A Novel Predictive Value for the Transannular Patch Enlargement in Repair of Tetralogy of Fallot

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Background. In tetralogy of Fallot, whether relieving right ventricular outflow tract obstruction requires transannular patch enlargement (TAPE) of the pulmonary valve depends on pulmonary valvular annulus size. The z-score of pulmonary annulus is most commonly used as a predictor of the need for TAPE. However, the z-score is a complex value affected by height, body weight, body surface area, and different reference populations. Therefore, we hypothesized that the great artery annulus size ratio (pulmonary valvular annulus size to aortic valve annuls size [GA ratio]) may be a better predictor of the need for TAPE.

Methods. We analyzed 122 patients retrospectively who had undergone total correction of tetralogy of Fallot between January 2007 and March 2015. We categorized the patients into two groups, TAPE versus non-TAPE. Great arterial annuli sizes were evaluated in each group, and the GA ratio cutoff values for TAPE were calculated.

Results. In total, 40 patients (32.8%) required TAPE. Both GA ratios and z-scores were smaller in the TAPE group than in the non-TAPE group (0.51 versus 0.67, $p < 0.0001$, and -2.46 versus -0.85, $p < 0.0001$, respectively). In receiver operating characteristics analyses, the z-score and GA ratio cutoff values were -1.67 (area under the curve $= 0.797$) and 0.56 (area under the curve $= 0.900$), respectively, demonstrating that the GA ratio was a more powerful diagnostic tool as a predictor of TAPE ($p = 0.014$).

Conclusions. Our results suggest that the GA ratio is a useful predictor for TAPE and can be applied readily and simply in clinical practice.

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The first successful surgical correction of tetralogy of Fallot (TOF) was reported in 1954. The original repair consisted of ventricular septal defect (VSD) closure through a large right ventriculotomy and right ventricular outflow tract (RVOT) obstruction relief with transannular patch enlargement (TAPE) of the pulmonary valve [1]. Since then, several operative techniques have been reported, including transatrial repair of the VSD and relief of RVOT obstruction without ventriculotomy [2] and transatrial-transpulmonary repair [3, 4]. These new surgical strategies focus on maximal preservation of right ventricular function by avoiding or minimizing ventriculotomy. However, if the pulmonary valve is too small to be preserved, TAPE is inevitable. TAPE can cause pulmonary valve regurgitation, which can adversely affect long-term results after TOF repair. Conversely, unwise preservation of the pulmonary valve or annulus can also adversely affect long-term results of TOF repair.

Therefore, a reasonable indicator for TAPE is important for early and late results of TOF repair. To date, the z-score of the pulmonary valve annulus (PVA) has been used to predict the need for TAPE [5, 6]. The minimum z-score for TAPE may vary depending on the anatomic environment of RVOT and the institution's or surgeon's policy. Calculation of the z-score itself also has some problems. The z-score indicates how many standard deviations the case is from the mean. However, the z-score does not correct any errors that might be introduced by a skewed population distribution. The z-score is a complex value that is affected by height, body weight, body surface area, and reference population group [7]. Furthermore, there are several methods of calculating body surface area, which can affect the z-score. Inappropriate z-score use in surgical decision making may adversely affect operative outcomes [8].

We hypothesized that the ratio of PVA size to aortic valve annulus (AVA) size (PVA/AVA, or great artery annulus size ratio [GA ratio]) could be useful to predict the need for TAPE. The GA ratio can be determined

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Abbreviations and Acronyms

AUC = area under curve
AVA = aortic valve annulus size
GA = great artery annulus
PVA = pulmonary valve annulus
RVOT = right ventricular outflow tract
TAPE = transannular patch enlargement of pulmonary valve
TOF = tetralogy of Fallot
VSD = ventricular septal defect

readily using cardiac angiography, computed tomography, or a transthoracic echocardiogram and is not affected by other factors. The z-score comes from the absolute value of PVA size, which might have some error, depending on the measuring device or image types. However, using the GA ratio can minimize such errors and can also be reliably and constantly calculated by simple methods from various imaging modalities. For these reasons, we evaluated whether the GA ratio is a useful predictor of TAPE in TOF repair. These pilot results may be useful in TAPE decision making.

Material and Methods

Institutional Review Board approval was obtained for this study. In total, 122 patients who underwent TOF repair by a single surgeon (S.C.S.) between January 2007 and March 2015 at our institution were enrolled. Patients who had pulmonary atresia, absent pulmonary valve syndrome, atrioventricular septal defects, or left pulmonary artery interruption were excluded. A 72-year-old female patient was also excluded. Patient demographics are summarized in Table 1.

The median age at total repair was 6.2 months, and the median body weight was 7.1 kg. The median z-score was −1.34 and the GA ratio was 0.60. The location of VSD was perimembranous in 82 patients, muscular outlet in 33, and subarterial including total conal defect in 7. Thirty-seven patients (32.2%) had TAPE among patients with perimembranous or muscular outlet VSD, and 3 (42.9%) had TAPE among patients with subarterial VSD.

In total, 51 (41.8%) patients had palliative procedures before total correction (median age 16 days). Details about the palliative procedure are summarized in Table 2. To reduce the TAPE procedure, we usually used selective balloon valvuloplasty, a palliative systemic-to-pulmonary artery shunt, and a palliative infundibulectomy for symptomatic neonates when the PVA size was small. We have changed our policy for symptomatic neonatal TOF since 2008. Our main goal of management of symptomatic neonatal TOF is to avoid transannular patch as much as possible, because transannular patch in TOF could have an adverse impact on long-term results. Moreover, we believe that augmentation of antegrade blood flow through the pulmonary valve can stimulate the growth of the pulmonary valve annulus. Hence, we are doing balloon pulmonary vavuloplasty in patients with mainly valvar stenosis. In patients with valvar and infundibular stenoses, we are doing surgical infundibulectomy with forceful dilation of pulmonic valve to increase blood flow through the pulmonary valve. We use the Blalock-Taussig shunt only for patients with very small pulmonary annulus or atresia at the present time. Among 10 patients who underwent palliative infundibulectomy and valvotomy, 2 patients had TAPE during total correction.

Under arrested heart, pulmonary valves were inspected first through a longitudinal incision of the main pulmonary artery. After identifying pulmonary valve morphology, commissural fusions of the pulmonary valve leaflet were incised carefully, and sometimes valvar tetherings to the pulmonary artery wall were released with a scalpel. Then, infundibulectomy was performed before VSD closure through the tricuspid and pulmonary valves. During the infundibulectomy, we measured PVA size with a dilator (Sonden probes; Fehling Instruments, Karlstein, Germany). Sometimes, forceful dilation with a dilator was required. A normal PVA size was taken from the echocardiographic data of Daubeny and colleagues [9]. If the PVA measured in the operating room was smaller than the normal PVA minus 1 mm, we performed a limited transannular ventriculotomy extending from the valve annulus proximally for a distance of 10 mm. We included the patients who had only annulotomies in the TAPE group. We routinely measured right ventricular pressure just before decannulation. If the right ventricular pressure to peak systolic systemic pressure ratio was above 0.8, we considered TAPE under re-bypass. We sometimes used short-acting beta-blockers when noting an unexpectedly high peak right ventricular/systolic systemic pressure ratio. We did not use a separate

Table 1. Patients Demographics (n = 122)

Variable	Median (25th/75th percentile)	Range
Age, months	6.2 (5.1/8.3)	1.3–175.4
Weight, kg	7.1 (6.0/8.4)	1.4–30.6
Body surface area, m^2	0.34 (0.31/0.39)	0.12–1.13
PVA size, mm	8.2 (7.1/9.5)	3.9–15.8
PVA z-score	−1.34 (−2.40/−0.41)	−5.72 to 2.07
GA size ratio	0.60 (0.53/0.70)	0.35–0.90

GA = great artery annulus; PVA = pulmonary valve annulus.

Table 2. Palliative Treatment (n = 51)

Palliation Type	n (%)
Shunt[a]	13 (25.5)
Balloon[b]	27 (52.9)
Infundibulectomy	6 (11.8)
Balloon and infundibulectomy	3 (5.9)
Shunt and infundibulectomy	1 (2.0)
Balloon and shunt	1 (2.0)

[a] Shunt indicates systemic-to-pulmonary artery shunt. [b] Balloon indicates balloon pulmonary valvotomy.