

Results of urgent interventions in patients with Tetralogy of Fallot within the first three months of age

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Abstract:

Background: Most patients with Tetralogy of Fallot (ToF) undergo reparative surgery at around six months of age. However, some experience severe cyanotic spells during the neonatal or infancy period, requiring urgent interventions to increase pulmonary blood flow. We present our experience managing symptomatic Tetralogy of Fallot in infants younger than three months of age.

Methods: Retrospective review of patients younger than 3 months old with ToF and severe cyanotic spells who required intervention between January 2015 and December 2021. A total of 42 infants underwent urgent intervention (19 surgical procedures in group 1 and 23 transcatheter intervention in group 2). **Results:** Median age and weight were 38 days (IQR 19-70 days) and 3.7 Kg (IQR 3.4-4.2 Kg) in the surgical group (group 1) and 29 days (19-43 days) and 3.2 Kg (2.9-3.7 kg) in transcatheter group (group 2). In Group 1, nine infants (21.4%) had full surgical repair, eight (19%) required modified BTT shunt, one (2.4%) had isolated transannular patch and one (2.4%) received RV-PA conduit. In Group 2, nine infants underwent PDA stent (21.4%), nine had RVOT stent (21.4%), three required pulmonary valve balloon dilatation (7%) and two RVOT balloon dilatation (4.8%). Median ICU stay and hospital stay were four days (3-8) and nine days (7.5-20) in group 1, compared to one day (1-1.5) and five days (3-15.5) in group 2. Six infants (14.3%) had surgical procedures after unsuccessful transcatheter interventions. No infants died following surgical repair, while there was one mortality (2.4%) in the transcatheter group due to cerebral infarction following ECMO rescue. In group 2, median time to full repair was 10 months (6-12), and 13 months (10-19.5) in palliative surgical procedures of group 1. One patient (2.4%) in group 1 needed

reintervention after a salvage procedure before the full repair, while five patients (11.9%) in group 2 required further catheter reinterventions before proceeding to full repair.

Conclusion: Our experience demonstrates that in patients with Tetralogy of Fallot requiring urgent early intervention, excellent outcomes can be achieved when choice of procedure is tailored to patient-specific anatomy and clinical status. In patients with favorable anatomy, full repair can be performed as primary procedure with good long-term outcome.

Introduction:

Tetralogy of Fallot (TOF) affects about 3 out of every 10,000 live births, and is the most common cyanotic congenital heart defect ^{1,2}. The timing of the primary full surgical repair depends on comorbidities, severity of the lesion, and clinical presentation. In asymptomatic patients, the optimal timing for repair is between 3 and 11 months of life ^{2,3}. However, in a significant proportion of patients, severe right ventricular outflow tract (RVOT) obstruction, coupled with ductus arteriosus closure, can lead to refractory desaturations, necessitating urgent intervention. ^{4,5}. These interventions range from palliative surgical or transcatheter procedures to early primary surgical repair to ensure adequate pulmonary blood flow.. Palliative procedures can include either surgical (such as: modified BT shunt, Right ventricle to pulmonary artery (RV-PA) conduit and transannular patch), or trans-catheter including PDA stent, RVOT stent, pulmonary valve (PV) balloon dilatation and RVOT balloon dilatation ⁵⁻¹⁰. Algorithm 1 illustrates our TOF management in our institute. This study aims to assess the outcomes of urgent interventions in ToF patients younger than three months, comparing surgical and transcatheter approaches.

Material and methods:

-Study design and patient population:

Retrospective data collection was performed for all infants and neonates up to 3 months of age with TOF, who underwent an urgent intervention for recurrent cyanotic spells, between January 2015 and December 2021 at our institute. The cohort was divided into those that underwent surgical procedure (Group 1) or trans-catheter intervention (Group 2). A total of

42 infants were identified after exclusion of the abandoned trans-catheter procedures and exclusion of cases of TOF with absent pulmonary valve syndrome. Group 1 (surgical group) included 19 patients (45.2%) and Group 2 (trans-catheter group) had 23 cases (54.8%).

We compared the 2 groups regarding ICU stay, hospital stay, ECMO requirement, re-intervention rate till the final repair, time to final repair, complications and mortality.

-Statistical analysis:

Data analysis was done with the aid of the Statistical Package for Social Science (SPSS), version 26.0 for Windows 7.

Continuous data were expressed as median and interquartile range (IQR) and categorical variables as frequency (N) and percentage (%).

Mann Whitney U test compare median difference between group 1 and 2, significance when P value < 0.05. Chi Square test was used to compare proportions between group 1 and 2, significance when P value < 0.05.

Service arrangements:

In emergency cases such as unstable TOF case with cyanotic spells urgent Trans-thoracic echocardiography (TTE) and a cardiac CT with contrast are performed to confirm the diagnosis and to delineate the size of the branch pulmonary arteries, central pulmonary artery, RVOT anatomy and the anatomy of the VSD. As mentioned before in the algorithm, we tend to manage the cyanotic spell TOF cases, at the first instance, by means of medical management.

However, in case of failed medical management with recurrent severe episode with desaturation, the case is discussed in order to decide upon the best intervention for the patient based on underlying anatomy, weight and significant comorbidities.

-Ethical statement:

This study has been approved by Liverpool John Moores University Ethical committee with the following UREC reference: 25/NAP/005.

Results:

Group 1 consisted of 19 patients who had surgical interventions via median sternotomy that included: 9 cases of complete primary surgical repair (47.4%), 8 cases with modified BTT shunt (42%), 1 patient with RV-PA conduit (5.3%) and 1 patient had trans-annular patch with right pulmonary artery (RPA) plasty (5.3%).

Males represented 57.9 % (N=11) in group 1, while they were 65.2 % (N=15) in group 2 (p 0.313).

Group 2 contained 23 cases with trans-catheter procedures that included: 9 PDA stents (39.1%), 9 RVOT stents (39.1%), 3 cases of pulmonary valve (PV) balloon dilatation (13%) and 2 RVOT Balloon dilatation (8.6%). (Figure 1)

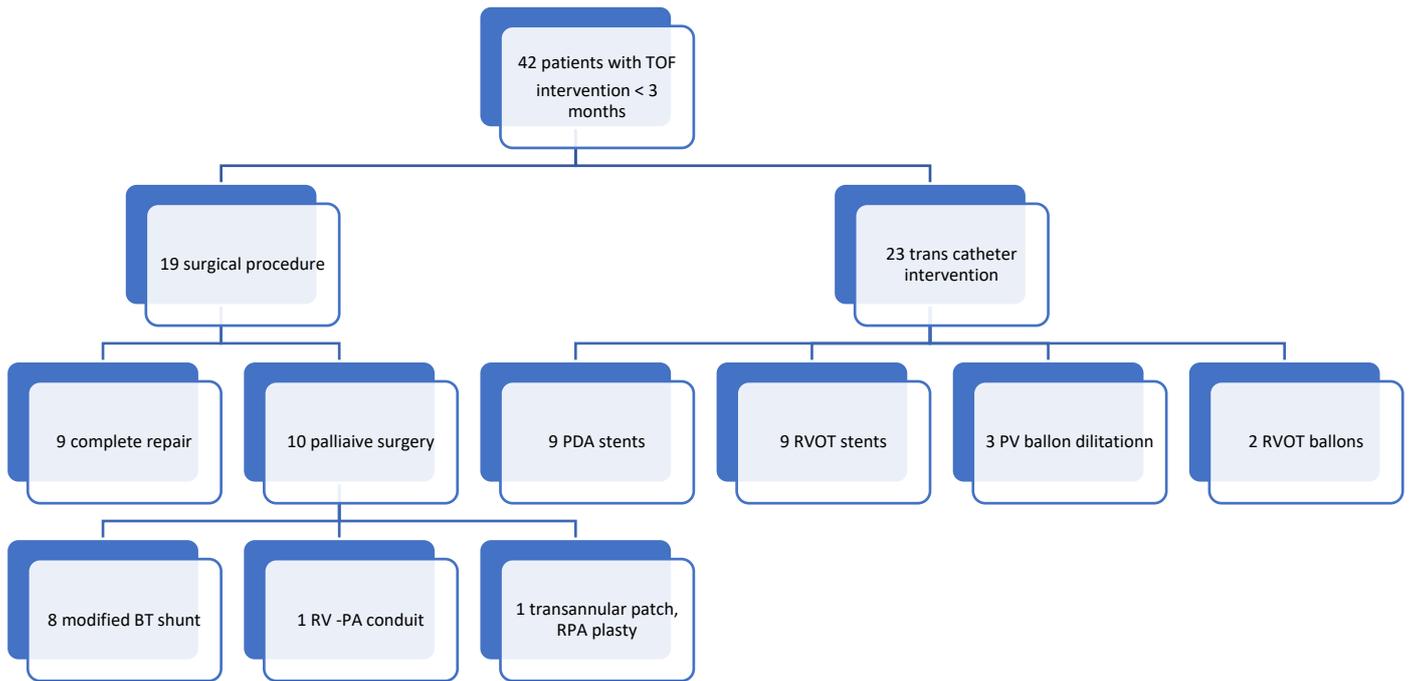


Figure 1 Cohort groups

Median age was 38 days (IQR 19-71) and 29 days (IQR 19-44), in group 1 and group 2, respectively (p 0.176), while median weight was 3.7 kgs (IQR 3.4-4.3) in group 1 and 3.2 kgs (IQR 2.9-3.8) in group 2 (p 0.043).

Median ICU stay was 4 days (IQR 3-8) in group 1 and 1 day (IQR 1-2) in group 2 (p <0.001), while the postoperative hospital stay was 9 days (IQR 7.5-20) and 5 days (IQR 3-16) in groups 1 and 2, respectively (p 0.062). (Table 1)

As mentioned before, group 1 included 9 cases of primary full repair and 10 palliative surgical procedures. Out of those 10 palliative surgical procedures, only 1 patient with modified BTT shunt (10%) required re-intervention before final surgical repair and needed unblocking the mBT shunt and adding a transannular patch.

Conversely, in group 2, there were 5 cases (21.7%) who needed further re-intervention before final surgical repair (p 0.21). Four RVOT stent cases needed re-intervention: 2 with new 2 RVOT stents, one had a stent balloon dilatation and one had multiple MAPCAs coiling. The 5th case was a case of RVOT balloon dilatation who required a PDA stent.

The median time to full repair was 13 months (IQR 10-19.5) in group 1, compared to 10 months (IQR 6-12) in group 2 (p 0.018).

The 9 cases in group 1 who had full surgical repair had a median age and weight of 59 days (IQR 31-74) and 4.4 kgs (IQR 3.8-4.7). None of these cases required any further intervention during the time of the follow up. Comparatively, the median age and weight for cases with palliative interventions either trans-catheter or surgical in both groups were 29 days (IQR 18-49) and 3.3 kg (IQR 2.9-3.7), with p 0.08 and p 0.00038 for age and weight, respectively.

In Group 1, no patients required ECMO with no mortality, while in group 2, one patient needed ECMO via neck cannulation and that patient died 35 days after the procedure (mortality 4.3%).

Finally, we need to mention that 6 cases in the surgical group 1 (31.6%) went to the cardiac theatre after abandoned cath-lab procedures as shown in table 2, 5 of which received a surgical palliation with mBTT shunt, and one underwent full repair.

Discussion:

In patients with ToF younger than 3 months of age, when symptoms start, there is no consensus on best management. Historically, palliative surgical procedures, such as the modified BT shunt, were preferred. However, transcatheter palliative interventions, including PDA or RVOT stenting, have gained recognition as safe and effective alternatives.^{11,12} A

retrospective study from Birmingham Children's Hospital compared RVOT stenting to surgical mBT shunts found no increase in mortality with lower PICU admission rates and shorter hospital stay in those who underwent RVOT stenting. They concluded that RVOT stenting should be first-line palliation in patients if not considered suitable or considered high risk for an early repair ¹¹. Complete primary early neonatal or early infant repair is not standard clinical practice, however there is increasing evidence that when certain criteria are met, this can be a safe option with good outcomes ^{11,12}.

Our findings align with prior studies suggesting that early repair in symptomatic ToF is feasible and safe.. ^{13,14}. Patient selection is crucial, with factors such as low weight, prematurity, unfavorable pulmonary artery anatomy, abnormal coronaries, and significant comorbidities influencing surgical risk. In these cases, a palliative procedure is advocated ¹⁵. In the present study we compared patients undergoing palliative transcatheter procedures, with those undergoing surgical procedures either palliations or full repair. In our group, those patients selected for a primary surgical repair had higher weights when compared with those undergoing a transcatheter palliative procedure.

There were no significant differences in mortality between the two groups in our study. One patient in the transcatheter group required ECMO and subsequently died. The length of ICU stay was however significantly shorter in the transcatheter group.

A notable finding was that six patients required surgical intervention after failed transcatheter procedures due to unfavourable anatomy, underscoring the limitations of the transcatheter approach in certain cases. In one case where the catheter intervention was unsuccessful a full repair was completed. However, in the other five cases, salvage palliative surgery was carried

out. This suggests that patient selection towards transcatheter intervention might not be the right one, and that palliative surgical procedure could be more appropriate.

Limitations

There may be temporal bias to the findings of this study as operator experience for these transcatheter procedures has increased over recent years in our department.

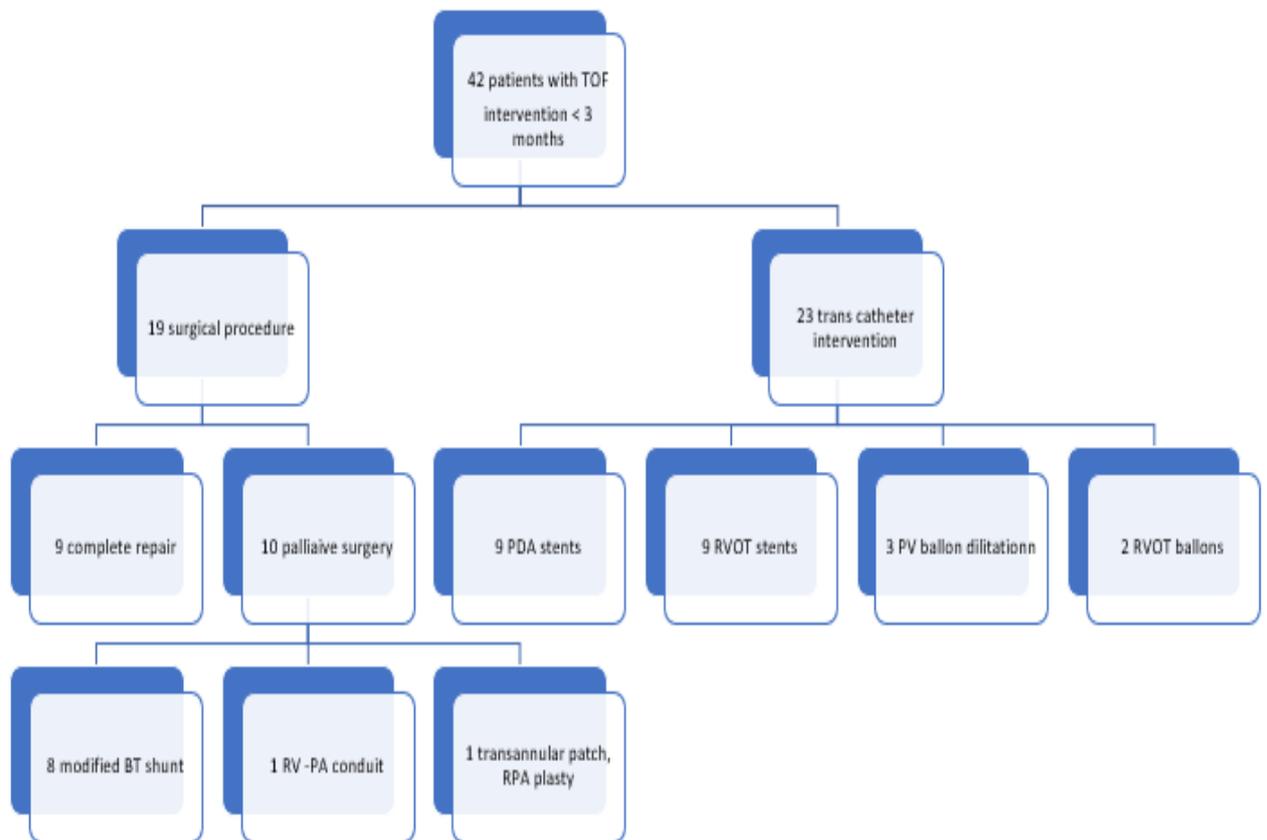
Conclusions

This study demonstrates that in young infants with symptomatic TOF refractory to medical management, feasible options include complete repair, palliative surgical shunts or transcatheter interventions. In choosing a management option patient weight and anatomy of RVOT and PDA should be considered to avoid failed catheter interventions.

Early surgical repair is a safe and feasible option in this group of patients. Longer term follow-up of this cohort is needed to assess outcomes and reintervention rates to further guide clinical decision making.

Figures:

Figure 1 (Cohort groups):



Tables:

Table 1: Demographic and perioperative data:

Variables	Group 1 (Surgical)	Group 2 (Trans-catheter)	p-value
N (%)	N= 19	N= 23	
Median (IQR)			
Gender (M)	11 (57.9 %)	15 (65.2 %)	0.313

Age (days)	38 (19-71)	29 (19-44)	0.176
Weight (kg)	3.7 (3.4-4.3)	3.2 (2.9-3.8)	0.043
ICU stay (days)	4 (3-8)	1 (1-2)	<0.001
Post-op Hospital stay (days)	9 (7.5-20)	5 days (IQR 3-16)	0.062
Reintervention	1/10 (10%)	5 (21.7%)	0.21
Time to repair (months)	13 (10-19.5)	10 (6-12) 0.018	0.018

Table 2: Surgical cases after abandoned trans-catheter procedures:

Primary Intervention	Cause of failure	Subsequent procedure
PDA Stent (Abandoned)	Too Curly PDA	Urgent Rt m BT Shunt
PDA Stent (Abandoned)	Significant desaturation, instability, high Lactate.	Emergency m BT Shunt on CPB.

PDA Stent (Abandoned)	Abnormal anatomy	Urgent Full Surgical Repair.
RVOT Stent (Abandoned)	Difficult anatomy & Guidewire perforating RVOT.	Urgent Rt m BT Shunt.
RVOT Stent (Abandoned)	Difficult to cross the RVOT.	Urgent Rt m BT Shunt.
RVOT Stent (Abandoned)	Difficult anatomy.	Elective Transannular patch + RPA plasty.

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