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# Closure of Restrictive Ventricular Septal Defects through a Right Axillary Thoracotomy

**Alexander Kadner, MD,**[1] Ali Dodge-Khatami, MD, PhD,[1] Hitendu Dave, MD,[1] Walter Knirsch, MD,[2] Dominique Bettex, MD,[3] René Prêtre, MD[1]

[1]Division of Congenital Cardiac Surgery and [2]Department of Cardiology, Children's Hospital, University of Zurich; [3]Department of Anesthesia, University of Zurich Hospital, Zurich, Switzerland

## ABSTRACT

**Objective.** To report the midterm results of an alternative minimally invasive approach for closure of ventricular septal defects (VSD) through a muscle-sparing minithoracotomy at the right midaxillary line.

**Material and Methods.** From September 2003 to December 2005, 22 patients (median age, 5 years; range, 1.5-12 years) underwent a right lateral axillary thoracotomy for closure of a perimembranous VSD. Special features of the approach included an incision between the anterior and posterior axillary fold, a muscle-sparing preparation over the fourth intercostal space, and the establishment of cardiopulmonary bypass with inguinal and superior vena cava cannulation. The ascending aorta was cross clamped and cardioplegic arrest was instituted. The VSDs were all approached through a right atriotomy and closed directly (17 patients) or with a patch (5 patients). Three patients underwent concomitant aortic valve repair.

**Results.** There was no mortality or significant surgical morbidity. Median cross-clamp and cardiopulmonary bypass times were 46 and 104 min, respectively. Follow-up was complete and ranged from 2 to 22 months (median, 20 months). All patients were in sinus rhythm. Echocardiography revealed no residual defects with competent aortic and tricuspid valves. The length of the incision ranged from 4 to 6 cm, was away from the mammary gland, and remained entirely covered by the adducted arm. All children recovered right shoulder function within days, and cosmetic results were very satisfying. One patient developed iliac artery stenosis following inguinal artery cannulation.

**Conclusion.** Closure of perimembranous VSDs in older children can be safely performed through a right axillary thoracotomy without compromising the accuracy of the repair. The cosmetic results are excellent.

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*Address correspondence and reprint requests to: Alexander Kadner, MD, Division of Congenital Cardiac Surgery, Children's Hospital, University of Zurich, Steinwiesstrasse 75, 8032 Zürich, Switzerland; 41-1-266-8020; fax: 41-1-266-8021 (e-mail: a.kadner@web.de).*

## INTRODUCTION

The standard approach for closure of a ventricular septal defect (VSD) is performed through a median sternotomy, which allows for good exposure of the surgical field and safe closure of the defect. However, the ensuing midline sternal scar presents a considerably unattractive cosmetic result, and may also have a negative psychological impact, especially in young female patients. A variety of alternative approaches, such as a limited skin incision with full sternotomy, a lower partial sternotomy, a transxyphoidal incision, and an antero- or postero-lateral thoracotomy have been applied to improve the cosmetic result [Tatebe 1992; van de Wal 1998; Giamberti 2000; Nicholson 2001; Yoshimura 2001; Boussaada 2005; Nishigaki 2005]. Particularly for female patients, the performance of an antero-lateral thoracotomy appeared to offer a superior cosmetic result by potentially hiding the scar in the submammarian fold. Recently however, the drawbacks of this approach in the long-term became evident by showing a high incidence of thorax deformities and, when applied in prepubescent female patients, of asymmetric breast development [Cherup 1986; Bleiziffer 2004].

The right axillary thoracotomy has already been advocated as a cosmetically attractive approach for the closure of congenital cardiac defects due to the fact that the resulting scar is hidden under the resting arm. However, it has been reported only as an approach for the repair of relatively simple congenital cardiac defects, such as atrial septal defect (ASD), partial atrio-VSD, and sinus venosus defect [Rosengart 1993; Yang 2001; Schreiber 2003; Pretre 2005].

Here we report our mid-term results and experiences of using the right axillary thoracotomy for the repair of VSDs in older children.

## MATERIAL AND METHODS

Between September 2003 and December 2005, 22 patients (16 male, 6 female) underwent surgical closure of VSDs through a right axillary thoracotomy. The patients had a median age of 5 years (range, 1.5-12 years). The diagnosis of VSD was made by echocardiography and showed restrictive, perimembranous VSDs. Three patients underwent additional

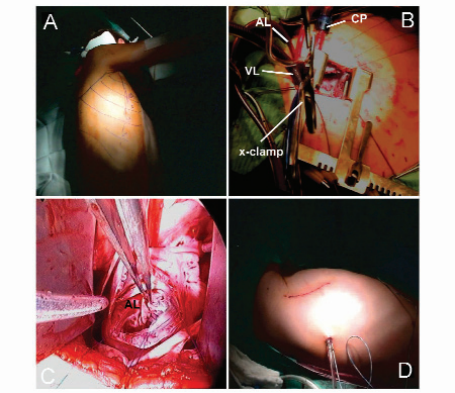


Figure 1. A, The patient is positioned in a left lateral position with the chest inclined to about 80°. The arm is elevated over the head. The intercostal spaces and the anterior axillary fold are marked to keep the skin incision between the anterior and the posterior axillary fold. B, The heart is retracted posteriorly by stay sutures, which are applied to the pericardium, and the right lung is retained under protective wet sponges. In this case, the ascending aorta was cannulated (AL indicates aortic line), and was inserted together with the superior vena cava cannula (VL indicates venous line) and the cardioplegic line (CP indicates cardioplegic line), through an additional incision in the third intercostal space. All cannulas were retained behind the reinserted spreader. C, Surgical field with the opened right atrium and the tricuspid valve. If the border of the perimembranous ventricular septal defect could not be precisely visualized, the anterior leaflet (AL) of the tricuspid valve was detached from the annulus. D, Postoperative result showing confinement of the incision between the anterior and posterior axillary line. Chest tube and pacing wires are installed.

cardiac procedures, such as a plasty of the aortic valve, or resection of a subaortic membrane. An intraoperative transesophageal echocardiogram followed by postoperative transthoracic echocardiograms were routinely performed in the intensive care unit and at 3 months after hospital discharge.

### *Surgical Technique*

The patient was positioned in a left lateral position with the chest inclined at about 80°. The arm was elevated over the head and supported on an armrest. To facilitate the iliac cannulation, the pelvis was allowed to rotate in a more supine angle at about 40° with an outstretched leg. The leg was always wrapped in a cooling mat.

Preoperatively, the fourth intercostal space and the anterior axillary fold were marked with a pen (Figure 1A). The skin incision was kept between the anterior and the posterior axillary fold, and the subcutaneous tissue was undermined. Following identification and mobilization of the anterior border of the latissimus dorsi, the periostium of the fifth rib was carefully detached, and the pleura was entered through the fourth intercostal space. The lungs were gently pushed posteriorly with a malleable retractor and the pericardium was longitudinally opened about 1 centimeter anterior to the phrenic nerve. Stay sutures were applied, which opened the pericardium, retracted the heart posteriorly, and retained the right lung under protective wet sponges.

In cases where the pericardium was difficult to visualize, inguinal cannulation and cardiopulmonary bypass were established prior to opening, allowing for the deflation of the lungs. For inguinal cannulation, a Bard cannula (C.R. Bard, Murray Hill, NJ, USA) was used for arterial cannulation, and a chest tube (16 F for patients less than 20 kg, 20 F for patients greater than 20 kg) for cannulation of the iliac vein. Vacuum-assisted drainage (vacuum between 10-25 mmHg) was applied to improve venous return.

Although external iliac artery cannulation was preferred to reduce the number of cannulas in the surgical field, the ascending aorta was cannulated if the iliac artery was judged to be too small for a safe femoral approach. This was the case in 3 patients, and the aortic cannula was inserted, together with the superior vena cava cannula and the cardioplegic line, through an additional incision in the third intercostal space (Figure 1B). The opening of the third intercostal space allowed for good exposure of the ascending aorta, its safe cannulation, and cross-clamping. In patients where arterial groin cannulation could be performed, no additional intercostal incision was made, and the superior vena cava cannula and the cardioplegic line were positioned through the already opened fourth intercostal space. Following cross clamping of the aorta, cold hypercalemic blood cardioplegia was infused, and the patient cooled to mild hypothermia. Carbon dioxide was insufflated into the thoracic cavity, and the right atrium opened. A left vent was placed via the right superior pulmonary vein.

Closure of the VSD was feasible without a patch in 17 patients by a continuous 7-0 prolene suture. In 5 patients, the VSD was closed with a Gore-tex patch (W.L. Gore, Flagstaff, AZ, USA), which was tailored accordingly to the morphology of the VSD. The patch was inserted with a continuous 7-0 prolene suture, starting at the posterior limb of the septo-marginal band. If the border of the VSD could not be precisely visualized because of the tricuspid subvalvular apparatus, the anterior leaflet of the tricuspid valve was

Figure 2. Postoperative result at 16 months. The scar is hidden under the resting arm, and no deformities of the thorax are observed.

detached from the annulus. Our group has previously described this approach and we believe that it provides several advantages compared to the detachment of the septal leaflet [Maile 2003]. When the anterior tricuspid leaflet was detached, the patch was sandwiched along the ventriculo-infundibular fold between the valve leaflet and the annulus. The anterior leaflet was reanastomosed with 7-0 PDS suture.

Additional procedures were performed in 4 patients. Three patients underwent a plasty of the aortic valve to resuspend a prolapsing right coronary leaflet. The valve was approached via a transverse aortotomy. A subaortic membrane occurred in 2 patients and was removed completely through the VSD. The membrane was confined to the septum and lateral part of the anterior leaflet of the mitral valve.

During atrial closure, warm cardioplegia was given, the heart de-aired, and the aortic cross clamp removed. After the routine transesophageal echocardiogram revealed good left ventricular function and stable sinus rhythm, the left vent was removed. Atrial and ventricular pacing wires were placed. After complete removal of the cannulas, a chest tube was placed, the pericardium was always closed, and the iliac vessels repaired with PDS sutures. To avoid iliac artery stenosis, special attention was given to carefully repair the vessel with single-interrupted stitches.

### *Results*

Closure of the restrictive VSD through a right axillary thoracotomy was possible in all patients (Figure 2). No conversion or extension of the incision beyond the anterior axillary fold was necessary. The median cross clamp and cardiopulmonary bypass times were 46 min (range, 23-108 min) and 104 min (range, 73-180 min), respectively.

There was no mortality and no significant morbidity. All patients were in sinus rhythm and no reoperation was required. Due to a residual VSD revealed by intraoperative transesophageal echocardiogram, a second run on bypass had to be performed in 1 patient. Postoperative echocardiography demonstrated the absence of any residual defects and competent aortic valves in all patients, including those with repair. No patient showed more than mild tricuspid valve insufficiency. No subaortic obstruction occurred.

All patients had an uneventful postoperative course. One complication was observed during follow-up, which has to be attributed to the femoral cannulation. A 4-year-old girl developed a postoperative stenosis of the iliac artery at the cannulation site. This complication is scheduled to be managed by a catheter balloon intervention in the coming months. Other complications, such as thrombosis of the iliac vessels or inguinal lymphorrhea, have not been noted. Follow-up was complete (range, 2-22 months; median, 20 months), and all patients have been seen by a staff member.

## DISCUSSION

The right axillary thoracotomy has already been shown to present a cosmetically attractive approach for the closure of congenital cardiac defects because the resulting scar is hidden under the resting arm [Rosengart 1993; Yang 2001; Schreiber 2003]. However, this alternative to a sternotomy or antero-lateral thoracotomy has been reported by other groups only as an approach for the repair of relative simple defects, such as ASDs, partial atrio-VSDs, and sinus venosus defects.

Since 2001, the right axillary thoracotomy has routinely been used for ASD repair at our institution with no morbidity and excellent cosmetic results. As our experience has grown with this lateral approach to ASD closure, we have expanded the same approach to the repair of a variety of congenital cardiac malformations, such as repair of partial abnormal pulmonary veinous return, partial atrioventricular canal, and for the closure of restrictive, perimembranous VSDs [Pretre 2005]. The technique was subsequently refined by sparing the cutting of any muscles of the thoracic wall and keeping the incision away from the breast bud tissue. By this refined technique, we hope to avoid the reported negative long-term sequels following the application of the antero-lateral thoracotomy, such as thorax and breast deformities [Cherup 1986; Bleiziffer 2004].

The results of the reported series show that this approach can be safely applied. There were no mortalities or significant morbidities. The exposure of the heart was adequate, and allowed for a controlled cannulation of the aorta, the superior vena cava, and placement of a left vent. We realized that the smaller thoracic cavity and the high elasticity of the rib cage, as well as the possibility to retract the heart posteriorly, provided adequate visualization of the surgical field and allowed for the application of conventional instruments (Figure 1C). This high flexibility of the thoracic structures in children also allows for limiting the skin incision between the anterior and posterior border of the axillary pitch, which results in a hidden scar under the resting arm.

In no patient did the incision need to be extended, or conversion to another approach have to be performed, and hence no tissue of the breast bud should have been injured. Future follow-up of our patients is ongoing to show if this approach avoids any malformation of the right breast. More than half of the patients of this study group were examined by a staff member for more than 20 months of postoperative follow-up. The cosmetic results were found to be excellent, with high patient and parental satisfaction. More important, none of the patients showed development of a thorax deformity, and no scoliosis has been detected by clinical examination with a scoliometer (National Scoliosis Foundation, Watertown, MA, USA) and the Adam's forward bend test, as reported by Cote et al [1998]. We are convinced that the careful sparing of the musculo-skeletal structures of the thoracic wall and a preserved normal intercostal space after closure of the chest are important contributing factors in avoiding these complications.

The other concern for the routine application of the right axillary thoracotomy approach pertains to inguinal cannulation in children [Komai 2001]. We observed 1 patient who developed stenosis of the iliac artery, which will be managed by a catheter balloon intervention. All other patients were followed with blood pressure measurements at the extremities during their routine cardiological follow-up visits. Given the finding that only 1 of our patients developed an iliac artery stenosis

after groin cannulation, we believe that this complication can be minimized by applying a meticulous surgical technique for the dissection, the cannulation, and especially the following reconstruction of the iliac vessels. A further contributing factor was the application of vacuum-assisted venous drainage, which allowed for the use of a relatively small-sized venous cannula. Although iliac artery cannulation was preferred to avoid any excessive installations in the surgical field, cannulation of the aorta was performed if the vessel was judged to be too small for cannulation. The additional incision performed at the third intercostal space allowed the insertion of the cardioplegic cannula, superior vena cava cannula, and the aortic cross clamp, allowing the cannulation of the aorta to be safely performed through the fourth intercostal space with the surgical field free of obtrusive installations.

We detached the anterior leaflet of the tricuspid valve for the closure of VSDs when the borders could not be precisely visualized due to the tricuspid subvalvular apparatus. This technique allows for improved exposure of periaortic tissue and helps to avoid injury to the conduction tissue [Maile 2003]. The postoperative and follow-up echocardiograms demonstrated good valvular function and no more than mild regurgitation. All patients were in sinus rhythm.

In summary, closure of restrictive VSDs in older children can be safely performed through a right axillary thoracotomy without compromising the accuracy of the repair. The cosmetic results are superior to that following a median sternotomy or an antero- or postero-lateral thoracotomy by hiding the resulting scar under the resting arm. Follow-up of up to 22 months has demonstrated no development of growth asymmetry of the thorax. However, future control is warranted to confirm the absence of the potential drawbacks of this approach, such as thorax or breast deformities.

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