Optimal Pulmonary Valve Annulus Diameter for Annulus Preservation in Tetralogy of Fallot May Be Far Smaller Than Normal Annulus Size

Dong-Hee Kim, MD, Ji Hye Lee, MS, Eun Seok Choi, MD, Chun Soo Park, MD, PhD, and Tae-Jin Yun, MD, PhD

We hypothesized that optimal pulmonary valve annulus (PVA) diameter upon annulus preservation (AP) in tetralogy of Fallot (ToF) may be far smaller than the normal diameter. Retrospective review of the 61 consecutive patients who underwent ToF repair between January 2016 and September 2017 was performed. Median age, body weight, and median PVA (Z) at repair were 166 days (interquartile range, IQR, 141–182 days), 7.4 kg (IQR, 6.6–8.0 kg), and −1.83 (IQR, −2.56 to −0.90), respectively. Upon AP, subvalvar and supravalvar obstructions were completely eliminated, leaving a pressure gradient only at the valve level. AP was achieved in 58 patients (95.1%). Pulmonary valve intervention comprised commissurotomy in 35 patients, commissurotomy with bougination in 8 patients, and transannular patching in 3 patients. For 15 patients, the pulmonary valve was left intact. Median PVA diameter measured by Hegar dilator after PV intervention was 8 mm (IQR, 7–9 mm), which was 3.9 mm (IQR, 2.3–4.3 mm) smaller than normal dimension and translated to a PVA (Z) of −1.85 (IQR, −2.40 to −0.78). Postrepair right and left ventricular pressure ratio was 0.47 ± 0.12. During the median follow-up duration of 353 days (IQR, 191–482 days), 4 patients (including 3 who underwent transannular patching) developed significant pulmonary regurgitation. Freedom from reintervention for PS, significant PS, and PR at 1 year was 92.4%, 83.2%, and 90.6%, respectively. Optimal PVA for AP may be far smaller than the normal diameter. Minimizing PV intervention upon AP can prevent superfluous postoperative PR.

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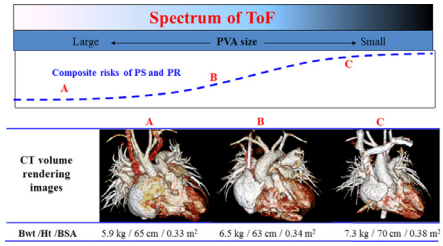
Keywords: Tetralogy of Fallot, Pulmonary valve annulus, Annulus preservation, Transannular patching



	A	B	C
Bwt /Ht /BSA	5.9 kg / 65 cm / 0.33 m²	6.5 kg / 63 cm / 0.34 m²	7.3 kg / 70 cm / 0.38 m²
Normal PVA (mm)	10.7 mm	10.9 mm	11.3 mm
Intraop. PVA (mm,Z)	9 mm (-1.7)	7 mm (-2.1)	7 mm (-2.5)
PV intervention	None	Commissurotomy only	Extensive valvulopasty
RVOT velocity	1.4 m/sec	2.1 m/sec	2.8 m/sec
PR	None	trivial	mild

CT images and surgical outcomes of the 3 patients from the study cohort.

Central Message

Optimal pulmonary valve annulus size for annulus preservation in tetralogy of Fallot is far smaller than commonly expected, provided subvalvar and supravalvar obstructions are completely eliminated.

Perspective Statement

The advantages of pulmonary valve annulus preservation in tetralogy of Fallot repair are well established. However, transannular patching is still widely performed, especially in the patients with a small annulus. In this study, we sought to verify that the optimal pulmonary valve orifice size can be far smaller than expected.

INTRODUCTION

Although the long-term adverse outcomes of transannular patching (TAP) in the repair of tetralogy of Fallot (ToF) are well established, there has not been a consequent decline in TAP frequency in practice.[1–6] Frequent application of TAP may be attributable to the lack of consensus on the conditions under which pulmonary valve annulus (PVA) preservation (AP) can be safely achieved[7–10] and not to the lack of standardized surgical techniques for the preservation of marginally small PVAs. The strategy for right ventricular outflow tract (RVOT) reconstruction in ToF repair depends on preoperative PVA (Z), intraoperative Hegar dilator measurement of PVA diameter, and intraoperative ventricular pressure profiles.[11–13] When deciding whether or not to attempt AP, the cut-off

Abbreviations: AP, annulus preservation; CPB, cardiopulmonary bypass; LV, left ventricle; PS, pulmonary stenosis; PR, pulmonary regurgitation; $P_{RV/LV}$, pressure ratio of the right ventricle and the left ventricle; PTFE, polytetrafluoroethylene; PV, pulmonary valve; PVA, pulmonary valve annulus; PVA (Z), *z*-score of pulmonary valve annulus; RV, right ventricle; RVOT, right ventricular outflow tract; RVOTO, right ventricular outflow tract obstruction; RV-PA, right ventricle to pulmonary artery; TAP, transannular patching; TOF, tetralogy of Fallot; VSD, ventricular septal defect

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values for each parameter vary among the surgeons or in the literature. If optimal RVOT reconstruction in ToF stipulates minimal composite risks of pulmonary stenosis (PS) and pulmonary regurgitation (PR), preservation of the PVA should be accompanied by minimal pulmonary valve (PV) intervention to maintain the structural integrity of the PV. This will lead to the highest degree of valve competence for each valve with different morphology while leaving acceptably low RVOT pressure gradients. In this regard, we hypothesized that the optimal PVA size may be far smaller than normal and even smaller than the target PVA diameter for AP in current practice.

METHODS

Retrospective review of the 61 consecutive patients who underwent ToF repair between January 2016 and September 2017 at a single center was performed. Patients with pulmonary atresia, absent pulmonary valve syndrome, or atrioventricular septal defect were excluded. Forty-nine patients (80%) were diagnosed as having ToF prenatally. For patients with prenatal diagnosis, immediate postnatal assessment and careful home monitoring were practiced. Median age at the corrective operation was 166 days (interquartile range [IQR], 141−182 days), and 33 patients (54.1%) were male. Median body weight and height at the time of operation were 7.4 kg (IQR, 6.6−8.0) and 67 cm (IQR, 64.6−70.2), respectively. Fifty-eight patients (95.1%) were electively operated on, and 3 patients (4.9%) underwent urgent operations. Five patients (8.2%) had undergone systemic-pulmonary shunt (SPS) prior to repair during the neonatal period, and indications for SPS were for the growth of small branch pulmonary artery ($n = 1$), to establish blood flow to the interrupted left pulmonary artery ($n = 1$), and to facilitate growth of a small PVA ($n = 3$).[14] On prerepair echocardiography, median diameter of the PVA and PVA (Z) (calculated by Pettersen's method[15]) were 7.3 mm (IQR, 6.4−8.3) and −1.83 (IQR, −2.56 to −0.90), respectively. Ventricular septal defect (VSD) types were perimembranous in 45 patients (73.8%), subarterial in 4 patients (6.6%), and muscular outlet in 12 patients (19.7%). Branch pulmonary artery stenosis was observed in the right side in 13 patients (21.3%), in the left side in 3 patients (4.9%), and in both pulmonary arteries in 3 patients (4.9%). Data collection, collation, and analysis were approved by the institutional review board (IRB no.: 2018-0471), and the need for informed consent was waived because of the retrospective nature of the study.

Surgical Techniques

The operations were carried out under moderate hypothermic (28°C) cardiopulmonary bypass (CPB) with aortic and bicaval cannulation, aortic cross-clamping, and myocardial protection with intermittent infusion of cold blood cardioplegia at the aortic root. After oblique right atriotomy, parietal extension of the infundibular septum was resected extensively until pulmonary valve was clearly seen from the right ventricular inlet. A Hegar dilator was introduced through the tricuspid valve to measure the pulmonary valve orifice diameter. If the orifice was larger than a normal PVA minus 5 mm, we elected not to explore the PV through the pulmonary arteriotomy. We referred to echocardiography-based normograms to ascertain the normal PVA dimensions of each patient. If the orifice was smaller than the normal PVA minus 5 mm, the main pulmonary artery was incised longitudinally for the careful assessment of PV morphology. If the valve leaflets were thin and functional, the PV was left intact without any intervention for AP. Otherwise, various surgical techniques, including commissurotomy, commissural mobilization from the pulmonary arterial wall, leaflet division (bicuspidalization or tricuspidalization), leaflet excision, and shaving of the lumpy valve leaflets, were employed to increase effective PV orifice area. PVA size was then measured with Hegar dilators. If it was still smaller than normal PVA dimension minus 5, the pulmonary arteriotomy was extended down to RVOT, crossing the annulus to achieve a minimal right ventriculotomy (less than 10 mm) for TAP placement. After coming off CPB, the ratio of right ventricular pressure to left ventricular pressure ($P_{RV/LV}$) and the pressure gradient between the tight ventricle (RV) and the pulmonary artery (PA) were directly measured. If $P_{RV/LV}$ was greater than 0.8 with a significant gradient between RV and PA, the patient was put back on CPB and a mini-infundibular incision (10 mm) was made for RVOT muscle resection and infundibular patch (IP) placement using a polytetrafluoroethylene (PTFE) patch (Gore Acuseal cardiovascular patch, Gore-Tex, CA). If $P_{RV/LV}$ was still higher than 0.8 after the placement of IP, the patient went back on CPB again for TAP. Various techniques of peripheral pulmonary angioplasty (eg, patch angioplasty, carinoplasty in the bifurcation of the main pulmonary artery, left pulmonary artery wedge resection, and repair to correct the acute angulation and stenosis) were employed if indicated.

Statistical Analysis

Categorical variables were presented as frequencies and percentages, and continuous variables were presented as mean with standard deviation or median with interquartile range (IQR) according to the distribution of the data. Distributional normality was tested using the Kolmogorov-Smirnov method. Linear regression analysis was conducted to assess the difference between preoperative and intraoperative PVA (Z) according to the changes in preoperative PVA (Z). Kaplan-Meier survival estimation was used for the analysis of time-related adverse events, and differences between the subgroups were tested using the log-rank test. Cox proportional hazards model was fitted to identify the risk factors for decreased time to adverse events. Statistical analysis was performed using SPSS Statistics version 22 (IBM, Armonk, NY), R software version 3.4.4 (www.r-project.org), and GraphPad statistical software package version 5 (GraphPad, San Diego, CA). A P value less than 0.05 was considered statistically significant.

RESULTS

There was no postoperative mortality. AP was achieved in 58 patients (95.1%), and TAP was required for 3 patients (4.9%). Forty-nine patients (80.3%) underwent both main pulmonary artery and infundibular patching, and isolated main pulmonary artery patches or isolated infundibular patches were placed in 4 patients (6.6%) and 3 patients (4.9%), respectively. Five patients did not undergo any patch widening (8.2%). Surgical interventions on the PV in patients with AP comprised extensive PV intervention including commissurotomy in 35 patients (60.3%), extensive PV intervention followed by intraoperative bougination with Hegar dilators in 8 patients (13.8%). Fifteen patients (24.6%) received no PV intervention. The median intraoperative PVA diameter was 6 mm (IQR, 5−7 mm) before the

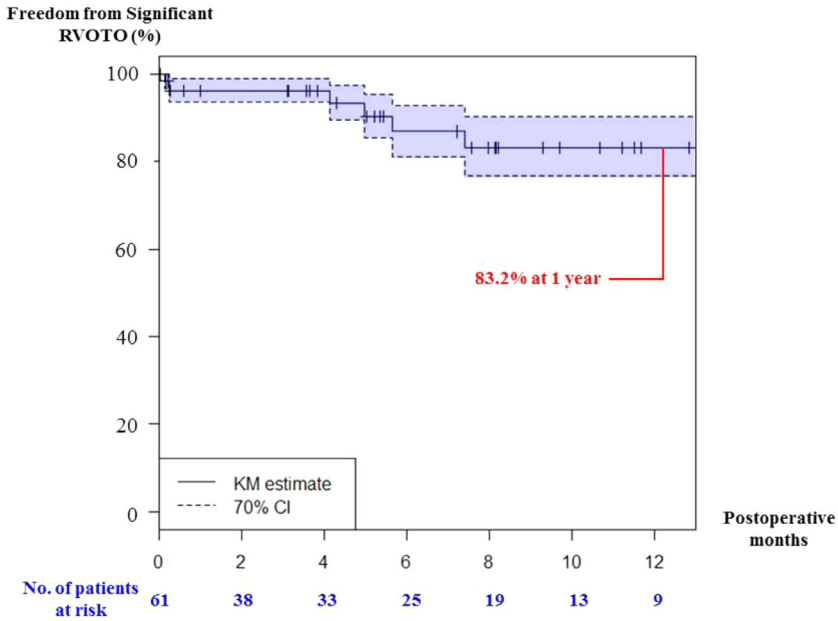


Figure 1. Freedom from significant right ventricular outflow tract obstruction.
CI, confidence interval; KM, Kaplan-Meier; RVOTO, right ventricular outflow tract obstruction.

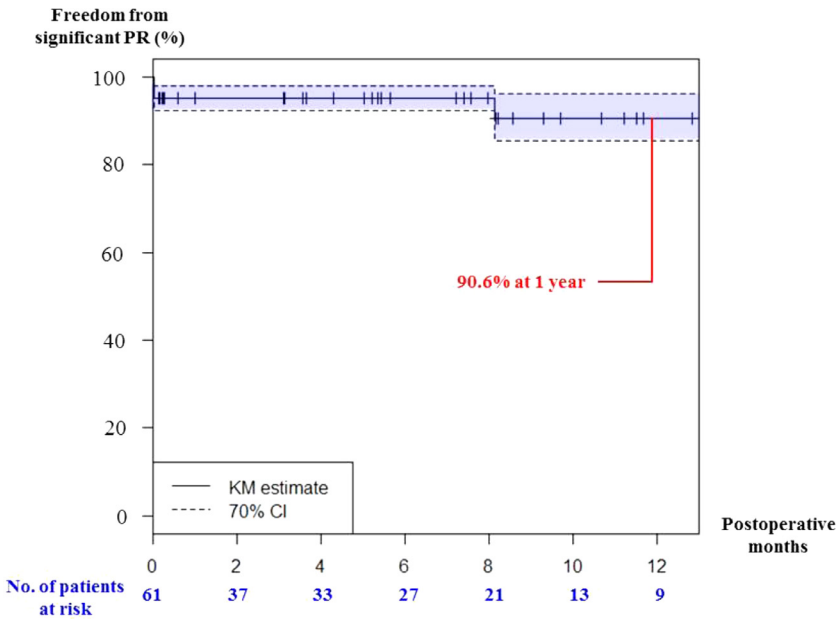


Figure 2. Freedom from significant pulmonary regurgitation.
CI, confidence interval; KM, Kaplan-Meier; PR, pulmonary regurgitation.

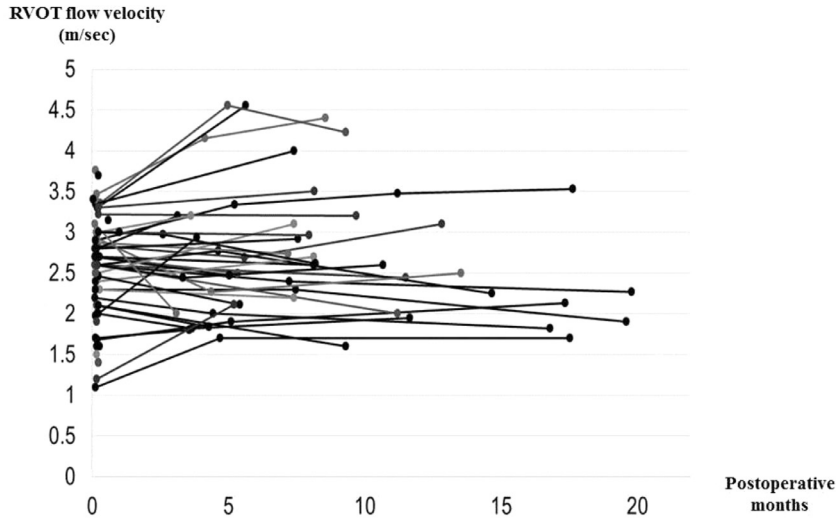


Figure 3. Postoperative changes in RVOT flow velocity.
RVOT, right ventricular outflow tract.

valvuloplasty. After PV interventions, median PVA diameter increased to 8 mm (IQR, 7−9), which was 3.9 mm (IQR, 4.3−2.3 mm) smaller than normal and translated to a median PVA (Z) of −1.85 (IQR, −2.40 to −0.78). $P_{RV/LV}$ directly measured by pressure needle after coming off bypass was 0.47 ± 0.12. On intraoperative transesophageal echocardiography, the mean RVOT forward flow velocity was 2.55 ± 0.63 m/s, and significant residual RVOT obstruction (flow velocity ≥ 3.5 m/s) was observed in 2 patients (2/61, 3.3%). Postoperative PR was null in 23 patients (37.7%) and trivial to mild PR in 35 patients (35/61, 57.4%). Except for 3 patients with TAP, there was no patient with moderate or severe PR. Follow-up echocardiography was done in 39 patients (63.9%) at the median follow-up duration of 157 days (IQR, 124−224 days): among them, 1 patient newly developed moderate PR and 5 patients developed significant RVOTO. One-year freedom from significant RVOTO was 83.2% and freedom from significant PR (≥moderate) was 90.6% (Figs. 1 and 2). Postoperative changes in RVOT velocity in the entire cohort were depicted in Figure 3. During the median follow-up period of 353 days (IQR, 191−482), 3 patients underwent catheter (n = 1) or surgical (n = 2) reintervention for RVOTO (Table 1). One-year freedom from reintervention for RVOTO was 92.4% (Fig. 4). Cox regression analysis identified high intraoperative $P_{RV/LV}$ as a risk factor for the decreased time to the development of significant RVOTO (P = 0.001) or reintervention for RVOTO (P = 0.036), while PVA (Z) on preoperative echocardiography or translation of intraoperatively measured PVA diameter into z-score were not related to the development of RVOTO or reintervention for RVOTO (Tables 2 and 3). Freedom from significant RVOTO or reintervention for RVOTO stratified by preoperative PVA (Z) and translation

Table 1. Characteristics of the Patients With Reintervention for Right Ventricular Outflow Tract Obstruction

Patient	OP Age (d)	Preoperative Echocardiography		Intraoperative Measurement		RV/LV Pressure	Postoperative Echocardiography		Cause of Reintervention	Procedure (Days After Operation)
		PVA (mm)	PVA (Z)	PVA (mm)	PVA (Z)		RVOT Forward Flow (m/s)	PR Grade		
#1	124	7.5	−1.62	7	−2.06	0.60	3.35	Trivial	RVOTO	Ballon valvuloplasty (251) PV repair, PA angioplasty (404)
#2	85	6.5	−1.03	7	−1.94	0.45	3.47	None	RVOTO	Ballon valvuloplasty (274)
#3	243	6.2	−3.89	7	−3.02	0.76	3.30	Trivial	RVOTO, aneurysmal change	Aneurysmectomy, RV-PA conduit insertion, PA angioplasty (177)

LV, left ventricle; PA, pulmonary artery; PR, pulmonary regurgitation; PV, pulmonary valve; PVA, pulmonary valve annulus; PVA (Z), z-score of pulmonary valve annulus; RV, right ventricle; RVOT, right ventricular outflow tract.

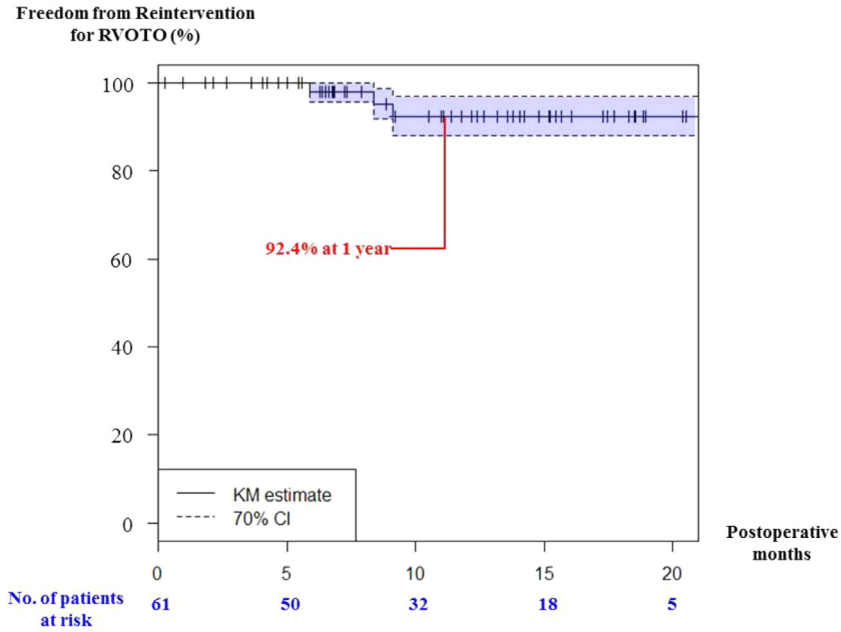


Figure 4. Freedom from reintervention for RVOTO.
RVOTO, right ventricular outflow tract obstruction.

Table 2. Results of Cox Regression Analysis for Significant Right Ventricular Outflow Tract Obstruction

Variable	Univariate *P* Value	Multivariate *P* Value	Exp (B)	Lower 95% CI	Upper 95% CI
Sex	0.163				
Age	0.141				
Body weight	0.525				
Preoperative PVA (Z)*	0.392				
Previous shunt history	0.073‡				
$P_{RV/LV}$ (0.01 increase)	0.001‡	0.001	1.120	1.045	1.201
The number of PV leaflet	0.607				
PA abnormalities	0.404				
VSD location	0.484				
PV intervention method	0.226				
MPA patching	0.504				
Infundibular patching	0.428				
Intraoperative PVA (Z)†	0.118				

CI, confidence interval; LV, left ventricle; MPA, main pulmonary artery; PA, pulmonary artery; PV, pulmonary valve; PVA (Z), *z*-score of pulmonary valve annulus; RV, right ventricle; VSD, ventricular septal defect.
*Preoperative PVA (Z) was measured by echocardiography and calculated using echocardiographic nomogram.
†Intraoperative PVA (Z) was measured by Hegar dilators after PV intervention and calculated using echocardiographic nomogram.
‡Variables with univariate *P* value below 0.1 were used for multivariate analysis.

of intraoperatively measured PVA diameter into *z*-score are depicted in Figures E1–E4. Receiver operating characteristic curve analysis showed that patients with $P_{RV/LV}$ above 0.59 (95% confidence interval, 0.78–1.00; area under the curve, 0.896; sensitivity, 85.7%; specificity, 90.7%) appeared to have a higher probability of developing RVOTO. Characteristics of the 15 patients who received no PV intervention are summarized in Table E1, which shows that none of these patients developed significant RVOTO or PR during follow-up.

DISCUSSION

In the spectrum of ToF, determination of surgical strategy should be individualized, based on the anatomic disposition of each patient. For instance, there is a subset of patients whose PVA is large enough to preserve with a minimal or no intervention on the PV. Excessive surgical intervention may result in superfluous or preventable PR (Fig. E5). In this study, we found that the gap between preoperative PVA (Z) and translation of intraoperatively measured PVA diameter into *z*-score increased as the preoperative PVA (Z) increased ($r^2 = 0.429$,

Table 3. Results of Cox Regression Analysis for Reintervention Attributed to Right Ventricular Outflow Tract Obstruction

Variable	Univariate *P* Value	Multivariate *P* Value	Exp (B)	Lower 95% CI	Upper 95% CI
Sex	0.397				
Age	0.589				
Body weight	0.921				
Preoperative PVA (Z)*	0.400				
Previous shunt history	0.814				
$P_{RV/LV}$ (0.01 increase)	0.036‡	0.036	1.109	1.007	1.221
The number of PV leaflets	0.692				
PA abnormalities	0.995				
VSD location	0.499				
PV intervention method	0.893				
MPA patching	0.628				
Infundibular patching	0.620				
Intraoperative PVA (Z)†	0.181				

CI, confidence interval; LV, left ventricle; MPA, main pulmonary artery; PA, pulmonary artery; PV, pulmonary valve; PVA (Z), *z*-score of pulmonary valve annulus; RV, right ventricle; VSD, ventricular septal defect.
*Preoperative PVA (Z) was measured by echocardiography and calculated with echocardiographic nomogram.
†Intraoperative PVA (Z) was measured by Hegar dilators after PV intervention and calculated with echocardiographic nomogram.
‡Variables with univariate *P* value below 0.1 were used for multivariate analysis.

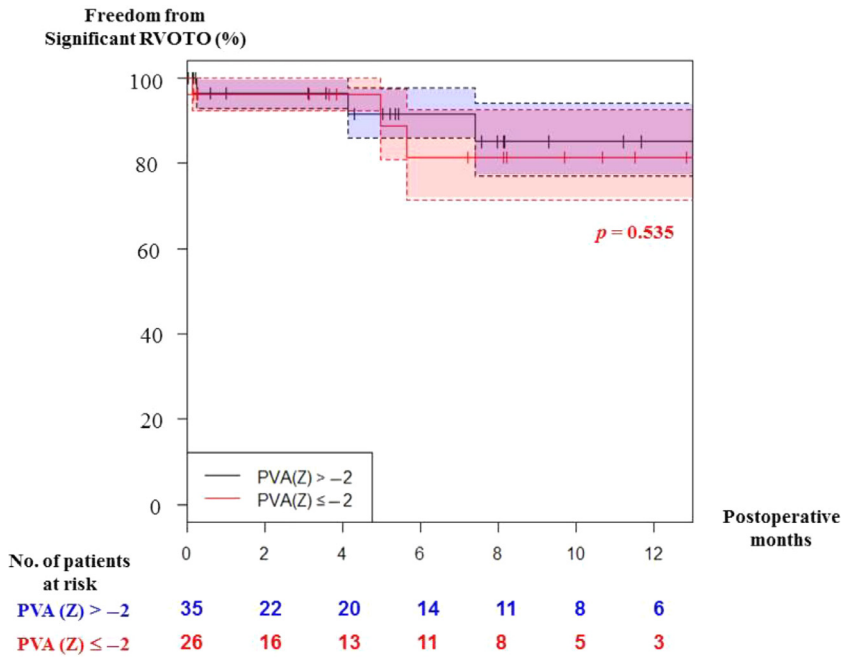


Figure E1. Freedom from significant RVOTO according to the preoperative PVA (Z).
CI, confidence interval; KM, Kaplan-Meier; PVA (Z), *z*-score of the pulmonary valve annulus; RVOTO, right ventricular outflow tract obstruction.

$P < 0.001$), which may signify that PV orifice widening was not fully practiced intraoperatively in patients with sizable PVAs while aggressive surgical intervention on the PV was performed in patients with marginally small PVAs (Fig. E6).

During the study period, AP was achieved in most of the patients. The proportion of patients with AP was higher than previous studies including ours,[7,15–17] which may be attributable not to the improvement in surgical technique but to the conceptual evolution that optimal PVA diameter for AP might be far smaller than it has been previously believed to be. Prenatal diagnosis with vigilant postnatal home monitoring to identify a subset of patients who would benefit from early repair before PVA (Z) gets smaller may also have contributed to the higher incidence of AP. Extended indication of systemic-pulmonary shunt to induce outgrowth of the PVA over the somatic growth may have also facilitated AP for the patients who would have required TAP under the early primary repair strategy. The determination of PVA preservation should be

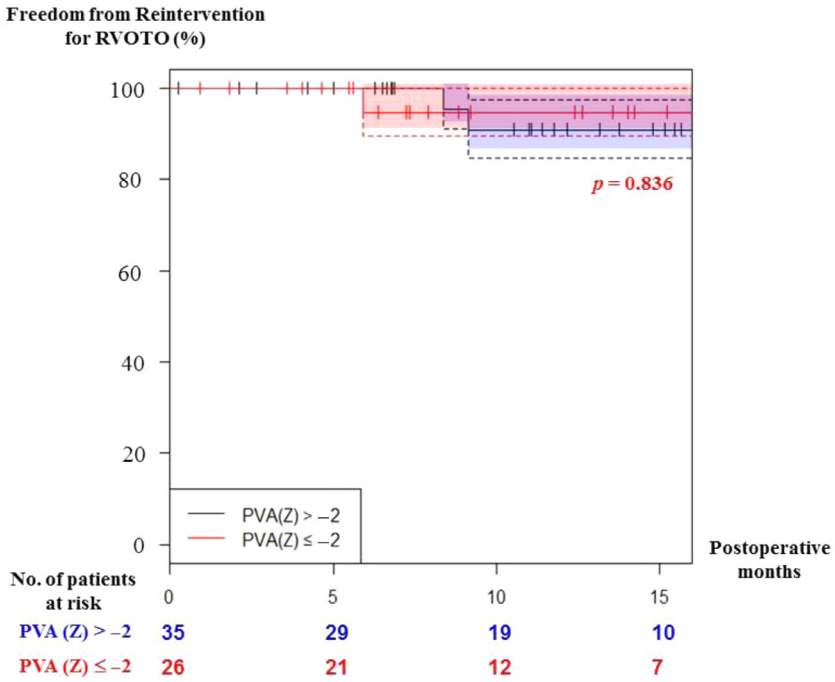


Figure E2. Freedom from reintervention for RVOTO according to the preoperative PVA (Z).
CI, confidence interval; KM, Kaplan-Meier; PVA (Z), *z*-score of the pulmonary valve annulus; RVOTO, right ventricular outflow tract obstruction.

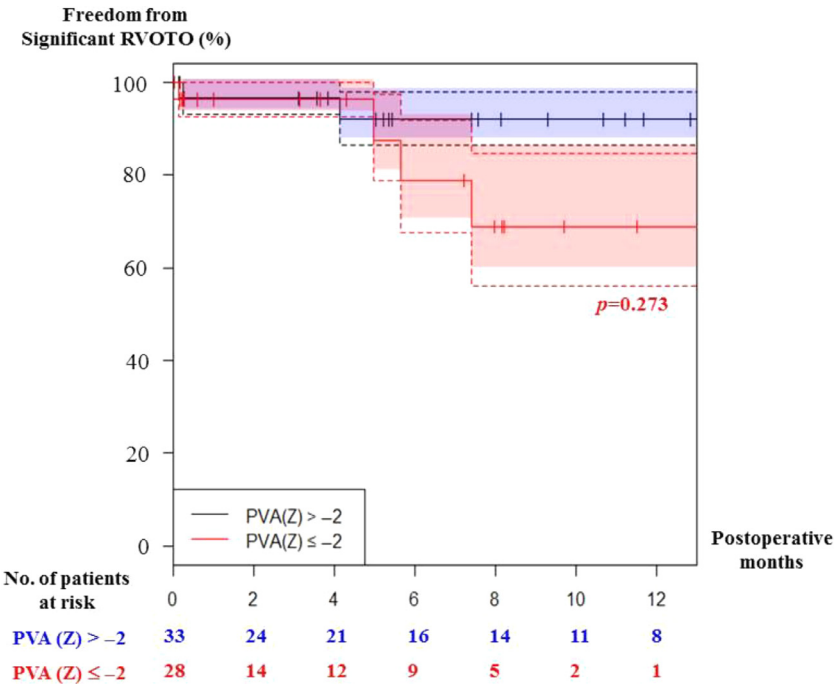


Figure E3. Freedom from significant RVOTO according to the translation of intraoperative PVA dimension into PVA (Z).
CI, confidence interval; KM, Kaplan-Meier; PVA (Z), *z*-score of the pulmonary valve annulus; RVOTO, right ventricular outflow tract obstruction.

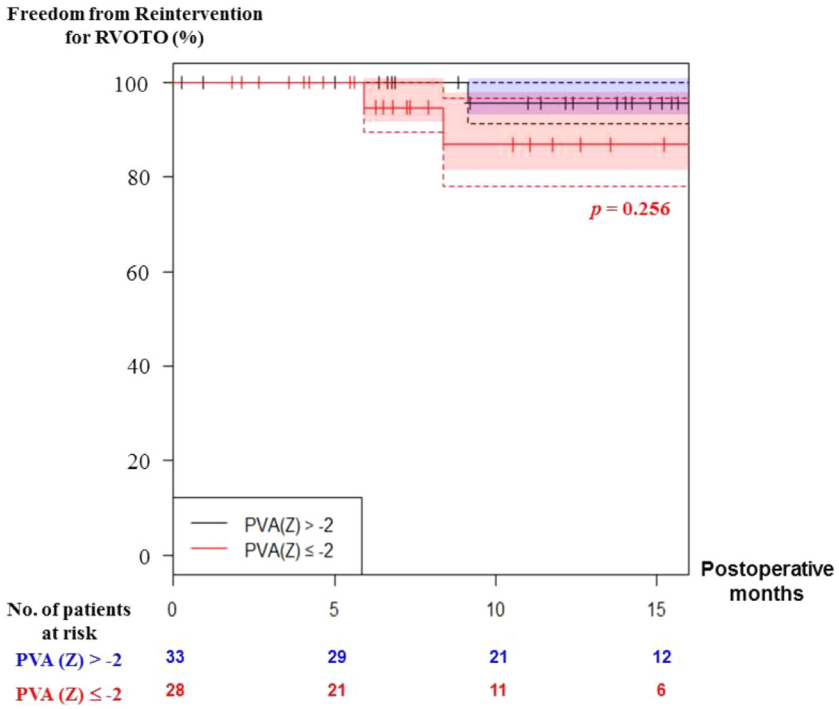
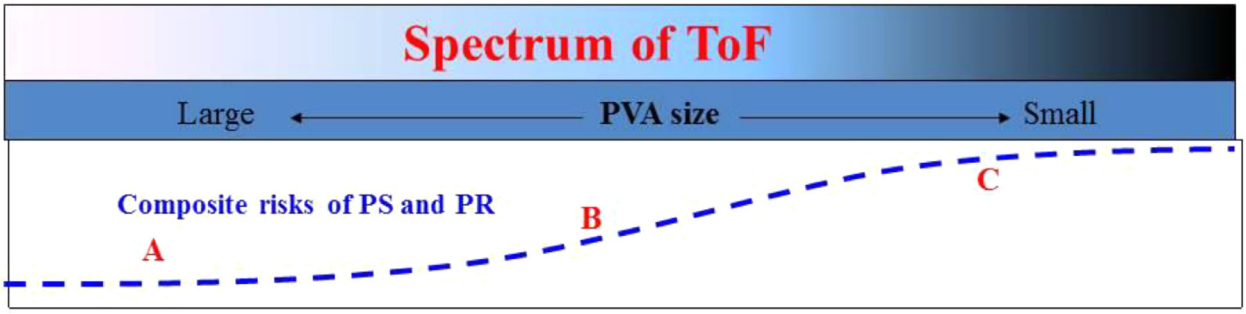


Figure E4. Freedom from reintervention for RVOTO according to the translation of intraoperative PVA dimension into PVA (Z). CI, confidence interval; KM, Kaplan-Meier; PVA (Z), *z*-score of the pulmonary valve annulus; RVOTO, right ventricular outflow tract obstruction.

Table E1. Characteristics of Patients Without Pulmonary Valve Intervention at Repair With Annulus Preservation

Patients	Age (d)	Previous Shunt	Preoperative Echocardiography		PV Leaflets	MPA Patching	Infundibular Patching	Intraoperative Measurement		RV/LV Pressure	Postoperative Echocardiography	
			PVA (mm)	PVA (Z)				PVA (mm)	PVA (Z)		RVOT Forward Flow (m/s)	PR Grade
#1	171	N	7.6	−1.68	Bicuspid	Y	Y	8	−1.70	0.39	2.2	Trivial
#2	170	N	7.0	−1.94	Bicuspid	Y	Y	7	−2.80	0.55	2.6	None
#3	148	N	13.7	2.00	Bicuspid	N	N	12	1.00	0.29	1.1	None
#4	170	N	7.8	−1.80	Tricuspid	Y	Y	7	−2.50	0.31	2.1	Mild
#5	194	N	11.2	0.59	Tricuspid	N	Y	11	0.48	0.41	2.4	None
#6	159	N	6.6	−2.56	Bicuspid	Y	Y	7	−2.72	0.29	2.5	None
#7	180	N	8.6	−1.07	Bicuspid	N	N	10	−0.05	0.35	1.7	None
#8	160	N	7.5	−1.58	Bicuspid	Y	Y	7	−2.40	0.30	2.3	None
#9	179	N	9.7	−0.28	Bicuspid	N	Y	8	−1.63	0.55	2.8	Trivial
#10	160	N	12.0	0.78	Bicuspid	N	N	10	0.18	0.56	1.2	None
#11	175	N	6.9	−1.68	Bicuspid	Y	Y	7	−2.62	0.45	3.4	None
#12	166	N	9.5	1.23	Tricuspid	N	N	9	−0.29	0.50	1.4	Mild
#13	182	N	8.8	−0.43	Bicuspid	Y	Y	7	−2.40	0.43	1.5	None
#14	192	N	10.7	0.74	Bicuspid	N	N	10	0.18	0.43	2.1	None
#15	262	Y	11.0	0.06	Bicuspid	Y	Y	9	−1.29	0.37	1.9	None

MPA, main pulmonary artery; PR, pulmonary regurgitation; PV, pulmonary valve; PVA, pulmonary valve annulus; PVA (Z), *z*-score of pulmonary valve annulus; RVOT, right ventricular outflow tract.



	A	B	C
CT volume rendering images			
Bwt /Ht /BSA	5.9 kg / 65 cm / 0.33 m^2	6.5 kg / 63 cm / 0.34 m^2	7.3 kg / 70 cm / 0.38 m^2
Normal PVA (mm)	10.7 mm	10.9 mm	11.3 mm
Intraop. PVA (mm,Z)	9 mm (-1.7)	7 mm (-2.1)	7 mm (-2.5)
PV intervention	None	Commissurotomy only	Extensive valvulopasty
Postop. RVOT velocity	1.4 m/sec	2.1 m/sec	2.8 m/sec
Postop. PR	None	trivial	mild

Figure E5. CT images and surgical outcomes of the 3 patients from the study cohort. Patient A, 5.3-month-old boy, had sizable PVA, and received no intervention on the PV upon PVA preservation. He showed low RVOT flow velocity and no PR postoperatively. Patient B, 4.3-month-old girl, had marginally small PVA, and received minimal intervention on the PVA upon PVA preservation. She developed mild RVOT obstruction and trivial PR. Patient C, 6.1-month-old girl, had small PVA, and received extensive intervention on the PV upon PVA preservation. She developed marginally high RVOT pressure gradient and mild PR.
BSA, body surface area; Bwt, body weight; CT, computed tomography; Ht, height; Postop., postoperative; PR, pulmonary regurgitation; PS, pulmonary stenosis; PV, pulmonary valve; PVA, pulmonary valve annulus; RVOT, right ventricular outflow tract; ToF, tetralogy of Fallot.

based on a comprehensive understanding of the anatomic characteristics of the RVOT.[17–19] Valvar, subvalvar, and supravalvar components of RVOTO should be fully addressed before the final determination of RVOT reconstruction strategy. This study shows that a very small PVA (ie, 4–5 mm smaller than the normal PVA dimension) can be preserved, provided subvalvar and supravalvar stenoses are completely eliminated. Given that long-term exposure of the RV to the volume overload (ie, PR) may be more detrimental than to the pressure overload (ie, RVOTO), strategic bias toward leaving minimal PR at the expense of a certain amount of RVOTO may be sensible in terms of preservation of right ventricular function.[20,21]

In this study cohort, an infundibular incision was made in most patients. Some would argue that right ventricular incision may lead to ventricular dysfunction, dilatation, and the development of ventricular arrhythmia. However, we trust that the right ventricular remodeling process has more to do with PR than the ventricular incision per se. Infundibular patching is beneficial in the complete resection of subvalvar muscle crowding, effective augmentation of the subvalvar diameter, and for excellent visualization of a VSD. However, aneurysmal change of the infundibulum, particular in association with significant residual RVOTO, can be a caveat.[21–23] Thus, we have tried to minimize the total length of the infundibular incision, keeping it within the area of the conal septal deviation. In this series, only 1 patient developed RVOT aneurysm necessitating surgical intervention.

CONCLUSIONS

The optimal PVA diameter for AP may be far smaller than the normal diameter. Therefore, PV intervention upon AP should be minimal to prevent superfluous postoperative PR.

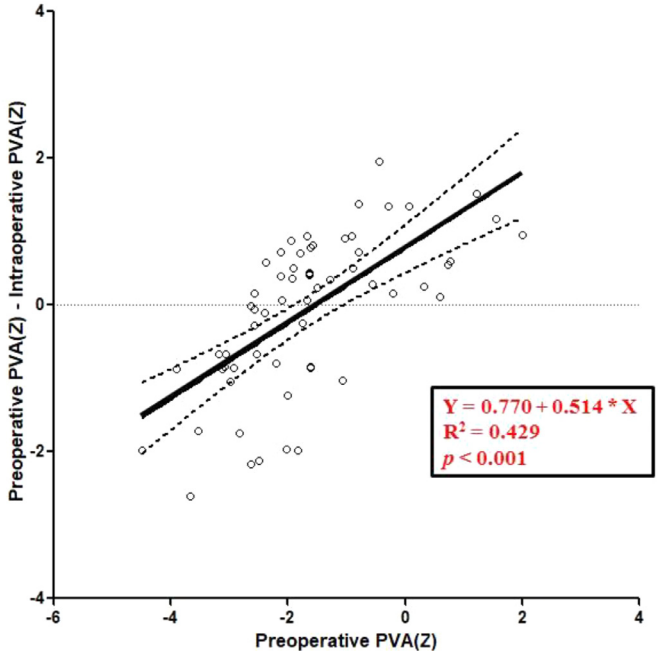
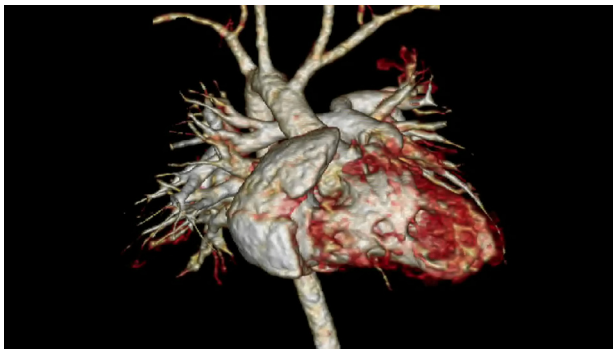


Figure E6. Regression analysis for preoperative PVA (Z) and the gap between preoperative and intraoperative PVA (Z).
PVA (Z), *z*-score of the pulmonary valve annulus; RVOTO, right ventricular outflow tract obstruction.

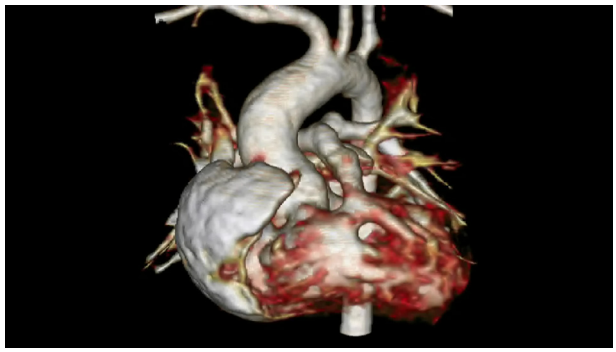
Longer term follow-up is mandatory to delineate the advantages of preserving a marginally small PVA.

SUPPLEMENTARY MATERIAL

The following is the supplementary data to this article:



Video 1. Urgent operation was performed for a 75-day-old boy with ToF and frequent hypoxic spell episodes. Body weight and PVA (Z) at operation were 5.6 kg and −1.8, respectively. After the parietal band and hypertrophic anterior free wall of the RV were extensively excised, large PM VSD was closed through the tricuspid valve. A longitudinal incision was made on the main pulmonary artery to measure the PVA diameter, which was 7 mm by a Hegar dilator and 3.3 mm smaller than normal (10.3 mm). Because the PV leaflets looked thin and functional, we elected not to intervene on the PV. Pulmonary arteriotomy was closed with a round Acuseal patch. Cardiopulmonary bypass time and aortic cross-clamping time were 112 minutes and 78 minutes, respectively. Postrepair RV to LV pressure ratio was 0.48 (39 mm Hg/81 mm Hg). On intraoperative echocardiography, there was no PR or VSD leakage, and RVOT flow velocity was 2.4 m/s. He was discharged home at postoperative day 10 without any complications.



Video 2. Urgent surgical correction for ToF was performed for a 23-day-old boy with recent episodes of cyanotic spell. His body weight and PVA (Z) at operation were 4.1 kg and −2.0, respectively. For better surgical exposure of VSD and complete relief of infundibular stenosis, right ventriculotomy (10 mm in length) was made. After the parietal band was extensively excised, large PM VSD was closed through the right ventriculotomy. A longitudinal incision was made on the main pulmonary artery to explore the PV morphology, which showed severe commissural fusion of the right commissure. PV orifice diameter was initially measured as 3 mm before PV intervention, and was enlarged to 5 mm after extensive commissurotomy, which was 4.1 mm smaller than normal (9.1 mm). Both pulmonary arteriotomy and right ventriculotomy were closed with a round Acuseal patches. Cardiopulmonary bypass time and aortic cross-clamping time were 88 minutes and 57 minutes, respectively. Postrepair RV to LV pressure ratio was 0.65 (43 mm Hg/66 mm Hg). On intraoperative echocardiography, there were trivial PR and no VSD leakage, and RVOT flow velocity was 3.0 m/s. He was discharged home without any complication at postoperative day 9.

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