



Optimal Use of Z-Scores to Preserve the Pulmonary Valve Annulus During Repair of Tetralogy of Fallot

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Abstract

Objective: The size of the pulmonary annulus measured as a z-score is often used to determine when to insert a transannular patch (TAP). Multiple “cutoffs” are quoted in the literature; this could lead to inappropriate insertion. We aimed to determine whether the use of z-scores derived from different populations may have contributed to the varied “cutoffs” quoted. **Methods:** PubMed was searched using the terms: “tetralogy,” “Fallot,” “transannular,” “patch,” “mortality,” and “death.” Studies published between January 1, 2005, and October 5, 2017, were included; studies without participants under the age of 18 years and studies that did not describe the operative procedure were excluded. **Results:** Of 52 papers retrieved, 19 were included representing 2,500 repaired patients; 1,371 (54.8%) had a TAP. Five (26.3%) papers representing 638 patients (25.5%) quoted a z-score “cutoff” and what data set was used; “cutoffs” ranged from -2 to -4 and were derived from 2 different data sets. Three studies quoted a data set that has been shown in previous work to be problematic; the only quoted “cutoffs” of -4 were from two of these studies. **Conclusions:** Surprisingly few (26.3%) studies mention what pulmonary annulus size “cutoff” was used to decide when to insert a TAP. Z-scores derived from different populations were used by different studies and it is possible that this may have contributed to the varied “cutoffs” quoted. Recommendations to perform valve-sparing surgery in pulmonary annuli as small as -4 may not be warranted. Future papers should record “cutoffs” employing recommended z-score data set.

Keywords

pulmonary, annular, transannular, patch, z-score, tetralogy, Fallot

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Introduction

Outcomes after surgical repair of Tetralogy of Fallot (TOF) are optimized by achieving a sound closure of the ventricular septal defect and ensuring that there is adequate relief of right ventricular outflow tract obstruction (RVOTO).¹ In efforts to eliminate RVOTO, the integrity of the pulmonary annulus (PA) is sometimes compromised by inserting a transannular patch (TAP). Among other considerations, the pulmonary annular z-score is used to decide when to insert a TAP. On one hand, the insertion of a TAP is thought to expose patients to an increased risk of late sudden cardiac death (SCD)²; on the other hand, the operative mortality increases if significant RVOTO persists.¹ Typically, a TAP will be inserted if the pulmonary annular z-score is less than -2 .³ In 2005, Stewart et al suggested that it was safe to preserve pulmonary annuli as small as -4 .⁴ Since then z-score “cutoffs” ranging from 0 to -4 have been quoted in the literature.⁵ Awori et al demonstrated that the indiscriminate use of z-scores, derived from different data sets, could result in errors in determining the actual dimensions of cardiac

structures.⁶ For example, they demonstrated that a patient with a body surface area of 0.2 m^2 and an aortic valve annulus z-score of -3 described using the Daubeney et al’s⁷ z-score would have twice as much flow through their aortic valve as a patient of the same size with a z-score of -3 described using the Zilberman et al’s⁸ z-score. Table 1 demonstrates similar flow discrepancies across pulmonary annuli of various sized patients. In related work, the same authors found that the indiscriminate use of z-scores derived from different data sets resulted in the possibility of patients with pulmonary atresia and intact ventricular septum being allocated to the wrong surgical pathway.¹⁰ The multiple “cutoffs” quoted for TAP

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Abbreviations and Acronyms

PA	pulmonary annulus
RV	right ventricular
RVOTO	right ventricular outflow tract obstruction
SCD	sudden cardiac death
TAP	transannular patch
TOF	tetralogy of Fallot
VSS	valve-sparing surgery

Table 1. Comparison of Flow Across Pulmonary Annulus.^a

BSA (Patient Age)	PVAD at z-score -3		Flow Ratio D:P
	D	P	
0.2 (neonate)	6.0	5.0	2.1:1
0.4 (6 months)	8.3	6.8	2.2:1
0.55 (3 years)	9.9	8.5	1.8:1
1.10 (10 years)	14.0	12.5	1.6:1

Abbreviations: BSA, body surface area; PVAD, pulmonary valve annulus diameter (in mm).

^aD indicates Daubeny's z-score⁷; P, Pettersen's z-score⁹.

insertion may have resulted from a similar indiscriminate use of z-scores and could result in the "inappropriate insertion of" or "failure to insert" a TAP. This study aimed to determine whether the indiscriminate use of z-scores derived from different data sets may have contributed to the multiple "cutoffs" for TAP insertion quoted in the literature.

Patients and Methods

Two searches were made of PubMed using the "advanced" setting. Search terms and filters are shown in Table 2; all filters were combined with the instruction "AND." Both searches were restricted to the period beginning on January 1, 2005, and ending on October 5, 2017. Results obtained from searches 1 and 2 were combined with the instruction "OR" to give the final search result. Retrieved articles with no participants under the age of 18 years and articles that did not describe the operative procedure were excluded.

Results

Fifty-two papers were retrieved, 19 of which were included and are shown in Table 3. The 19 papers represented 2,500 patients who had repair of TOF; 1,371 (54.8%) had a TAP inserted. Ten (52.6%) of 19 papers representing 1,621 (64.8%) patients did not mention what "cutoff" was used for TAP insertion; four of 19 mentioned the "cutoff," but not data set. Five (26.3%) papers of 19 representing 638 (25.5%) patients described what pulmonary valve annulus dimension "cutoff" and z-score data set used to determine when to insert a TAP.

Table 2. Filters and Search Terms.

Filter	Search Terms 1	Search Terms 2
Title	Tetralogy	Tetralogy
Title	Fallot	Fallot
Title/abstract	Transannular	Transannular
Title/abstract	Patch	Patch
Title/abstract	Death	Mortality

Discussion

Gatzoulis et al noted that pulmonary incompetence was the predominant lesion in patients who had late SCD after repair of TOF; they also found that TAP was a risk factor for SCD.² The authors reasonably suggested that preservation or restoration of pulmonary valve function may reduce SCD. This suggestion generated interest in the preservation of the PA during repair of TOF resulting in proponents of "valve-sparing surgery" (VSS) challenging existing PA size "cutoffs" for TAP insertion.⁴ The grounds for such challenges must be carefully examined as there is evidence that failure to adequately relieve RVOTO at the time of repair of TOF significantly increases operative mortality.¹ In addition, there is evidence suggesting that pulmonary incompetence and TAP insertion may not be risk factors for late SCD.^{30,31}

We examined 2,500 patients; only 638 (25.5%) recorded a TAP insertion "cutoff" that identified the z-score data set used. In the majority of patients, it was impossible to determine the criteria used by the surgeon to decide when to insert the TAP. In the papers where "cutoffs" were adequately recorded, they ranged from -2 to -4 and each paper quoted one of two z-score data sets: either Rowlatt¹⁶ or Daubeny.⁷ The majority of papers (2/3) that quoted a "cutoff" of -4 used the Daubeny's data set. This data set has been shown elsewhere to provide significantly larger actual dimensions of cardiac structures for any given z-score.⁶ This means that a patient with a PA score of -4 as described using the Daubeny data set would have a larger PA than a patient with a PA score of -4 described using the Rowlatt's data set. This may be why Stewart was able to recommend a "cutoff" of -4.⁴

Awori et al examined the likelihood of inadequately relieving RVOTO during repair of TOF. They found that once the PA valve z-score falls below -1.3 (using the recommended data set), failure to insert a TAP would result in an unacceptable PA gradient in 25 of 100 patients.³² They cautioned against sparing the PA when the PA z-score was smaller than this. At first glance, this recommendation may not appear justifiable in the light of late SCD seemingly associated with pulmonary incompetence. However, QRS elongation has been shown to be the strongest predictor for ventricular arrhythmia and there is evidence to suggest that pulmonary stenosis leading to right ventricular (RV) hypertrophy may play a greater role in QRS elongation and SCD than pulmonary incompetence.³³ In addition, other authors have not found a TAP to be a risk factor for SCD as Gatzoulis has.³⁴ The evidence that repaired patients

Table 3. Studies Retrieved.

Author	Year	N	TAP (%)	Z Score	Data Set
Sen et al ¹¹	2016	80	51 (63.8)	–	–
Saygi et al ¹²	2015	122	97 (79.5)	–2	Daubene ⁷
Devendran et al ¹³	2015	79	59 (74.7)	–2	–
d'Udekem et al ¹⁴	2014	675	433 (64.1)	–	–
Mimic et al ¹⁵	2014	251	132 (52.6)	–3	Rowlatt ¹⁶
Sasikumar et al ¹⁷	2014	20	0 (0.0)	–	–
Kim et al ¹⁸	2013	326	160 (49.1)	–	–
Attanawanich et al ¹⁹	2013	93	93 (100)	–	–
Hua et al ²⁰	2011	139	7 (5.0)	–3	Rowlatt
Hashemzadeh and Hashemzadeh ²¹	2010	101	60 (59.4)	–	–
Kanter et al ²²	2010	37	1 (33.3)	–2	–
Gerling et al ²³	2009	124	44 (35.5)	–	–
Bono et al ²⁴	2009	24	0 (0.0)	–4	Daubene ⁷
Tamesberger et al ²⁵	2008	90	59 (65.6)	–2	–
He ²⁶	2008	67	18 (26.9)	–	–
Seddio et al ²⁷	2007	69	55 (79.7)	–	–
Ozkara et al ²⁸	2006	35	24 (68.6)	–2	–
Kolcz and Pizarro ²⁹	2005	66	58 (87.9)	–	–
Stewart et al ⁴	2005	102	20 (16.7)	–4	Daubene ⁷

Abbreviation: TAP, transannular patch.

with TOF have reduced longevity compared to the normal population is clear; however, there is conflicting evidence that TAP insertion leading to pulmonary valve incontinence and RV dilatation increases long-term mortality. On the contrary, there is evidence to suggest that inadequate relief of RVOTO may be the genesis of QRS elongation, which is a predictor for ventricular arrhythmia and SCD.³³

In conclusion, it is possible that the indiscriminate use of z-scores derived from different data sets may have contributed to the wide range of “cutoffs” for insertion of a TAP reported in the literature. Recommendations in the literature that the PA may be spared even when it is as small as –4 may have resulted from the use of z-score data sets that have been shown to be problematic.⁶ Such data sets predict larger dimensions for cardiac structures corresponding to a particular z-score. Using z-scores derived from such data sets could result in failure to insert a TAP when one is indicated. In light of this and considering the fact that residual RVOTO may actually provide a substrate for increased late SCD, we feel that suggestions for VSS for pulmonary valve annuli as small as –4 may not be justified at present. We recommend that future papers record what TAP insertions “cutoffs” were employed and that z-scores derived from the ideal data set be used. The ideal data set for z-scoring has been suggested^{6,9} and it would seem reasonable to insert a TAP once the PA z-score is less than –2.³²

Declaration of Conflicting Interests

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