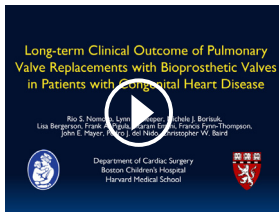


CONCLUSIONS

Bioprosthetic PVR in patients with CHD has acceptable short-term outcomes, despite younger patients having more reinterventions. Independently of age, different valve types have different rates of reintervention. These differences in patient age and valve type may be important in valve selection and follow-up.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: http://webcast.aats.org/2015/Video/Tuesday/04-28-15_4E_0905_Nomoto.mp4.



Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

References

- Gengsakul A, Harris L, Bradley TJ, Webb GD, Williams WG, Siu SC, et al. The impact of pulmonary valve replacement after tetralogy of Fallot repair: a matched comparison. *Eur J Cardiothorac Surg*. 2007;32:462-8.
- Warner KG, O'Brien PK, Rhodes J, Kaur A, Robinson DA, Payne DD. Expanding the indications for pulmonary valve replacement after repair of tetralogy of Fallot. *Ann Thorac Surg*. 2003;76:1066-71.
- Flameng W, Rega F, Vercauteren M, Herijgers P, Meuris B. Antimineralization treatment and patient-prosthesis mismatch are major determinants of the onset and incidence of structural valve degeneration in bioprosthetic heart valves. *J Thorac Cardiovasc Surg*. 2014;147:1219-24.
- Zhang X, Loberiza FR, Klein JP, Zhang MJ. A SAS Macro for estimation of direct adjusted survival curves based on a stratified Cox regression model. *Comput Methods Programs Biomed*. 2007;88:95-111.
- Zubairi R, Malik S, Jaquiss RD, Imamura M, Gossett J, Morrow WR. Risk factors for prosthesis failure in pulmonary valve replacement. *Ann Thorac Surg*. 2011;91:561-5.
- Caldarone CA, McCrindle BW, Van Arsdell GS, Coles JG, Webb G, Freedom RM, et al. Independent factors associated with longevity of prosthetic pulmonary valves and valved conduits. *J Thorac Cardiovasc Surg*. 2000;120:1022-31.
- Albert JD, Bishop DA, Fullerton DA, Campbell DN, Clarke DR. Conduit reconstruction of the right ventricular outflow tract: lessons learned in a twelve-year experience. *J Thorac Cardiovasc Surg*. 1993;106:228-36.
- Baskett RJ, Ross DB, Nanton MA, Murphy DA. Factors in the early failure of cryopreserved homograft pulmonary valves in children: preserved immunogenicity? *J Thorac Cardiovasc Surg*. 1996;112:1170-9.
- Rajani B, Mee RB, Ratliff NB. Evidence for rejection of homograft cardiac valves in infants. *J Thorac Cardiovasc Surg*. 1998;115:111-7.
- Saleeb SF, Newburger JW, Geva T, Baird CW, Gauvreau K, Padera RF, et al. Accelerated degeneration of a bovine pericardial bioprosthetic aortic valve in children and young adults. *Circulation*. 2014;130:51-60.
- Baskett RJ, Ross DB, Nanton MA, Murphy DA. Factors in the early failure of cryopreserved homograft pulmonary valves in children: preserved immunogenicity? *J Thorac Cardiovasc Surg*. 1996;112:1170-9.
- Rajani B, Mee RB, Ratliff NB. Evidence for rejection of homograft cardiac valves in infants. *J Thorac Cardiovasc Surg*. 1998;115:111-7.
- Zubairi R, Malik S, Jaquiss RD, Imamura M, Gossett J, Morrow WR. Risk factors for prosthesis failure in pulmonary valve replacement. *Ann Thorac Surg*. 2011;91:561-5.
- Grunkemeier GL, Li HH, Naftel DC, Starr A, Rahimtoola SH. Long-term performance of heart valve prostheses. *Curr Probl Cardiol*. 2000;25:73-154.
- Chikwe J, Filsoufi F. Durability of tissue valves. *Semin Thorac Cardiovasc Surg*. 2011;23:18-23.
- Borger MA, Ivanov J, Armstrong S, Christie-Hrybinsky D, Feindel CM, David TE. Twenty-year results of the Hancock II bioprosthesis. *J Heart Valve Dis*. 2006;15:49-55.
- McClure RS, Narayanasamy N, Wiegerinck E, Lipsitz S, Maloney A, Byrne JG, et al. Late outcomes for aortic valve replacement with the Carpentier-Edwards pericardial bioprosthesis: up to 17-year follow-up in 1,000 patients. *Ann Thorac Surg*. 2010;89:1410-6.
- Walley VM, Rubens FD, Campagna M, Pipe AL, Keon WJ. Patterns of failure in Hancock pericardial bioprostheses. *J Thorac Cardiovasc Surg*. 1991;102:187-94.
- Lee C, Park CS, Lee CH, Kwak JG, Kim SJ, Shim WS, et al. Durability of bioprosthetic valves in the pulmonary position: long-term follow-up of 181 implants in patients with congenital heart disease. *J Thorac Cardiovasc Surg*. 2011;142:351-8.
- Shinkawa T, Anagnostopoulos PV, Johnson NC, Watanabe N, Sapru A, Azakie A. Performance of bovine pericardial valves in the pulmonary position. *Ann Thorac Surg*. 2010;90:1295-300.
- Chen PC, Sager MS, Zurakowski D, Pigula D, Baird CW, Mayer JE, et al. Younger age and valve oversizing are predictors of structural valve deterioration after pulmonary valve replacement in patients with tetralogy of Fallot. *J Thorac Cardiovasc Surg*. 2012;143:352-60.
- McKenzie ED, Khan MS, Dietzman TW, Guzmán-Pruneda FA, Samayoa AX, Liou A, et al. Surgical pulmonary valve replacement: a benchmark for outcomes comparisons. *J Thorac Cardiovasc Surg*. 2014;148:1450-3.
- Butany J, Feng T, Luk A, Law K, Suri R, Nair V. Modes of failure in explanted Mitroflow pericardial valves. *Ann Thorac Surg*. 2011;92:1621-7.
- Geva T. Indications for pulmonary valve replacement in repaired tetralogy of Fallot: the quest continues. *Circulation*. 2013;128:1855-7.
- Schubert SA, Myers JL, Kunselman AR, Clark JB. Early outcomes of pulmonary valve replacement with the Mitroflow bovine pericardial bioprosthesis. *Ann Thorac Surg*. 2015;99:1692-9.
- Laux D, Vernat M, Lambert V, Gouton M, Ly M, Peyre M, et al. Atrioventricular valve regurgitation in univentricular hearts: outcomes after repair. *Interact Cardiovasc Surg*. 2015;20:622-30.
- Rossano JW, Grenier MA, Dreyer WJ, Kim JJ, Price JF, Jefferies JL, et al. Effect of body mass index on outcome in pediatric heart transplant patients. *J Heart Lung Transplant*. 2007;26:718-23.

Key Words: congenital, pulmonary valve, replacement, bioprosthetic

Discussion



Dr. J. Brown (Indianapolis, Ind). PVR is an extremely important topic for us to be discussing, particularly as it pertains to CHD and adults with CHD, in that the pulmonary valve, at least at our institution, is 5 times more in need of replacement than the aortic valve in children. Rio S. Nomoto, a third-year medical student at Tufts, and her colleagues from Boston have done a phenomenal job in analyzing and presenting a large series of patients requiring PVR whose mean age was 21 years; however, half of their patients were aged less than 18 years.

This analysis was done over 18 years. Seventy percent of the patients had the diagnosis of TOF, and 70% of the patients previously had a transannular patch. Pulmonary regurgitation was the primary indication for PVR in

approximately 80% of their patients. Their early and late mortality was extremely low, at 3%. And again, echocardiogram follow-up was available in approximately 70% of the patients receiving PVR. Echocardiogram evidence of structural valve dysfunction was present on echocardiogram in only 60% of their patients, with pulmonary stenosis being twice as common as pulmonary regurgitation for the definition of structural valve deterioration, and again, only 44 patients have required reintervention to date.

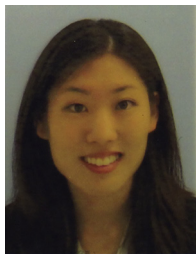
Three pericardial stented valves were compared with a small group of porcine valves. Children aged less than 18 years had a 5-fold higher incidence of reintervention than children aged more than 18 years. Some 100% of children aged less than 6 years were predicted to require PVR on a Kaplan–Meier curve, and in children aged less than 12 years, the need for PVR is predicted to be 75% at 10 years. Obviously, older children fared better.

Again, the only independent risk factor for reoperation was the valve type, with a Sorin Mitroflow (Milan, Italy) and untreated bovine pericardial valves having the greatest need for reintervention. The Sorin valve was the most common and the most recently used valve substitute, which they started using in 2006, and again, porcine valves were used in only 22 patients.

I have a few comments and questions. First, this was an excellent presentation and a well-written article that they provided for me to review. Their statistical analysis was extensive and exhaustive. This article confirms the statement that has been made over and over again that PVR remains a weak link in our management of CHD, particularly in children aged less than 12 years. Your article, like others, has demonstrated that the failure mode for pericardial valves is stenosis, being twice as common as regurgitation.

Our center has minimal experience with bovine pericardial valves in the pulmonary position, and we have favored biologic stentless valves in a series of more than 1200 patients over the past 30 years, because I guess we thought that the stentless valve had a bigger effective orifice area and appeared to be more durable than stented valves, at least in our experience.

How did you define prosthetic valve dysfunction or failure in your series? What was the gradient across the stentless valves at the time of reintervention?



Rio S. Nomoto (*Boston, Mass.*). It was difficult in this study of more than 600 patients to define structural valve deterioration and, more specifically, the onset of deterioration. Therefore, we defined valve failure as reintervention, which is the primary outcome measure of the study. However, we do think it is

important to note that even when we looked at the latest echocardiogram obtained on each patient, only 16% had evidence of moderate or greater stenosis or regurgitation.

Dr Brown. What was the gradient across the valves? In the patients you had to reintervene in, what was the gradient that you use for the need for reintervention?

Rio S. Nomoto. I'm not sure exactly what the numbers are, the averages are, but the primary indication for reintervention was generally based on symptoms. Right ventricular outflow gradient and deterioration of the right ventricular function were also considered.

Dr Brown. Did you have a degree of pulmonary regurgitation that prompted you for reintervention? Did you use only echocardiography or magnetic resonance imaging (MRI) data comparing end-diastolic volumes as an indication for reoperation? Did you operate on asymptomatic patients who met a specific criteria?

Rio S. Nomoto. I think that would be different for each patient. So there would be cases in whom the echocardiogram would be more important than symptoms depending on the patient.

Dr Moon. Chris?



Dr C. Baird (*Boston, Mass.*). Most of these patients also had MRI scans, and indexed ventricular volume also played an important role in that.

Dr Brown? Well, because this Sorin Mitroflow was your most common valve used and the most recent pulmonary valve substitute, are you still using the Sorin Mitroflow for PVR?

Rio S. Nomoto. We have stopped using the Sorin Mitroflow valves and are following up on these patients more closely.

Dr Brown. Currently, what is your valve replacement of choice, particularly for children aged less than 12 years?

Rio S. Nomoto. In the youngest infant patients, we continue to use homografts when needed. For younger children with a large enough annulus for a stented valve, we have tended to use stented porcine valves, although admittedly, we have not defined a specific age cutoff for using porcine valves. In older children and younger adults, we are implanting the Edwards Magna Ease valve (Carpentier-Edwards, Irvine, Calif). However, recently we have begun implanting more stentless porcine valves.

Dr Brown. Because TOF included your largest patient population for PVR, have your surgeons changed their management of the RVOT at the time of initial repair? Dr Baird may want to tackle that one.

Dr Baird. We have changed this over time, and now we tend to try to spare more valves, and obviously we are not doing as many transannular patches. Does that answer your question?

Dr Brown. It does. Do you have any idea of what your incidence of transannular patching is for tetralogy currently?

Dr Baird. Very low, probably less than 10%.

Dr Brown. Do you have a hypothesis as to why 1 of the nontreated pericardial valves had the highest degree of structural valve degeneration and another untreated pericardial valve had the lowest?

Rio S. Nomoto. We have tried answering this question, but we do not have a definite answer. What this does suggest is that there is likely more than a single factor, such as the lack of antimicrobial treatments, involved in failure of these valves. Because both the CE Perimount valves and Magna valves (Irvine, Calif) have similar stent design, this might suggest that the stent plays an important role.

Dr Brown. Jeff Poynter, a Kirklin-Ashburn fellow, reported last year a multi-institutional series on PVRs in children aged less than 2 years and demonstrated that the bovine jugular valve had the best outcomes, at least in children aged less than 2 years. It turns out that the bovine jugular valve has been the valve replacement of choice at our place for the last 16 years. What is your experience thus far with the bovine jugular venous valve?

Rio S. Nomoto. We did not look at the bovine jugular vein valves and instead focused on the surgical reintervention in this study. However, we could in the future collaborate with the cardiologists to look at that data.

Dr Brown. I think what it points out is that this is an ongoing issue. We are still questing for a pulmonary valve that will last 20 years in a child or young adult, and we still don't have the answer. So we need a multi-institutional, much larger series of patients that will help us answer that question.



Dr E. Verrier (*Seattle, Wash*). Did you separate the age issue versus the size of the valve issue? So in many of these instances you can tailor a patch that will allow a certain size valve and therefore a different gradient, a different set of hemodynamics, and, at least certainly in comparison with the aortic position, a different outcome if you use a bigger valve. Over the years, have you seen a correlation between the size of that valve and its long-term durability and does that influence now how you approach these reoperations?

Dr Baird. That is an important question. Several years back, Dr Peter Chen published our experience, and what we found is that actually oversizing the valve led to

increased structural valve deterioration. So we generally try not to oversize the valves.

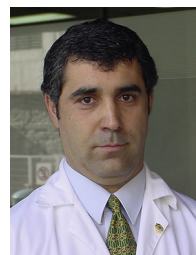
Dr Verrier. The only question that comes up, it is a little bit to the Tirone David operation, is does it have an impact if you then are going to go back in the older adult to put a transcatheter valve in the pulmonary position and does that affect your decision on what size of valve to put in now?

Dr Baird. It does, and it is important to note that if you put in too large a valve it makes it difficult right now do a transcatheter valve without stacking stents in there. So a 23 or a 25 valve may be the ideal valve for that at this time.

Dr J. Forbess (*Dallas, Tex*). Wonderful presentation. Over time you were clearly operating on younger and younger patients, but when you looked at the outcomes, the reintervention rate is a lot higher, and I was curious, how many of those younger patients were largely asymptomatic or completely asymptomatic and you were operating on the basis on right ventricular dimension data derived from MRI and those thresholds were developed from distinctly older patient data sets?

This is a question that has been worrying me. When parents bring me an 11-year-old who is completely asymptomatic but has an RV that by MRI criteria that are out there and being used by our field, the patient meets criteria for a valve replacement, but I know that that valve is not going to last that long, should we be observing some of those patients until they are done with their teen years, for instance, and then putting the valve in?

Dr Baird. So, Joe, I think your question, summarized, is should we be operating on these children sooner or later, and fundamentally over the last several years we have tended to operate sooner before the ventricles become too dilated, thinking that ultimately we can put a transcatheter valve in these later, but we would try to preserve ventricular function early.



Dr P. Becker (*Santiago, Chile*). What is your current policy regarding anticoagulation or platelets antiaggregation, and has this policy evolved over time?

Dr Baird. Generally we treat these patients with aspirin, which hasn't changed too much over time.