Clinical Investigation

Long-Term Follow-Up Study of Temporary Tricuspid Valve Detachment as Approach to VSD Repair

without Consequent Tricuspid Dysfunction

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Temporary tricuspid valve detachment improves the operative view of certain congenital ventricular septal defects (VSDs), but its long-term effects on tricuspid valve function are still debated.

From 2002 through 2012, we performed a prospective study of 68 children (mean age, 1.28 ± 1.01 yr) who underwent transatrial closure of VSDs following temporary tricuspid valve detachment. Sixty patients had conoventricular and 8 had mid-muscular VSDs. All were in sinus rhythm. Seventeen patients had systemic pulmonary artery pressures. Preoperative echocardiograms showed trivial-to-mild tricuspid regurgitation in 62 patients and tricuspid dysplasia with severe regurgitation in 6 patients. Patients were clinically and echocardiographically monitored at 30 postoperative days, 3 months, 6 months, every 6 months thereafter for the first 2 years, and then once a year.

No in-hospital or late death was observed at the median follow-up evaluation of 5.9 years. Mean intensive care unit and hospital stays were 1.6 ± 1.1 and 7.3 ± 2.7 days, respectively. Residual small VSDs occurred in 3 patients, and temporary atrioventricular block in one. After VSD repair, 62 patients (91%) had trivial or mild tricuspid regurgitation, and 6 moderate. Five of these last had severe tricuspid regurgitation preoperatively and had undergone additional tricuspid valve repair during the procedure. The grade of residual tricuspid regurgitation remained stable postoperatively, and no tricuspid stenosis was documented. All patients were in New York Heart Association class I at follow-up.

Temporary tricuspid valve detachment is a simple and useful method for a complete visualization of certain VSDs without incurring substantial tricuspid dysfunction. ***(Tex Heart Inst J 2016;43(5):392-6)***

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Transatrial correction of a ventricular septal defect (VSD) usually provides good exposure of the defect's margins. However, tricuspid chordal attachments can conceal those margins and make difficult the placement of sutures, thereby distorting the tricuspid valve (TV) and possibly leading to postoperative regurgitation, the continued presence of VSDs, and heart block.

In 1962, Hudspeth and colleagues[1] first described annular detachment of the TV as a means of improving the surgeon's intraoperative view of certain VSDs. Initially, there were concerns that temporary TV detachment might impair valve function, lengthen operative time, and increase the incidence of postoperative heart block. Later evidence has supported the wisdom of improving VSD exposure in this manner, especially when multiple chordal attachments obscure the margins of the defect, when there is a redundant aneurysmal tricuspid septal leaflet, and when the position of the VSD is relatively high in the septum with outlet extension.[2,3]

During the past few years, several authors have discussed possible further modifications to the technique, intended to minimize trauma to the valve; but the long-term effects of temporary TV detachment are still controversial. We now report an analysis of outcomes, with particular regard to tricuspid function in the long term.

Patients and Methods

We undertook a prospective, observational study from January 2002 through December 2012. Our institutional review board approved the study and waived the need for patient consent.

Sixty-eight patients at our institution underwent TV detachment, followed by VSD closure via the transatrial approach (Table I). A modified circumferential TV detachment technique has been applied, when indicated, in up to 45% of all VSD repairs performed at our center. This relatively high rate of use is consequential to a consistent number of low-weight patients—in whom, we believe, TV detachment is particularly effective in avoiding dangerous traction upon the tiny TV apparatus.[3]

The mean age at operation was 1.28 ± 1.01 years. Sixty patients had conoventricular VSDs (42 as an isolated anomaly), and 8 had mid-muscular defects with outlet extension (3 of these 8 patients had multiple defects with associated small, restrictive apical VSDs). Seventeen patients had systemic pulmonary artery pressure, and all 68 patients were in sinus rhythm preoperatively.

Preoperative echocardiograms showed trivial-to-mild tricuspid regurgitation in 62 patients and tricuspid dysplasia with severe regurgitation in 6 patients. No preoperative tricuspid stenosis was documented.

The diagnosis of VSD was established via preoperative transthoracic echocardiography and confirmed via intraoperative transesophageal echocardiography (TEE). Furthermore, all patients underwent intraoperative TEE after repair, in order to evaluate their left ventricular function, to look for possible residual VSDs, and to test the function of their tricuspid, pulmonary, aortic, and mitral valves.

TABLE I. Demographic and Preoperative Findings in the 68 Patients

Variable	Value
Age (yr)	1.28 ± 1.01
Male	41 (60)
Female	27 (40)
Type of VSD	
Conoventricular	60 (88)
Isolated	42
Mid-muscular*	8 (12)
Multiple	3
Systemic pulmonary artery pressure	17 (25)
NYHA functional class	
I	36 (53)
II	20 (29)
III	12 (18)
Grade of tricuspid regurgitation	
Trivial-to-mild	62 (91)
Severe	6 (9)

NYHA = New York Heart Association; Pts = patients; VSD = ventricular septal defect

*Outlet extension

Data are presented as mean ± SD or as number and percentage.

Surgical Technique

All approaches were via median sternotomy, and the patients underwent standard cardiopulmonary bypass with bicaval cannulation. Mild hypothermia (32 °C) was achieved and a cold-blood cardioplegic solution was administered antegrade in all cases, to arrest the heart. We opened the right atrium parallel to the atrioventricular groove, and we exposed the VSD after detaching the TV.

The TV was detached first at the anteroseptal commissure, then detached past the septal leaflet and counterclockwise toward the posteroseptal commissure. If an extension was needed, we continued the detachment clockwise toward the anterior leaflet, as described by Maile and colleagues.[4] The radial incision to disconnect the leaflets was carried out approximately 2 to 3 mm from the tricuspid annulus, to enable easier leaflet repair after VSD closure (Fig. 1A). The placement of marking stitches (one for each side of the detached leaflet) could be useful in the accurate repositioning of the leaflets at a later time.

In almost all cases, the VSDs were repaired with use of a pericardial patch fixed in glutaraldehyde and sown in continuous fashion with 6-0 Prolene suture (Figs. 1B and C). In the event that chordae tendineae were attached to the margin of the defect, they were severed and then repositioned onto the VSD patch. Especially in low-weight patients, who are likely to have very fragile leaflets, we think that reattaching the complete subvalvular apparatus might be useful in preventing any new postoperative valvular regurgitation. The leaflets were approximated with use of a continuous locked 7-0 Prolene suture (Fig. 1D).

After VSD closure and TV reattachment, we injected a cold saline solution into the right ventricle to properly test the valve's competence (hydrostatic test). In 6 patients, additional TV repair was needed because of severe preoperative TV regurgitation: 4 of the 6 underwent a cleft closure, and 2 of the 6 underwent "bicuspidalization," along with plication of the leaflets, for tricuspid dysplasia.

Follow-Up

All the patients underwent office visits at 30 postoperative days, at 3 months, at 6 months, and at every 6-month interval for 2 years, then were seen annually for a maximum of 8.3 years. Each visit was completed with a clinical examination, an electrocardiogram, and an echocardiogram. Standard transthoracic echocardiographic parasternal, apical, subcostal, and suprasternal views were obtained for each patient by a pediatric cardiologist who was blinded to the repair technique.

Statistical Analysis

Continuous and categorical variables were analyzed with use of the Student *t* test and the χ^2 test, respec-

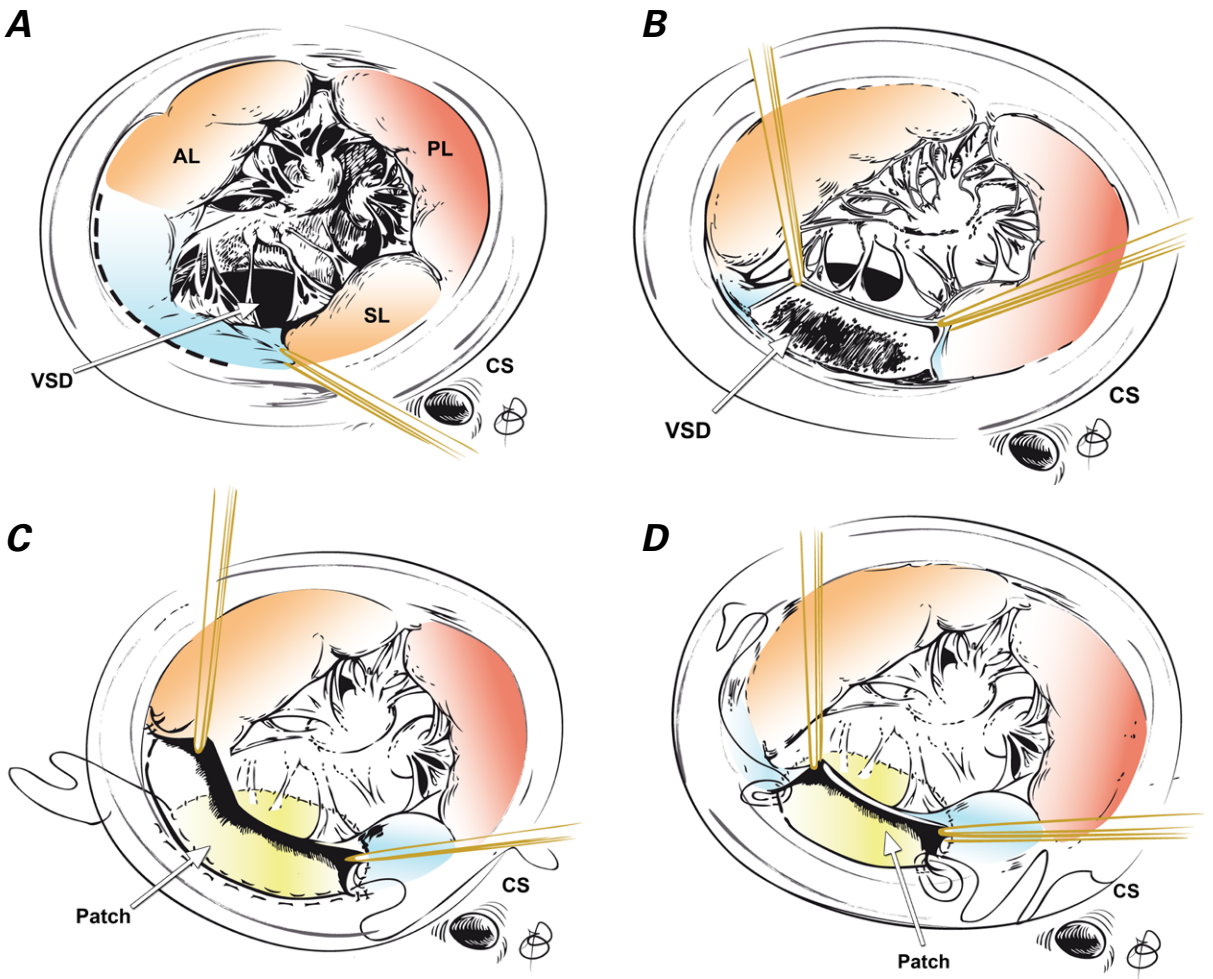

Fig. 1 *Artist's drawings show the surgical procedure.* ***A****) Detachment of the septal leaflet starts at the anteroseptal commissure toward the posteroseptal commissure, approximately 2 to 3 mm from the tricuspid valve annulus.* ***B****) The ventricular septal defect (VSD) is generally visible just below the septal leaflet, and if an extension is needed, the detachment is continued toward the anterior or posterior leaflet.* ***C****) To close the VSD, a pericardial patch is sutured with continuous 6-0 Prolene suture.* ***D****) The leaflets are reattached to the annulus with use of a continuous locked 7-0 Prolene suture.*

AL = anterior tricuspid leaflet; CS = coronary sinus; PL = posterior tricuspid leaflet; SL = septal tricuspid leaflet

tively. The time of surgery was understood to be time zero. The risk factors predictive of postoperative tricuspid regurgitation were studied with univariate analysis (the Student *t* test and the χ^2 test). A *P* value <0.05 was considered statistically significant. Statistical analysis was performed with use of the SPSS 17.0 program for Windows (IBM Corporation; Endicott, NY).

Results

The VSDs were repaired with a patch in 60 patients and by primary closure in the other 8 patients. The mean cardiopulmonary bypass time was 39 ± 18 min, and the mean cross-clamp time was 26 ± 8 min (Table II). The mean durations of intensive care unit and hospital stays were 1.6 ± 1.1 and 7.3 ± 2.7 days, respectively. There was no in-hospital or late death.

Additional surgical procedures were performed in 20 patients, including atrial septal defect repair (9), aortic coarctectomy (4), ligation of patent ductus arteriosus (3), aortic arch enlargement (2), subaortic membrane resection (1), and pulmonary enlargement (1).

Eight patients developed transitory left ventricular dysfunction that required inotropic support for the first 24 postoperative hours. A few residual, hemodynamically insignificant VSDs occurred in 3 patients, and one other patient had a temporary atrioventricular block. Patients with preoperative pulmonary hypertension attained normal values after the VSD repair.

The follow-up period was 100% complete (median, 5.9 yr; range, 0.6–8.3 yr). At the conclusion of the study, all patients were alive and in New York Heart Association class I. Postoperatively, 62 patients (91%) had trivial-to-mild tricuspid regurgitation, and 6 had

TABLE II. Intra- and Postoperative Data from 68 Patients

Variable	Value
Cardiopulmonary bypass time (min)	39 ± 18
Aortic cross-clamp time (min)	26 ± 8
Additional surgical procedures	20
Atrial septal defect closure	9
Aortic coarctectomy	4
Patent ductus arteriosus ligation	3
Aortic arch enlargement	2
Subaortic membrane resection	1
Pulmonary artery enlargement	1
Intensive care unit stay (d)	1.6 ± 1.1
Hospital stay (d)	7.3 ± 2.7
Residual VSD	3
Arrhythmia*	1
Postoperative TR	
Trivial-to-mild	62
Moderate	6**

TR = tricuspid regurgitation; VSD = ventricular septal defect

*Temporary atrioventricular block

**Of these 6 patients, 5 had severe TR preoperatively, and 1 developed moderate TR postoperatively.

No patient had postoperative tricuspid stenosis. All patients were in New York Heart Association functional class I at the time of follow-up evaluation (median, 5.9 yr; range, 0.6–8.3 yr).

Data are presented as mean ± SD or as number.

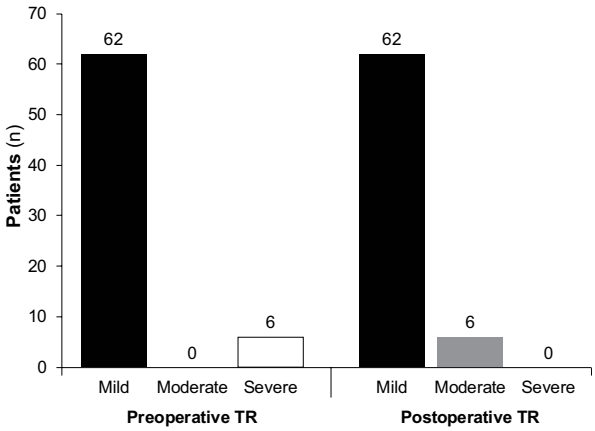

Fig. 2 *Graph shows that, postoperatively, 62 patients had mild tricuspid regurgitation (TR) and 6 had moderate TR. Five of these last had presented with preoperative tricuspid dysplasia and severe regurgitation.*

moderate (Fig. 2). Upon univariate analysis, tricuspid dysplasia with associated severe regurgitation was found to be the main preoperative determinant of postoperative moderate tricuspid regurgitation (P=0.043). Upon testing, the following risk factors were statistically insignificant for severe postoperative tricuspid regurgitation: younger age (generally considered to be ≤6 mo) (P=0.121), female sex (P=0.091), low weight (≤3 kg) (P=0.067), systemic pulmonary artery pressure (P=0.071), the type of VSD (P=0.12), additional surgical procedures (P=0.097), and broad extension of TV detachment (arbitrarily defined as ≥15 mm) (P=0.087).

Tricuspid valve function remained stable over the postoperative observation period, and no significant further deterioration of TV competence was observed. In addition, there was no TV stenosis at follow-up.

Discussion

Tricuspid valve detachment is a safe and reliable means of improving the exposure of certain VSDs without affecting long-term TV function. It has been particularly useful in treating low-weight patients and patients with more complex congenital heart diseases.[3]

The successful transatrial correction of the VSD requires adequate views of the defect's margins in order to avoid residual defects, complete heart block, and distortion of the TV itself. Certain cases, of course, might result in difficult or partial views of the VSD's limits, despite intense retraction of the TV.[5] Temporary TV detachment improves the exposure of the angles between the conal septum, the aortic annulus, and the ventriculo-infundibular fold, minimizing the incidence of residual defects.[6]

As reported by Russell and colleagues,[7] circumferential detachment of the anterior tricuspid leaflet can be performed safely and does not impair the growth of the TV, regardless of the patient's age and preoperative clinical conditions.

However, Kay and co-authors[8] already had described a successful variant of the above-mentioned technique—a longitudinal incision of the septal tricuspid leaflet as an alternative, to improve VSD exposure without increasing the risk of postoperative tricuspid regurgitation.

Conversely, Tatebe and associates[9] described the progression of moderate tricuspid regurgitation, probably related to the TV detachment procedure, in 2 of 13 infants who underwent VSD repair. The authors showed that the use of continuous suture for repair of the radial tricuspid incision is a risk factor for regurgitation and should be avoided.

Kapoor and colleagues[10] described a different technique to improve the views of some VSDs. It consists of detaching the subvalvular tricuspid apparatus (the chordae, the relative papillary muscle, or both) from the septum to enable complete leaflet retraction. After VSD closure, the subvalvular apparatus is reattached with pledgeted sutures to the septum itself, or to the patch used for the VSD closure. Our main concern with this strategy regards the free-valve regurgitation that might occur in the event of dehiscence of the chordae tendineae or the papillary muscle.

In accordance with the prevalent literature, we tend to think that detaching the tricuspid leaflets from the annulus is less risky than reattaching the tiny chordae, especially in neonates or in patients whose chordae cross the defect—or in those with noncompliant right ventricles. The truth is that we prefer to detach the tricuspid septal leaflet, just under the anteroseptal commissure, because it results (in our experience) in the best compromise between a small TV incision and excellent exposure of the VSD.

Two techniques have been described for repairing the incision of the tricuspid leaflets: the leaflets can be repaired with a separate suture after VSD closure or, alternatively, closed within the same suture used to fix the patch.[11] Both techniques are effective and are not associated with significant postoperative tricuspid regurgitation.[12] In any event, we prefer the first approach, for which we use a continuous locked suture to avoid distortions of the leaflets that might lead to postoperative regurgitation.

Furthermore, in our experience reported here, we have seen that tricuspid dysplasia with severe regurgitation is, by univariate analysis, the only risk factor for postoperative moderate insufficiency. The other tested (and excluded) risk factors were low weight at operation, younger age, female sex, the presence of systemic pulmonary artery pressure, the type of VSD, and the necessity of associated operative procedures. In addition, there was no demonstrable correlation between the degree of postoperative tricuspid regurgitation and the extension of the TV detachment.

The outcome of our series was excellent, for there was minimal morbidity and no death. Transesophageal echocardiography at long-term follow-up evaluation showed only one trivial residual VSD (the other 2 of 3 in toto underwent spontaneous closure) and no significant tricuspid regurgitation in 91% of the patients. No TV stenosis was documented, and the entire group showed normal TV growth, in accordance with the weight and height percentiles. Therefore, we might assume that TV growth was unimpaired by the reported technique.

We conclude that the addition of TV detachment reliably improves the exposure of VSDs without compromising long-term TV function.

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