Sultan Qaboos University Med J, November 2024, Vol. 24, Iss. 4, pp. 540–547, Epub. 27 Nov 24
Submitted 22 May 24
Revision Req. 2 Jul 24; Revision Recd. 20 Jul 24
Accepted 11 Aug 24
https://doi.org/10.18295/squmj.11.2024.077

CLINICAL & BASIC RESEARCH

Comparison of Immediate Outcomes of Pulmonary Valve-Sparing and Transannular Patch Techniques for Correction of Tetralogy of Fallot

Mohammed H. Al Ghafri,[1] Sumaiyah O. Al Toubi,[2] *Madan M. Maddali,[3]
Panchatcharam M. Sathiya,[2] Sachin Jose,[2] Hamood N. Al-Kindi[4]

abstract: ***Objectives:*** This study primarily aimed to compare the mechanical ventilation durations between pulmonary valve-sparing and transannular patch repair techniques in the surgical correction of Tetralogy of Fallot. Secondary objectives included comparison of demographic characteristics, cardiopulmonary bypass parameters, postoperative vasoactive inotrope requirements, incidence of cardiac conduction abnormalities, echocardiographic findings, intensive care unit and hospitalisation durations, reoperations rates, morbidity and mortality between the 2 approaches. ***Methods:*** This retrospective cohort study was conducted at the Royal Hospital, Muscat, Oman, between January 2016 and December 2019. This study included 102 paediatric patients who underwent complete surgical correction of Tetralogy of Fallot over 3 years, either by a pulmonary valve-sparing technique (Group 1, n = 43) or by transannular patch repair (Group 2, n = 59). Data for both primary and secondary outcomes were extracted from hospital records. ***Results:*** Mechanical ventilation duration was significantly shorter in Group 1 (P = 0.039). Patients in Group 1 were generally older, with shorter cardiopulmonary bypass and aortic clamp times, lower inotrope scores, and shorter chest tube retention, intensive care unit and hospitalisation periods. Junctional ectopic tachycardia and severe pulmonary regurgitation were significantly more common in Group 2, while right ventricular outflow tract peak pressure gradients were higher in Group 1. Multivariate analysis identified patient weight as the only independent predictor of mechanical ventilation duration. ***Conclusion:*** Pulmonary valve preservation was associated with better early outcomes, including reduced mechanical ventilation duration, lower vasoactive inotrope scores, decreased postoperative arrhythmias and shorter hospital stay.

Keywords: Cardiac Surgical Procedures; Cardiac Valve Annuloplasty; Pulmonary Valve Insufficiency; Tetralogy of Fallot; Cohort Studies; Retrospective Studies.

Advances in Knowledge

- *This study compares the immediate postoperative outcomes of 2 techniques in the tetralogy of Fallot correction, clarifying their safety and efficacy profiles.*
- *It analyses the duration of mechanical ventilation, intensive care unit and hospital stays and overall recovery rates.*
- *The findings guide surgeons in choosing optimal surgical approaches, potentially standardising protocols and improving patient outcomes.*

Application to Patient Care

- *Surgeons can tailor personalised treatment plans based on informed decisions.*
- *Identifying safer surgical techniques aids in reducing complications and supports smoother recoveries.*
- *Evidence-based data facilitates the development of standardised care protocols and enhances training for new surgeons.*
- *Clear information on postoperative expectations helps families prepare and improves overall satisfaction.*
- *Immediate postoperative outcomes provide a foundation for future long-term follow-up studies.*

In the complete surgical repair of Tetralogy of Fallot (ToF), 2 primary approaches are employed: a pulmonary valve-sparing technique and transannular patch repair.[1] Evidence indicates that long-term survival following ToF repair is favourable, with over 95% of patients reaching adulthood.[2] The goal of an ideal ToF repair is a complete closure of the ventricular septal defect, functional pulmonary valve preservation and unobstructed right ventricular outflow tract.[2] The transannular patch technique effectively addresses right ventricular outflow tract obstruction; however, it may lead to significant pulmonary valve regurgitation, potentially causing chronic right ventricular volume overload and dysfunction. Such complications can progress to heart failure, increased risk of arrhythmias and, in some cases, sudden cardiac death.[3,4] In comparative studies of long-term outcomes, patients who underwent valve-sparing ToF repair demonstrated improved 30-year survival rates, reduced need for cardiovascular reinterventions and a lower incidence of pulmonary valve replacements compared to those who underwent transannular patch procedures.[2] Consequently, there has been a shift towards a more aggressive pulmonary

Department of [1]Pediatric Intensive Care, [3]Anesthesia, & [4]Cardiothoracic Surgery, Royal Hospital, Muscat, Oman; [2]Oman Medical Specialty Board, Muscat, Oman.
**Corresponding Author's E-mail: madanmaddali@hotmail.com*

valve-sparing approach in ToF repairs. This approach may enhance pulmonary annulus growth and reduce the frequency of the late reinterventions, though it may also leave some residual right ventricular outflow obstruction.[1,5]

The decision to perform either a valve-sparing repair or a transannular patch repair is generally based on the anatomical characteristics and degree of dysplasia of the pulmonary valve. Surgeons assess the size of the pulmonary valve annulus and any pathological changes in the valve tissue to guide their choice, reflecting accepted variations in surgical practice. While overall long-term survival following ToF repair is promising, studies have suggested that non-valve-sparing operations may be negatively impact early postoperative survival, particularly in the first 6 years.[6]

Limited data exist on the immediate postoperative outcomes for children undergoing valve-sparing ToF repairs, especially in comparison to outcomes following transannular approach repairs. This study aimed to address this gap by hypothesising that immediate postoperative outcomes would be comparable between both surgical approaches, as the adverse effects of pulmonary regurgitation typically associated with transannular patch repairs may take years to manifest. Using standardised tracheal extubation criteria for post-cardiac surgery in children, this study assumed that successful mechanical ventilation withdrawal would indicate adequate respiratory and haemodynamic stability, regardless of the ToF repair technique used.

The primary objective of this study was to compare postoperative mechanical ventilation duration in children who underwent complete ToF repair by either a pulmonary valve-sparing approach or a transannular patch. Secondary objectives included comparisons of cardiopulmonary bypass parameters, inotrope requirements, postoperative transthoracic echocardiographic findings related to atrioventricular and pulmonary valves and right ventricular outflow gradients, incidence of cardiac conduction abnormalities and morbidity and mortality between both groups. Additionally, duration of intensive care unit (ICU) and hospital stay, as well as reinterventions within 24 months of the primary operation, were documented.

Methods

This retrospective cohort study included 102 paediatric patients (under 13 years of age) with a preoperative diagnosis of ToF and confluent pulmonary arteries who underwent complete surgical correction at the National Heart Center, The Royal Hospital, Muscat, Oman, between January 2016 and December 2019. Children with confluent pulmonary arteries who received primary complete correction were included. Cases with pulmonary atresia, absent pulmonary valve syndrome, atrioventricular septal defects and nonconfluent branch pulmonary arteries were excluded. No patients in this cohort exhibited an anomalous left anterior descending artery originating from the right coronary artery and crossing the right ventricular outflow tract.

Patients were divided into 2 groups: Group 1 (n = 43) underwent pulmonary valve-sparing surgery, while Group 2 (n = 59) received a transannular patch repair. The choice of surgical approach was based on the operating surgeon's discretion, informed primarily by preoperative echocardiography-derived z-scores for the pulmonary valve annulus (threshold: z-score of −2). All surgeries were performed under narcotic-based general anaesthesia with invasive haemodynamic monitoring, complemented by standard American Society of Anesthesiologists monitoring guidelines. Intraoperative echocardiography (transoesophageal, transthoracic or epicardial) was routinely used before and after cardiopulmonary bypass to confirm the adequacy of the surgical correction.

Surgical correction was conducted on cardiopulmonary bypass with mild hypothermia. In Group 2 patients, the transannular patch was fashioned using either bovine pericardium or treated autologous pericardium, without the use of a monocusp valve. Adequate repair was defined by intraoperative echocardiography findings of: (1) <3 mm residual atrial septal defect; (2) <3 mm residual ventricular septal defect from the right ventricular aspect; (3) ≤40 mmHg peak gradient across the right ventricular outflow tract; (4) no residual gradient with free pulmonary regurgitation or mild residual gradient ≤40 mmHg accompanied by less than mild pulmonary regurgitation; (5) ≤40 mmHg gradient across the main and branch pulmonary arteries; and (6) mildly abnormal sinus and/or atrioventricular node function manageable with external cardiac pacing.[7] Conversely, the repair was considered inadequate if the echocardiographic findings did not align with the above values, and an immediate attempt at correcting the residual lesions was made.

Following haemodynamic stabilisation and haemostasis, patients were transferred to the ICU for continued haemodynamic monitoring and mechanical ventilation. Analgesia and sedation were maintained using continuous infusions of fentanyl and dexmedetomidine. Data on demographic characteristics, cardiopulmonary bypass parameters, vasoactive inotrope scores (VIS) upon ICU arrival and VIS at 48 hours postoperatively were extracted from patient records. VIS was calculated as follows:

dopamine dose (µg/kg/min) + dobutamine dose (µg/kg/min) + 100 × epinephrine dose (µg/kg/min) + 10 × milrinone dose (µg/kg/min) + 10 000 × vasopressin dose (unit/kg/min) + 100 × norepinephrine dose (µg/kg/min).[8]

Postoperatively, all children were supported with mechanical ventilation using synchronised intermittent mandatory ventilation mode with pressure control and pressure support. Standardised criteria were strictly followed by all intensivists to ensure consistency in tracheal extubation. The criteria included normothermia (nasopharyngeal temperature: 36–37°C), responsiveness to stimuli/commands, age-appropriate haemodynamic parameters,[9] VIS ≤10, stable haemostasis, adequate urine output (>2 mL/kg/hour) and satisfactory ventilator mechanics. Mechanical ventilation criteria for tracheal extubation required that the child maintain adequate tidal volume with pressure support of 6–10 cm H2O, minimal ventilatory settings (fraction of inspired oxygen ≤0.5 and positive end-expiratory pressure ≤6 cm H_2O) and acceptable arterial blood gas values (pH >7.35 and PaO_2 >80 mmHg). Tracheal extubation was performed when these criteria were met, regardless of the time of day, and the duration of mechanical ventilation was recorded in hours. Reintubation within 48 hours was classified as failed tracheal extubation.[10]

Postoperative morbidity data were collected on the incidence of complications such as chylothorax, pericardial effusion (assessed by echocardiography) and acute renal failure, which was defined according to the pRIFLE criteria.[11] Additionally, incidence of re-exploration for surgical bleeding were obtained.

Cardiac rhythm abnormalities, including junctional ectopic tachycardia (JET), temporary heart block and complete heart block requiring permanent pacemaker implantation, were recorded. Echocardiography findings, specifically concerning the grade of tricuspid and pulmonary regurgitation and the gradient across the right ventricular outflow tract, were evaluated by paediatric cardiologists postoperatively. Data on mortality rates, lengths of ICU and hospital stays and any re-interventions within the 2 years post-surgery were also recorded.

Continuous variables were described using the mean, median, standard deviation and interquartile range, while categorical variables were expressed as frequencies and percentages. The Mann–Whitney U test was used for median comparisons between groups and associations between categorical variables were assessed using a Chi-squared test (Fisher's exact or Likelihood ratio test as applicable). Univariate analysis was conducted to investigate the association between patient characteristics and prolonged mechanical ventilation (>24 hours), followed by multivariate analysis to identify predictors of prolonged ventilation. A *P* value <0.05 was considered statistically significant. Statistical analyses were conducted using The Statistical Package for Social Sciences (SPSS), Version 29.0 (IBM Corp., Armonk, New York, USA).

The Scientific Research Committee at The Royal Hospital granted ethical approval for this study (#36/2022) and individual patient consent was waived due to the study's retrospective nature.

Results

Children in the valve-sparing group (Group 1) were older than those in the transannular patch group (Group 2; median age: 15 [3–194] versus 13 [4–53], *P* = 0.024) [Table 1]. The median duration of mechanical ventilation was longer in the trans-annular patch group (23 [8–144] hours versus 16.5 [5–96] hours; *P* = 0.039), as was the cardiopulmonary bypass time (*P* <0.001) and aortic cross-clamp time (*P* = 0.048) [Table 2]. Additionally, VIS recorded at admission to the ICU (*P* = 0.012) and after 48 hours (*P* = 0.002) was lower in the valve-sparing group [Table 2]. The incidence of chylothorax, pericardial effusion, acute renal failure, re-exploration and the need for re-operation for residual lesions were similar between both groups.

However, the median ICU stays (2 [1–7] days versus 3 [1–16] days; *P* = 0.003), chest drainage tube retention (3 [2–10] days versus 4 [2–27] days; *P* <0.001) and total hospital stay (8 [5–33] days versus 11 [6–35] days; *P* <0.001) were significantly shorter in the valve-sparing group (Group 1) [Table 2]. The transannular patch group (Group 2) showed a higher incidence of JET (Group 2: 11 [18.6%] versus Group 1: 1 [2.3%]; *P* = 0.012) [Table 3]. Mild-to-moderate pulmonary regurgitation was significantly more common in Group 1 (*P* <0.001), while Group 2 had a significantly higher incidence of severe pulmonary regurgitation (*P* <0.001) [Table 3]. The right ventricular outflow gradient was also significantly higher in the valve-sparing technique group (24.74 ± 12.41 mmHg versus 16.71 ± 14.24; *P* = 0.002) [Table 3].

In terms of tracheal extubation outcomes, 5 children in the transannular patch group required reintubation, whereas none of the children in the valve-sparing group experienced extubation failure. Over the 2-year postoperative period, 4 of the 43 children in Group 1 required surgical reintervention for right ventricular outflow tract obstruction. In contrast, 2 of the 59 children in Group 2 underwent transcatheter pulmonary and branch pulmonary arterioplasty for severe pulmonary regurgitation, though this difference was not statistically significant (*P* = 0.237).

Mechanical ventilation lasting over 24 hours was considered prolonged. Univariate analysis identified age, weight and VIS at ICU admission as factors associated with prolonged mechanical ventilation across the cohort [Table 4]. Multivariate binary logistic regression analysis revealed that patient weight was an independent risk factor for mechanical ventilation exceeding 24 hours (OR = 0.591, 95% confidence interval: 0.398–0.879; *P* = 0.009) [Table 5].

Discussion

This study examined the immediate outcomes of valve-sparing versus transannular patch repair in the complete correction of ToF. Children in the valve-sparing group were older than those in the transannular patch group, likely due to more favourable anatomy that supported growth. In the valve-sparing group, cardiopulmonary bypass and aortic cross-clamp times, as well as durations of mechanical ventilation, ICU and hospital stay, were shorter, with lower VIS scores at ICU admission and after 48 hours. There were also reduced morbidity in the valve-sparing group, with no mortality in either group. These findings contradict the initial hypothesis that outcomes would be similar, instead suggesting that a valve-sparing technique may provide superior immediate postoperative outcomes.

Mechanical ventilation duration was used as a surrogate marker for surgical success. Extubation timing in paediatric cardiac patients depends on stable cardiovascular function, adequate ventilatory reserves and favourable pulmonary mechanics, including effective diaphragmatic function.[12] During the current study, the extubation criteria were agreed upon by all stakeholders managing these children, ensuring a consistent approach.

Ismail *et al.* found no significant difference in mechanical ventilation duration between valve-sparing and transannular repairs in children with ToF.[13] In contrast, the present study observed a significantly shorter duration in the valve-sparing group (*P* = 0.039). Egbe *et al.* reported a median ventilation duration of 19 hours (range: 0–136 hours) following ToF repair,[14] consistent with the current study's findings of shorter ventilation duration favouring valve-sparing group in terms of the mean duration of mechanical ventilation (*P* = 0.039). Egbe *et al.* also found patient weight to be associated with mechanical ventilation duration.[14] In the current study, ventilation lasting >24 hours was considered prolonged. Univariate analysis showed that older age, greater weight and lower ICU admission VIS were linked to ventilation <24 hours, regardless of the surgical technique. Multivariate binary logistic regression analysis further identified weight as an independent predictor, reducing the risk of prolonged ventilation by 40.9% with each unit increase in weight.

Intraoperative data also supported a valve-sparing approach in the present study. Ismail *et al.* reported longer cardiopulmonary bypass and aortic cross-clamp times in the transannular patch group (*P* = 0.008 and *P* = 0.002, respectively).[13] The current study similarly had significantly longer cardiopulmonary bypass and aortic cross-clamp times in the transannular patch group (*P* <0.001 and *P* = 0.048, respectively). Factors such as cardiopulmonary bypass duration, myocardial oedema, potential ventriculotomy, myocardial infundibular resection and patch type used to close the ventricular septal defect or enlarge the right ventricular outflow tract impact right ventricular diastolic function postoperatively.[15] However, diastolic function was not regularly assessed pre- or postoperatively in the current study. Additionally, all patients in this study underwent routine creation of a small patent foramen ovale (2–3 mm) to manage potential haemodynamic challenges, given the elevated diastolic pressure in the right ventricle often seen post-repair. This patent foramen ovale likely impacted oxygen saturation levels,

Table 1: Characteristics of patients with pulmonary valve sparing or transannular patch techniques (N = 102)

Variable	Valve-sparing group (n = 43)		Transannular patch group (n = 59)		*P* value*
	Mean ± SD	Median (min.–max.)	Mean ± SD	Median (min.–max.)	
Age at the time of surgery in months	23.88 ± 30.96	15 (3–194)	14.12 ± 8.85	13 (4–53)	0.024
Weight in kg	9.66 ± 6.14	8.7 (4.4–44.4)	8.14 ± 1.76	7.8 (4.9–13.9)	0.220
Gender	n (%)				
Male	27 (62.8)		36 (61.0)		1.000
Female	16 (37.2)		23 (39.0)		

SD = standard deviation.

**Using Mann-Whitney U test/Fisher's exact test*

Table 2: Perioperative details of included patients (N = 102)

Variable	n (%)				*P* value
	Valve-sparing group (n = 43)		Transannular patch group (n = 59)		
	Mean ± SD	Median (min.–max.)	Mean ± SD	Median (min.–max.)	
Cardiopulmonary bypass time in minutes	116.35 ± 28.96	110 (77–207)	172.48 ± 142.97	138 (83–1034)	<0.001
Aortic cross-clamp time in minutes	88.19 ± 24.94	86 (46–173)	107.54 ± 46.92	100 (46–279)	0.048
Duration of mechanical ventilation in hours	20.43 ± 18.05	16.5 (5–96)	32.40 ± 33.92	23 (8–144)	0.039
VIS on admission	6.64 ± 4.14	5 (0–15)	8.84 ± 5.46	7 (3.3–30)	0.012
VIS at 48 hours	0.62 ± 1.58	0 (0–5)	3.88 ± 10.52	0 (0–76)	0.002
Age at time of surgery in months	-	15 (3–194)	-	13 (4–53)	
Duration of ICU stay in days	2.42 ± 1.65	2 (1–7)	4.36 ± 3.63	3 (1–16)	0.003
Chest tube retention in days	3.84 ± 1.53	3 (2–10)	6.03 ± 4.43	4 (2–27)	<0.001
Total hospital stay in days	9.10 ± 4.81	8 (5–33)	12.61 ± 5.84	11 (6–35)	<0.001
Chylothorax	1 (2.3)		5 (8.5)		0.397
Pericardial effusion	0 (0)		2 (3.4)		0.507
Acute Renal failure	0 (0)		2 (3.4)		0.507
Re-exploration	0 (0)		4 (6.8)		0.136
Extubation failure	0 (0)		5 (8.5)		0.072
Re-operation	4 (9.3)		2 (3.4)		0.237
2-year survival	43 (100)		59 (100)		

SD = standard deviation; VIS = vasoactive inotrope score; ICU = intensive care unit.

**Using Mann-Whitney U test/Fisher's exact test.*

illustrating its relevance in managing postoperative haemodynamics.

In the present study, VIS at ICU admission and and after 48 hours were significantly lower in the valve-sparing group than in the transannular patch group (6.64 ± 4.14 and 0.62 ± 1.58; *P* = 0.012 and 0.002, respectively). These findings align with that of Ismail *et al.*'s study.[13]

The median length of ICU stay reported after the primary repair of ToF was 6 days (range: 2–21 days).[14] Hirsh *et al*. reported a mean length of ICU stay of 9 ± 8 days.[16] Kolcz and Pizarro reported a mean duration of ICU stay of 7 days, while Tamesberger *et al*. reported a median length of 6 days (range: 1–77 days) of ICU stay after the primary repair of ToF.[17,18] Ismail *et al*. also reported that valve-sparing procedures correlated with shorter ICU stays compared to transannular patch surgery (*P* = 0.009).[13] However no statistically significant difference was observed between groups regarding chest tube drainage duration and the total hospital stay.[13] The study found significant benefits favouring the valve-sparing approach in ICU stay, chest tube drainage duration and total hospital stay duration.

Hospital stay length is an important metric in determining surgical outcomes, often prolonged by factors such as extended aortic cross-clamp time, delayed sternal closure, prolonged mechanical ventilation and unsuccessful tracheal extubation.[12,19] The present study suggests that children in the transannular patch group experienced longer aortic cross-clamp times and duration of mechanical ventilation, contributing to an extended hospital stay.

Both the valve-sparing and transannular patch groups had comparable incidences of severe renal failure requiring dialysis (*P* = 0.14).[13] There were no significant difference regarding acute renal failure, chylothorax, pericardial effusion, re-explorations or failed tracheal extubation.

JET incidence post-congenital heart surgery typically ranges from 3% to 10%.[20–22] In this study, JET occurred in 2.3% of the valve-sparing group versus 18.6% in the transannular patch group (*P* = 0.012).

Pulmonary regurgitation (PR) is common, affecting 40–85% of patients. Symptoms may not appear for 5–10 years due to right ventricular adaptation, but symptomatic PR requires timely intervention.[1] Despite the high rate of severe PR among

Table 3: Postoperative conduction issues and postoperative echocardiographic findings

Variable	n (%)		*P* value
	Valve-sparing group (n = 43)	Transannular patch group (n = 59)	
Junctional ectopic tachycardia	1 (2.3)	11 (18.6)	0.012*
Heart block	2 (4.7)	10 (16.9)	0.068*
Need for permanent pacemaker	3 (7.0)	2 (3.4)	0.648*
Mean tricuspid regurgitation jet velocity in mmHg ± SD	21.75 ± 9.47	28.18 ± 13.74	0.187†
Mean right ventricular outflow tract peak pressure gradient in mmHg ± SD	24.74 ± 12.41	16.71 ± 14.24	0.002†
Pulmonary regurgitation		n = 18	<0.001‡
Mild	-	12 (66.7)	
Moderate	-	5 (27.8)	
Severe	-	1 (5.6)	

SD = standard deviation.

**Using Fisher's exact test. †Using Mann-Whitney U test. ‡Using likelihood ratio/Fisher's exact*

the transannular patch group (87.8%) in this study, reoperations rates within 2 years were similar between groups (P = 0.237). Ismail *et al*. reported severe PR in 86% of children who underwent transannular repair versus 32% in the valve-sparing group (P <0.05).[13] The findings of the present study show a high incidence of severe PR in the transannular patch group (87.8%, P <0.001), which is consistent with those of Ismail *et al*.[13] However, the valve-sparing group had a significantly higher incidence of mild-to-moderate PR.

In the cohort of patients who underwent valve-sparing procedures (Group 1), 4 children required reoperation within 2 years, whereas only 2 children in the transannular patch group (Group 2). This short-term outcome aligns with the primary aim of valve preservation, though it can results in an increased gradient at the right ventricle outflow tract. However, the difference in reoperation rates between the groups did not reach statistical significance. Blais *et al*. previously highlighted a higher long-term reoperation

Table 4: Univariate analysis showing the association between prolonged duration of mechanical ventilation and patient characteristics

Variable	Mean ± SD		*P* value*
	Duration of mechanical ventilation		
	<24 hours	≥24 hours	
Age in months	24.60 ± 30.80	12.38 ± 5.81	0.012
Weight in kg	10.23 ± 5.85	7.36 ± 1.52	0.003
Type of surgery in n (%)			
Valve sparing	17 (56.7)	13 (43.3)	0.655
Transannular patch	28 (50.9)	27 (49.1)	
Cardiopulmonary bypass time	147.84 ± 141.47	160.63 ± 95.00	0.638
Aortic cross clamp time	95.67 ± 33.92	106.18 ± 47.65	0.241
VIS on admission	7.15 ± 3.75	10.06 ± 6.27	0.013
Rhythm problem – JET	n (%)		
No	41 (55.4)	33 (44.6)	0.335
Yes	4 (36.4)	7 (63.6)	

SD = standard deviation; VIS = vasoactive inotrope score;

JET = junctional ectopic tachycardia.

**Using independent samples t-test/Chi-square test (Fisher's exact)*

Table 5: Multivariate binary logistic regression analysis to determine the independent risk factors of longer duration ≥24 hours of mechanical ventilation

Variable	Beta regression coefficient	*P* value*	OR (95% CI)
Age at the time of surgery in months	−0.036	0.444	0.964 (0.879–1.058)
Weight in kg	−0.525	0.009	0.591 (0.398–0.879)
Type of surgery			
Transannular patch (reference)			1.000
Valve sparing	0.654	0.299	1.924 (0.559–6.622)
Cardiopulmonary bypass time	0.002	0.457	1.002 (0.997–1.007)
Aortic cross-clamp time	0.006	0.502	1.006 (0.989–1.023)
VIS on admission	0.098	0.091	1.103 (0.984–1.236)
Rhythm issues - JET			
No (reference)			1.000
Yes	0.153	0.852	1.166 (0.233–5.840)

OR = odds ratio; CI = confidence interval; VIS = vasoactive inotrope score;

JET = junctional ectopic tachycardia.

**Nagelkerke R^2 = 0.372 (for effect size), overall accuracy = 67.9%.*

rate in patients who underwent transannular patch repair, suggesting the potential for more reoperations over extended follow-up.[2]

A statistically significant difference was found when comparing the mean duration of mechanical ventilation between valve-sparing and transannular patch techniques. However, categorising ventilation duration into 2 groups (<24 hours versus ≥24 hours) yielded no significant difference. This discrepancy could be due to the non-normal distribution of mechanical ventilation duration, prompting the use of a Mann–Whitney U test instead of an independent samples t-test for comparing mean ventilation times. Additionally, univariate and multivariate analyses were performed for the categorised ventilation duration (<24 hours versus ≥24 hours).

The study revealed that children undergoing transannular patch repair were generally younger than those receiving valve-sparing correction ($P = 0.024$). Intraoperative assessment largely guided the approach, with decisions based on valve annulus size, morphology and the surgeon's potential to preserve the valve. Due to the variations in surgical approaches by different surgeons, valve-sparing procedures were often chosen for older, larger children, while transannular patches were more common among younger, smaller infants. Surgical discretion played a critical role, with echocardiographic parameters serving as supportive, rather than definitive, criteria.

This retrospective study provides insights into the comparative outcomes of transannular repair and valve-sparing approaches for ToF. However, the study design includes several inherent limitations, such as potential biases in technique selection, unmeasured confounding variables, inconsistencies in data collection and temporal changes (e.g. surgical, anaesthetic and postoperative care advancements) that could affect replicability. Although preoperative z-scores of the pulmonary valve were initially assessed to gauge pulmonary valve stenosis severity and valve-sparing feasibility, the final surgical approach was guided by intraoperative assessments. This approach emphasises the intricate nature of congenital heart surgeries, particularly in managing ToF.

The participation of multiple surgeons in this study naturally led to variations in decision-making. These included differences in the preference for valve preservation versus transannular patch use, influenced by each surgeon's experience and real-time intraoperative conditions. Addressing the limitations of this retrospective design, future prospective studies are needed to minimise bias, improve data accuracy and provide a more robust evaluation of both immediate and long-term outcomes for each technique. Despite these limitations, this study highlights the promising benefits of valve-sparing procedures for a specific subgroup of patient with ToF. Future research focusing on long-term outcomes and potential complications will be essential to fully assess the efficacy and durability of these surgical techniques in managing this condition.

Conclusion

Patients undergoing valve-sparing surgery for the complete repair of ToF demonstrate improved outcomes in the immediate postoperative period compared to those receiving transannular patch repair. Notable advantages include reduced durations of mechanical ventilation, lower VIS, shorter ICU and overall hospital stays. Additionally, a child's weight may serve as a significant predictor of the duration of mechanical ventilation.

The uniqueness of this study lies in its focused examination of immediate postoperative outcomes, specifically regarding the timing of tracheal extubation in children undergoing either transannular patch repair or the pulmonary valve-sparing approach. This study represents a pioneering effort in Oman, providing valuable insights into efficacy of various surgical approaches and their implications for early recovery and clinical outcomes in this specific patient population.

Authors' Contribution

MHAG, MMM and HNAK concentualised and designed the study. MHAG, MMM and SOAT collected the data. MHAG, MMM, PMS and SJ analysed and interpreted the data. MHAG and MMM supervised and validated the work. MHAG, MMM and HNAK drafted and edited the manuscript. All authors approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

No funding was received for this study.

References

1. van der Ven JPG, van den Bosch E, Bogers AJCC, Helbing WA. Current outcomes and treatment of tetralogy of Fallot. F1000Res 2019; 8:F1000 Faculty Rev–1530. https://doi.org/10.12688/f1000research.17174.1.
2. Blais S, Marelli A, Vanasse A, Dahdah N, Dancea A, Drolet C, et al. Comparison of Long-term outcomes of valve-sparing and transannular patch procedures for correction of tetralogy of Fallot. JAMA Netw Open 2021; 4:e2118141. https://doi.org/10.1001/jamanetworkopen.2021.18141.

3. Gatzoulis MA, Elliott JT, Guru V, Siu SC, Warsi MA, Webb GD, et al. Right and left ventricular systolic function late after repair of tetralogy of Fallot. Am J Cardiol 2000; 86:1352–7. https://doi.org/10.1016/s0002-9149(00)01241-8.

4. Gatzoulis MA, Balaji S, Webber SA, Siu SC, Hokanson JS, Poile C, et al. Risk factors for arrhythmia and sudden cardiac death late after repair of tetralogy of Fallot: A multicentre study. Lancet 2000; 356:975–81. https://doi.org/10.1016/S0140-6736(00)02714-8.

5. Ducas RA, Harris L, Labos C, Nair GKK, Wald RM, Hickey EJ, et al. Outcomes in young adults with tetralogy of Fallot and pulmonary annular preserving or transannular patch repairs. Can J Cardiol 2021; 37:206–14. https://doi.org/10.1016/j.cjca.2020.04.014.

6. Smith CA, McCracken C, Thomas AS, Spector LG, St Louis JD, Oster ME, et al. Long-term outcomes of tetralogy of Fallot: A study from the pediatric cardiac care consortium. JAMA Cardiol 2019; 4:34–41. https://doi.org/10.1001/jamacardio.2018.4255.

7. Larrazabal LA, del Nido PJ, Jenkins KJ, Gauvreau K, Lacro R, Colan SD, et al. Measurement of technical performance in congenital heart surgery: A pilot study. Ann Thorac Surg 2007; 83:179–84. https://doi.org/10.1016/j.athoracsur.2006.07.031.

8. McIntosh AM, Tong S, Deakyne SJ, Davidson JA, Scott HF. Validation of the vasoactive-inotropic score in pediatric sepsis. Pediatr Crit Care Med 2017; 18:750–7. https://doi.org/10.1097/PCC.0000000000001191.

9. Peds Cases. Pediatric Vital Signs Reference Chart. From: https://www.pedscases.com/pediatric-vital-signs-reference-chart Accessed: July 2024.

10. Newth CJ, Venkataraman S, Willson DF, Meert KL, Harrison R, Dean JM, et al. Weaning and extubation readiness in pediatric patients. Pediatr Crit Care Med 2009; 10:1–11. https://doi.org/10.1097/PCC.0b013e318193724d.

11. Soler YA, Nieves-Plaza M, Prieto M, García-De Jesús R, Suárez-Rivera M. Pediatric risk, injury, failure, loss, end-stage renal disease score identifies acute kidney injury and predicts mortality in critically ill children: A prospective study. Pediatr Crit Care Med 2013; 14:e189–95. https://doi.org/10.1097/PCC.0b013e3182745675.

12. Dodgen AL, Dodgen AC, Swearingen CJ, Gossett JM, Dasgupta R, Butt W, et al. Characteristics and hemodynamic effects of extubation failure in children undergoing complete repair for tetralogy of Fallot. Pediatr Cardiol 2013; 34:1455–62. https://doi.org/10.1007/s00246-013-0670-z.

13. Ismail SR, Kabbani MS, Najm HK, Abusuliman RM, Elbarbary M. Early outcome of tetralogy of Fallot repair in the current era of management. J Saudi Heart Assoc 2010; 22:55–9. https://doi.org/10.1016/j.jsha.2010.02.006.

14. Egbe AC, Nguyen K, Mittnacht AJ, Joashi U. Predictors of intensive care unit morbidity and midterm follow-up after primary repair of tetralogy of Fallot. Korean J Thorac Cardiovasc Surg 2014; 47:211–19. https://doi.org/10.5090/kjtcs.2014.47.3.211.

15. Maitre G, Schaffner D, Lava SAG, Perez MH, Di Bernardo S. Early postoperative beta-blockers are associated with improved cardiac output after late complete repair of tetralogy of Fallot: A retrospective cohort study. Eur J Pediatr 2024; 183:3309–17. https://doi.org/10.1007/s00431-024-05597-1.

16. Hirsch JC, Mosca RS, Bove EL. Complete repair of tetralogy of Fallot in the neonate: results in the modern era. Ann Surg 2000; 232:508–14. https://doi.org/10.1097/00000658-200010000-00006.

17. Kolcz J, Pizarro C. Neonatal repair of tetralogy of Fallot results in improved pulmonary artery development without increased need for reintervention. Eur J Cardiothorac Surg 2005; 28:394–9. https://doi.org/10.1016/j.ejcts.2005.05.014.

18. Tamesberger MI, Lechner E, Mair R, Hofer A, Sames-Dolzer E, Tulzer G. Early primary repair of tetralogy of Fallot in neonates and infants less than four months of age. Ann Thorac Surg 2008; 86:1928–35. https://doi.org/10.1016/j.athoracsur.2008.07.019.

19. Mercer-Rosa L, Elci OU, DeCost G, Woyciechowski S, Edman SM, Ravishankar C, et al. Predictors of length of hospital stay after complete repair for tetralogy of Fallot: A prospective cohort study. J Am Heart Assoc 2018; 7:e008719. https://doi.org/10.1161/JAHA.118.008719.

20. Makhoul M, Oster M, Fischbach P, Das S, Deshpande S. Junctional ectopic tachycardia after congenital heart surgery in the current surgical era. Pediatr Cardiol 2013; 34:370–4. https://doi.org/10.1007/s00246-012-0465-7.

21. Andreasen JB, Johnsen SP, Ravn HB. Junctional ectopic tachycardia after surgery for congenital heart disease in children. Intensive Care Med 2008; 34:895–902. https://doi.org/10.1007/s00134-007-0987-2.

22. Batra AS, Chun DS, Johnson TR, Maldonado EM, Kashyap BA, Maiers J, et al. A prospective analysis of the incidence and risk factors associated with junctional ectopic tachycardia following surgery for congenital heart disease. Pediatr Cardiol 2006; 27:51–5. https://doi.org/10.1007/s00246-005-0992-6.