary or aortic homograft instead of bovine jugular vein graft simplifies reconstruction. The practice of implanting an oversized homograft into neonates and small children to increase the time to replacement has been challenged by several studies that have found that homograft oversizing does not improve conduit longevity, and may even result in decreased longevity in children.

For children, adolescents, and adults, the options for prosthesis include synthetic conduits, stented prosthetic valves, and homografts. For larger conduits (> 19 mm) durability of the prosthetic valve within a Dacron conduit appears to be superior to that of homografts. Thus, implantation of a stented pericardial or pericardial valve within the native outflow tract or conduit is the preferred method for this age group. There is very little data to suggest that valve type or method of implantation (native outflow vs Dacron conduit) impacts durability, although one study reported that a pericardic valve within Dacron conduit was associated with accelerated deterioration compared with the pericardial or pericardial valve implanted into native RVOT.

Conclusion

In summary, options for RVOT reconstruction vary by age group. Risk factors for early structural valve deterioration include young age at operation and non-Ross operation for most prostheses. In neonates and infants, aortic homografts are preferred only in patients with elevated pulmonary artery pressures. In older children and adults, prosthetic valve reconstruction is preferred over homograft. Conduit oversizing may be associated with accelerated valve deterioration, but further investigation is necessary to confirm this finding.