# **Original Research Article**

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# Transatrial approach for total correction of tetralogy of Fallot: our centre experience over three years

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#### **ABSTRACT**

**Background:** The objective of this study was to evaluate the early and mid-term outcome of total correction of tetralogy of Fallot (TOF) done through transatrial approach avoiding ventriculotomy with or without transannular patching.

**Methods:** Of 210 patients undergoing total correction for TOF between January 2016 and January 2019, 180 patients were operated via transatrial approach. The ventricular septal defect closure, infundibular resection and pulmonary valvotomy were performed through the right atrium. Age ranged from 12 months to 44 years (mean, 2.6 years), 104 patients were male and 76 patients were females.

**Results:** Three patients (1.67%) died in early post-operative period. Pulmonary complications were seen in 8 (4.44%), septicemia in 1 (0.55%), low output syndrome in 2 (1.10%) and temporary arrhythmias in 6 (3.33%) patients. Reintubation was needed in 3 (1.67%) patients. Early reoperation was needed in 3 (1.67%) patients in view of post-operative bleeding. There were no mediastinal or deep sternal wound infections. None of our patient had complete heart block. There were no late deaths or late reoperations. Echocardiography before discharge did not reveal significant residual VSD in any patient. The mean right ventricular outflow tract pressure gradient was 28 mmHg (range of 20 to 44 mmHg) which decreased on follow-up echocardiography to 16 mmHg (range of 14 to 24 mmHg) at mean follow up of 23 months. None of our patient had severe pulmonary or tricuspid regurgitation or severe right ventricular dysfunction on follow up.

**Conclusions:** Transatrial repair of TOF is associated with remarkably low morbidity and mortality in our early experience.

**Keywords:** Tetralogy of Fallot repair, Transatrial correction, Pulmonary complications

#### **INTRODUCTION**

Tetralogy of Fallot (TOF) is the most common congenital cyanotic heart disease and accounts for 5% of all congenital heart lesions.<sup>1</sup> The cephalad and anterior deviation of infundibular septum is etiology leading to the cardinal features of ventricular septal defect (VSD), right ventricular hypertrophy (RVH), pulmonary stenosis (PS) and aortic override.<sup>2</sup>

The surgical approaches for TOF repair involve either an initial palliation by construction of a systemic to pulmonary artery shunt followed by a definite repair or primary complete repair.<sup>3</sup> TOF was traditionally repaired through a right ventriculotomy with or without transannular patch.<sup>4</sup> Despite excellent early results, there were concerns that the resultant scar may increase the incidence of ventricular arrythmias and sudden death and impair the right ventricular function. Transannular

patching (TAP) enhances the pulmonary annulus size usually at the expense of pulmonary regurgitation (PR) which leads to RV dysfunction with time and poor long-term results.<sup>5</sup>

Transatrial repair of TOF was first reported in 1963 by Hudspeth et al eliminating the complications of ventriculotomy.<sup>6</sup> It was reintroduced by Edmunds et al in 1976 and popularized in recent years.<sup>7</sup> In this review, we would discuss our experience with total TOF repair via transatrial approach, without transventricular or transpulmonary incision and even without transannular patching although accepting two size smaller Hegar probe of that predicted by Rowllat charts in some cases, with good mid-term results.

Our objective is to study morbidity and mortality in patients operated for tetrology of Fallot with transatrial approach without either ventriculotomy or transannular patch and comparison of our results with already publish results from other techniques.

#### **METHODS**

Database of all patients who were operated for TOF, in Dr. RML Hospital, New Delhi, between January 1, 2016 and January 1, 2019 was collected. Patients of any age, who were operated for TOF through transatrial approach in our institute were included in our study.

Patients with concomitant procedures were excluded from our study except those who underwent patent foramen ovale or atrial septal defect (ASD) closure or patent ductus arteriosus (PDA) ligation or takedown of aortopulmonary shunt. Syndromic patients as well as patients with multiple ventricular septal defects (VSDs) were also excluded.

During the above said period, a total of 210 patients were operated for TOF in our centre. Out of 210 patients, 25 patients underwent intracardiac repair through right atrial (RA)-right ventricular (RV) approach, 15 of them needed TAP while 10 of these needed pulmonary artery (PA) augmentation as well. In 5 patients repair was done through RA-PA approach, 2 of these needed TAP, while 3 of these needed pulmonary artery augmentation also.

Statistical analysis performed on 180 pts in which transatrial approach was used for intra cardiac repair of TOF. Demographic and investigation data were collected from pre-operative, intra operative, post-operative data from the echocardiography reports, perfusion reports, clinic, inpatient and operative notes for all these patients. Patients were further scheduled follow up after discharge. Continuous variables were presented as mean±standard deviation (normally distributed data). Categorical variables were presented as percentage.

#### Surgical technique

A uniform operative technique was used with bicaval cannulation for cardiopulmonary bypass and moderate systemic hypothermia. Any patent shunts were taken down. Ductus arteriosus dissected and ligated if present. Main pulmonary artery separated from aorta and both its branches were fully mobilised, which aids in pulmonary valve inspection through Right atrium. Myocardial protection was then achieved with delNido cold blood cardioplegia delivered through aortic root supplemented with ice slush. Following the cardioplegic arrest, the right atrium was opened by an incision starting from the base of the right atrial appendage and extending to the medial aspect of the inferior vena cava. The left side of the heart was vented through PFO. Two everting 5-0 prolene stay sutures were placed on right atrium and hanged on the left sternal blade. Via a right atriotomy and working through the tricuspid valve, the parietal extensions of the infundibular septum were divided parallel to the aortic annulus up to the level of the pulmonary valve. The dissection was completed by excision of the obstructing parietal bands, anterior infundibular trabeculations and the septal bands. In all case, the pulmonary valve was inspected by holding the leaflets and any tethering if seen, was released and commissurotomy done when needed to relieve any stenosis. Hegar dilators were then used to assess the size of the pulmonary annulus.

Adequacy of RVOT resection was assessed by Jhajhria infundibular resection adequacy assessment technique (JIRAAT). Keeping the index finger inside the RVOT and thumb outside, we could assess the residual anterior bands and the thickness of RVOT to prevent over/ under resection<sup>8</sup>.

Ventriculotomy/ TAP was avoided by liberally coring the RVOT, and accepting pulmonary annulus one or two size smaller Hegar probe than the mean diameter as per Rowllat chart. Patients in whom pulmonary annulus is still negotiating only smaller than two size hegar probe than the mean diameter as per Rowllatchart, TAP was done and excluded from our study.

The VSD was then closed using interrupted prolene sutures and a tailored dacron patch. The tricuspid valve was assessed for competence and any distortion created by the VSD patch was repaired. PFO (2-3 mm) was left open in patients in whom smaller pulmonary annulus was accepted to prevent postoperative RV failure at the expense of mild cyanosis.

Routine post-cardiopulmonary bypass (CPB) RV pressures were not measured. RV pressures were assessed only in patients who had difficulty in weaning from CPB or required higher ionotropic support to wean from CPB. After the routine use of JIRAAT, no patient required CPB for residual RVOT band resection.

According to this operative protocol, RVOT resection, VSD closure, assessment of tricuspid valve function (and tricuspid valvuloplasty, if needed) and pulmonary annulus assessment followed by pulmonary valvotomy, if needed, were accomplished through single incision in the right atrium in all patients. All patients underwent postoperative and before discharge echocardiographic assessment of the repair. This included investigation of the presence and magnitude of any residual RVOT obstruction, pulmonary and/or tricuspid valve insufficiency and residual VSD, as well as assessment of overall RV and LV function.

#### **RESULTS**

Of total 210 patients operated in our centre over three years, transatrial correction was possible in 180 (85%) patients. Age of our patient ranges from 12 month to 44 years. Most of our patients were of the age of 1 to 5 years with mean age of  $2.67\pm0.38$  years (Table 1). Out of 180 patients in our study, 104 patients were males and 76 patients were females with male:female ratio of 1.36:1.

Table 1: Age wise distribution of patients.

Age group (yrs)	N	%
1-2	59	32.7
>2-5	57	31.6
>5-12	37	20.5
>12	27	15

Table 2: Associated cardiac anamolies.

Anomaly	N	%
PDA	28	15.5
ASD	14	7.7
Right aortic arch	7	3.8
Left SVC	2	1.1
Dextrocardia	1	0.5

Table 3: Operative data and early hospital course.

Variables	Mean±SD
CPB time (min)	100±3
Cross clamp time (min)	77±1
<b>Intubation time (hours)</b>	11±2
ICU stay (hours)	42±1
Hospital stay (days)	4±1

Associated congenital cardiac anomalies were present in 45 (25%) patients (Table 2). PDA being the most common followed by ASD. Major aortopulmonary collateral arteries were present in 28 (15.5%) patients and were coiled a day preoperatively. Shunts were taken down once on CPB.

In our study, the mean pre-operative RV/PA gradient was 80, mean cross clamp time was 77 minutes (range of 44

minutes to 122 minutes), post-operative mean intubation time was 11 hours (range of 4 hours to 30 hours) with mean ICU stay being 42 hours (range of 30 to 78 hours). Mean post-operative hospital stay was 4 days (range of 3 to 24 days). The inotropic support on coming off bypass or during ICU stay was required in 35% (63 cases) while 65% (117 cases) no inotropes were needed (Table 3).

In our study of 180 patients, postoperative complications occurred in 24 patients (13.3%). Three patients died in early post-operative period. Pulmonary complications were seen in 8 (4.44%) patients, septicemia in 1 (0.55%), low output syndrome in 2 (1.10%) and temporary arrhythmias in 18 (10%) patients. Reintubation was needed in 3 (1.67%) patients. Early reoperation was needed in 3 (1.67%) patients in view of post-operative bleeding. Thirty patients (16.16%) received packed red blood cells or other blood products, postoperatively. There were no mediastinal or deep sternal wound infections. There were no neurologic complications or seizures in early postoperative period. None of our patient had complete heart block while RBBB was present in 16 patients (Table 4). Temporary pacemaker was needed in 6 of our patients.

**Table 4: Post-operative complications.** 

Complication	N	%
Reintubation	3	1.67
Reoperation	3	1.67
Pleural effusion	8	4.44
Septicemia	1	0.55
Low output syndrome	2	1.10
Temporary pacemaker need	6	3.33
RBBB	16	8.88
Wound infection	0	0
Neurological complications	0	0
Persistent cardiac arrhythmia	0	0
Complete heart block	0	0
Early deaths	3	1.66
Late death	0	0

Echocardiography before discharge did not reveal significant residual VSD in any patient. The mean RVOT pressure gradient was 28 mmHg (range of 20 to 44 mmHg). Out of 177 patients, 6 of our patients have mild PR while 2 patients had moderate PR. Trace to mild TR was seen in 8 patients and moderate tricuspid regurgitation (TR) was seen in 3 patients. Mild impairment in RV function was seen in 6 patients while 2 patients had moderate impairment in RV function. None of our patients had severe valvular insufficiency or severe RV dysfunction (Table 5).

# Follow up

In this study, there was no late postoperative mortality in mean follow-up period of 23 months (range of 10 to 34

months). One more patient developed mild PR, while in one patient PR decreased from moderate to mild in follow up period. Mild TR was noted in one more patient in follow up period, TR did not worsen in any other patient in our series. None of our patient developed fresh impairment in RV function in follow up period. The gradient decreased on late follow-up echocardiography to mean 16 mmHg (range of 14 to 24). The early (within first month) and late (more than 6 months) postoperative echocardiography findings in are delineated in Table 5.

Table 5: Echocardiographic parameters.

Parameter	Early (N)	Late (N)
Pulmonary regurgitation		
No PR	165	165
Mild PR	9	10
Moderate PR	3	2
Severe PR	0	0
Tricuspid regurgitation		
No TR	166	165
Mild TR	8	9
Moderate TR	3	3
Severe TR	0	0
RV function		
Normal RV function	169	169
Mild RV dysfunction	6	6
Moderate RV dysfunction	2	2
Severe RV dysfunction	0	0
RVOT gradient (mmHg)		
Mean RVOT gradient	28	16

## **DISCUSSION**

Right ventriculotomy had been the the approach of choice for years for correction of TOF in view of its excellent early results and low learning curve. Howevever, increased incidence of RV dysfunction on long term follow up secondary to pulmonary/tricuspid insufficiency and arrhythmias from ventriculotomy scar have shifted the surgical approach to RA in most centres and is rapidly gaining popularity. P.10 Length and extend of infundibular obstruction, size and position of VSD as well as degree of aortic override does not relate to feasibility of this approach. Only limitation to this approach being hypoplastic annulus and hypoplastic pulmonary arteries requiring TAP or arterioplasty.

The efficacy of the transatrial approach has been demonstrated by several investigators. <sup>11,12</sup> Our centre has been using this approach since last eight years in all age group of patients, with about 85% of cases being done with this approach since last three years.

In our series of 180 patients operated over time span of three years, patients of all age groups were included, although majority of patients are of 1-5 years age group. Previously our institutional policy was to operate till the child gain weight upto ten kilograms, but this policy has also been dropped since last two years in view of good results of early total correction of TOF through transatrial approach supplemented by JIRAAT.<sup>8</sup> Consequently, rarely nowadays TOF patients are considered for palliative shunt surgeries.

The overall mortality of transatrial approach has been reported between 0-5% by Giannopoulos et al, our series report similar low mortality of 1.66%, which is quite less than 1-20% of overall mortality in transventricular strategy. Higher mortality rates in transventricular approach had been attributed to RV failure because of pulmonary insufficiency and arrhythmias from ventricular scar site. 10

Lower incidence of arrhythmia is being one of the main advantages of this technique reflected in long term results. None of our patient had complete heart block requiring pacemaker or permanent arrhythmia requiring antiarrythmic medication, although right bundle branch block (RBBB) was present in 8.8% patients in follow up ECG. Airan et al in 2006 reported much higher incidence of heart block (35%) with this technique. Dietl et al demonstrated higher incidence of arrhythmias in transventricular approach as compared to transatrial. Kawashima et al similarly reported decreased incidence of ventricular arrhythmia in transatrial approach as compared to transventricular approach.

Tricuspid valve incompetence can occur during VSD patch closure due to entrapment of chordae or valve tissue in suture or patch or leaflet injury during traction for visualising RVOT. Incidence of TR is more in patients when leaflet detachment or leaflet incision technique used for VSD closure, none of our patient needed this technique. None of our patient had severe tricuspid regurgitation, although mild to moderate TR was present in 6.6% of patients which doesn't increased on follow-up echocardiogram.

Stewart and colleagues reported an incidence of 70-80% of moderate to severe pulmonary regurgitation if TAP has been done as compared to 15-35% if valve sparing approach had been used.<sup>17</sup> These higher degrees of pulmonary regurgitations are leading cause of postoperative RV distension and dysfunction. We have no case of severe pulmonary regurgitation or severe RV dysfunction in our series although mild PR was present in 6.6% and moderate PR was present in 0.8% of patients in follow-up echocardiogram. Dietl et al also showed that the transatrial approach decreases the prevalence of both RV dysfunction and pulmonary regurgitation, and also would reduce the risk of ventricular arrhythmia without a concomitant increase in atrial arrhythmia.<sup>11</sup> In that sense, these results will decrease mortality and reoperation rates in transatrial approach.

The crucial drawback against transatrial approach is higher residual RVOT gradient. In this review, the

postoperative RVOT gradient results were encouraging and comparable to other studies. The mean RVOT gradient in early postoperative echocardiogram was 28 mmHg. The gradient gradually declined noticeably on follow up echocardiogram to a mean of 16 mmHg. Moreover, the pressure gradient ranges are decreasing with increase in our experience with the procedure. The decrease in dynamic RVOT gradient overtime after surgery has also been described by Koushal et al. 18 With the routine use of JIRAAT in which we assess the residual RVOT bands between our thumb and index finger, residual RVOT gradients have decreased considerably, along with the advantage of preventing over resection of RVOT. To prevent higher RVOT gradient, many authors maximize annulus by at least 1 to 2 mm greater than normal values. We in our Institute accepts two size smaller Hegars probe of that predicted by Rowlatt charts to avoid over resection that leads to pulmonary regurgitation.<sup>19</sup> Voges et al, 2008 in a series of 216 patients demonstrated no increase in RV pressure load or reoperation rate for residual RVOT obstruction if restrictive enlargement of the pulmonary annulus is done, they performed transannular patching only in patients with native pulmonary annulus z-score less than -4. Further in their series, if TAP was performed, enlargement was aimed to diameter within range of zscore of -2. We too imply some degree of RVOT narrowing than leaving pulmonary valve incompetent as the former is well tolerated by the patient.

## **CONCLUSION**

this study shows that transatrial correction of the TOF is associated with excellent early and mid-term results. Our results confirm that this approach is safe (low mortality), and it also contributes to the preservation of satisfactory right ventricular function by preserving the pulmonary valve and avoiding ventriculotomy. Although the learning curve of this technique is relatively higher.

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Institutional Ethics Committee

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