Long-Term Outcomes After Right Ventricular Outflow Tract Conduit Placement

Juthamas Hannarong, M.D., Teerapong Tocharoenchok, M.D.

Division of Cardiothoracic Surgery, Department of Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

ABSTRACT

Objective: Our aim was to report on the long-term outcomes of patients who underwent RV-PA conduit placement at our institute.

Materials and Methods: We retrospectively reviewed 407 RV-PA conduit placements from January 1997 to December 2018. The primary outcomes were freedom from and risk factor(s) for conduit re-operation. The secondary outcomes were survival, freedom from conduit dysfunction and conduit-related catheter intervention.

Results: Of all the included patients, 209 were male (51.4%) and the median age at the operation was nine years (IQR 6, 18 years). The most commonly used conduit types were bovine jugular vein conduit (125, 30.7%), pulmonary homograft (122, 30.0%), and aortic homograft (76, 18.7%). The median follow-up time was 5.1 years (IQR 0.9, 9.2 years). The overall survival was 92.2% at 5 years. Freedom from re-operation was 95.4% and 84.2%, at 5 and 10 years. Factors related to conduit reoperation were age at operation less than 1 year, diagnosis rather than pulmonary atresia or stenosis, conduit size less than 18 mm, and conduit z-score greater than 3 (all $p<0.01$). In multivariate analysis, a significant contributing factor for re-operation was small conduit size (13 mm or smaller; HR 6.87 (95%CI 2.36, 20.01); $p<0.001$, 14–17 mm; HR 3.20 (95%CI 1.28, 8.00); $p=0.013$). Freedom from conduit dysfunction was 84.4 and 61.6% at 5 and 10 years. Freedom from conduit intervention was 94.4% and 89.3% at 5 and 10 years.

Conclusion: Our study showed that patients had excellent survival with acceptable freedom from re-operation despite deteriorated conduit function. Small conduit size is associated with re-operation.

Keywords: Allografts; heterografts; reoperation; survival analysis; ventricular outflow obstruction (Siriraj Med J 2023; 75: 473-480)

Presentation: The Asian Society for Cardiovascular & Thoracic Surgery (ASCVTS) 2020, Chiang Mai, Thailand, 7-10 February 2020

INTRODUCTION

The placement of a valved conduit between the right ventricle (RV) and pulmonary artery (PA) is a crucial part of congenital heart defect repairs. It is usually performed in patients with discontinuity between the right ventricle and branch pulmonary arteries, or in patients with significant pulmonary stenosis or insufficiency. Despite the initial success of these procedures, long-term outcomes are affected by hemodynamic sequelae of conduit dysfunction with subsequent need for re-intervention and re-operation.[1,2] Several options are available, and the advantages, limitations, and associated factors of each have previously been described.[1,3,4] However, comparison of different valved conduit materials and sizes in the right ventricular outflow position in large cohorts is scarce.

Corresponding author: Teerapong Tocharoenchok
E-mail: Teerapong.toc@mahidol.ac.th
Received 31 January 2023 Revised 13 April 2023 Accepted 14 April 2023
ORCID ID:http://orcid.org/0000-0001-9983-3915
https://doi.org/10.33192/smj.v75i6.261096

All material is licensed under terms of the Creative Commons Attribution 4.0 International (CC-BY-NC-ND 4.0) license unless otherwise stated.

Many types of conduit material have been used at our institute for decades.[5] The placement of homografts, xenografts and institutional-developed synthetic valved conduits in recent years has made up one of the largest registries in this region with high follow-up rates at our grown-up congenital heart clinic.

Our objectives were to describe long-term outcomes of right ventricular-pulmonary artery (RV-PA) conduit placement at our institute and to identify factors associated with conduit re-operation.

MATERIALS AND METHODS

Study design

We retrospectively examined clinical outcomes of all RV to PA conduit placements in congenital cardiac defects between January 1997 and December 2018 at the Faculty of Medicine Siriraj Hospital, Thailand. Patients with anatomic left ventricle to PA conduit and patients with inaccessible records were excluded. This study was approved by the Siriraj Institutional Review Board (COA no. Si 004/2019). Patient consent was waived as there were minimal risks for the subjects.

Study parameters and outcomes

Study parameters included demographics, primary cardiac diagnosis and surgical indications, previous operation(s), type and size of the conduit, concomitant procedure(s), postoperative clinical outcomes, re-intervention and re-operation, and status at the last follow-up.

Conduit function was assessed using transthoracic echocardiography, cardiac magnetic resonance imaging, and/or cardiac catheterization performed by paediatric cardiologists per standard guidelines. Conduit dysfunction was defined by evidence of aneurysmal change, conduit dehiscence, moderate or greater valve incompetence and/or moderate or greater conduit stenosis. Conduit re-operation was indicated in symptomatic patients with moderate or severe conduit stenosis or regurgitation, in an asymptomatic patient with severe conduit stenosis or regurgitation accompanied by right ventricular dysfunction or dilatation, and in a patient with conduit aneurysm or dehiscence.

The primary outcomes were freedom from conduit reoperation and independent factors associated with it. Secondary outcomes included overall survival, freedom from conduit dysfunction, and transcatheter intervention of the conduit.

Statistical analysis

Data was described in frequencies, medians with interquartile ranges, or means with standard deviations. The variables between the two study groups were compared using independent T-test samples or Pearson Chi-Square test (or non-parametric equivalents where appropriate), with statistical significance defined as a p-value of less than 0.05. The continuous variables (age, conduit size, conduit Z score, operative era) and categorical variables with multiple subcategories (morphologic indication, conduit type, type of operation) were grouped into no more than three subgroups for analysis. Survival rates were calculated using the Kaplan–Meier method and the log-rank test for adjusting the differences between subgroups. The Cox proportionate hazard model was used to determine both univariable and multivariable relationships between time-to-conduit re-operation and associated variables. Data analysis was carried out using SPSS™ software version 20.0 (SPSS Inc., IBM Company, Chicago, Illinois, USA).

RESULTS

Baseline characteristics (Table 1 and study flow diagram)

A total of 415 RV to PA conduit placements were performed in 382 patients during the study period with 8 of them being excluded from the analysis due to a lack of follow-up data. Of the remaining 407 conduits, the median age at the time of conduit placement was 9 years (interquartile range 6 to 18 years) with an average conduit size of 20.56±4.15 mm.

Operative detail (Table 1 and Fig 1)

Indications for surgery were pulmonary atresia or stenosis in 341 patients (83.8%) and truncus arteriosus in 56 patients (13.8%). A total of 289 conduits (71.0%) were used as part of the primary total repair. The conduit material in 201 patients (49.4%) was a homograft and xenograft in 185 patients (45.5%). The trend of conduits used has changed over time as homografts were mostly used in the 1990s and 2000s, but bovine jugular vein conduits have become more common since 2011.

Overall outcomes (Fig 2)

Of the 407 patients with available follow-up data, the median follow-up duration was 5.1 years (interquartile range 0.9 to 9.2, maximum 23.3 years), with 33 deaths (8.1%), 103 instances of conduit dysfunction (25.3%), 26 conduit transcatheter interventions (6.4%), and 44 conduit re-operations (10.8%).

The overall survival was 92.2% at 5 years and remained plateaued over 20 years. The overall freedom from reoperation was 95.4% and 84.2% at 5 years and 10 years, respectively. Overall freedom from transcatheter

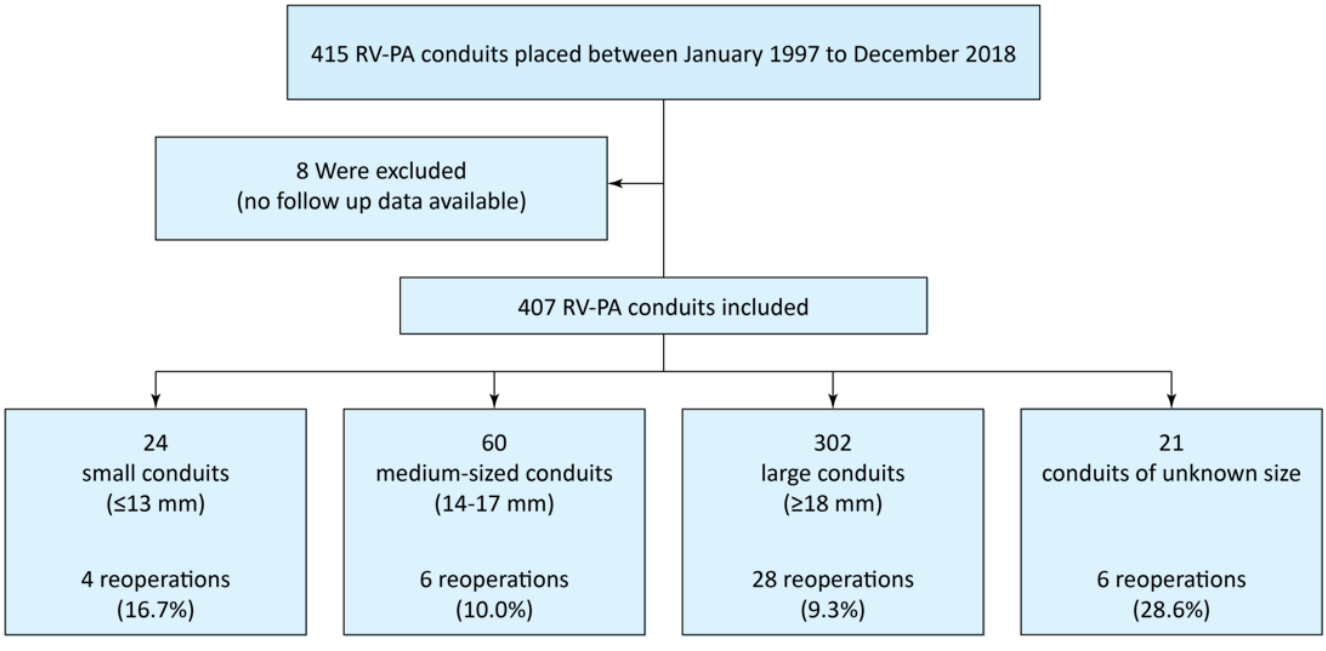
TABLE 1. Baseline characteristics and operation details.

Demographic data (n=407)	N	%	Number (%)		P-value
			Re-operation	No re-operation	
Sex					0.159
Male	209	51.4	27 (12.9)	182 (87.1)	
Female	198	48.6	17 (8.6)	181 (91.4)	
Age (year) Median 9 (IQR 6,18)					0.222
<1	42	10.3	8 (19)	34 (81)	
1–10	184	45.2	18 (9.8)	166 (90.2)	
>10	181	44.5	18 (9.9)	163 (90.1)	
Indication for conduit placement					**0.026**
PA group	164	40.3	14 (8.5)	150 (91.5)	
PS group	177	43.5	18 (10.2)	159 (89.8)	
Truncus arteriosus	56	13.8	12 (21.4)	44 (78.6)	
Ross procedure	8	2.0	0 (0)	8 (100)	
Conduit dysfunction	1	0.2	0 (0)	1 (100)	
Other	1	0.2	0 (0)	1 (100)	
Surgery type					0.820
Primary conduit placement	289	71.0	33 (11.4)	256 (88.6)	
Conduit placement after total repair	73	17.9	7 (9.6)	66 (90.4)	
Conduit replacement	45	11.1	4 (0.8)	41 (99.2)	
Conduit position					0.504
Heterotopic	278	68.3	32 (11.5)	246 (88.5)	
Orthotopic	129	31.7	12 (9.3)	117 (90.7)	
Conduit type					**<0.001**
Aortic homograft	76	18.7	12 (15.8)	64 (84.2)	
Pulmonic homograft	122	30.0	18 (14.8)	104 (85.2)	
Edward porcine valved conduit	4	1.0	0 (0)	4 (100)	
Stentless porcine valve conduit	40	9.8	3 (7.5)	37 (92.5)	
Hancock valve conduit	11	2.7	5 (45.5)	6 (54.5)	
Bovine jugular vein conduit	125	30.7	3 (2.4)	122 (97.6)	
Goretex tube with 0.1 mm GoreTex trileaflet valve	15	3.7	0 (0)	15 (100)	
Autologous pericardial tube with pericardial valve	2	0.5	1 (50)	1 (50)	
Freestyle porcine aortic root valve	3	0.7	0 (0)	3 (100)	
Dacron graft	2	0.5	0 (0)	2 (100)	
Unspecified homograft	3	0.7	0 (0)	3 (100)	
Unspecified conduit	4	1.0	2 (50)	2 (50)	
Conduit materials					**0.002**
Homograft	201	49.4	30 (14.9)	171 (85.1)	
Xenograft	185	45.5	12 (6.5)	173 (93.5)	
Synthetic	17	4.2	0 (0)	17 (100)	
Other	4	1.0	2 (50)	2 (50)	

TABLE 1. Baseline characteristics and operation details. (Continued)

Demographic data (n=407)	N	%	Number (%)		P-value
			Re-operation	No re-operation	
Conduit size (mm) Mean 20.56 (SD 4.15)					**0.042**
Small size (≤ 13 mm)	24	5.9	4 (16.7)	20 (83.3)	
Medium size (14–17 mm)	60	14.7	6 (10.0)	54 (90.0)	
Large size (≥ 18 mm)	302	74.2	28 (9.3)	274 (90.7)	
Missing data	21	5.2	6 (28.6)	15 (71.4)	
Conduit z-score Median 0.90 (IQR 0.07,1.61)					**0.001**
<1	207	50.9	13 (6.3)	194 (93.7)	
1-3	151	37.1	18 (11.9)	133 (88.1)	
>3	26	6.4	7 (26.9)	19 (73.1)	
Missing data	23	5.7	6 (26.1)	17 (73.9)	

PA group = pulmonary atresia group; PS group = pulmonary stenosis group;
Homograft group = aortic homograft, and pulmonic homograft;
Xenografts group = Edward porcine valved conduit, Stentless porcine valve conduit, Hancock valve conduit, Freestyle porcine aortic root valve, and bovine jugular vein conduit;
Synthetic group = GoreTex tube with 0.1 mm GoreTex trileaflet valve



Study flow diagram

intervention was 94.4% at 5 years and 89.3% at 10 years. The overall freedom from conduit dysfunction was 84.4% at 5 years, and 61.6% at 10 years.

Factor associated with conduit reoperations (Table 2 and Fig 3)

In univariate analysis, the infantile age group witnessed the worst freedom from reoperation (67.1% at 10 years versus 84.6% for 1 – 10 years and 86.9% for the older than 10 years group). Diagnosis of truncus arteriosus was also associated with reoperation (40.6% at 10 years versus 12.5% for pulmonary atresia and pulmonary stenosis group). The conduit size of 13 mm or smaller had the lowest freedom from reoperation (36.7% at 10 years versus 61.5% for 14 – 17 mm and 88.5% for 18 mm or larger).

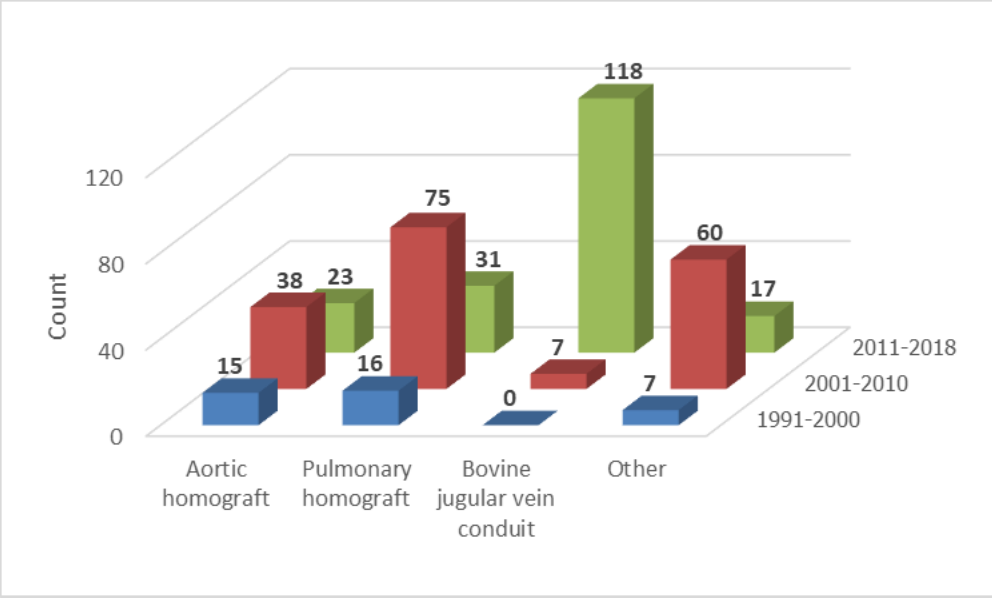


Fig 1. Type of conduit by operation era

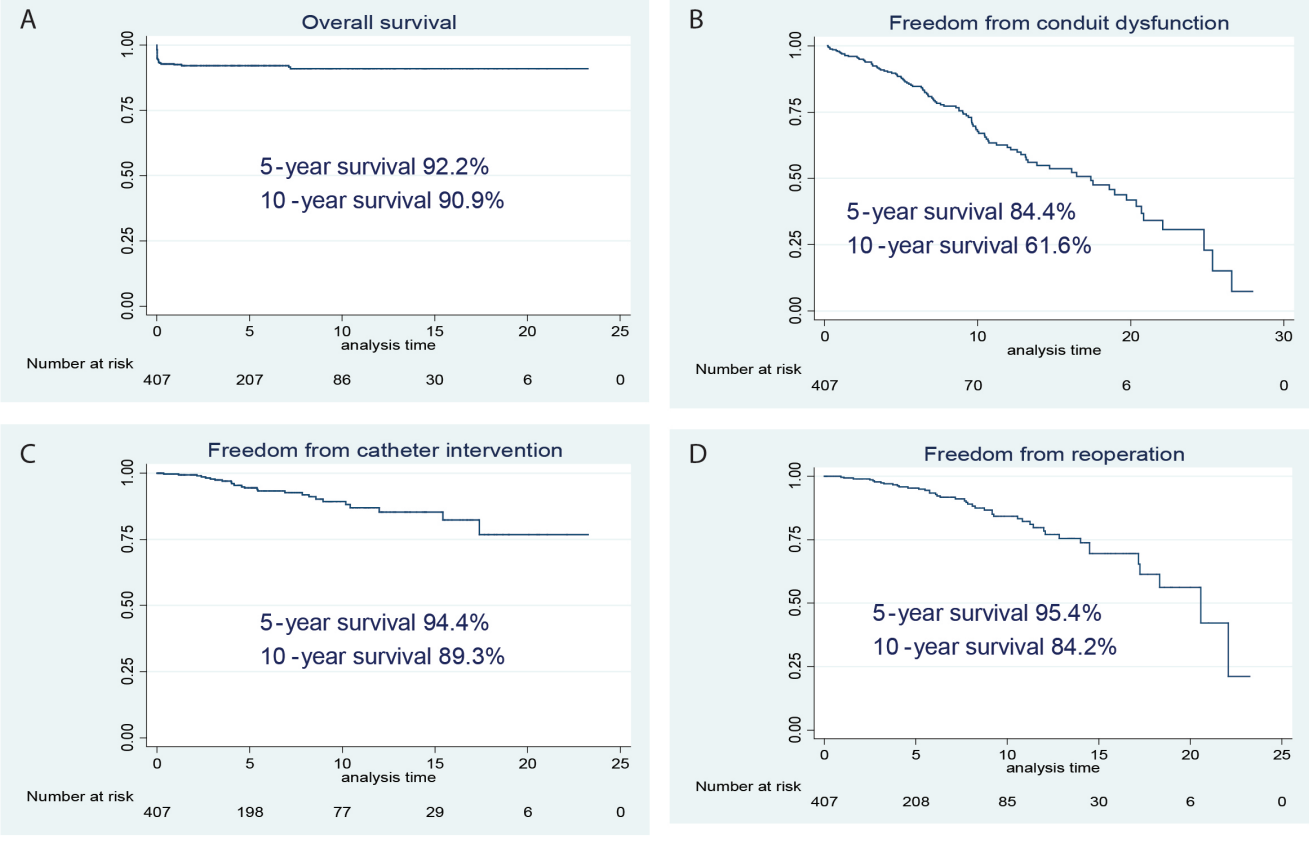


Fig 2. Overall long-term outcomes

Only having small- or medium-sized conduits remained significant in the multivariate model at an adjusted hazard ratio of 6.87 (95%CI 2.36, 20.1, p<0.001) and 3.20 (95%CI 1.29, 8.00, p=0.013) reference to large-sized conduits.

DISCUSSION

We found that even with good long-term survival outcomes, most RV to PA conduits deteriorated over time and at some point, would require re-intervention and/or re-operation. The smaller the implanted conduit, the higher risk for re-operation, with up to a 6.87 times adjusted hazard ratio when compared with large conduits.

This is consistent with studies from other groups that demonstrated small conduits as an independent risk for conduit re-operation.[2,4,6,7] Other risk factors for

TABLE 2. Factors associated with conduit re-operation.

Factors	Crude HR	Univariate (95%CI)		P-value	Adjusted HR	Multivariate (95%CI)		P-value
Sex								
Male	1.681	0.91	3.103	0.097				
Female	1							
Age (year)								
<1 year	3.627	1.55	8.488	**0.003**	0.553	0.101	3.034	0.496
1–10 years	0.977	0.505	1.888	0.944	0.666	0.281	1.577	0.355
>10 years	1				1			
Primary diagnosis								
PA group	1				1			
PS group	1.059	0.52	2.155	0.875	0.932	0.428	2.028	0.859
Others	4.154	1.903	9.069	**<0.001**	1.62	0.393	6.677	0.504
Surgery Type								
Primary conduit placement	1							
Conduit placement post-total repair	1.035	0.45	2.378	0.936				
Conduit replacement	1.483	0.518	4.244	0.463				
Position of Conduit								
Heterotopic	1.127	0.564	2.255	0.735				
Orthotopic	1							
Type of conduit								
Aortic homograft	1.284	0.333	4.942	0.717				
Pulmonic homograft	1.207	0.331	4.396	0.776				
Bovine jugular vein conduit	1							
Material of conduit								
Homograft	1							
Xenografts	1.019	0.493	2.11	0.959				
Conduit size								
Small (≤13 mm)	6.725	2.306	19.611	**<0.001**	6.869	2.359	20.004	**<0.001**
Medium (14-17 mm)	3.197	1.278	7.993	**0.013**	3.204	1.283	8	**0.013**
Large (≥18 mm)	1				1			
Conduit z-score								
<1	1				1			
1–3	1.321	0.645	2.707	0.447	1.096	0.495	2.429	0.821
>3	3.033	1.191	7.721	**0.02**	2.435	0.661	8.978	0.181

PA group = pulmonary atresia group; PS group = pulmonary stenosis group;
Homograft group = aortic homograft, and pulmonic homograft;
Xenografts group = Edward porcine valved conduit, Stentless porcine valve conduit, Hancock valve conduit, Freestyle porcine aortic root valve, and bovine jugular vein conduit;

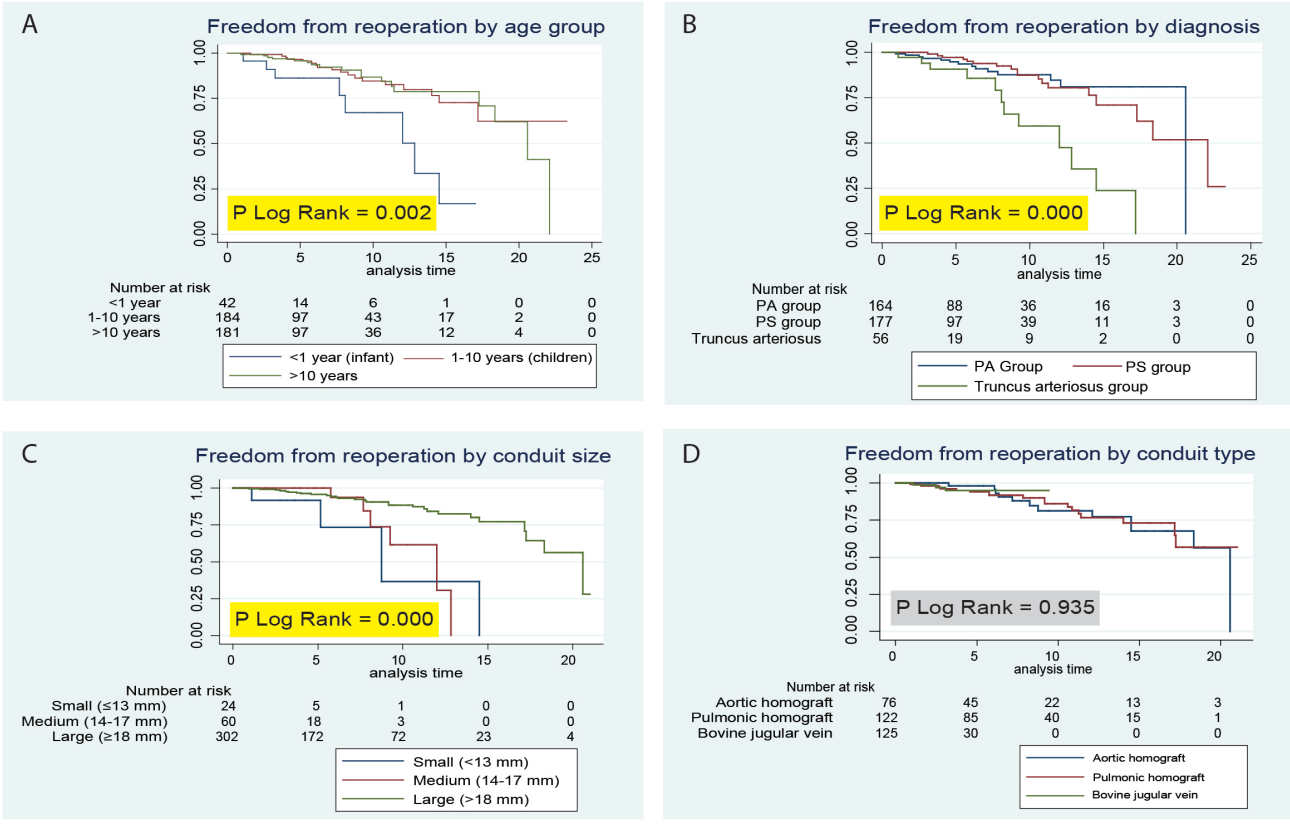


Fig 3. Freedom from conduit re-operation

re-operation include younger age and diagnosis of truncus arteriosus in other studies[4,8] failing to achieve statistical significance in our multivariate analysis. The diagnosis of truncus arteriosus and younger age at conduit placement could easily confound the outcomes as both almost always need small conduits. The type of conduit and position of conduit (i.e. orthotopic versus heterotopic) are associated with conduit longevity in other studies[9,10] showed no difference in this study. The reason for these findings might be due to the limited follow-up time and heterogeneity of our patients. One interesting finding in the univariate model is that oversizing the conduit (z score of more than 3) seems to jeopardise the durability of the conduit as opposed to lengthening it. This finding is consistent with other studies.[11-13]

Our study is by far the largest series of RV to PA conduit in this region with a long follow-up time of up to 20 years and contains multiple conduit types. However, several limitations exist, such as recent advances in conduit re-intervention, especially transcatheter pulmonary valve implantation,[14] which allows deferment or even avoidant re-operation that may lead to an overestimation of the longevity of conduits implants in the recent era. Also, despite evidence in several studies,[15,16] the durability of polytetrafluoroethylene over other biologic conduits cannot be demonstrated in this cohort as it was just introduced at our institute in 2018.[17] A further study is warranted to compare this promising conduit with the pulmonary homograft.

CONCLUSION

Our study demonstrates excellent long-term survival following RV to PA conduit placement with acceptable freedom from re-operation and catheter re-intervention despite the deterioration of conduit function over time. The use of a small conduit is an independent risk factor for conduit re-operation.

ACKNOWLEDGEMENTS

We acknowledge the contributions of Nerisa Thornsiri from the clinical epidemiology unit, who performed statistical analysis of this study.

Declarations

Funding: The research received no specific grants from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicting interests: None declared

Abbreviations

PA = pulmonary artery
PA group = pulmonary atresia group
PS group = pulmonary stenosis group

REFERENCES

1. Dearani JA, Danielson GK, Puga FJ, Schaff HV, Warnes CW, Driscoll DJ, et al. Late follow-up of 1095 patients undergoing operation for complex congenital heart disease utilizing pulmonary ventricle to pulmonary artery conduits. Ann Thorac Surg 2003;75(2):399-410; discussion 410-1. DOI: 10.1016/s0003-4975(02)04547-2.
2. Romeo JLR, Mokhles MM, van de Woestijne P, de Jong P, van den Bosch A, van Beynum IM, et al. Long-term clinical outcome and echocardiographic function of homografts in the right ventricular outflow tractdagger. Eur J Cardiothorac Surg 2019;55(3):518-26. DOI: 10.1093/ejcts/ezy265.
3. 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(6):1022-30; discussion 1031. DOI: 10.1067/mtc.2000.110684.
4. Brown JW, Ruzmetov M, Rodefeld MD, Vijay P, Turrentine MW. Right ventricular outflow tract reconstruction with an allograft conduit in non-ross patients: risk factors for allograft dysfunction and failure. Ann Thorac Surg 2005;80(2):655-63; discussion 663-4. DOI: 10.1016/j.athoracsur.2005.02.053.
5. Laohaprasitiporn D, Treeratanapaiboon N, Nana A, et al. Truncus Arteriosus: Siriraj Experience. Siriraj Med J 2008;60:53-56.
6. Junnil P, Cheanvechai C, Namchaisiri J, Saprungruang A, Thitivaraporn P, Chomvilailuk M, et al. Long-term course after pediatric right ventricular outflow tract reconstruction. Asian Cardiovasc Thorac Ann 2021;29(6):483-9. DOI: 10.1177/0218492320983449.
7. Forbess JM, Shah AS, St Louis JD, Jaggers JJ, Ungerleider RM. Cryopreserved homografts in the pulmonary position: determinants of durability. Ann Thorac Surg 2001;71(1):54-59; discussion 59-60. DOI: 10.1016/s0003-4975(00)01788-4.
8. Mery CM, Guzman-Pruneda FA, De Leon LE, Zhang W, Terwelp MD, Bocchini CE, 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(2):432-9, 441 e1-2. DOI: 10.1016/j.jtcvs.2015.10.069.
9. Gerestein CG, Takkenberg JJ, Oei FB, Cromme-Dijkhuis AH, Spitaels SE, van Herwerden LA, et al. Right ventricular outflow tract reconstruction with an allograft conduit. Ann Thorac Surg 2001;71(3):911-7; discussion 917-8. DOI: 10.1016/s0003-4975(00)02440-1.
10. Bell D, Prabhu S, Betts KS, Chen Y, Radford D, Whight C, et al. Long-term performance of homografts versus stented bioprosthetic valves in the pulmonary position in patients aged 10-20 years. Eur J Cardiothorac Surg 2018;54(5):946-52. DOI: 10.1093/ejcts/ezy149.
11. Karamlou T, Ungerleider RM, Alsoufi B, Burch G, Silberbach M, Reller M, et al. Oversizing pulmonary homograft conduits does not significantly decrease allograft failure in children. Eur J Cardiothorac Surg 2005;27(4):548-53. DOI: 10.1016/j.ejcts.2004.12.054.
12. Karamlou T, Blackstone EH, Hawkins JA, Jacobs ML, Kanter KR, Brown JW, 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(4):829-38. DOI: 10.1016/j.jtcvs.2006.06.034.
13. Askovich B, Hawkins JA, Sower CT, Minich LL, Tani LY, Stoddard G, et al. Right ventricle-to-pulmonary artery conduit longevity: is it related to allograft size? Ann Thorac Surg 2007;84(3):907-11; discussion 911-2. DOI: 10.1016/j.athoracsur.2007.04.104.
14. Durongpisitkul K, Dangrungroj E, Chungsomprasong P, Thongcharoen P, Subtaweesin T, Sriyoschati S, et al. Outcomes of Transcatheter Pulmonary Valve Replacement and Surgical Pulmonary Valve Replacement: A Cohort Analysis. JSCAI 2022;1. DOI: 10.1016/j.jscai.2022.100408.
15. Shinkawa T, Chipman C, Bozzay T, Tang X, Gossett JM, Imamura M, et al. Outcome of right ventricle to pulmonary artery conduit for biventricular repair. Ann Thorac Surg 2015;99(4):1357-66. DOI: 10.1016/j.athoracsur.2014.07.095.
16. Miyazaki T, Yamagishi M, Maeda Y, Taniguchi S, Fujita S, Hongu H, et al. Long-term outcomes of expanded polytetrafluoroethylene conduits with bulging sinuses and a fan-shaped valve in right ventricular outflow tract reconstruction. J Thorac Cardiovasc Surg 2018;155(6):2567-76. DOI: 10.1016/j.jtcvs.2017.12.137.
17. Tocharoenchok T, Siriprompatr S, Subtaweesin T, Tantiwongkosri K, Nitiyarom E, Sriyoschati S. Early Outcome of Simplified Standardized Trileaflet Polytetrafluoroethylene Valved Conduit Placement. World J Pediatr Congenit Heart Surg 2022;13(6):723-30. DOI: 10.1177/21501351221117707.