27% and 48% at 10 and 15 years, respectively. If the median time to reintervention was 17.7 years in the current study, one has to wonder whether reintervention in some patients may have been delayed and if they would have benefited with earlier reintervention.

In conclusion, the authors present a large retrospective review of pulmonary bioprosthesis in children and young adults. They confirm that younger patients, smaller valves, and certain valve types are at risk of earlier reintervention. Although adult patients fared better with regard to reintervention, given the young age at time of intervention for these adult patients, even a median time of 17.7 years to intervention necessitates that patients will need potentially multiple valve procedures in their lifetime. This underscores the importance of evaluation strategies, including bioprosthetic valve dysfunction, for patients with

pulmonary valve disease to delineate the most appropriate valve and time for surgical or transcatheter intervention.

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See Article page 345.

Commentary: In pursuit of the perfect pulmonary valve....

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Improved surgical outcomes for congenital heart disease have resulted in a population of patients with residual cardiac lesions that must be addressed later in life. The most common is right ventricular outflow tract (RVOT) stenosis or regurgitation that necessitates RVOT reconstruction, usually requiring implantation or replacement of the pulmonary valve (PVR). In an ideal world, the perfect pulmonary valve would be implanted via a minimally invasive

A new-generation bovine pericardial valve in the right ventricular outflow tract.

CENTRAL MESSAGE

The pursuit for the perfect pulmonary valve, which is both durable and easy to implant and maintain, has yet to bear fruit.

procedure, last forever, and not require anticoagulation. Such a perfect valve does not exist. What does exist is a plethora of suboptimal alternatives. Although some reports have shown excellent durability,¹ homografts and xenografts have limited long-term freedom from reintervention in the majority of studies. Mechanical valves in the low-pressure pulmonary circulation demonstrate increased thrombosis rates despite adequate and difficult anticoagulation. For these reasons, the most common choice for PVR is one of the many types of bioprosthetic valves.

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Disclosures: The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Received for publication Aug 12, 2020; revisions received Aug 12, 2020; accepted for publication Aug 13, 2020; available ahead of print Aug 15, 2020.

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J Thorac Cardiovasc Surg 2021;161:365-7

0022-5223/\$36.00

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<https://doi.org/10.1016/j.jtcvs.2020.08.036>

FIGURE 1. Chest radiograph demonstrating a new-generation bovine pericardial valve in the right ventricular outflow tract.

By opting for a bioprosthetic valve, one accepts the reality that all bioprosthetic valves eventually fail and will require reintervention. Numerous studies have examined the longevity of bioprosthetic valves following PVR in an attempt to identify risk factors associated with failure. In this issue of the *Journal*, Baird and colleagues² present outcomes of a multi-institutional cohort of more than 1200 patients with PVR. And, as demonstrated in previous studies, they report that less than two-thirds of the valves function adequately at 10 years following PVR. Valve failure can be related to technical, patient-related, and prosthesis-related factors. Whereas the surgical approach to PVR is fairly standard, studies have suggested that the orientation or location of the valve in the RVOT may alter flow dynamics, and thereby, valve durability. Younger patient age is a well-known risk factor for valve degeneration, again confirmed in the current analysis.² Somatic overgrowth in younger patients would render an otherwise functional valve stenotic. In addition, it has been suggested that the more aggressive immune-mediated reaction seen in younger age group accelerates structural valve deterioration. For a given age of the patient, valves in the native RVOT or in the orthotopic position tend to last longer. Prosthesis-related factors that may impact valve durability include the presence of a stented ring, and the origin of the valve tissue. The 2 major tissue sources of bioprosthetic valves are bovine pericardium and porcine heart valve. Baird and colleagues² report that the Sorin valve with bovine pericardium mounted outside the stent frame had high reintervention rates following PVR, similar to failure of this valve in the aortic position.³ Although the porcine St Jude valve is reported to have had similar longevity to the Sorin valve in this study, the St Jude valve was implanted in only 4% of patients, which questions the reliability of this conclusion. In fact, another recent report in the *Journal*

from Kwak and colleagues⁴ reported better reintervention profile for the porcine Hancock valve compared with pericardial valve over a median follow-up of 10.5 years. Given the substantial practice-pattern differences, not the least of which surrounds the variable use of antiplatelet and anticoagulant agents, the jury is still out on which bioprosthetic valve is preferable for PVR.

A key problem inherent to retrospective valve studies is that valve outcomes are often outpaced by technological progress. In the context of PVR, every available bioprosthesis was initially designed for the left heart and borrowed for use in the RVOT based upon potentially flawed assumptions that performance should remain equivalent despite the drastically different anatomy and physiology. Driven by performance in the left heart, valve construction and leaflet tissue processing are constantly modified. In that regard, the current iteration of the bovine pericardial valve with an expandable frame (INSPIRIS; Edwards Lifesciences Corp, Irvine, Calif; Figure 1) was not represented in the present study. And, to be meaningful, studies need to follow patients for over a decade to capture actual valve outcomes. Despite the actuarial analyses presented, the median follow-up in the present study was under 4 years. Lastly, as percutaneous approaches to RVOT valves become more commonplace, the indications for reintervention will inevitably soften. To be generalizable, studies, in particular multi-institutional ones, should follow standard criteria for follow-up and reintervention.

Have we then lost the pursuit of the perfect pulmonary valve and are resigned to the fate of using currently available alternatives? Biomedical engineering will likely come to our rescue with novel solutions that are already in the horizon. The Xeltis valve (Xeltis, Eindhoven, Netherlands) uses a bioabsorbable polymer matrix designed to enable endogenous tissue restoration, allowing the patient's own cells to gradually replace the polymer with native tissue.⁵ Because the valve and conduit can potentially become native tissue, there should be no immune reaction and the valve should grow with the patient, as any native tissue would. The performance of this valve is currently under evaluation in clinical studies. An alternative approach has used a balloon-expandable synthetic bileaflet valve.⁶ The inert synthetic material is expected to avoid an immune response and the stent-loaded design facilitates serial expansions to keep up with somatic growth. It is innovations such as these that continue to fuel hope and keep our pursuit alive.

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