MAR Clinical Case Reports (2023) 4:11

Research Article

Electrocardiogram Changes Post-Surgical Repair of Tetralogy of Fallot with Valve-Sparing Versus Transannular Patch: A Retrospective Observational Study

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Received: 18 October 2023

Published: 03 November 2023

Abstract

Objective:*Long-term survival post tetralogy of Fallot (TOF) repair depends on several factors, including the extent of chronic right ventricular adaptation to surgery. The impact of QRS duration (QRSd) has been an important determinant of life-threatening arrhythmia post-TOF repair. This single-center retrospective study was designed to evaluate changes in QRSd post-TOF repair using either a pulmonary valve-sparing approach (VSA) or transannular patch (TAP).*

Methods: *Data from patients undergoing TOF repair between Jan 2016 and Dec 2019 were analyzed to compare the changes in the QRSd following intracardiac repair after VSA (Group 1) or TAP (Group 2). Among 105 patients who underwent TOF surgical repair, 60 patients were included in the study (Group 1: 30 vs. Group 2: 30). Patients had electrocardiograms (ECGs) recorded pre-and-post surgery. The primary outcome was to compare the change in QRSd (ΔQRSd) before and after surgery between the two groups.*

Results: *The mean length of postoperative follow-up was 35.9 months in Group 1 and 34.47 months in Group 2. The mean* ***[****SD****]*** *difference in QRSd values (QRSd2−QRSd1) was shorter in Group 1 (45.67* ***[****22.79****]*** *ms) than in Group 2 (49.63* ***[****23.76****]*** *ms); however, these were not statistically significant (P = 0.428). The PR interval was similar between the two groups in both preoperative and postoperative ECG.*

Conclusion: *At a short-term follow-up, both surgical approaches (VSA and TAP) resulted in similar QRSd post-TOF repair. Studies with longer follow-ups are required to evaluate the association of surgical approach with the prolongation of QRSd and mortality.*

Keywords: *Electrocardiogram, pediatric patients, QRS duration, tetralogy of Fallot, transannular patch, valve-sparing approach.*

Introduction

Tetralogy of Fallot (TOF) is the most common form of cyanotic congenital heart disease where children often run the risk of ventricular arrhythmias and sudden cardiac death.[1-4] It is one of the first cardiac anomalies to be successfully repaired by congenital cardiac surgeons.[1, 2] Obstruction of the right ventricular outflow tract (RVOT), ventricular septal defect (VSD), an overriding aorta, and hypertrophy of the right ventricle (RV) are the cardinal features associated with TOF.[5] The surgical intervention in TOF dates back to 1954 when techniques such as ventriculotomy were employed by placing a pulmonary transannular patch (TAP) to relieve the RVOT obstruction or use of palliative care in the form of the Blalock–Taussig–Thomas shunt.[2, 6, 7] Currently, the strategies used in the TOF treatment have witnessed a major paradigm shift and resulted in significant long-term survival (20-year survival of almost 60% to 83%), the remarkable being pulmonary valve-sparing approach (VSA) and TAP repair.[4, 6, 8, 9]

The pathophysiology of TOF manifests as a crosstalk between the anatomy of the heart, its electrical impulse, and its mechanical function.[10, 11] To gain a proper insight into the adverse patient outcomes, an electrocardiogram (ECG) metrics of depolarization and repolarization or more concisely the QRS complex has always proved efficacious.[12, 13] There is overall limited knowledge about the difference in ECG changes post-TOF repair based on the surgical approach. This study compares the ECG alterations post-TOF repair in pediatric patients from a single tertiary cardiac center involving the two important surgical approaches for TOF repair, VSA and TAP.

Patients and Methods

Study population and design

This was a retrospective study, including all infants with TOF who underwent surgical repair using either VAS or TAP in our institution. We included all children who had baseline preoperative ECG (ECG1) and late post-operative ECG (> 1 year after surgery, ECG2). Children with TOF having pulmonary atresia, absence of pulmonary valve (PV), atrioventricular septal defect, and incomplete ECG data were all excluded from the study.

The primary outcome of the study was to compare the changes in the QRSd following intracardiac repair using VAS or TAP approach. The secondary outcomes were to compare the two techniques for the changes in the rhythm, PR intervals, and ECG findings of PV regurgitation, tricuspid valve regurgitation, and RV dilatation. Baseline characteristics were obtained for all patients, including gender, median age, associated syndromes, collaterals, side of the aortic arch, presence of cyanotic spells before surgery, and pre-operative palliative procedures. In addition, ECG data were recorded pre-operative (ECG1 for QRSd1) and follow-up (ECG2 for QRSd2). Rhythm, heart rate, QRSd, and PR intervals were recorded from ECGs stored in the electronic hospital information system. To overcome the bias in the variation of the preoperative QRSd and the follow-up duration on the outcome, we matched both groups with a tolerance level of 5 ms in the preoperative ECG and 3 months of follow-up, respectively.

Statistical analysis

Statistical Package for Scientific Studies (SPSS) version 13.0 for Windows (by IBM) was used for analysis. All parameters were analyzed descriptively. The Mann–Whitney test was used to evaluate differences between the two groups for the continuous variables, and Kruskal–Wallis test (non-parametric approach) was used to assess the differences between the two groups for the categorical variables. Statistical differences were considered significant if the P value was less than 0.05.

Ethics

An institutional ethics review board was sought to obtain the required permission for the study.

Results

Patient baseline characteristics

Data from 105 pediatric patients who underwent surgical repair of TOF from Jan 2016 to Dec 2019 were available. In total, 79 patients had available ECGs before surgery (ECG1) and in the last follow-up visit (> 1 year after surgery, ECG2). After matching the two groups based on the postoperative follow-up duration, 60 patients were included in the study (Group 1 **[**VSA**]**: 30 vs. Group 2 **[**TAP**]**: 30). Baseline characteristics were balanced in both groups (Table 1). About 60% of the patients were male and 23.3% were syndromic.

The mean (SD) age of the pediatric patients was 20 (17.0) months and 18 (26.0) months for Groups 1 and 2, respectively. Most patients (79.7%) had aortic arch (L-R); about 11.7% of patients had major aortopulmonary collateral arteries (MAPCAS). Overall, 11.7% of patients underwent palliative procedures such as modified Blalock–Taussig shunt (MBTS), RVOT stent, patent ductus arteriosus (PDA) stent, or pulmonary valvuloplasty, and preoperative cardiac catheterization was offered to 28.3% of the patients.

Change in QRSd and follow-up

The mean **[**SD**]** preoperative QRS duration (QRSd1) was similar between the two groups (Group 1: 67.27 **[**8.31**]** ms vs. Group 2: 70.70 **[**15.14**]** ms, P = 0.583) (Table 2). The mean length of the postoperative follow-up duration was 35.9 months in Group 1 and 34.47 months in Group 2 (P = 0.641). At follow-up, the mean **[**SD**]** QRSd2 increased remarkably with time (post-surgery from baseline ECG) in both groups (Group 1: 112.93 **[**23.73**]** ms vs. Group 2: 120.33 **[**18.80**]** ms); however, intergroup variation was not significant (P = 0.370). The mean **[**SD**]** difference between QRSd2 and QRSd1 (ΔQRSd) was shorter in Group 1 (45.67 **[**22.79**]** ms) as compared to Group 2 (49.63 **[**23.76**]** ms), although the difference was not statistically significant (P = 0.428) (Figure 1). The mean **[**SD**]** preoperative PR interval was similar between the two groups (Group 1: 127 **[**18.0**]** ms vs. Group 2: 128 **[**26.0**]** ms, P = 0.870) (Table 2). At follow-up, there was no difference in the mean **[**SD**]** PR interval between the two groups (Group 1: 133 **[**24.0**]** ms vs. Group 2: 133 **[**21.0**]** ms, P = 0.950).

RV dilatation and ΔQRSd association

The association of RV dilatation with ΔQRSd and the correlation between the TR and RVOT pressure gradient with ΔQRSd were analyzed (Table 3). About 24 patients in Group 1 had no RV dilatation compared to only 10 patients in Group 2. However, there was no statistical association between the degree of RV dilatation and ΔQRSd (P = 0.546). Around six patients in Group 1 had mild dilatation (70.67 ms) compared to 15 patients in Group 2 (53.07 ms). There was no difference in the TR gradient for all pediatric patients in both groups before and after surgery. Consistent with this, the RVOT gradients were also similar in both groups.

Variables	Group 1 VSA (n = 30) n (%)	Group 2 TAP (n = 30) n (%)	Total (n = 60) n (%)	*P*
Nationality				
Omani	29 (96.7)	28 (93.3)	57 (95.0)	1.000
Non-Omani	1 (3.3)	2 (6.7)	3 (5.0)	
Gender				
Male	17 (56.7)	19 (63.3)	36 (60.0)	0.792
Female	13 (43.3)	11 (36.7)	24 (40.0)	
Age (months)				
Mean [SD]	20 [17.0]	18 [26.0]	——	0.733
Syndromic				
Yes	7 (23.3)	7 (23.3)	14 (23.3)	1.000
No	23 (76.7)	23 (76.7)	46 (76.7)	
MAPCAS				
Yes	3 (10.0)	4 (13.3)	7 (11.7)	1.000
No	27 (90.0)	26 (86.7)	53 (88.3)	
Aortic arch (L-R)				
Yes	22 (75.9)	25 (83.3)	47 (79.7)	0.532
No	7 (24.1)	5 (16.7)	12 (20.3)	
Palliative procedure				
Yes	6 (20.0)	1 (3.3)	7 (11.7)	0.103
No	24 (80.0)	29 (96.7)	53 (88.3)	
Preoperative cardiac catheterization procedures				
Yes	11 (36.7)	6 (20.0)	17 (28.3)	0.252
No	19 (63.3)	24 (80.0)	43 (71.7)	

Table 1: Baseline characteristics of the patients enrolled in the study

Variables	**Group 1 VSA (n = 30) Mean (SD)**	**Group 2 TAP (n = 30) Mean (SD)**	***P****
Postoperative follow-up duration (months)	35.90 (13.11)	34.47 (13.29)	0.641
QRSd1 (preoperative) (ms)	67.27 (8.31)	70.70 (15.14)	0.583
QRSd2 (last follow-up) (ms)	112.93 (23.73)	120.33 (18.80)	0.370
QRSd2 – QRSd1 (ΔQRSd) (ms)	45.67 (22.79)	49.63 (23.76)	0.428
PR1 (preoperative PR interval) (ms)	127 (18.0)	128 (26.0)	0.870
PR2 (last follow-up PR interval) (ms)	133 (24.0)	133 (21.0)	0.950

*Mann–Whitney, Non-parametric test

Table 2: Change in QRSd (ΔQRSd) and the PR interval between the surgical approaches

ΔQRSd (QRSd2 – QRSd1)	**Group 1 VSA (n = 30)**			**Group 2 TAP (n = 30)**		
	n	**Mean (SD)**	***P****	**n**	**Mean (SD)**	***P****
RV dilatation No dilatation Mild dilatation Moderate dilatation Severe dilatation	 24 6 ———	 66.42 (8.32) 70.67 (8.07) ———	0.533	 10 15 4 1	 50.56 (29.87) 53.07 (15.49) 35.0 (38.24) 34.0	0.546
TR gradient (mmHg) – Spearman's rho	30	–0.347	0.065	30	–0.057	0.769
RVOT gradient (mmHg) – Spearman's rho	30	–0.145	0.445	30	–0.171	0.367

*Kruskal–Wallis test (Non-parametric approach)

Table 3: Association of RV dilatation with ΔQRSd and the correlation between the TR gradient and RVOT pressure gradient with ΔQRSd

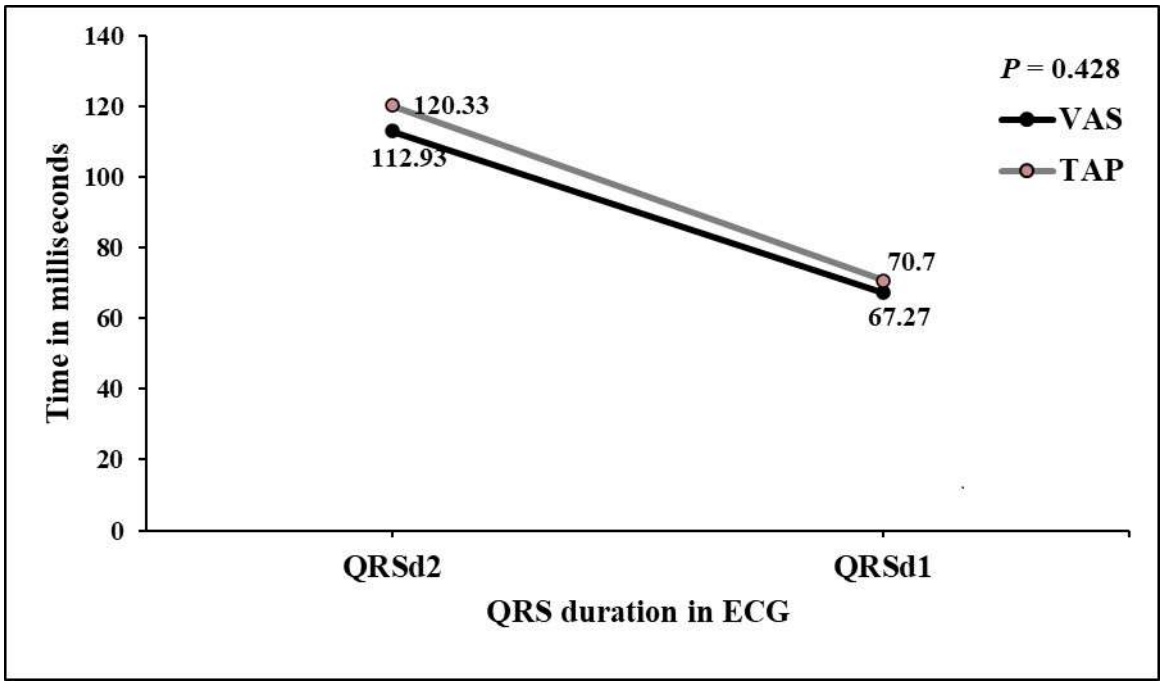

Figure 1: QRS duration in ECG of pediatric patients for VSA and TAP. The QRSd2 and QRSd1 were comparable between the two surgical interventions, with those for VSA being lesser, but not statistically significant.

Discussion

Our study monitored the ECG changes post-TOF correction in pediatric patients for the two currently used techniques, VSA and TAP. The main findings suggest that both techniques under observation are comparable. The postoperative ECG changes following TOF surgical repair depicted that QRSd increased remarkably after surgery, regardless of the surgical approach. This could probably be due to the right bundle branch block (RBBB) induced by the closure of the VSD in both techniques.**[**14**]** Usually, RBBB at various levels causes the conduction delay to begin right away after surgery.**[**14, 15**]**

The present study reported a lower ΔQRSd for Group 1 as compared to Group 2, although the difference was not statistically significant. TOF repair frequently results in electromechanical desynchrony, which presents mechanically as a right-sided septal/apical flash and electronically as a broad QRS duration (QRSd).**[**11, 13, 16**]** Ineffective RV mechanics are a result of early septal activation, pre-stretching of the RV basal lateral wall, and subsequent post-systolic shortening.**[**13**]** The impact of QRSd has been an

important determinant of life-threatening arrhythmias in corrected TOF patients.[17] A prolonged QRS complex is linked to an increased risk of sudden cardiac death and ventricular arrhythmia in corrected-TOF patients.[18-21] It has also been closely associated with RV anomalies and is a predictor of malignant ventricular arrhythmias.[19] TOF patient autopsies who died from sudden cardiac death revealed that the RV myocardium had considerable fibrosis at the ventriculotomy site and the septum, with intact conduction tissues.[19] Children and adults with Fallot were reportedly more prone to have ventricular arrhythmias and abrupt death when the QRSd was 170 ms or longer and 180 ms or longer, respectively.[20] Studies have also identified QRSd of more than 120 ms as a risk factor for death in conditions of heart failure with preserved systolic function (HFPSF).[22] In another study, a longer QRS length of 120 to 149 ms showed higher mortality at 60 months (P = 0.001), wherein the rise of QRS prolongation levels was linked to systolic dysfunction documenting graded increases in mortality.[23] Severe prolongation of QRSd might be related to chronic volume overloading of the RV or the presence of chronic pressure causing PV regurgitation. This was reported in patients undergoing TAP post-TOF repair with significant PV regurgitation during the follow-up who had significant residual valvular stenosis.[20] In the current study, about 24 patients in Group 1 had no RV dilatation compared to only 10 patients in Group 2. Studies have shown that TAP exposes patients to chronic PV regurgitation, while VSA might partly relieve pulmonary obstruction, preserve RV function, and lower the frequency of late arrhythmias, all of which are determinants of long-term outcomes.[6, 24]

Patients with congenital pulmonary stenosis or corrected TOF frequently experience PV regurgitation consequently, which poses a serious threat such as arrhythmias and an array of cardiac disorders.[25]

Recently, research revealed that prolonged PR interval may be linked to higher mortality and morbidity.[26-28] Atrial fibrillation and pacemaker implantation are both more likely to occur when the PR interval is prolonged.[26, 27] In a community-based study, a prolonged PR interval was directly related to all-cause mortality.[28] Moreover, late prolongation of PR interval that is synonymous with atrioventricular conduction on standard 12-lead ECG is also clinically important in considering the risk of developing lethal arrhythmias in patients post-TOF repair along with patients suffering from ischemic heart disease or heart failure.[29] In the present study, the PR interval was similar between the two groups in both baseline ECG and the last follow-up, indicating no significant changes post-TOF repair.

This study upholds the real-world scenario of TOF, a congenital heart defect in children, and the use of an ECG in monitoring the patient's condition. It also compared the two techniques (VSA and TAP) and

reflected the concern of such defects in infants and how they can be mitigated surgically using well-established surgical interventions. One limitation of this study was that the retrospective analysis was done from recorded data from a single center with a small cohort of pediatric patients. In addition, the follow-up duration was only 3 years, whereas studies have reported longer follow-ups of 20–30 years.**[**7, 8, 24**]** Furthermore, the QRSd in the present study groups was not prolonged to the limit that is associated with possible adverse events.**[**18-21**]** This may suggests the QRSd prolongation might need a longer time to develop and may be linked to the degree of RV dilatation regardless of the surgical technique used in TOF repair. Future studies with larger sample sizes and longer follow-up periods are needed to effectively evaluate the association of surgical approach, the QRSd prolongation, and the risk of sudden cardiac death.

Conclusion

In conclusion, both surgical approaches (VSA and TAP) resulted in similar QRS during the short term follow up. Studies with longer follow-ups are required to evaluate the association of surgical approach with the prolongation of QRSd and mortality.

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