Original Article

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Transverse Split Sternotomy for Repair of Tetralogy of Fallot: Mid Term Results

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Abstract

Background: Mini-invasive pediatric cardiac surgery has been slow to gain pace due to limited surgical exposure and long learning curve. We started performing transverse sternal split (TSS) to improve surgical exposure with advantage of mini incision in tetralogy of Fallot (TOF) and here we have reviewed our short and mid -term results. *Methods:* Retrospectivereview of patientsof TOF (n=23) operated using TSS (Group 1) from January-2015 to Dec-2016 was performed. Patients were compared with matched patients operated using midline sternotomy (Group 2). Further,TSS group wasdivided into two sub-groups: Group 1A-patients operated in 2015 (n=11) & Group 1B-patients operated in 2016(n=12). Pre-operative, intraoperative and post-operative datawere collected and analyzed. *Results:* There was no significant difference in mortality, residual defects and morbidity between TSS and sternotomy group. Mean preparation ($p<0.001$), cross clamp ($p=0.001$), CPB ($p<0.001$), and surgery time ($p<0.001$) were significantly higher in TSS group than sternotomy group. However, mean duration of ventilation, ICU and hospital stay were significantly lower($p<0.05$) in TSS group. Whileanalyzing TSS sub-groups, mean preparation, cross clamp, CPB and surgery time were significantly lower ($p<0.05$) in group 1B as compared to group 1A, however all remained higher than sternotomy group. Cosmetic result was satisfactory without sternal dehiscence in TSS group and all were in NYHA-Iat mean follow-up of 17.6±7.4 months. *Conclusions:* The TSS is good alternative to a midlinesternotomy for TOF repair in selected patients with satisfactory cosmetic results without compromising the surgical exposure or quality of repair. With increase in expertise, operative duration can be decreased although it remains higher than midline sternotomy.

Keywords: Sternotomy; Mini Invasive; Tetralogy of Fallot.

Introduction

Due to complete visualization of cardiac structures, ease of cannulation, and rapid diagnosis and management of complications, midline sternotomy has remained the standard approach for pediatric cardiac surgery. Different approaches of minimally invasive pediatric cardiac surgery have been slow to gain pace due to limited exposure of the heart and great vessels and long learning curve [1]. All these approaches, also, have limitation of the need for total central cannulation in infants and small children further compromising the surgical field [1,2]. Therefore, these approaches are mainly suitable only for simple congenital cardiac defects that can be repaired through the right atrium (RA). Although, Tetralogy of Fallot (TOF) has been operated through themini-invasive approaches, but it has been limited to trans-RA repair only [1,3].

In aarticle from our institute, we described the technique of transverse split sternotomywith cervical cannulation for mini-invasive repair of simple congenital cardiac defects in infants and children weighing > 7.5Kg [4,5]. The vascular access in these patients was through right common carotid artery (Rt. CCA), right internal jugular vein (Rt. IJV) and inferior vena cava (IVC) cannulation. Using same technique, we have performed intracardiac repair for TOF in 23 patients. In this article, we present our early and mid-termresults.

Patients and Methods

We retrospectively reviewed the data of 23 pediatric patients (14 males) operated for minimally invasive surgical correction of TOF using transverse splitsternotomy (Group 1). All patients were operated by the single surgical team. The design of the study was approved by the Research Ethics Committee of the institution and informed consent was waved off due to retrospective nature of the study. Preoperative data including age, sex, weight, height, echocardiographic anatomy etc. were collected from hospital medical records. .

Operative Technique

Patients were operated by transverse split sternotomy with cervical cannulation. Detailed surgical procedure has already been described in previous article from our institute [5]. In brief, the patients with hypoplastic pulmonary annulus were operated through right atrial (RA) and trans-annular incision while the patients with adequate size pulmonary annulus were operated through RA and right ventricular (RVOT) incision.Whenever requiredanterior leaflet of the tricuspid valve (ATL) was detached [6] from the annulus to improve the exposure of the ventricular septal defect and hypertrophied infundibular muscle. RVOT, Pulmonary annulus and main pulmonary artery were augmented with glutaraldehyde fixed autologous pericardium.TEE was routinely performed to confirm the adequacy of repair and rule out any residual or additional ventricular septal defect. Right ventricle and aortic root pressures were checked and right and left ventricle pressure (pRV/LV) ratio was also calculated.

Following operation, patients were shifted to the intensive care unit (ICU) and managed as per our ICU protocols. The intraoperative and postoperative data including preparation time, aortic cross clamp time, CPB time, duration of surgery, duration of ventilation, hospital and ICU stay and post-operative morbidity were also collected from hospital records.

After discharge from the hospital, follow up data were collected either from hospital records or via telephonic conversation to assess the cosmetic result, sternal stability and any other infirmity.

To compare the effect of mini-invasive technique on aortic cross clamp time, CPB time, duration of surgery, ICU and hospital stay, we also retrospectively collected the operative, ICU and postoperative data of 25 matched patients operated by the same surgical team through median sternotomy approach along with central cannulation, however with the same operative protocol and principles (Group 2). We also evaluated our own results of mini-invasive approach by dividing the patients into two groups depending upon year of operation: Group 1A= Patients operated between January 2015-December 2015 (n=11) Group 1B= Patients operated between January 2016- December 2016 (n=12) to see the effect of learning curve on surgical outcome..

Statistical Analysis

Statistical analysis was performed using SPSS version 20 software (SPSS, Inc., Chicago, IL, USA). All data are expressed as mean ± standard deviation or percentages, as appropriate. To evaluate differences between groups, the unpaired Student's t test for continuous variables and the chi-square test for categorical variables were used. A p value<0.05 (for a two sided test) was considered significant.

Results

Mean age of the patients was 29.65±9.18 months (range 15-44 months) and mean weight was 12.24±1.89 Kg (range 7.5 to 15 kg). Transverse split sternotomy was performed in 3rd intercostal space in 20 patients and in 4th intercostal space in 3 patient. There was no significant intraoperative complication related to exposure, orcannulation. All the patients regained sinus rhythm following removal of aortic cross clamp with good ventricular contractility. Intraoperative TEE did not show significant ventricular dysfunction in any of the patients and no patient required high dose of inotropes. No patient required conversion to upper or lower midline sternotomy. There was no hospital mortality.

Comparison of TSS group (Group- 1) and mid-line sternotomy group (Group -2) has been shown in table 1. Demographic details including age, sex, weight, height and BSA were comparable inboththe groups. Also, there was no statistically significant difference in terms of number of patients requiring trans RA/RVOT repair and patients requiring trans annular patch and/or left pulmonary arterial plastybetween boththe groups.

Intraoperative and postoperative details of both groups have been shown in Table 2. The mean aortic cross-clamp and CPB time were 71.23±11.84 minutes and 106.63±20.69 minutes respectively in group 1. Both the durations were significantly more in patients operated by TSS technique compared to midline sternotomy group (Table 2, p=0.001 & p<0.001 respectively). However, there was no significant difference in RVOT gradient (p=0.59) and mean pRV/LV (p=0.70) in both groups. The mean duration of ventilation (p=0.02), ICU stay (p=0.03) and hospital stay (p=0.01) were significantly higher in group 2 as compared to TSS groupwhereas surgery time (p<0.001) and preparation time (p<0.001) were significantly higher in TSS group. However, there was no significant difference in post-operative complications, mean VIS score or residual defectsbetween both the groups (Table 2, p>0.05).

To assess the effect of learning curve on surgical outcome, we further divided our study cohort patients into two groups by year in which they got operated. As shown in table 3, the mean aortic cross clamp time and CPB time were significantly lower (p=0.017 & p=0.046 respectively) in patients operated in the year 2016 (Group 1B) compared to patients operated in the year 2015 (Group 1A). The mean duration of surgery (p=0.001) as well as preparation time (p=0.009) were significantly less in group 1A than group 1B. (Table 3). However, total duration of ventilation (p=0.92), ICU stay (p=0.54), hospital stay (p=0.55) and post-operative complications (p=0.92) were not significantly different between both the groups.

Postoperative course was uneventful in all, except in one patient who had residual RVOT gradient of 45 mm Hg. Optimal healing was obtained in all the patients, and there was no case of wound infection, sternal instability, or neurologic impairment in TSS group.

Follow-up

Follow-up was 100% complete. At last follow-up (mean 17.6±7.4 months, range 12-30months), there

Table 1: Demographic Profile

	Group 1 (TSS) (n=23)	Group 2 (Sternotomy)(n=25)	p value
Age (Months, Mean±SD)	29.65 ± 9.18	27.84 ± 12.94	0.582
Sex (Male)	14 (60.8%)	15 (60%)	0.815
Weight (Kg, Mean±SD)	12.24 ± 1.89	12.08 ± 3.73	0.854
Height (cm, Mean±SD)	93.30 ± 2.74	89.76 ± 14.36	0.247
BSA (m^2)	0.56 ± 0.05	0.54 ± 0.13	0.493
Surgery			
Trans RA/RVOT Repair (n)	14 (60.8%)	14 (56%)	0.961
Trans Annular Patch+ LPA Plasty (n)	04 (17.4%)	04 (16%)	0.796
Trans Annular Patch (n)	05 (21.7%)	07 (28%)	0.867

BSA- Body Surface Area, RA- Right Atrium, RVOT- Right Ventricular Outflow Tract, LPA- Left Pulmonary Artery

Table 2: Intraoperative and Postoperative Data including Echocardiography and Complications

	Group 1 (TSS, n=23)	Group 2 (Sternotomy, n=25)	P value
Hypoplastic pulmonary annulus (n)	9	11	0.961
LPA stenosis (n)	4	4	0.796
Preparation time (Minutes, Mean±SD)	41.43 ± 4.48	21.56 ± 3.93	**<0.0001**
Bypass time(Minutes, Mean±SD)	106.63 ± 20.69	75.12 ± 20.95	**<0.0001**
Cross clamp time (Minutes, Mean±SD)	71.23 ± 11.84	56.32 ± 17.33	**0.001**
Surgery time (Minutes, Mean±SD)	168.56 ± 13.34	120.6 ± 10.13	**<0.0001**
RVOT Gradient (mmHg, Mean±SD)	32.04 ± 7.85	33.2 ± 7.19	0.596
pRV/LV (Mean±SD)	0.69 ± 0.10	0.70 ± 0.08	0.703
Ventilation time (Hours, Mean±SD)	13.73 ± 2.63	15.44 ± 1.7	**0.019**
ICU Stay (Days, Mean±SD)	1.26 ± 0.54	1.88 ± 0.72	**0.031**
VIS	11.74 ± 3.87	12.39 ± 5.19	0.672
Hospital Stay (Days, Mean±SD)	4 ± 0.67	4.64 ± 0.86	**0.011**
Residual defect			
Mild TR (n)	2 (8.7%)	2 (8.0%)	0.663
Small apical VSD (n)	1 (4.3%)	2 (8.0%)	0.941
Tiny residual defect (n)	1 (4.3%)	1 (4.0%)	0.508
RV/LV Dysfunction (n)	1 (4.3%)	1 (4.0%)	0.508
Complication			
Right pleural effusion (n)	2 (8.7%)	3 (12.0%)	0.921
Wound Complication (n)	0	1 (4.0%)	0.966

RVOT- Right Ventricular Outflow Tract, LPA- Left Pulmonary Artery, RV- Right Ventricle, LV- Left Ventricle, VSD- Ventricular Septal Defect, TR- Tricuspid Regurgitation, VIS- Vasoactive-Inotropic Score

Table 3: Intraoperative and Postoperative Data including Echocardiography and Complications in TSS Group

	Group 1 A (n=11)	Group 1 B (n=12)	P value
Preparation time (Minutes, Mean±SD)	43.81 ± 2.99	39.25 ± 4.39	**0.009**
Bypass time(Minutes, Mean±SD)	113.54 ± 23.62	98.08 ± 8.81	**0.046**
Cross clamp time (Minutes, Mean±SD)	76.27 ± 12.66	65.08 ± 7.69	**0.017**
Surgery time (Minutes, Mean±SD)	177.27 ± 12.32	159.33± 7.50	**0.001**
RVOT Gradient (mmHg, Mean±SD)	31.90 ± 8.09	32.16 ± 7.65	0.937
pRV/LV (Mean±SD)	0.69 ± 0.10	0.70 ± 0.10	0.813
Ventilation time (Hours, Mean±SD)	13.42 ± 2.5	14.09 ± 2.8	0.552
ICU Stay (Days, Mean±SD)	1.18 ± 0.40	1.17 ± 0.38	0.951
Hospital Stay (Days, Mean±SD)	3.92 ± 0.53	4.09 ± 0.83	0.569
Hypoplastic pulmonary annulus (n)	4 (36.3%)	5 (41.6%)	0.867
LPA stenosis (n)	2 (18.1%)	2 (16.6%)	0.964
Residual defect			
Mild TR (n)	1 (9.09%)	1 (8.3%)	0.498
Small apical VSD (n)	1 (9.09%)	0	0.964
Tiny residual defect (n)	1 (9.09%)	0	0.964
RV/LV Dysfunction (n)	0	1 (8.3%)	0.964
Complication			
Right pleural effusion (n)	2 (18.1%)	0	0.421
Wound Complication (n)	0	0	-

RVOT- Right Ventricular Outflow Tract, LPA- Left Pulmonary Artery, RV- Right Ventricle, LV- Left Ventricle, VSD- Ventricular Septal Defect, TR- Tricuspid Regurgitation

wereno deaths and all the patients were asymptomatic. One patient, who had a residual gradient of 45mmHg across right ventricular outflow tract at the time of discharge; the gradient reduced to 30 mmHg in follow-up and patient remained asymptomatic till last follow up.

The cosmetic results were considered good by the parents or guardian of all the patients. Figure 1 shows the convincing cosmetic result after TOF repair with TSS technique. None of the patients had wound infection, keloid, or abnormal sternal movement during follow-up.

Discussion

Mini-invasive cardiac surgery for pediatric patients has been slow to gain popularity. Moreover, technique has remained restricted to repair of simple congenital cardiac defects with a limited experience for the repair of complex lesions due to variousli-mitations of these mini-invasive techniques [1].

In last two decades, reports on minimal invasive repair of TOF have been published. All these repairs have been performed through RA [1, 3, 7, 8]. However, Trans RA approach is suitable only for patients with adequate size pulmonary annulus without any branch pulmonary artery stenosis. Also there is a risk of inadequate resection of hypertrophied muscle bundles and significant residual gradient across RVOT due to limited exposure. Moreover, if there is a need for right ventriculotomy, it will require full sternotomy which may be a messy affair in the presence of total central cannulation especially through thoracotomy.

Our results show that both trans RA and trans annular repair of TOF can be performed through transverse split sternotomy with surgical results comparable to midline sternotomy and without increasing the risk of intraoperative or postoperative complications. Transverse sternotomy, however, has many advantages over other mini-invasive approaches [1, 7, 8]. This technique provides equally good exposure of right ventricle free wall, main and branch pulmonary arteries as well as aorta, and patent ductus arteriosus if present as achieved with full sternotomy.

Therefore, if required, augmentation of the pulmonary annulus or branch pulmonary arteries can be easily accomplished. Also similar to full sternotomy, it is easy to deal with left SVC and patent ductus arteriosus if present, which is an important shortcoming of others mini-invasive techniques Thus, this approach as compared to right thoracotomy approach has the advantage of having access to the RVOT, pulmonary arteries, left SVC and patent ductus arteriosus, if present.

While comparing TSS group to sternotomy group, both aortic cross clamp and CPB duration were significantly higher in TSS group. However, it did not have any significantdeleteriouseffectson outcome of the patientsas shown bycomparable mortality and morbidity between both the groups. Further, TSS group showed lesserpostoperative ventilation duration, ICU and hospital stay showing advantage of mini-invasive over conventional surgery.The postoperative pRV/LV and RVOT gradient were also comparable in both groups further adding to the adequacy of repair through TSS.

Minimally invasive cardiac surgery requires expertise and steep learning curve. To compare this we divided our study cohort patients into two groups by year at which they got operated. We have observed that withincrease inthe experiences and expertise, aortic cross clamp time, CPB time as well as total surgical duration cansignificantly reduce without compromising the quality of repair. Thus this approach has an advantage of having a shorter learning curve as exposure achieved through it is similar to sternotomy approach.

Another advantage of this technique, as already cited in our previous publication, is that it is cosmetically appealing and maintains the sternal stability [1,10] as with other techniques using partial splitting of sternum. It also avoids many disadvantages of thoracotomy approach including the risk of damage to mammary gland, mal-development of pectoralis muscle and scoliosis [9,11,12]. Certain limitations of this approach also have be kept in mind like, need for RVOT incision to get better exposure of VSD and ligation of the both internal mammary arteries. However, despite this, we have not seen any problem with sternal healing or stability on follow up.

One of the limitation of our study is small number of patients. To completely evaluate the technique, we need larger number of patients and longer duration of follow-up. Also all patients needed RV incision so they need close follow up for possible arrhythmias. Further, we also don't know about feasibility and options in patient with trans-annular patch, when they need to be re-operate due to pulmonary regurgitation and ventricular dilation.

To summarize, transverse split sternotomy with peripheral cervical cannulation is a safe technique for the repair of TOF in small children without compromising the exposure or quality of repair. The cosmetic results are good rather superior to those of standard full sternotomy in our experience. With increase in expertise the surgical duration can be decreased without affecting the quality of repair.It has also an advantage of having a shorter learning curve as the surgical exposure is similar to sternotomy group.

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