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Mid-term results of right axillary incision for the repair of a wide range of congenital cardiac defects☆

Hitendu Hasmukhlal Dave [a,*], Maurice Comber [a], Theo Solinger [a], Dominique Bettex [b], Ali Dodge-Khatami [a], René Prêtre [a]

[a] Department of Congenital Cardiac Surgery, University Children's Hospital Zurich, Steinwiesstrasse 75, 8032 Zurich, Switzerland
[b] Department of Cardiac Anaesthesia, University Children's Hospital Zurich, Steinwiesstrasse 75, 8032 Zurich, Switzerland

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Abstract

Objective: We evaluated the mid-term results of the right axillary incision used for the repair of various congenital heart defects. **Methods:** All the patients who were operated with this incision between March 2001 and December 2007 were reviewed. There were 123 patients (median age 4.7 {0.4—19.4} years and median weight 16.6 {3.8—62} kg) undergoing atrial septal defect (ASD) closure (62), repair of partial anomalous pulmonary venous connection (PAPVC) (22), correction of partial atrioventricular septal defect (AVSD) (19), and restrictive perimembranous ventricular septal defect (VSD) (20). Additional procedures involved tricuspid valve plasty (10), mitral annuloplasty (3), reduction plasty of the aortic sinus (2), resuspension of the aortic valve cusp (2), sub aortic membrane resection (1), or reimplantation of Scimitar vein (1). The surgical technique involved peripheral (groin) and central (SVC ± aorta) cannulation for institution of cardiopulmonary bypass. Fibrillatory arrest was used for repair of ASDs and cardioplegic arrest for repairs involving the atrioventricular valves as well as VSDs. The median CPB and aortic clamp times were 72 (35—232) and 0 (0—126) min, respectively. **Results:** There was no need for conversion to another approach in any patient. Early morbidity included transient paresis of left upper arm (1), stenting of SVC after repair of a sinus venosus defect (1) and revision for bleeding (1). Follow-up echo showed no residual defect in 116 patients and minor residual defects in 7 patients: tiny ASD (2), tiny VSD (1) and mitral regurgitation (4). One patient developed stenosis in the right external iliac artery used for cannulation, necessitating surgical intervention. All the patients are in excellent condition after a median follow-up of 4.1 (0.4—7.1) years. The incision healed well and the thorax and the breast showed no deformity on follow-up. **Conclusions:** The right axillary incision provides a quality of repair for various congenital defects similar to that obtained by using standard surgical approaches. Because of its deceitful location, and the camouflaging effect of being hidden by the resting arm, it has superior cosmetic appeal compared to conventional incisions. The incision does not interfere with subsequent development of the thorax or the breast (in case of females).

Keywords: Minimally invasive congenital heart surgery; Muscle sparing thoracotomy; Right lateral minithoracotomy; Right axillary incision; External iliac artery and vein cannulation

1. Introduction

Ever since the first intra-cardiac repair of an atrial septal defect by Lewis and Varco in 1952, congenital heart surgery has continued to evolve and mature, so as to become a widely available treatment modality with excellent results. Simple defects like an atrial septal defect can now be corrected with a mortality and morbidity approaching zero percent. In the meantime, interventional cardiology has developed significantly so as to make it possible to affect therapeutic closure of simple defects as well as relieving valvar and vascular obstructions. Catheter based repairs as an alternative to the surgical gold standard have become popular thanks to its minimally invasive appeal and excellent cosmetic outcome, sometimes even at the cost of suboptimal result [1,2]. While the simultaneous advancement of surgical and catheter based techniques has been all for the patient good, the ultimate goal is to accomplish a perfect repair that ensures a normal survival and the best quality of life, physically as well as psychologically.

While surgery continues to be identified with an incision, many alternative approaches to a standard sternotomy [3] have been explored to reduce invasiveness of surgery, while at the same time ensuring a perfect repair. These include a small incision with a full sternotomy [4], partial sternotomy [5,6], antero-lateral thoracotomy [7,8] as well as posterior thoracotomy [9,10]. While a sternal scar, however small, continues to be at a disadvantage because of it attracting a stigma of being a heart patient, the antero-lateral thoracotomy (in spite

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* Corresponding author. Tel.: +41 44 2668003/2668020; fax: +41 44 2668021.
E-mail addresses: hitendu@hotmail.com, hitendu.dave@kispi.uzh.ch (H.H. Dave).

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of being once considered superior to a sternotomy) has eventually fallen out of vogue because of reports of thoracic cage deformity (caused by rib deformation and atrophy of severed pectoral muscles) and asymmetric development of breasts when used prepubescently [11].

While we started with a posterior thoracotomy in the year 2000, we were unhappy with the extent of the incision (especially with division of important thoracic wall flat muscles). Hence from 2001 onwards, we shifted to the sub-axillary (muscle sparse) approach. We have progressively used an axillary incision to repair atrial septal defect (ASD), partial anomalous pulmonary venous connection (PAPVC), partial atrioventricular septal defect (pAVSD), and restrictive peri-membranous ventricular septal defect (VSD) and have recruited 123 patients till December 2007 [12]. A right axillary incision provides the best direct plane of vision to the atrial septum, AV valves and the membranous ventricular septum. It is also one of the least muscularly covered parts of the thoracic cage allowing for a less invasive access through the thoracic cage and to the heart. Additionally, the sub-axillary location of the scar, being far away from the breast, and being naturally covered by a resting arm provides excellent cosmetic result.

2. Materials and methods

All patients operated upon using a right axillary incision starting from March 2001 up until December 2007 were included in this study (Table 1). There were 123 patients (66 females; 57 males): median age 4.7 (0.4—19.4) years and median weight 16.6 (3.8—62) kg. The incision was primarily used for closure of osteum secundum ASD. As experience accumulated and confidence grew about exposure of various parts of the heart, the approach was successively applied for correcting PAPVC of right-sided pulmonary veins including performance of the Warden procedure (SVC reinsertion onto the RA appendage) and relocation of the scimitar vein to the left atrium, repair of pAVSD and closure of restrictive peri-membranous/sub aortal VSD.

Intraoperative transesophageal echocardiography and postoperative trans-thoracic echocardiography at regular intervals was performed in all patients. Follow-up was complete and ranged from 0.4 to 7.1 years (median 4.1 years).

2.1. Position and thoracotomy

The patient is placed in a left lateral with slightly backward reclining position. The lower torso and pelvic region is placed in a 45° position to allow access to the inguinal region. A marked anterior axillary line and 4th intercostal space (best performed in supine position with the arm resting by the side) serve as guiding parameters for the axillary incision. A longitudinal or an oblique incision is performed in the right axilla not extending the anterior axillary line. The skin is undermined so as to be able to slide to the desired operative field. The latissimus dorsi is mobilized free of its facial attachments and the digitations of serratus anterior overlying the 4th intercostal space are identified and split. Care is taken to avoid injury to the long thoracic nerve and artery plying posteriorly on the serratus anterior muscle. A subperiosteal entry through the superior margin of the 5th rib is performed, and the pericardium is opened 2 cm anterior to the phrenic nerve. Placing stay sutures along both the margins of the pericardium and fixing them to the surrounding drapes keep the lungs at bay. Sometimes institution of cardiopulmonary bypass through inguinal cannulation (and thereby deflation of the lungs) is necessary to achieve adequate exposure of the heart. Once achieved, the vena cava superior is circumvented and cannulated directly with a right angle, metal tipped, wire reinforced venous cannula (Fig. 1). After completion of the procedure, decannulation and hemostasis is performed. The opened pericardium is approximated with interrupted stitches. A subperiosteal epidural catheter is placed in the posterior intercostal groove created extrapleurally for bupivacaine infusion. A thorax drain is inserted and the thorax closed in layers.

2.2. Inguinal vessel cannulation

Groin arterio-venous cannulation is used in all but too small (weighing less than 10 kg) patients. The external iliac vessels along their course just above the inguinal ligament are dissected and looped. A suitably sized (Fig. 2) thoracic drain (16—20 F according to the size of the vein) is inserted first through a generous transverse incision in the vein. A silk snare around the upfront vein prevents any blood loss. A similar clean-cut transverse incision on an excluded segment of the external iliac artery is used to gently pass a Bard arterial cannula (C.R. Bard Inc.) (Fig. 3).

A silk snare around the artery, and multiple fixations, secure the arterial line from dislodgement. With additional cannulation of the SVC and a gentle negative suction (−15 to −20 mmHg) venous drainage, cardiopulmonary bypass is instituted. At the end of the procedure, the arteriotomy is sutured with interrupted fine Polydioxanone (PDS) sutures and the venotomy with continuous PDS sutures (Fig. 3).

Table 1
Demographic data and the type of repairs.

	No. of patients	Median age (months)	Median weight (kg)	Median aortic clamp time (min)	Median CPB time (min)
O.S. ASD	62	49.5 (4.5—192)	16 (3.8—62)	0 (0—126)	55.5 (35—239)
Sinus venosus ASD (± PAPVC)	22	60.8 (8—197)	16.8 (6.3—46.7)	0 (0—42)	90 (39—150)
pAVSD (inclusive five transitional or complete AVSD)	19	75.8 (8—147.6)	19.6 (6.7—46)	43 (31—96)	105 (68—200)
VSD	20	67.5 (13—240)	19.6 (6—62)	44.5 (23—117)	100 (72—202)

O.S. ASD: osteum secundum atrial septal defect; PAPVC: partial anomalous pulmonary venous connection: pAVSD: partial atrioventricular septal defect; VSD: ventricular septal defect; values in brackets are range.

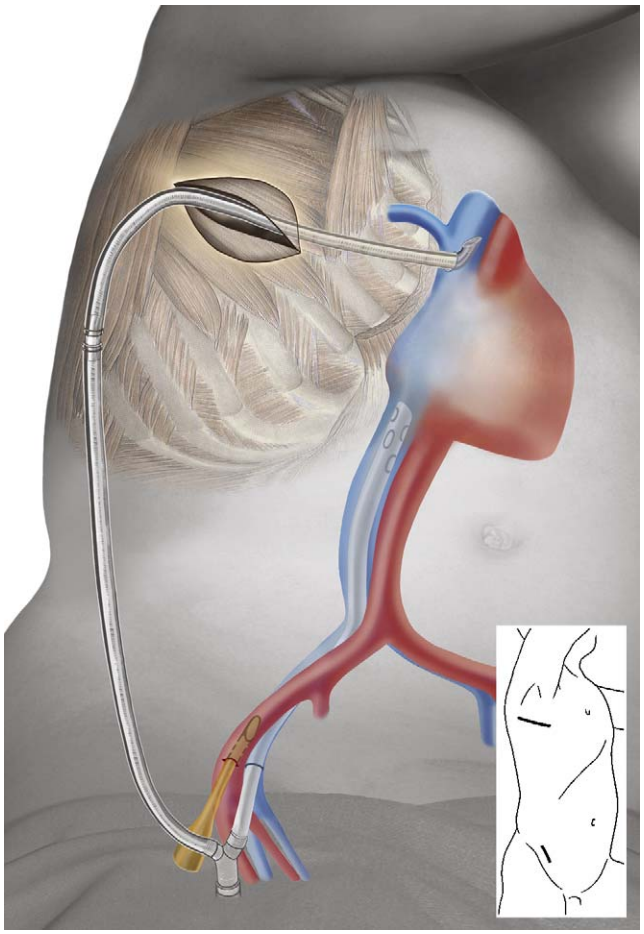

Fig. 1. Schematic drawing of typical cannulation, for a procedure through an axillary incision. Inset at the right lower corner shows the location of the right axillary working port and the incision for right groin cannulation.

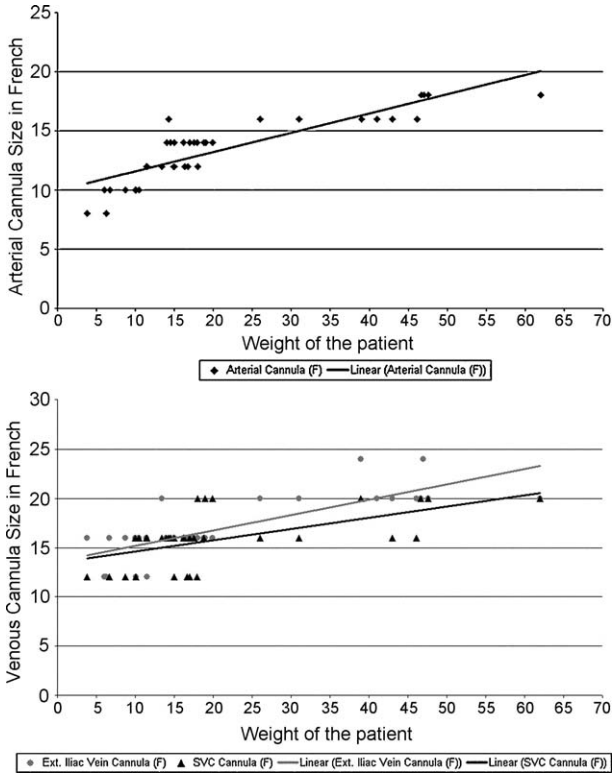

Fig. 2. Scatter graph showing the cannula sizes used as per weight of the patient.

2.3. Myocardial preservation

Induced ventricular fibrillation was used for closure of ASD with or without anomalous venous drainage. After establishment of CPB, fibrillator pad was suture secured to the ventricular myocardium and right atriotomy performed under fibrillatory arrest. ASD closure was performed, while ensuring (echocardiographically) that fibrillation was maintained and the left ventricle did not get distended [13]. Left ventricular decompression could be easily performed when needed by making the mitral valve incompetent with the suction tip. Cardiotomy suctioning of left heart is kept to a bare minimum to keep it air free as far as possible. Fibrillatory arrest was convenient in the sense that it avoided aortic cross-clamping and cardioplegic cannula in an already congested operative space. However cardioplegic arrest was used for correction of partial AVSD and closure of VSD. Additional access through the 3rd intercostal space was used to park the aortic cross-clamp, SVC cannula and the cardioplegic cannula, thus allowing the 4th intercostal space as the working port. A left heart vent was inserted through the right superior pulmonary vein. Carbon dioxide insufflation at 0.3—0.5 l/min was used until the septal defects were closed. Online blood CO_2 concentrations were carefully monitored for exceptional rise (7 kPa) due to resorption of the insufflated gas.

2.4. Surgical technique of repair

Direct ASD closure (secundum and primum) was performed in 50 and 17 patients (when enough tissue was present), while an autologous pericardial patch was used for the same in 12 and 2 patients, respectively. Left AV valve cleft was adapted in patients with a partial AVSD. If a residual leak was noted on valve testing, a posterior annuloplasty with resorbable suture was added in three patients. One small inlet VSD (intraoperatively diagnosed during partial AVSD repair) was directly suture closed. Sinus venosus defects were closed directly using a flap of the atrial septum in five patients or with a pericardial patch in five patients. PAPVC of the right pulmonary veins was corrected by using a baffle closure of the defect and relocation of the SVC drainage to the right atrial appendage (Warden procedure) in 11 patients while a double patch technique was used in 1 patient. Relocation of a scimitar vein to the left atrium was performed in one patient. VSD was closed directly in 16 patients and with a xenopericard patch in 4 patients. VSD was approached through a detached anterior leaflet of the tricuspid valve in 11 patients and without it in 9 patients. Other additional procedures included tricuspid antero-septal commissural plasty (10), resuspension of a prolapsing right aortic cusp through an aortotomy (2), reduction plasty of aneurysmatic aortic sinus (2) and sub aortal membrane resection through the VSD (1).

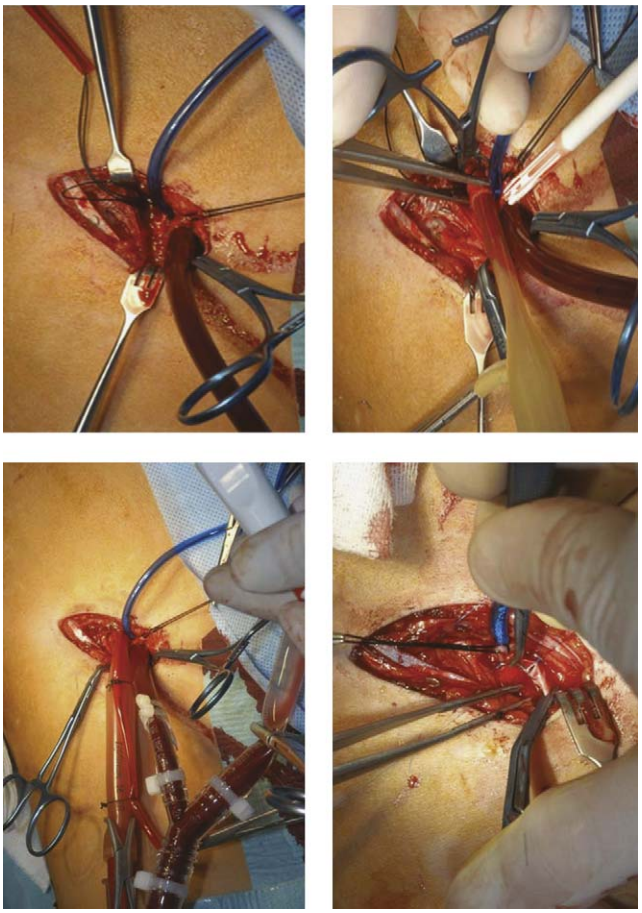

Fig. 3. (a) External iliac vein cannulation with a thorax drain. (b) External iliac artery cannulation with a Bard straight cannula. (c) Set-up during cardiopulmonary bypass through the groin cannula. (d) Decannulation of inguinal cannulae followed by arterial repair first and an ongoing vein repair.

3. Results

Intracardiac repair could be completed in all patients through the right axillary incision. Thanks to intraoperative online transesophageal echocardiography, a second run of CPB (with the already installed cannulae and extracorporeal system) helped to correct residual ASD (4) and VSD (1) in five patients.

There was no immediate or late mortality. No patient required a reoperation/catheter intervention for correction of residual intracardiac lesion (shunt or valve dysfunction). There was no residual defect in 116 patients and trivial in 6 patients; small residual ASD (2), small residual VSD (1) and trivial to mild mitral regurgitation (3). One patient with an intermediate AV canal defect had mild to moderate mitral regurgitation, which although remaining stable on follow-up, needed strict vigil. The later case was not subjected to annuloplasty for fear of creating mitral stenosis.

One patient (early on in our series) suffered a transient paresis of the left arm on day 2 after ASD closure. An MRI detected an ischemic injury in the right cerebral hemisphere consistent with an embolic stroke; the child recovered fully in 2 days. Other complications included need for stenting for SVC stenosis after repair of a sinus venosus defect (1) and rethoracotomy for bleeding (1).

Inguinal wounds healed normally with no incidence of lymphorrhea. One patient (5.5 years old) developed external iliac artery closure 10 months after ASD repair using groin cannulation. She needed a saphenous vein interposition graft to replace the diseased segment. None of the girls in pubescence (13 out of a total of 66) showed any breast deformity during follow-up. There was no clinical deformity of the chest or the vertebral column with growth in any of these patients.

4. Discussion

Repair of simple congenital heart defects using standardized approaches has become routine and has shown excellent results [14]. Since atrial and ventricular septal defects are repaired contemporarily, with negligible early morbidity and mortality, the quality of life aspects of these patients have increasingly become the subject of scrutiny. The late impact of these defects is defined as much by the cosmetic aspect of the scar, as by the functional recovery of the musculoskeletal system used to approach them. A visible sometimes grotesque mid-sternotomy scar continues to be a strong reminder of 'the heart patient stigma' with deleterious psycho-social consequences. In contrast, non-surgical trans-catheteral interventions, because of their minimal invasiveness and excellent cosmetic results, are more appealing to patients and primary care physicians, sometimes even at the cost of suboptimal results.

While adult cardiac surgery embarked on evolving minimally invasive techniques in the early 1990s, congenital cardiac surgery did not witness a parallel evolution in adopting minimally invasive techniques, essentially because cardiopulmonary bypass continued to be necessary for performing intracardiac procedures. However, the site and size of the incision as well as manubrium and muscle sparing approaches continued to remain the focus of experimentation in order to minimize the trauma of exposure.

Various incisions such as a right antero-lateral thoracotomy, a right posterior thoracotomy, partial inferior sternotomy and right para-median access have been described by other groups, with this view in mind [15,16]. All these variations have however proved suboptimal, either with respect to visibility of the scar, deformation of the thoracic cage or asymmetrical development of the breast; especially when used in pre-pubescent females. A sternotomy scar, however small, has prompted some of the children to avoid going to the swimming pool for fear of inviting unwanted sympathy from peers.

Keeping in mind that the priority in performing a repair for congenital cardiac defect is to ensure a perfect repair that provides the longest life expectancy and the best quality of life, we have embarked on a minimally invasive program since 2001 [12,17,18]. Our condition however was to maintain the same excellent results as achieved with the classic approach, while at the same time improving the functional and cosmetic outcome.

Since most of the simple heart defects such as atrial septal defects, partial anomalous pulmonary venous return and ventricular septal defects are approached through a right atriotomy, we sought to progressively perform these defects

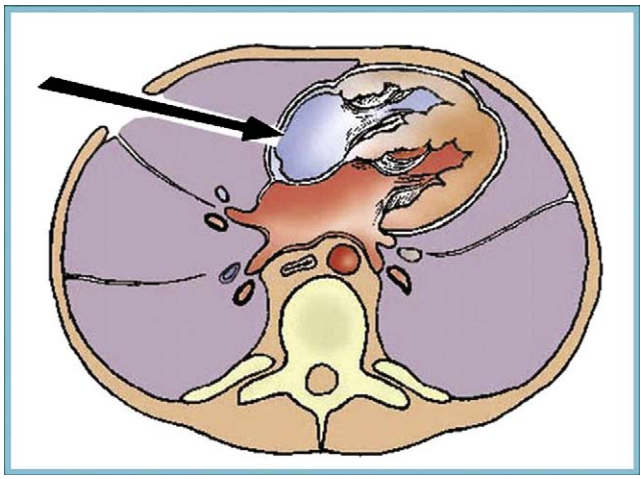

Fig. 4. Schematic drawing of a cross-section of the chest at the level of axillary incision showing its suitability to perform various trans-right atrial procedures on the atrial and membranous ventricular septum.

(with incremental difficulty) through a right axillary incision [19,20] which is best suited with a linear plane of vision to the necessary structures (Fig. 4).

This incision, being located in a muscle free area, away from the breast bud and farthest from the anterior and posterior hinge points, provides adequate exposure with minimum traction. Because of its location in the armpit, it gives the best cosmetic result (remaining hidden underneath the resting arm), and it does not interfere with the development of the chest or the breast. Finally, its location in the right axilla deceives one to believe that it can be anything but for a heart ailment (because the heart lies in the left hemi thorax) (Fig. 5).

From 2001 to 2007, we have used this approach in 123 children with simple intracardiac defects, with no need for

Fig. 5. Clinical pictures of a child late after axillary approach to repair an intra-cardiac defect; cosmetically excellent scar which is invisible with the arm by the side.

conversion to another approach, meaning thereby that it provides a safe, reliable access. The cosmetic result of the scar is excellent in the great majority of patients (Fig. 5). The thorax development has been normal, possibly because no muscle is divided and the intercostal space is anatomically recreated. The location far away from the hinge points also means that they can be spread apart with minimal possible stress and also thereby without causing rib fracture or injury to the costochondral junction. We expect that the breast develops normally, because we avoid transgressing the anterior axillary line. If needed, the incision can be extended posteriorly and mobilized so that it can slide anteriorly and overlie the operating area.

Right external iliac artery and vein cannulation for cardiopulmonary bypass and later reconstruction need to be delicately performed. One of our patients developed closure of the cannulated right external iliac artery (the exact cause of which is not known) needing interposition reversed saphenous vein graft. In general, we prefer not to cannulate the peripheral artery in children weighing less than 10 kg. In such cases, the ascending aorta is cannulated, sometimes through an additional access in the 3rd intercostal space.

In repairs performed using fibrillatory arrest, vigilance is needed to ensure that the fibrillatory pads maintain contact with the myocardium and that the fibrillatory arrest is continuously assessed electro and echocardiographically. The reduced overview of the heart due to small exposure is adequately compensated by online transesophageal echocardiographic monitoring, which looks for filling status of the left ventricle, cardiac activity and presence of air bubbles [21].

Amongst established surgical techniques, the best suited for the axillary approach [22] was selected without compromising on the quality of repair. Direct closure of primum [23] and secundum atrial septal defects (because of the dilated atria) as well as restrictive ventricular septal defects, were established to be safe through the classic sternotomy approach, before being applied to the axillary approach. Though a direct closure of septal defects was preferred to save on the duration of fibrillatory arrest, patch closure is equally acceptable and possible to be used through an axillary approach.

The results of repair performed match those performed through a conventional approach with 116/123 having a perfect outcome. It is notable that we could also perform adjuvant procedures on the mitral, tricuspid and aortic valves [24], as well as on the aortic sinus (using an aortotomy), Warden procedure for PAPVC and reimplantation of a scimitar vein through the axillary incision with very good outcome.

Future evolution should involve designing intelligent cannulae which minimize dependence on peripheral vessels for instituting cardiopulmonary bypass [25], low profile aortic clamp and cardioplegia delivery systems, self retaining spreaders to spread open the atriotomy, and versatile deep operating instruments (perhaps robots) to further the use of this approach.

5. Conclusion

While the conventional approaches to treat simple heart defects have become routine, the stigma of being 'a heart

patient' still haunts a child after repair; whether it be in the midst of peers in the swimming pool or in the course of building a personal relationship. The axillary incision provides adequate access for safely and reliably performing simple repairs. At medium-term follow-up, these approaches have become more acceptable to the patients and their caretakers, thanks to their excellent somato-cosmetic results, while maintaining the existing gold standard of the quality of repair. We hope that the early optimism would result in a better long-term psychosocial integration of these patients.

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Appendix A. Conference discussion

Dr C. Schreiber (*Munich, Germany*): In Munich, we operate all patients with a simple ASD, provided they weigh more than 10 kg, through a minimally invasive midaxillary incision. We do that now for more than 3 years. But I must say that I am not brave enough to extend the indications to the extreme you have done. Two questions remain.

Because you reported on a patient with a vascular problem, why put a peripheral vessel at risk? We are only cannulating through the chest.

And two, would you, with your expertise, operate in the near future on even more complex lesions? And if so, I think I should come and see you doing so.

Dr Dave: We acknowledge that you have pioneered the incision and we have taken the work forward, by escalating its use for little more complex lesions.

We do share your concern about peripheral arterial cannulation. We do not know what was the cause of iliac artery stenosis in this particular patient. We subjected the first 50 of our series of patients to a systematic recall and examination for the peripheral arterial problem and we did not encounter this. In this series, we have had a significant group of patients operated, who were in the 10 to 15 kg weight group, and none of them have had this problem as yet. But the concern still remains. As for kids below 10 kg, we anyway cannulate the ascending aorta (thus avoiding the peripheral artery).

And the second question?

Dr Schreiber: Would you, with your expertise, even do more complex lesions in the near future through the described access?

Dr Dave: I forgot to mention, in this group of 19 partial AVSD, there were 3 or 4 patients with the transitional type that is with a restrictive ventricular septal defect, and we did not find it extremely more difficult than otherwise, to be able to close it. But I think except for aggressively pursuing this approach for perimembranous VSD closures, I don't foresee that with the present hardware, we are in a position to escalate to more complex procedures. Maybe René Pretre may want to add a comment there.

Dr Schreiber: For a VSD, usually good for training younger surgeons, might be very difficult to assist through a minimally invasive thoracotomy. It is pretty much only the surgeon who sees something during the case. That comes on top.

Dr R. Pretre (*Zurich, Switzerland*): Well, we extended this approach, just like it was shown, to the structures located just below the AV valves. And the VSD was one of these structures. Now, as you saw, those VSDs were restrictive VSDs in all the patients. I think the youngest patients were probably 4 years of age in this group.

A step we have not done, yet, is the resection of a subaortic membrane, for instance. I know a few groups also operate subaortic stenosis through a lateral thoracotomy. I have always been afraid to be able to do a complete myectomy with this incision, and I have not embarked with it yet.

Back to your comment regarding the peripheral cannulation, this is a critique we really accept and is might be a drawback indeed. My rational to cannulate the iliac vessels is to keep the thoracic incision small. If something should happen with a central cannulation, you're lost. If you switch the

potential risk on the periphery, you have a control on that at all time. I am still afraid that a problem on the arterial cannula or anything like that might happen. That was the main reason why we chose that site for cannulation. We have developed a very fine technique to open up the artery and the vein, and later to close them, with interrupted stitches. And so far, we have not seen many vascular problems.

Dr Schreiber: There are not many surgeons and many institutions which will do nowadays a midline sternotomy for a simple ASD in prepubescent patients, and I personally think, since we have the cardiologists on our backs, we should not do this at all. The midaxillary thoracotomy allows for very nice cosmetic results. But again, the approach is more complex and in my mind centers with expertise in minimally invasive approaches should be visited.