

COMPARISON OF TRANS-RIGHT ATRIAL VERSUS COMBINED (TRANS-RIGHT ATRIAL, TRANS-RIGHT VENTRICULAR) APPROACH FOR INTRA-CARDIAC REPAIR OF TETRALOGY OF FALLOT: SINGLE-CENTER EXPERIENCE

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Abstract

Background and Objective: We compared trans-right atrial (t-RA) versus combined (trans-right-atrial and trans-ventricular (t-RA/RV) approaches for intra-cardiac repair of Tetralogy of Fallot (TOF) for the pre-operative and post-operative right ventricular (RV) function. The RV function was calculated using a tricuspid annular plane systolic excursion (TAPSE) using two-dimensional (2-D) echocardiography.

Materials and Methods: This was a retrospective study. Fifty-three patients operated for the intra-cardiac repair of TOF between August 2019 and March 2021 were included in the study and divided into two groups based on the approach for repair as follows: t-RA or combined (t-RA/RV) approach. The first group (t-RA) had twenty-one patients, and the second group (combined t-RA/RV approach) had thirty-two patients. The assessment of pre-operative and post-operative RV function was done using TAPSE. Records of follow-up at 1 month and 3 months were evaluated.

Results: Age, body surface area (BSA), preoperative saturation, cardiopulmonary bypass time, aortic cross-clamp time, postoperative intensive care unit (ICU) stay, and hospital stay were similar in both groups. However, t-RA/RV group had more pleural effusions (9 vs. 1 patients, $P < 0.05$), but had more improvements in Right Ventricular outflow tract (RVOT) gradients. There were no differences in arrhythmias in either group. Pre-operative TAPSE for both groups was similar (1.46 ± 0.27 vs. 1.61 ± 0.31 , $P > 0.05$) and so was the post-operative TAPSE at discharge (1.54 ± 0.31 vs. 1.49 ± 0.33 , $P > 0.05$), at 1 months (1.64 ± 0.25 vs. 1.48 ± 0.32 , $P > 0.05$) and 3 months (1.75 ± 0.19 vs. 1.7 ± 0.15 , $P > 0.05$).

Conclusion: Both approaches provide adequate palliation with effective improvements in RVOT gradients for patients with TOF. A limited right ventriculotomy does not adversely affect early RV function or increase the incidence of arrhythmias at the immediate post-operative period and early follow-up. More extensive studies with prospective randomized design and longer follow-ups are needed to address these issues further.

Keywords: Tetralogy of Fallot, transatrial approach, intracardiac repair.

Introduction

Tetralogy of Fallot (TOF) is the most common cyanotic congenital cardiac anomaly.[1] Initially, intra-cardiac repairs of TOF were undertaken through a right ventriculotomy incision with or without the use of a transannular patch.[2,3]

With increasing expertise of infundibular resection and ventricular septal defect (VSD) closure through the trans-septal right atrial approach, more and more intracardiac repairs for TOF were advocated through a trans-right atrial (t-RA) approach.[4] It was considered that the trans-right ventricular (t-RV) approach increases the incidence of Right Ventricular dysfunction, arrhythmias, and sudden

death. The t-RA approach supposedly has a longer learning curve and leaves residual RVOT obstruction than a t-RV approach.[5]

Both approaches are popular depending on the anatomical subset and surgeon preference and experience. Various studies assess the RV's long-term functional outcome after intra-cardiac repair of TOF. Still, comparative studies to determine the immediate and early postoperative RV function using either approach are very few.[6] Because of the more complicated anatomy of the RV and failure to trace its endocardial surface completely, assessment of the RV function is difficult.[7]

Tricuspid annular plane systolic excursion (TAPSE) is a simple measure of RV ejection fraction that can be assessed at the bedside by M-mode 2-D echocardiography. Various studies have validated it as a reliable measure of the systolic function of the RV.[8] The present study compares the pre-operative and immediate post-operative RV function between t-RA versus t-RA/RV approach for TOF repair using the TAPSE.

Materials and Methods

Patients

Fifty-three patients operated on for the intra-cardiac repair of TOF between August 2019 and March 2021 by t-RA or combined (t-RA/RV) approach were included in this study. Twenty-one patients underwent surgery through the t-RA approach, while thirty-two patients were operated on using the combined (t-RA/RV) approach. Being a retrospective study, consent could not be obtained. However, informed consent was obtained from the parents of all patients before surgery. This study was performed at CHL Hospital, Indore, Madhya Pradesh.

Patients who underwent emergency surgery were not included in the study.

For patient evaluation, echocardiography, cineangiography, or computed tomography angiography were used pre-operatively, as indicated. The primary outcome parameter was TAPSE. Secondary outcome parameters were duration of mechanical ventilation (hours), pleural effusion, arrhythmias, intensive care unit (ICU) stay, and total hospital stay.

Surgical procedure

A single surgeon performed surgery in a standard manner. Anesthesia was induced and maintained by weight-related doses of thiopental, fentanyl, midazolam, and pancuronium. Cardiopulmonary bypass (CPB) was carried out using a nonpulsatile roller pump, membrane oxygenators, and standard (uncoated) extracorporeal circuits under moderate hypothermia (28°C). The circuit was primed with appropriate amounts of Plasmalyte-A solution, mannitol, and sodium bicarbonate. Blood was added as required. For both groups of patients, aorto-bicaval cannulation, cold bloodroot cardioplegia, and closure of VSD using a Dacron patch were carried out. In the t-RA group, the VSD closure, infundibular resection, and pulmonary valvotomy were performed through the right atrium.

In contrast, in the t-RA/RV group, the VSD closure was performed either through RA or through a limited

ventriculotomy incision made in the in RV outflow tract starting 0.5 cm below the annulus and extending for a length of 1–2 cm. Infundibular resection and pulmonary valvotomy were also carried out through this incision. Pulmonary valve stenosis was managed by commissurotomy if commissural fusion was present or release of tethering and also by dilating the pulmonary valve using an appropriate sized Hegar dilator. The ventriculotomy was then closed using an RV outflow tract patch using autologous pericardium. From either route, the assessment of the pulmonary annulus was made by passing a Hegar dilator expected for the patient's weight.

Intra-operative and post-operative data

Peroperative data included CPB and aortic cross-clamp times. Intra-operative transesophageal echocardiography was performed in all patients to assess the repair adequacy and biventricular function. Postoperatively patients were continuously assessed for hemodynamic stability and managed by the ICU team.

Echocardiographic assessment

Records of echocardiographic assessment were evaluated retrospectively. TAPSE was taken as a surrogate for RV function and was calculated in the apical four-chamber view using M-Mode echocardiography. The longitudinal excursion of the lateral annulus of the tricuspid valve toward the apex (TAPSE) at peak systole has been found to have a good correlation with isotopic derived RV ejection fraction.[9] It was recorded preoperatively, on the postoperative day two, at the time of discharge from the hospital, and subsequently at 1 month and 3 months of follow up.

Statistical analysis

A qualified statistician performed statistical analysis using IBM SPSS Statistics software for Windows, version 23 (IBM Corp., Armonk, NY, USA). Data are presented as mean \pm standard deviation for continuous variables among the two groups. Nonparametric Mann–Whitney U test was used to compare baseline and post-intervention numerical variables. The Chi-square test was used to compare ordinal and categorical variables. $P < 0.05$ was considered statistically significant.

Results

There were 21 patients in Group 1 (operated through t-RA route) and 32 in Group 2 (Operated through a combined t-RA/RV approach). Patient demographics are shown in Table 1.

Table 1: Preoperative details of patients

Variables	Group 1 (n=21)	Group 2 (n=32)	P-value
Age	5.2±4.1	4.9 ±4.0	0.664
Weight (kg)	16.9±12.1	17.2±11.7	0.81
BSA (m ²)	0.71±0.32	0.69±0.34	0.91
Sex (M: F)	16:5	24:8	0.09
Preoperative saturation (%)	75	72	0.31

BSA: Body surface area; M: male; F: female

There were no differences between the two groups concerning demographics, preoperative RVOT gradient, and RV function. The patients in each group underwent intracardiac repair by either approach by a single surgeon operating in a reproducible manner. The pulmonary artery annulus of each patient was sized preoperatively as described above, and a Z-value of the pulmonary annulus up to -3 was accepted to avoid a transannular patch. Intra-operative and post-operative results are detailed in Table 2.

Table 2: Perioperative details of patients

Parameters	Group 1	Group 2	P-value
CPB time (min)	84.2±26.7	106.8±31.6	0.075
Aortic cross-clamp time (min)	56.3± 24.1	69.2±22.3	0.21
Mechanical ventilation (hours)	12.8±5.2	14.8±6.9	0.94
Pleural effusion (n)	1	9	0.025
Arrhythmia	2	4	0.34
ICU stay (hours)	58.2±23.2	60.2±21.9	0.71
Hospital stay (days)	6.2±1.2	6.8±2.1	0.19

ICU: intensive care unit; CPB: Cardiopulmonary bypass

The two groups had comparable CPB and aortic cross-clamp times. There was one early death in group 1, while two were in group two. All deaths were related to low cardiac output syndrome. There were no significant differences between the two groups concerning the duration of mechanical ventilation, ICU stay, and hospital stay. However, a significant number of patients in Group 2 had pleural effusion.

In Group 1, only two patients had postoperative sinus tachycardia that resolved spontaneously. In Group 2, four patients had postoperative arrhythmias. Two of these had

sinus tachycardia that resolved spontaneously, and two had ectopic junctional tachycardia that was controlled with core cooling, reduction in catecholamine support, and amiodarone.

Assessment of right ventricular function

The mean pre-operative TAPSE for Group 1 was 1.46 ± 0.27 cm, and that for Group 2 was 1.61 ± 0.31 cm, and the difference between the two groups was not significant [Table 3].

Table 3: Echocardiographic parameters of patients

Parameters	Group 1	Group 2	P-value
Mean normal TAPSE (cm) for age	1.82± 0.25	1.88±0.21	0.74
Pre-operative TAPSE (cm)	1.46±0.27	1.61±0.31	0.06
Post-operative TAPSE (cm) at discharge	1.54 ± 0.31	1.49 ± 0.33	0.36
Post-operative TAPSE (cm) 1month	1.64 ± 0.25	1.48 ± 0.32	0.48
Post-operative TAPSE (cm) 3 months	1.75±0.19	1.7±0.15	0.61

TAPSE: tricuspid annular plane systolic excursion

Age-wise normal TAPSE values for both the groups were evaluated and compared between the two groups, which revealed well-matched groups without any statistically significant differences. After TOF repair, there was a reduction in the mean TAPSE for both groups;

however, the differences between the groups were not significant. At 1 month of follow-up, echocardiography

revealed marginal improvement of TAPSE values in Group 1, while in Group 2, the TAPSE values remained static. However, this was not statistically significant.

At 3 months follow up, TAPSE values improved to 1.75 ± 0.19 versus 1.7 ± 0.15 in Groups 1 and 2, respectively, P > 0.05 [Figure 2]. The mean preoperative gradient across the RVOT in Group 1 was 73.64 ± 12.8 mmHg, and in Group

2, it was 77.36 ± 11.6 ($P > 0.05$). After TOF repair, the mean gradients fell to 18.96 ± 8.6 mmHg in Group 1 and 10.8 ± 2.74 mmHg in Group 2, and the difference between the groups was statistically significant ($P = 0.02$). These gradients did not change significantly at follow-up.

Discussion

Multiple approaches have been described to achieve a secure closure of the VSD and achieve optimal relief of RVOT obstruction while performing intra-cardiac repair for TOF.[10,11] The transventricular route was used classically to close the VSD and relieve the RVOT gradient by infundibular resection. The ventriculotomy was then repaired and simultaneous enlargement of the RV outflow using a patch that may or may not extend across the pulmonary valve annulus. However, there have been concerns that a long ventricular incision[10] leads to an increased incidence of ventricular scarring that may lead to late ventricular tachyarrhythmias and sudden death. The RV incision has been shown to disrupt RV geometry, causing delayed RV dysfunction.[12] The RA approach was first described by Hudspeth *et al.* and Edmunds *et al.*[13,14] It gained popularity because it is thought to avoid the disadvantages of a long ventriculotomy. Also, it prevents the deleterious long-term consequences of pulmonary regurgitation by preserving the pulmonary valve. The other advantages of the RA approach include avoidance of possible injury to the ventricular branch of the right coronary artery and reduced incidence of arrhythmias occurring at a later age.[15] However, a higher incidence of complete heart block and tricuspid regurgitation with a trans-atrial approach has been reported in some studies.[10] Also, a significant number of patients undergoing t-RA repair had residual RVOT gradients requiring reoperation in a significant subset of the patient in one series.[5] The trans-RA/RV approach probably combines the advantages of the two approaches. In this approach, the VSD is preferably closed from the right atrium, and the infundibular resection is performed through a small ventriculotomy. Performing the RVOT resection through a limited right ventriculotomy allows for direct visualization of the obstructing infundibular bands and permits infundibular enlargement by placing an RVOT patch. The pulmonary valve exposure is also better than the t-RA approach allowing more accurate pulmonary commissurotomy without opening the pulmonary artery.

Direct assessment of RV function has been difficult echocardiographically because the RV does not conform to any geometrical shape. Cardiac magnetic resonance (CMR) imaging is the gold standard for calculating the RV ejection fraction.[16] CMR is, however, not available universally, is expensive, takes a longer time to perform, requires sedation, and often endotracheal intubation, especially in younger infants and children. Hence, TAPSE, a preload-dependent assessment of longitudinal systolic motion of the

lateral annulus of the tricuspid valve, is used to assess RV function. It can be easily measured by doing M-mode 2-D echocardiography at the bedside.[17-21]

This study compared the early results of the two approaches in a retrospective manner. The groups were well matched concerning age, body surface area, and cardiac anatomy. The consistency of the surgical procedure could be gauged easily from the uniform CPB and aortic cross-clamp times. The study showed that early tracheal extubation was possible in both groups. The significant difference between the two groups was in a higher amount and a longer duration of pleural effusion in patients in the t-RA/RV group. However, this did not translate into more prolonged ICU and hospital stays statistically when the two groups were compared. There was an overall decrease in RV function after intra-cardiac repair of TOF in both the groups with gradual recovery at the end of 1 month and 3 months. The differences in the mean value of TAPSE were not significant at any point in time. Patients who operated using the t-RA/RV approach did have less mean TAPSE values than those who operated on the t-RA approach. However, this did not translate into significant differences in the need for ICU stay or hospital stay. The other relevant finding in this study was a significant decrease in the RVOT gradient when the infundibular resection was performed using a combined t-RA/RV approach. This relief of RVOT gradient through the smaller ventriculotomy incision did not produce statistically significant arrhythmias and RV dysfunction in the immediate and early post-operative period. Theoretically, this offers an attractive approach for infundibular resection and pulmonary valvotomy. Moreover, this approach may reduce the incidence of reoperations in the long term because late reoperations following TOF repair are more often due to residual RVOT gradients than due to other factors.[26] However, the concerns of a ventriculotomy on the RV function in the long-term remain.

Limitations

Our study design was retrospective in a manner with its shortcomings. Also, this study was limited to a small number of patients operated by a single surgeon with a short duration of follow-up. There is a need for conducting larger prospective randomized multicenter studies involving more patients with a longer follow-up to assess differences in RV function, arrhythmias, need for late reoperation, and exercise capacity in either group.

Conclusion

Both approaches provide adequate palliation with effective improvements in RVOT gradients for patients with TOF. A limited right ventriculotomy does not adversely affect early RV function or increase the incidence of arrhythmias at the immediate post-operative period and early follow-up. More extensive studies with prospective randomized designs and

longer follow-ups are needed to address these issues further.

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