VSD exposure by tricuspid valve chordal detachment– a retrospective matched study

Amr Ashry, MD [1,2], Sophia Khan,MD [3], Melonie Johns,MRCPCH [3], Denise Moran, MSc [3], Heba M. Mohammed, MD [4] , Robyn Lotto, PhD [5], Ramesh Kutty,FRCS [1], Ram Dhannapuneni, FRCS [1], Rafael Guerrero, FRCS [1,6], Attilio Lotto, FRCS [1,5]

1. Congenital Cardiac Surgery Service, Alder Hey Children's Hospital, Liverpool, United Kingdom.
2. Department of Cardiothoracic Surgery, Assiut University Hospital, Faculty of Medicine, Assiut University, Assiut, Egypt.
3. Paediatric Cardiology Service, Alder Hey Children's Hospital, Liverpool, United Kingdom.
4. Department of Public Health and Community Medicine, Faculty of Medicine, Assiut University, Assiut, Egypt.

5. Faculty of Health, Liverpool John Moores University, Liverpool, United Kingdom.
6. School of Medicine, University of Liverpool, Liverpool, UK.

Corresponding Author:

Attilio Lotto, FRCS-CTh
Consultant Congenital Cardiac Surgeon
Alder Hey Children Hospital, Liverpool, United Kingdom.
Professor in Congenital Cardiac Surgery
Liverpool John Moores University.
Address: E Prescot Road, Liverpool, L14 5AB, United Kingdom.
Phone number: +447512622025   E-mail: Attilio.lotto@alderhey.nhs.uk

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Abstract:

Background: Transatrial approach is the standard method in repairing ventricular septal defect in pediatric population. However, tricuspid valve (TV) apparatus might obscure the inferior border of the VSD risking the adequacy of repair by leaving residual VSD or heart block. Detachment of the TV chordae has been described as an alternative technique to TV leaflet detachment. Aim of this study is to investigate the safeness of such technique.

Methods: Retrospective review of patients who underwent VSD repair between 2015 and 2018. Group A (n=25) had VSD repair with TV chordae detachment were matched for age and weight to group B (n=25) without tricuspid chordal or leaflet detachment. ECG and echocardiogram at discharge and at 3 years of follow-up were reviewed to identify new ECG changes, residual VSD and TV regurgitation.

Results: Median age in group A and B were 6.13 (IQR 4.33-7.91) and 6.33 (4.77-7.2) months. New onset right bundle branch block (RBBB) was diagnosed at discharge in 28% (n=7) of group A versus 56% (n=14) in group B (p= 0.044), while the incidence dropped to 16% (n=4) in group A versus 40% (n=10) in group B (p= 0.059) in the 3 years follow-up ECG. Echocardiogram at discharge showed moderate tricuspid regurgitation in 16% (n=4) in group A and 12% (n=3) in group B (p=0.867). 3 years follow-up echocardiography revealed no moderate or severe tricuspid regurgitation and no significant residual VSD in either group.

Conclusion: No significant difference in operative time was observed between the two techniques. TV chordal detachment technique reduces the incidence of postoperative RBBB without increasing the incidence of TV regurgitation at discharge.

Introduction:

Ventricular septal defect (VSD) is the most common congenital heart defect, accounting for 20% of all congenital cardiac anomalies[1]. Transatrial approach is the standard approach to repair VSD with excellent results and low mortality and morbidity.

However, when the VSD is obscured by the tricuspid valve (TV) tensor apparatus, the repair can be more complex, and can result in a suboptimal repair leaving a residual VSD, tricuspid valve insufficiency, or post-operative rhythm complications such as complete atrioventricular (AV) block and right bundle branch block (RBBB)[2-4]. As a result, surgeons have adopted adjuncts to the transatrial method of repairing the VSD such as tricuspid valve septal leaflet detachment and tricuspid valve chordae tendineae detachment to improve the exposure while repairing the VSD[5-7]. However, concerns remain over possible associated complications, in particular in relation to TV chordal detachment.

The aim of our study is to investigate the effect of tricuspid valve chordal detachment technique on the incidence of post-operative tricuspid regurgitation, heart block and residual VSD during the early post-operative period, and at three years follow-up.

Material and methods:

Study design and patient population:

This study has been approved by Liverpool John Moores University Ethical committee NAHPGT(APNP)2000. Data was collected for all patients who had undergone surgical VSD repair via standard transatrial approach at Alder Hey Children's Hospital (2015 –

2018). Inclusion criteria included patients with isolated perimembranous VSD or with VSD associated with atrial septal defect (ASD), patent foramen oval (PFO) and patent ductus arteriosus (PDA). All VSDs were non-restrictive perimembranous type. We excluded muscular and subarterial VSDs from the study. Patients with concomitant complex cardiac anomalies alongside the VSD, such as complete atrioventricular septal defect, double outlet right ventricle, transposition of the great arteries were excluded, as were patients with trisomy 21 and those with preoperative rhythm abnormalities. Patients with incomplete data were also excluded. The decision to exclude patients with trisomy 21 was taken as patients with this genetic disposition have been shown to have a higher incidence of developing heart block requiring pacemaker placement following VSD repair[8].

Twenty-five patients who had undergone surgical VSD closure with tricuspid valve chordal detachment (TVCD) technique (group A) were statistically matched for age and weight to 25 patients (group B) who had undergone surgical repair of perimembranous VSD without the need for tricuspid leaflet detachment or tricuspid chordal detachment during the same period.

All patients were elective patients as we excluded any patient who required more than oral medication. Group A included 8 asymptomatic patients and 17 symptomatic patients, while group B included 6 asymptomatic patients and 19 patients with symptoms (the symptoms included; failure to thrive, feeding difficulties, breathlessness and recurrent chest infections). Eight patients in group A did not require medications and 17 patients required anti-failure medications (13 on diuretics only and 4 on diuretics + ACE inhibitor). Similarly, 8 patients in group B did not require medications and 17 patients required anti-failure medications (15 on diuretics only and 2 on diuretics + ACE inhibitor).

Median follow-up for group A was 46.5 months (IQR 42-48) and 46 months (IQR 44-48) for group B. We managed to assess echocardiogram at 3 years follow-up in all patients in the 2 groups. Echocardiography images and standard 12-lead ECG were reviewed independently by two pediatric cardiologists in order to assess rhythm disturbances at baseline and at discharge as well as the degree of tricuspid regurgitation and presence of residual VSD at discharge and at 3 years follow-up.

Regarding preoperative tricuspid valve function: Group A showed 12 patients with no tricuspid regurgitation (TR), 12 mild TR and 1 moderate TR, while group B had 15 patients with no TR, 9 with mild TR and 1 moderate TR. We considered tricuspid regurgitation to be significant if it was moderate or severe.

We have used the AHA/ACCF/HRS to define complete RBBB in infants (< 1year of age). These criteria include a QRS duration of > 90 msec and rsr, rsR, or rSR in leads V1 or V2.[9]

Surgical technique:

All patients underwent cardiopulmonary bypass with the use of bicaval cannulation under normothermia. A left atrial vent was inserted through the patent foramen ovale (PFO), the atrial septal defect (ASD) when present or the right upper pulmonary vein. The heart was arrested with antegrade infusion of cold blood cardioplegia. A standard oblique right atrial incision was made, and the right atrium retracted to expose the VSD.

In case of presence of TV chordal attachment to the inferior border of the VSD as shown in figure 1A, the chordae tendineae were temporarily detached from the septum, lifted backwards towards the surgeon by using polypropylene 6/0 pledgeted sutures, allowing better exposure of the VSD margins as demonstrated in figure 1B. This permitted a better visibility of the critical area close to the inferior border of the VSD allowing a wider placement of sutures and positioning of the patch, aiming to avoid the conduction system on the right ventricle. A patch is sutured to the muscular component of the VSD either with interrupted sutures or a continuous suture line, while the area across the TV septal leaflet is secured with interrupted pledgeted sutures. The previously detached chordae tendineae were sutured back to their original point of insertion or to the corresponding patch area as shown in figure 1C. This technique was reported by Kapoor et al in 2000[7]. Figures 2A, 2B and 2C are operative photographs illustrating the technique.

Statistical analysis:

Data analysis was undertaken using SPSS version 26. Categorical data are presented in the form of frequencies and percentages. Quantitative variables were tested for normality by Shapiro-Wilk test and expressed as median (IQR) according to their distribution. Mann Whitney U test was used to compare difference between two independent groups in quantitative data. Chi square test was used to compare proportion between the two groups. The level of significance was considered at P value < 0.05.

Results:

Our cohort consisted of 50 patients: Group A (n=25) who underwent VSD closure with tricuspid valve chordal detachment (TVCD) was compared with statistically matched group B (n=25) who underwent VSD closure without need for tricuspid valve chordal detachment or leaflet detachment. Group A included 11 inlet, 10 outlet and 4 inlet-to-outlet perimembranous VSDs, with median maximum diameter of 7.1 mm (IQR 6.5 – 7.9 mm). Group B included 13 inlet, 7 outlet and 5 inlet-to-outlet perimembranous VSDs, with median maximum diameter of 8.5 mm (IQR 6.8 – 9.9 mm). All demographic and perioperative data are summarized in table 1.

Normal sinus rhythm resumed spontaneously after VSD closure in all patients, and none needed temporary external pacing. All patients underwent an intraoperative transesophageal or epicardial echocardiogram which excluded the presence of significant (>2mm) residual VSD and significant (>moderate) new tricuspid valve regurgitation. No patients needed to go back on CPB for further surgical repairs. ECG analysis before discharge showed absence of new postoperative complete heart block in both groups, but new onset of right bundle branch block (RBBB) was noted in 28% (n=7) of the TVCD group A versus 56% (n=14) in group B (p=0.044). Three years follow-up ECG showed that the incidence of RBBB dropped in the TVCD group A to 16% (n=4) compared to 40% in group B (n=10) (p=0.059). Echocardiogram at discharge confirmed the absence of significant residual VSD requiring re-intervention in both groups. Group A had 13 patients at discharge with small (<2mm) residual VSD with median VSD size of 1.5 mm (IQR 1.3-1.9 mm), while group B had 7 patients at discharge with small (<2mm) residual VSD with median VSD size of 1.85 mm (IQR 1.5-2.0 mm) (p=0.083). Moderate tricuspid regurgitation was noted at discharge in 16% (n=4) in TVCD group A and 12% (n=3) in group B (p=0.867). Small residual VSD at 3 years follow-up Echo was noted in 3 cases in group A with median VSD diameter of 1 mm (IQR 0.8-1.1 mm), compared to 4 cases in group B with median VSD diameter of 1.1 mm (IQR 0.95-1.2 mm) (p=0.684). At 3 years follow-up no patients had moderate or severe tricuspid regurgitation in either group. Mild tricuspid regurgitation was found in 11 patients (44%) of TVCD group A and 12 patients (48%) in group B at 3 years follow-up (p=0.777). Table 2 demonstrates the outcomes in both groups.

Group A showed good RV function at discharge for all the patients except 1 case of mildly impaired RV function with mildly dilated RV. At 3 years, RV function was good in all cases and no patient showed RV dilatation. Group B had good RV function at discharge for all the patients except 3 cases of mildly impaired RV function. Mildly dilated RV was noticed in 5 patients in this group. At 3 years, RV function was good in all cases. 2 patients showed mildly dilated RV in group B at 3 years follow-up echo.

There was no statistically significant difference in group A or group B in terms of patients with occurrence of RBBB by type of VSD, as shown in table 3.

In group A, the rate of occurrence of RBBB by type of VSD was 27.3%, 30% and 25% for inlet, outlet, inlet-to-outlet VSD respectively. While, in group B, rate of occurrence of RBBB was 53.8%, 57.1% and 60.0% for inlet, outlet, inlet-to-outlet VSD respectively.

Discussion:

VSD is the most common congenital heart defect. Isolated VSD is generally repaired surgically via transatrial approach with less than 1% mortality in the pediatric population. However, a number of associated morbidities are still noticeable with the surgical VSD repair such as residual VSD, tricuspid valve regurgitation, complete heart block and right bundle branch block (RBBB). These complications may occur due to suboptimal exposure of the defect at the time of repair. In a subset of patients with tricuspid valve chordae crossing or inserting at the margins of the VSD, exposure of the margins to perform a safe and effective repair can be challenging. Therefore, in order to optimize the VSD exposure, surgeons have adopted some additional techniques to better expose the margins. Septal leaflet detachment of the tricuspid valve is a widely adopted and reported technique.

Since 1962, when Hudspeth and colleagues reported their technique of tricuspid valve septal leaflet detachment with extension of the incision either into the anterior or posterior leaflet, many surgeons have utilized tricuspid leaflet detachment to improve visualization of the VSD margins[5]. Aeba *et al.*[10] retrospectively studied the outcomes of VSD surgical closure in 87 patients. They observed that the tricuspid valve detachment (TVD) group had longer cardiopulmonary bypass time and aortic cross-clamp time than the non-TVD group, without significant difference between the 2 groups regarding TV regurgitation and residual VSD. Russell et al.[11] demonstrated no significant difference between TVD group and the non-detachment group following surgical VSD repair with respect to cardiopulmonary bypass time, cross-clamp time or rate of occurrence of post-operative tricuspid regurgitation. Similarly, Bang et al. found that detachment of the TV can be used safely for better exposure of the VSD without increased risk of tricuspid regurgitation in infants younger than 3 months [12].

Another technique described in 2000 by Kapoor et al. involves tricuspid chordal detachment for VSD exposure and subsequent chordal repositioning after VSD patch closure [7]. A recent study showed that neither the chordal detachment technique nor the leaflet detachment technique is associated with increased TV regurgitation postoperatively when compared to a large control group of patients who had the VSD closed in the standard fashion [13].

While several studies have documented good short-term results using techniques of tricuspid valve leaflet detachment or chordal detachment, there are no long-term reported outcomes for the tricuspid valve chordal detachment technique. Our study investigates the effect of tricuspid valve chordal detachment technique on the incidence of post-operative tricuspid regurgitation, heart block, and residual VSD during the early post-operative period, and at follow-up three years after surgery. We have compared our TVCD group with a matched group where TVCD was not needed as the VSD margins were readily visible

With VSDs often located in close proximity to the conduction system, rhythm abnormalities are frequently recognized complications following surgical repair. While the occurrence of complete heart block (CHB) is rare (1%), RBBB has previously been reported to occur in up to 80% of VSD patients who were operated on with the right ventricular (RV) approach[14]. Over the last few decades, with repair being performed most often by the transatrial approach, the incidence of post-operative RBBB has fallen but is still reported in some series to be up to 40% [14-15]. In our cohort the overall the incidence of RBBB at discharge was 28% in group A and 56% in group B. There were no cases of CHB.

Comparing the two surgical techniques used in our center, we demonstrated a significant difference in the rate of occurrence of post-operative new onset RBBB, with the TV chordal detachment technique having a significantly lower incidence. The importance of this observation is amplified when we consider that the “control” group did not have TV chordae obscuring the VSD margins, hence there was no need to adopt techniques to increase exposure and visibility for the repair. In the follow-up, we still see a higher incidence of RBBB in group B, although not statistically significant. These results have prompted us to review the latest advances in the understanding of the anatomy of the specialized conduction system. The reason for the above findings might reside in the anatomy of the bundle of His and its branches. As described by

Nagarajan et al in 2019, the right bundle branch (RBB) usually takes a short intramuscular course within the septum before emerging in the subendocardium of the RV at the base of the medial papillary muscle [16]. The presence of a VSD could displace the course of the RBB even further. In cases where thick chordae are obscuring the inferior margin of the VSD, the surgeon might be forced to anchor the patch more widely with respect to the VSD margins, and thus more inferiorly towards the medial papillary muscle. In doing so, sutures to secure the VSD patch may be placed close to where the RBB emerges from the muscle, theoretically increasing the risk of injuring it. On the other hand, when the obscuring chordae are detached and retracted back, the VSD inferior margin is well exposed, and the patch can be positioned more precisely in the usual way, without increasing the risk of injury of the conduction system (figure 3)[16]. Moreover, our study suggests that there is no correlation between VSD subtype (inlet, outlet, inlet-to-outlet) and risk of RBBB postoperatively (table3).

Although RBBB may not account for significant morbidity in the short-term, there may be longer-term effects such as ventricular dyssynchrony, which may lead to a reduction in cardiac systolic function[13]. Considering this, along with the fact that no significant difference in the incidence of TR was seen, our results support the use of the TV chordal detachment technique, when needed to optimize surgical exposure, to improve long-term patient outcomes.

In our study, no patients needed reoperation for residual VSD at discharge and at 3 years follow-up. There was no significant difference between the TVCD group and the non-detachment group regarding bypass time, cross-clamp time, ICU length of stay, and hospital stay. Moreover, there was no significant difference regarding tricuspid regurgitation in the 2 groups at discharge. No patient had more than mild TR at 3 years follow-up. No patients needed permanent pacemaker insertion in the 2 groups. TVCD technique appears to be protective with respect to the risk of development of RBBB, as we had 28% of patients with RBBB at discharge in the TVCD group compared with 56% of patients in the non-detachment group (p=0.044). At 3 years follow-up, the incidence of RBBB had diminished in both groups, to 16 % in TVCD group A compared to 40% in group B (p=0.059). In our view, tricuspid valve chordal detachment technique can be associated with excellent results in young infants with difficult VSD exposure.

Limitations:

The study limitations include being a retrospective, single center study in a nonrandomized design. Large prospective and multicenter studies should be performed to further clarify the outcomes following surgical VSD repair with tricuspid valve chordal detachment technique.

Conclusion:

Tricuspid valve chordal detachment technique can be used safely to improve the exposure of the VSD margin, optimizing the repair without increased risk of tricuspid regurgitation. The technique was associated with reduced incidence of right bundle branch block after VSD repair. Moreover, it does not prolong bypass time, cross-clamp time or hospital stay.

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Tables:

Table 1: Perioperative data

Variable	Group A (n=25)	Group B (n=25)	P Value
Age (months)	6.13 (4.33-7.91)	6.33 (4.77-7.20)	0.861*
Weight (Kg)	5.70 (4.79-6.40)	5.31 (4.56-6.37)	0.684*
Sex			0.254**
Male	13 (52.0%)	9 (36.0%)	
Female	12 (48.0%)	16 (64.0%)	
Bypass time (minutes)	76.00 (65.50-109.50)	69.00 (60.0-104.0)	0.264*
Cross clamp time (minutes)	48.00 (39.50-68.50)	39.00 (32.5-76.0)	0.135*
Post-operative stay (days)	6.0 (5.0-8.0)	5.0 (5.0-7.5)	0.620*
ICU stay (days)	1.0 (1.0-2.0)	1.0 (1.0-1.0)	0.755*

Group A= Chordal detachment group
Group B= non-Chordal detachment group
Data expressed as frequency (%) in qualitative data, median (IQR) in quantitative variable
* Mann Whitney U test
**Chi square test

Table 2: Outcomes

Variables	Group A (n=25)	Group B (n=25)	P-Value*
TR (at discharge)			
▪ No	3 (12.0%)	4 (16.0%)	0.867
▪ Mild	18 (72.0%)	18 (72.0%)	
▪ Moderate	4 (16.0%)	3 (12.0%)	
Residual VSD (at discharge)			
▪ No	12 (48.0%)	18 (72.0%)	0.083
▪ Tiny	13 (52.0%)	7 (28.0%)	
RBBB (at discharge)			
▪ Yes	7 (28.0%)	14 (56.0%)	**0.044**
▪ No	18 (72.0%)	11 (44.0%)	
RBBB (at 3 years)			
▪ Yes	4 (16.0%)	10 (40.0%)	0.059
▪ No	21 (84.0%)	15 (60.0%)	
Residual VSD (at 3 years)			
▪ No	22 (88.0%)	21 (84.0%)	0.684
▪ Tiny	3 (12.0%)	4 (16.0%)	
TR (at 3 years)			
▪ No	14 (56.0%)	13 (52.0%)	0.777
▪ Mild	11 (44.0%)	12 (48.0%)	

Data expressed as frequency (%) in qualitative data
*Chi square test

Table 3: RBBB in groups A and B according to type of VSD

Types of VSD	Group A			Group B		
	RBBB		P-Value*	RBBB		P-Value*
	Yes (n=7)	No (n=18)		Yes (n=14)	No (n=11)	
▪ Inlet	3 (27.3%)	8 (72.7%)	0.980	7 (53.8%)	6 (46.2%)	0.970
▪ Outlet	3 (30.0%)	7 (70.0%)		4 (57.1%)	3 (42.9%)	
▪ Inlet to Outlet	1 (25.0%)	3 (75.0%)		3 (60.0%)	2 (40.0%)	

*Chi square test was used to compare proportion between groups

Figure legends:

Figure 1A: Transatrial view of the VSD, partially covered by TV leaflet and its chordae tendineae.

Figure 1B: The chordae tendineae detachment.

Figure 1C: VSD Patch and chordae tendineae re-attachment.

Figure 2A: Tricuspid valve chordae crossing the VSD.

Figure 2B: TV chordae tendineae detachment.

Figure 2C: TV chordae tendineae re-attachment after VSD patch closure.

Figure 3: Atrioventricular (AV) conduction system [16]
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