Title:

Staged Repair of Tetralogy of Fallot: A Strategy for Optimizing Clinical and Functional Outcomes

Running Head:

Staged Repair of Tetralogy of Fallot

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ABSTRACT

Background: This study evaluated the impact of a staged surgical strategy incorporating a modified Blalock-Taussig shunt (BTS) for tetralogy of Fallot (TOF) on pulmonary valve annulus (PVA) growth, the rate of valve-sparing repair (VSR) at the time of intracardiac repair (ICR), and long-term functional outcomes.

Methods: This retrospective study included 330 patients with TOF who underwent ICR between 1991 and 2019, including 57 patients (17%) who underwent BTS. The mean follow-up period was 15.0±7.3 years. We compared the data of patients who underwent BTS and those who did not undergo BTS before ICR.

Results: The median age and body weight before BTS were 71 (28–199) days and 4.3 (3.3–6.8) kg respectively. There were no in-hospital or interstage deaths after BTS. The PVA Z-scores of patients with BTS revealed significant growth after BTS (from -4.2±1.8 to -3.0±1.7, $P<0.001$). VSR was eventually performed in 207 (63%) patients, including 26 (46%) patients who underwent staged repair. The overall freedom from pulmonary regurgitation-related reintervention were 99.7%, 99.1%, and 95.8% at 1, 5, and 20 years, respectively.

Conclusions: A staged surgical strategy incorporating BTS as the first palliation for symptomatic patients resulted in no mortality. BTS may have contributed to the avoidance of primary transannular

patch repair (TAP) and facilitated PVA growth; therefore, approximately half of the symptomatic neonates and infants were recruited for VSR. Staged repair may have led to functionally-reliable delayed TAP, thereby resulting in less surgical reinterventions.

(238 words)

Glossary of Abbreviations

ICR	=	intracardiac repair
PA	=	pulmonary artery
PR	=	pulmonary regurgitation
PV	=	pulmonary valve
PVA	=	pulmonary valve annulus
PVA(Z)	=	pulmonary valve annulus Z score
RVOT	=	right ventricular outflow tract
RVOTS	=	right ventricular outflow tract stenosis
TAP	=	transannular patch repair
TOF	=	tetralogy of Fallot
VSD	=	ventricular septal defect
VSR	=	valve-sparing repair

INTRODUCTION

Tetralogy of Fallot (TOF), the most common cyanotic heart defect, can be surgically-treated with low perioperative mortality[1]. However, residual post-surgical structural lesions have adverse consequences, including exercise intolerance, arrhythmia, heart failure, and sudden cardiac death[2]. These late complications were almost uniformly manifested in adult survivors after intracardiac repair (ICR) during eras when transannular patch repair (TAP) use was ubiquitous[3,4].

Six to 12 months was proposed as the ideal age for elective ICR in the 1990s[5]. During the past two decades, however, early primary ICR has been extended to cyanotic neonates and small infants[6,7]. The potential disadvantages of early ICR are longer intensive care unit stays, increased risk of reinterventions, and more frequent TAP use[8].

Our strategy is to delay ICR by using a Blalock-Taussig shunt (BTS) in symptomatic neonates and infants as initial palliation. Despite being a successful strategy adopted by many institutions, there are limited data regarding its long-term functional outcomes[8-11]. Therefore, this study aimed to determine whether an initial BTS procedure aids in recruiting symptomatic neonates and infants for valve-sparing repair (VSR) and to evaluate long-term outcomes stratified by ICR type.

PATIENTS AND METHODS

This retrospective, nonrandomized, single-institution study included 330 patients with isolated TOF who underwent ICR at Okayama University Hospital between January 1991 and July 2019, including 57 patients who underwent BTS. Patients with pulmonary atresia, absent pulmonary valve, atrioventricular septal defect, and any associated anomalies were excluded. This study was approved by the Institutional Review Board of the hospital, and the requirement for written informed consent was waived due to the observational nature of the study. A thorough review of medical records was conducted, and preoperative, intraoperative, postoperative, and follow-up data were collected.

The criteria for primary ICR included a pulmonary artery (PA) index >150 mm^2/m^2, left ventricular end-diastolic volume >80% of the normalized value, age older than 6 months, and body weight >5 kg. For symptomatic neonates and small infants who did not fulfill the criteria, BTS was performed as the first palliation. Prostaglandin, oral beta-blockers, and more feedings were administered to suspend any interventions during the neonatal period as possible. Because of the long waiting list, most of the eligible candidates were approximately 6 to 8 kg when ICR was finally performed.

Our institutional approach involves VSR for patients with a preoperative pulmonary valve annulus (PVA) Z score [PVA(Z)] ≥-2.0 and TAP for patients with a preoperative PVA(Z) <-4.0; the quality and number of the PV leaflets and coronary anatomy are also considered A monocusp fashioned from a 0.1

mm polytetrafluoroethylene membrane was utilized for TAP. For patients with a marginal pulmonary valve (PV) [-4.0≤PVA(Z)<-2.0], infundibular muscle resection and pulmonary valvotomy were first attempted before trying to pass Hegar probes through the annulus of those with PVA(Z) ≥-2.0. If Hegar probes of adequate size could not pass or if the final intraoperative right ventricle:left ventricle pressure was >0.6, then TAP was eventually performed. Because ventricular septal defect (VSD) closure and muscle resection were routinely performed through the tricuspid valve, isolated right ventriculotomy was not performed.

Criteria for right ventricular outflow tract stenosis (RVOTS)-related reintervention included peak pressure gradient > 50 mmHg or right ventricle:left ventricle pressure >2/3. Criteria for PR-related reintervention were moderate or greater PR and severe RV dilatation (RV end-diastolic volume index ≥160 mL/m^2 or RV end-systolic volume index ≥80 mL/m^2).

PV Measurements

All recordings of two-dimensional, M-mode, and Doppler images were obtained according to the American Society of Echocardiography guidelines, and Z scores were generated[12]. The PVA was measured during systole in the parasternal long-axis or short-axis view (whichever best-demonstrated the valve hinge points). The right ventricular outflow tract (RVOT) at the narrowest point and VSD were measured during systole in the parasternal short-axis view. The RVOT and VSD index values were calculated and divided by the body surface area.

For patients undergoing prior BTS, echocardiography was performed before BTS and before ICR to determine whether PVA increments occurred. If PVA(Z) was greater before ICR, then the PVs were defined as “grown PV”. Patients with grown PV who achieved VSR were defined as “recruited” patients, and the impact of BTS on VSR was analyzed.

Statistical analysis

Continuous variables were reported as median (interquartile range) for skewed data or mean (standard deviation) for normally distributed data. Categorical variables were reported as absolute frequency (percentage). Continuous variables were compared using Student’s *t*-test or Mann-Whitney U test based on the normality of data. Categorical variables were compared using Pearson’s χ^2 test. Predictable factors for time-related outcomes were tested using Cox regression analysis. Univariate analysis was performed to identify variables with $P<0.10$ that were entered in a stepwise fashion into a multivariate Cox proportional hazards regression model to determine the independent predictors of outcomes. The hazard ratio (HR) and 95% confidence interval (CI) were reported for significant multivariate risk factors. Estimates of freedom from reintervention were made by the Kaplan-Meier method. The level of statistical significance was set at $P<0.05$. All statistical analyses were performed with SPSS version 22 (Chicago, IL).

RESULTS

Demographics

Demographics are summarized in Table 1. The median age and weight at ICR were 449 (317–631) days and 8.6 (7.5–9.9) kg respectively. Neither neonates nor small infants <3.0 kg underwent primary ICR. Patient characteristics were compared between those who underwent BTS as the first palliation (staged repair group) and those who did not undergo BTS (primary ICR group) (Table 1). Age and weight at ICR were not different between groups. The PVA(Z) before ICR was significantly lower in the staged repair group than in the primary ICR group (-3.0±2.1 vs. -2.1±1.9, $P=0.004$). Of the 330 patients, 207 (63%) underwent VSR.

No in-hospital death occurred. One patient who underwent ICR died of post-transfusion hepatitis two months after discharge; the overall mortality was 0.3%.

Functional outcomes of the VSR and TAP groups

The stratified patient characteristics based on surgical approach are summarized in Table 2. The

PVA(Z) was significantly higher in the VSR group (-1.5±1.7 vs. -3.5±1.5, P<0.001).

The follow-up duration was 15.0±7.3 years. Overall, 8% underwent surgical reintervention. Freedom from surgical reintervention at 1, 10, and 20 years were 99.5%, 96.9%, and 93.5% in the VSR group and 97.6%, 91.6%, and 85.8% in the TAP group, respectively (P=0.023) (Figure 1A). PR-related reintervention was only required by patients in the TAP group (VSR: 0%; TAP: 8%). There was no difference in the frequency of RVOTS-related reintervention between groups (VSR: 4%; TAP: 2%). Freedom from PR-related reintervention at 1, 10, and 20 years were 100%, 100%, and 100% in the VSR group, and 99.2%, 97.5%, and 91.7% in the TAP group, respectively (P=0.001) (Figure 1B). Freedom from RVOTS-related reintervention at 1, 10, and 20 years were 100%, 97.3%, and 94.0% in the VSR group, and 99.2%, 97.4%, and 97.4% in the TAP group, respectively (P=0.306) (Figure 1C).

Long-term follow-up echocardiography was available for 282 patients (86%) (Table 2). Moderate or greater PR was more prevalent in the TAP group (VSR: 13%; TAP: 61%). Freedom from moderate or greater PR at 1, 10, and 20 years were 98.9%, 87.8%, and 78.5% in the VSR group, and 71.2%, 53.4%, and 35.4% in the TAP group, respectively (P<0.001) (Figure 1D).

BTS and its impact

Fifty-seven patients (17%) underwent BTS as the first palliation. The median age and weight at BTS were 71 (28–199) days and 4.3 (3.3–6.8) kg respectively (Table 3). There were no in-hospital or interstage deaths after BTS. PVA growth was evident through BTS [PVA: from 5.2 (4.3–6.1) to 8.1 (7.0–9.0) mm, $P<0.001$; PVA(Z): from -4.2±1.8 to -3.0±1.7, $P<0.001$]. Additionally, the proportion of patients with a tiny PVA [PVA(Z)<-4] decreased significantly (from 54.4% to 31.6%, $P<0.001$). Eventually, 46% of patients who had staged repair underwent VSR.

Patients who underwent staged repair were further divided into two groups: those who underwent VSR with grown PV (recruited group, n=20) and others (non-recruited, n=37) (Table 3). The PVA(Z) before BTS (-3.6±1.4 vs. -4.5±1.9, $P=0.063$), change in PVA (Z) (1.1±1.7 vs. 0.5±2.0, $P=0.006$), and VSD index [37.2 (32.3–42.7) vs. 30.8 (26.2–37.9) mm^2/m^2, $P=0.119$] were greater in the recruited group. The conduit index did not differ between groups [18.1 (14.0–19.3) vs. 17.7 (14.6–19.1) mm^2/m^2, $P=0.842$]. An intervention for BTS was only required in the non-recruited group (5 vs. 0, $P=0.085$).

The PVA(Z) before BTS and before ICR in the staged repair group were plotted and stratified by the ICR type. Twenty-six (46%) of the 57 staged repair patients eventually achieved VSR (Figure 2A). Although 31 patients had to undergo TAP, 21 (68%) had a grown PV; this contributed to a functionally-reliable TAP with a monocusp (Figure 2B).

From the multivariate analysis, PVA(Z)>-5 (HR: 8.91; 95% CI: 1.73–45.8, $P=0.009$), VSD index >30 (HR: 6.09; 95% CI: 1.24–30.0, $P=0.026$), and RVOT index >10 (HR: 4.36; 95% CI: 1.10–17.3, *P*=0.036) were anatomical factors associated with recruitment (Table 4).

COMMENT

Our study demonstrated that symptomatic neonates and small infants, who comprised 17% of the cohort, underwent BTS without any significant mortality. This staged surgical strategy incorporating BTS contributed to PVA growth in a majority of the patients and allowed a switch to VSR in approximately half of them. Avoiding early primary ICR and switching to VSR as much as possible led to a reduction of PR-related reinterventions (only 3% at 20 years after surgery).

VSR vs. TAP

The overall temporal trend of TAP use has been 23% to 50% during the past 50 years[13]. TAP application damages the PV integrity, leading to an increased risk of PR and long-term morbiditiy[2,14]. The adverse consequences of chronic PR raised interest in techniques and indications for sparing PV.

In the present study, VSR was mostly performed when PVA(Z)≥-4[15]. As RVOTS-related reintervention did not differ between the VSR and TAP groups, our cut-off PVA(Z) for VSR was reasonable. PR-related reintervention occurred in the TAP group only, which supported our strategy of facilitating PVA growth and subsequently achieving VSR as much as possible. Recent studies demonstrated that early primary ICR at ~3 months was associated with increased TAP use and inadequate RVOTS release, resulting in more frequent late reinterventions[15,16.]. In contrast, we observed satisfactory freedom from PR-related reintervention in the TAP group (91.7% at 20 years) despite the high follow-up rate. This outcome was based on a delayed ICR strategy involving the suspension of ICR until the patients were ≥5 kg irrespective of ICR type and initial management. Isolated right ventriculotomy was not performed for muscular RVOTS release with either technique (VSR or TAP). The transannular incision should be minimized in TAP cases to help maintain RV function and subsequently achieve good results.

Initial management of symptomatic neonates

The ideal staged repair approach for cyanotic neonates has remained a topic of discussion influenced by regional history and institutional experience. Some institutions favor BTS[8-11], whereas others favor RVOT stenting or patent ductus arteriosus (PDA)[17]. RVOT stenting is an effective and safe technique that increases the pulsatile forward flow of systemic venous blood to the PAs. The preferences is to not cross the PVA; however, another study showed that only one patient (8%) underwent stent implantation limited to the infundibulum and the others eventually underwent TAP[18]. This procedure poses the risk of distal stent migration and tricuspid regurgitation during implantation and removal[18]. PDA stenting is another alternative method. However, certain ductal anatomies might not be appropriate for PDA stenting, and this group included only patients who had technically successful stent placements[17]. Furthermore, there are technical challenges during subsequent surgical procedures and unique procedural complications[17].

In this study, there was no mortality among patients who underwent BTS. Additionally, no unplanned reintervention was required. This outcome supports our strategy of selecting BTS as the first palliation for symptomatic neonates and infants.

Impact of BTS on PVA growth

PVA growth after BTS has been reported previously[8,10,11]. In this study, PVA outgrowth with BTS placement over somatic growth was demonstrated, and approximately half of the patients with tiny PVA [PVA(Z)<-4] who were candidates for primary TAP benefited from our staged strategy. Even if PVA growth is insufficient for VSR because the initial PVA is too small, TAP would be technically easier than that performed in neonates, thus contributing to less reinterventions.

The mechanism of PVA growth is not yet fully understood; however, PVA growth is thought to be due to increased pulmonary blood flow through the PV from the VSD[10]. Because the lumen sizes of the peripheral PAs were smaller than those of the main PA, PVA enlargement was presumed to be difficult without increased transvalvular forward flow[10]. Nakajima et al. observed that blood flow through VSD from the dilated LV generated straight flow toward the PV after BTS[10]. This finding supported our assumption of predictable factors for recruitment (i.e., relatively larger VSD and RVOT as favorable).

Ultimate goal of TOF treatment

The goal of TOF treatment is the prevention of reinterventions. The current methods of TOF treatment have well-established excellent survival rates. Ultimately, the question lies with the type of surgical strategy to choose in order to achieve VSR that promises better functional outcomes. Performing VSR in neonates and small infants is considered ideal as it offers normal blood circulation during early life and incurs less medical expenses. However, studies have demonstrated that early primary repair, even with VSR, resulted in a high incidence of reinterventions[7,16]. Although it is technically feasible to perform ICR in a 3 kg neonate, it does not align with the ultimate goal for TOF patients. Our institutional policy is to perform VSR in a sophisticated manner to avoid any significant PR and RVOTS. Therefore, we believe that staged strategy should be selected, whenever necessary, for anatomic (small PVA) and physiologic (severe cyanosis) reasons, and that ICR for infants weighing approximately 6 to 8kg results in the best functional outcomes and minimizes the chance of subsequent reinterventions, thereby resulting in a better quality of life and incurring less lifetime medical expenses.

Limitations

The current study assumes the typical limitations of any retrospective study: selection bias and lack of randomization. Changes in perioperative management during the study period may have affected the results.Our study had a slightly unusual cohort distribution compared to other studies (i.e., few neonates). Furthermore, the multiple variables analyzed might reflect the development of different surgical approaches regarding the initial palliative versus primary total repair.

Conclusions

A staged surgical strategy incorporating BTS as the first palliation for symptomatic patients resulted in no mortality. BTS not only contributed to primary TAP avoidance but also facilitated PVA growth, recruited approximately half of symptomatic neonates and infants for VSR, and warranted functionally-reliable delayed TAP at the time of ICR, thereby leading to less surgical reinterventions as a whole. Reasonable PVA(Z) [PVA(Z)>-5], larger VSD, and larger RVOT may be predictors for adequate PVA growth leading to VSR. Further studies are necessary to validate this hypothesis.

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Table 1. Demographics of ICR (n=330)

Characteristics	**Overall (n=330)**		**Staged group (n=57)**		**Primary repair group (n=273)**		***P*-value**
Male	192	(58)	30	(53)	162	(59)	0.350
Age at ICR (day)	449	(317–631)	631	(477–852)	421	(290–574)	0.707
Neonates	0	(0)	0	(0)	0	(0)	-
Weight at ICR (kg)	8.6	(7.5–9.9)	8.9	(8.0–10.2)	8.5	(7.4–9.8)	0.449
Echocardiographic data before ICR							
PVA size (mm)	8.5	(7.5–9.9)	8.1	(7.1–9.0)	8.5	(7.6–10.0)	0.024
PVA Z score	-2.3	± 2.0	-3.0	± 2.1	-2.1	± 1.9	0.004
Catheterization data before ICR	n=213		n=53		n=160		
PA index (mm/m^2)	278	(230–336)	281	(230–336)	277	(230–335)	0.635
Operative data							
Valve-sparing repair	207	(63)	26	(46)	181	(66)	0.003
Trans-RA and -PA approach	292	(88)	54	(95)	238	(87)	0.104
Bicuspid valve	258	(78)	51	(89)	107	(39)	0.023
Aortic cross-clamp time (min)	85	± 26	104	± 32	81	± 22	<0.001
Hospital mortality	0	(0)	0	(0)	0	(0)	-
Late mortality	1	(0)	1	(1)	0	(0)	0.173

Data presented as median (interquartile range) or n (%) or mean (±SD). ICR, intracardiac repair; PA, pulmonary artery; PVA, pulmonary valve annulus; RA, right atrium; RVOT, right ventricular outlet tract.

Table 2. VSR vs. TAP (n=330)

Characteristics	**Overall (n=330)**		**VSR (n=207)**		**TAP (n=123)**		***P*-value**
Age at ICR (day)	449	(317–631)	428	(317–570)	527	(331–714)	0.081
Weight at ICR (kg)	8.6	(7.5–9.9)	8.4	(7.4–9.6)	9.0	(7.9–10.3)	0.018
Echocardiographic data before ICR							
PVA size (mm)	8.5	(7.5–9.9)	8.9	(8.1–10.2)	7.7	(6.5–8.5)	<0.001
PVA Z score	-2.3	±2.0	-1.5	±1.7	-3.5	±1.5	<0.001
Previous BTS	57	(17)	26	(13)	31	(25)	0.003
Bicuspid valve	258	(78)	153	(74)	105	(85)	0.012
Interval from ICR (year)	15.0	±7.3	12.1	±7.1	16.5	±6.5	<0.001
Reintervention							
Catheter reintervention	29	(9)	11	(5)	18	(15)	0.004
Balloon dilatation for branch PA	28	(8)	10	(5)	18	(15)	0.001
Surgical reintervention	26	(8)	9	(4)	17	(14)	0.002
PR-related	10	(3)	0	(0)	10	(8)	<0.001
RVOTS-related	11	(3)	8	(4)	3	(2)	0.485
branch PA-related	4	(1)	1	(0)	3	(2)	0.116
residual VSD-related	1	(0)	0	(0)	1	(1)	0.194
Long-term follow-up Echocardiography	n=282		n=181		n=101		

Interval from ICR (year)	13.0	±7.3	11.4	±7.2	15.7	±6.6	<0.001
Pulmonary regurgitation grade							
None	9	(3)	9	(5)	0	(0)	0.023
Trivial	52	(18)	49	(27)	3	(3)	<0.001
Mild	135	(48)	99	(54)	36	(36)	0.002
Moderate	74	(26)	22	(12)	52	(51)	<0.001
Severe	12	(4)	2	(1)	10	(10)	<0.001
RVOT pressure gradient (mmHg)	21	±14	22	±14	18	±13	0.018

Data presented as median (interquartile range) or n (%) or mean (±SD). BTS, Blalock-Taussig shunt; ICR, intracardiac repair; PA, pulmonary artery; PR, pulmonary regurgitation; PVA, pulmonary valve annulus; RVOT, right ventricular outlet tract; RVOTS, right ventricular outlet tract stenosis; TAP, transannular patch repair; VSD, ventricular septal defect; VSR, valve-sparing repair.

Table 3. Demographics of BTS (n=57)							
Characteristics	**Overall (n=57)**		**Recruited (n=20)**		**Non-recruited (n=37)**		***P*-value**
Male	30	(53)	12	(60)	18	(49)	0.413
Age at BTS (day)	71	(28–199)	105	(36–210)	60	(28-189)	0.620
Neonates	15	(26)	5	(25)	10	(27)	0.868
Weight at BTS (kg)	4.3	(3.3–6.8)	4.6	(3.3–7.0)	4	(3.3-6.0)	0.770
Echocardiographic data before BTS							
PVA size (mm)	5.2	(4.3–6.1)	5.3	(4.7–6.9)	5.0	(4.0–6.0)	0.276
PVA Z score	-4.2	±1.8	-3.6	±1.4	-4.5	±1.9	0.063
VSD size (mm)	8.6	(7.2–10.4)	9.2	(8.4–10.7)	8.0	(6.7–9.6)	0.108
VSD index (mm/m^2)	33.3	(27.7–40.0)	37.2	(32.3–42.7)	30.8	(26.2–37.9)	0.119
RVOT size (mm)	2.5	(1.9–3.5)	2.8	(2.0–4.6)	2.5	(1.9–3.1)	0.281
RVOT index (mm/m$^{2)}$	10.0	(8.0–13.2)	10.6	(8.1–13.0)	10.0	(8.0–13.2)	0.313
Catheterization data before BTS							
PA index (mm^2/m^2)	155	(123–230)	180	(135–235)	155	(123–199)	0.292
Qp/Qs	0.52	(0.40–0.60)	0.50	(0.49–0.77)	0.55	(0.38–0.56)	0.378
LVEDV (%N)	77	(66–83)	77	(67–82)	80	(63–85)	0.754
Echocardiographic data before ICR							
PVA size (mm)	8.1	(7.0–9.0)	9.0	(8.5–9.6)	7.2	(6.9–8.2)	0.002
PVA Z score	-3.0	±1.7	-1.8	±1.2	-3.8	±1.6	<0.001

Change in PVA Z score	0.9	±1.9	1.1	±1.7	0.5	±2.0	0.006
Catheterization data before ICR							
PA index (mm^2/m^2)	281	(230–336)	304	(282–361)	255	(225–303)	0.156
Qp/Qs	0.98	(0.83–1.25)	1.22	(0.96–1.39)	0.93	(0.79–1.09)	0.084
LVEDV (%N)	116	(100–136)	125	(104–166)	112	(97–127)	0.045
Conduit size							
3.0 mm	1	(2)	1	(5)	0	(0)	0.170
3.5 mm	6	(11)	2	(10)	4	(11)	0.810
4.0 mm	33	(58)	11	(55)	22	(59)	0.745
5.0 mm	17	(30)	6	(30)	11	(30)	0.983
Conduit index (mm/m^2)	18.0	(14.5–19.3)	18.1	(14.0–19.3)	17.7	(14.6–19.1)	0.842
On bypass	9	(16)	3	(15)	6	(16)	0.904
Incision type							
Sternotomy	21	(37)	9	(45)	12	(32)	0.421
Thoracotomy	36	(63)	11	(55)	25	(68)	0.421
Mortality	0	(0)	0	(0)	0	(0)	-
Time to repair (day)	569	±306	569	±392	569	±254	0.995
Intervention for BTS before repair	5	(9)	0	(0)	5	(14)	0.085
Grown pulmonary valve	43	(75)	20	(100)	23	(62)	0.002
Valve-sparing repair	26	(46)	20	(100)	6	(16)	<0.001

Data presented as median (interquartile range) or n (%) or mean (±SD). BTS, Blalock-Taussig shunt; ICR, intracardiac repair; LVEDV, left ventricular end-diastolic volume; PA, pulmonary artery; PVA, pulmonary valve annulus; VSD, ventricular septal defect; Qp/Qs, pulmonary blood flow/systemic blood flow ratio; RVOT, right ventricular outlet tract.

Table 4. Univariate and Multivariate Analysis of Predictable Factors for Recruitment (n=57)

Characteristics	***P*-value (Univariate)**	**HR (95% CI); *P*-value (Multivariate)**
PVA(Z) >-4	0.218	
PVA(Z) >-5	0.047	8.91 (1.73–45.8); *P*=0.009[a]
PVA(Z) >-6	0.199	
VSD index >30	0.070	6.09 (1.24–30.0); *P*=0.026[a]
RVOT index > 10	0.075	4.36 (1.10–17.3); *P*=0.036[a]

CI, confidence interval; HR, hazard ratio; PVA, pulmonary valve annulus; RVOT, right ventricular outlet tract; VSD, ventricular septal defect. Only variables with *P* <0.10 in the univariate analysis are displayed and entered into the multivariate Cox regression model.

[a] *P*<0.05 (multivariate)

FIGURE LEGENDS

Figure 1. Freedom from (A) all surgical reintervention, (B) PR-related reintervention, (C) RVOTS-related reintervention, and (D) moderate or greater PR.

Figure 2. Transition of PVA (Z) in the staged repair patients stratified by ICR type. PVA(Z) of patients who underwent (A) VSR and (B) TAP were plotted.