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ORIGINAL ARTICLE

Minimally Invasive Cardiac Surgery Without Peripheral Cannulation: A Single Centre Experience

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Background A minimally invasive approach without any peripheral cannulation was used as an alternative to median sternotomy for the correction of a wide range of cardiac defects with superior results and good cosmetic outcome.

Methods From October 2015 to March 2017, 145 patients underwent correction of congenital cardiac malformations with cardiopulmonary bypass through right anterior minithoracotomy (RAMT) with routine cannulation. The average age was 9.69 ± 4.38 years (range 2–21) and the average body surface area was 0.91 ± 0.27 square metres (range 0.5–1.7). The corrected defects included all types of atrial septal defect (ASD) and ventricular septal defects (VSD), partial atrioventricular septal defects with severe mitral regurgitation, mitral valve repair, repair of tetralogy physiology requiring outlet patch enhancement, isolated pulmonary stenosis (PS) and congenital coronary cameral fistula.

Results There was no operative mortality or major morbidity. All patients were alive at the time of this follow-up. The mean cardiopulmonary bypass time was 64.75 ± 22.28 minutes (range 30–175) and mean aortic cross clamp time was 37.53 ± 18.23 minutes (range 14–135). Fifty-five (55) patients were extubated in the operating room and the remaining 90 patients were extubated within 3 hours in the intensive care unit. Repair and cosmetic results were excellent in all patients. There were no conversions to full sternotomy. No neurological events were reported.

Conclusions Right anterior minithoracotomy without peripheral cannulation is safe and effective for the correction of a wide range of congenital heart defects including right ventricular outlet obstructions. The cosmetic results are satisfactory, avoiding psychosocial problems.

Keywords Congenital heart disease • Right anterior thoracotomy • Minimally invasive cardiac surgery • Congenital cardiac defects • Cardiopulmonary bypass

Introduction

Median sternotomy has been the conventional approach for correction of congenital cardiac defects for many years and at times unsightly, long midline scars arouse displeasure and psychological distress, especially in young female patients. The concept of minimally invasive surgery (MICS) for congenital heart disease in paediatric patients is broad and has the aim of reducing the trauma of the operation in the operating room using smaller incisions and in the intensive-care unit with fast-tracking strategies like early extubation, early hospital discharge and less exposure to transfused blood products. The aesthetic techniques designed to reduce surgical trauma [1–5] have placed profound pressure on the

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surgeons performing them as there is a demand for good technical precision, speed and gentleness in congenital heart repairs. Consequently, adoption of such techniques has proceeded at a slow pace and has been limited to straightforward repairs. We extended the use of right anterior minithoracotomy (RAMT) to repair congenital heart defects that were otherwise suitable for repair only by median sternotomy with good outcomes. Lesions involving the pulmonary valve and the right ventricular outflow tract are no longer a contraindication for RAMT as shown in this retrospective study, which details our experience with simplified cardiopulmonary bypass strategy.

Material and Methods

From October 2015 to December 2016, 145 patients underwent open heart operations through a RAMT approach. The average age was 9.69 ± 4.38 years (range 2–21) and the average body surface area was 0.91 ± 0.27 square metres (range 0.5–1.7). One hundred and forty (140) were younger than 16 years. The patient demographics, type of defect and surgical procedures are listed in Table 1. Institutional review board approval was obtained for the study. No decision algorithm was used as all cases except 15 with complex defects were addressed through RAMT. The presence of left superior venacava was not a contraindication.

Operative Technique

Induction of anaesthesia was standard akin to sternotomy cases with regular arterial and right internal jugular invasive lines. After the induction of general anaesthesia, the patient was placed in the left lateral position and a single dose epidural injection of 0.25% bupivacaine was administered in all cases in the sixth intervertebral space for perioperative analgesia. Anaesthesia was tailored to achieve early extubation. The patient was then turned supine and external defibrillation pads and a transoesophageal echocardiographic probe were placed to confirm the diagnosis and aid surgical correction. For the procedure, the right side of the chest was elevated to about 30 degrees by a sandbag and the right arm was raised and secured to a frame at the head end that isolates the surgical field from the anaesthesia work place. The left upper limb was positioned beside the body. Both the groins were prepared to allow access to femoral vessels. The intercostal space corresponding to the mid right atrium on postero-anterior view chest X-ray was chosen to enter the thorax and it gave good access to both the aorta and the inferior venacava (IVC). In patients with developed breasts, the submammary groove was used for the skin incision and, in cases of undeveloped breasts, the incision was placed in the fifth intercostal space anteriorly to avoid deformity of the breast and the pectoral muscle. The skin incision was approximately 6 cms to 7 cms long. The breast tissue was lifted from under the pectoral muscle after dissecting it off from its chest wall attachments to avoid breast deformity and the chest entered in the pre-determined intercostal space taking care not to injure the underlying lung, right internal mammary artery and intercostal vessels. The thymus was excised securing the vascular pedicle on a ligature and pericardium opened an inch anterior and parallel to the phrenic nerve. Superiorly, the pericardial incision was carried onto its reflection from aorta and inferiorly, onto the diaphragm. Traction of pericardial stay sutures brings the right atrium closer to the chest opening and exposes the aorta and IVC. Autologous pericardial patch was prepared and left in-situ for further use. After systemic administration of heparin, a purse-string suture was placed on the right atrial appendage. Gentle traction on this suture allows exposure of the whole

Table 1 Case Details.

Type of Defect	Procedure	Number of Cases	Mean Age (Range)	Mean BSA (Range)
ASD	Closure [Direct + Patch]	79	9.72 ± 4.39 (3–21)	0.91 (0.5–1.7)
VSD [Others]	Patch closure	25	9.69 ± 4.38 (2–21)	0.92 (0.5–1.7)
Subpulmonary VSD	Patch closure	17	9.67 ± 4.50 (3–21)	0.97 (0.5–1.7)
PAVSD with severe MR	Cleft mitral valve repair and ASD closure	9	9.13 ± 3.97 (3–17)	0.91 (0.5–1.4)
VSD with RVOTO	VSD closure with RVOT patch enhancement	10	9.92 ± 3.86 (3–17)	0.92 (0.5–1.4)
RHD with severe MS	Open mitral valvotomy	4	14.63 ± 4.73 (4–21)	1.24 (0.56–1.7)
Congenital coronary cameral fistula with ASD	Direct closure of fistula and ASD	1	5	0.61

Abbreviations: ASD, atrial septal defect; VSD, ventricular septal defect; PS, pulmonary stenosis; RVOT, right ventricular outflow tract; RVOTO, right ventricular outflow tract obstruction; MS, mitral stenosis; RHD, rheumatic heart disease; PAVSD, partial atrio-ventricular septal defect; OPV, open pulmonary valvotomy.

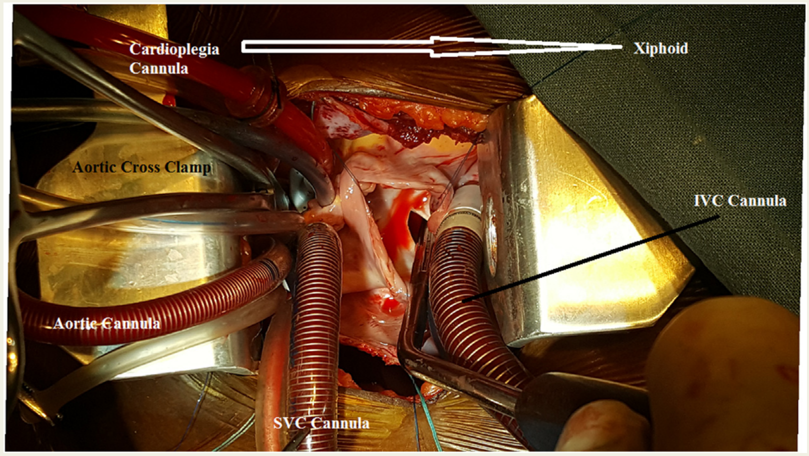

Figure 1 Operating surgeon's view of right anterior thoracotomy showing arterial, venous and cardioplegia cannula along with aortic cross clamp.
Abbreviations: IVC, inferior venacava; SVC, superior venacava.

ascending aorta. Purse-string sutures were initially placed on the highest point of the ascending aorta for aortic cannulation, lower ascending aorta for cardioplegic delivery and on the superior venacava (SVC) after passing the caval snare. The ascending aorta was cannulated with a straight cannula (Medtronic Inc., Minneapolis, MN, USA) and secured to the surgical drapes. Cardiopulmonary bypass (CPB) was initiated after cannulating the SVC and in some cases with large and dilated right atrium, the atria. Once the heart was emptied on CPB, the IVC snare was passed and IVC cannulated under control. The cardiotomy sucker was placed in the pericardial cavity to push the right ventricle posteriorly and expose the IVC for cannulation. Once on full CPB, the caval cannulae were positioned depending on the right atrial incision and cardioplegia cannula was placed on the lower ascending aorta. The aorta was cross-clamped as routine and the cross-clamp secured to the drapes by means of a silk suture. After the cardioplegic arrest of the heart, the repair was done under normothermic conditions. There was no need for specialised cannulae or clamps and through a separate incision on the chest wall (future chest drain site) a suction catheter delivering carbon-dioxide onto the field at three litres per minute was passed. Through a standard oblique right atriotomy or a longitudinal left atrial incision, or both, an acceptable exposure of the intracardiac anatomy could usually be obtained [Figure 1]. The subpulmonary VSD was exposed through the main pulmonary artery (MPA) after arranging all the cannulae towards the operating surgeons side [Figure 2]. The VSD was exposed by means of a bendy VSD retractor, by the assistant. In patients with right ventricular outflow obstruction (RVOTO), the MPA incision was extended onto the right ventricle allowing adequate excision of the obstructive muscle bundles and relief of the obstruction [Figure 3]. Placement of the RVOT patch with

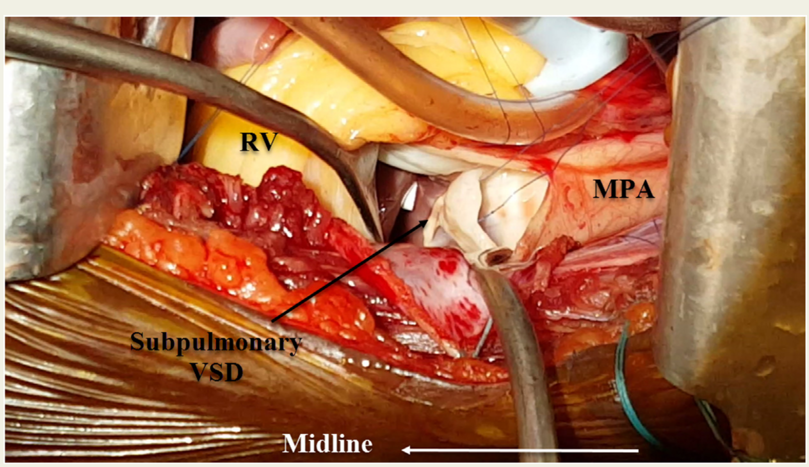

Figure 2 Right anterior mini thoracotomy with exposure of sub-pulmonary ventricular septal defects through main pulmonary artery.
Abbreviations: VSD, ventricular septal defect; MPA, main pulmonary artery; RV, right ventricle.

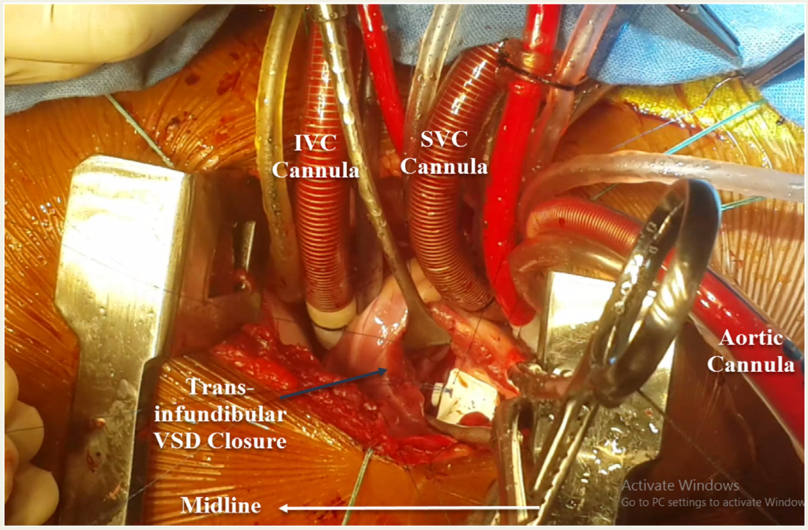

Figure 3 Right anterior mini-thoracotomy with opened right ventricular infundibulum and ventricular septal defects closure.
Abbreviations: IVC, inferior venacava; SVC, superior venacava; VSD, ventricular septal defect.

tanned pericardium was feasible on retraction of the opened right ventricular (RV) incision [10 patients, Figure 4]. In patients with partial AVSD (nine patients), the cleft mitral valve was repaired with interrupted 6-0 polypropylene sutures and ASD closed with native untanned pericardial patch. All VSDs were closed with Goretex patch [42 patients; W.L. Gore and Assoc., Flagstaff, AZ, USA]. The procedures for correcting the heart anomalies were almost the same as used in the median sternotomy approach. Primary continuous suture (22 patients) or pericardial patch was used (57 patients) for the closure of atrial septal defects (ASD). In four patients, severe mitral stenosis was corrected with open mitral valvotomy. One patient underwent repair of congenital right coronary to right atrium fistula by direct closure of the fistulous opening in the right atrium (RA). Insufflation of carbon-dioxide in the operating field and aortic needle vent to suction along with a head low position of the patient allowed easy de-airing of the heart. The absence of intracardiac air and the quality of repair were evaluated by trans-oesophageal echocardiography. Sinus rhythm was restored spontaneously in the majority and neonatal direct internal defibrillator paddles were required in 15 cases to convert ventricular arrhythmias. The heart was gradually weaned off CPB, haemostasis attained and a chest drain placed. The pericardium was suture closed directly over the heart leaving a small pericardial window towards the IVC and the chest closed in a routine fashion with an intradermal continuous suture for the skin.

Epidural bupivacaine given at induction along with rectal paracetamol (40 to 50 mg/kg) allowed good postoperative

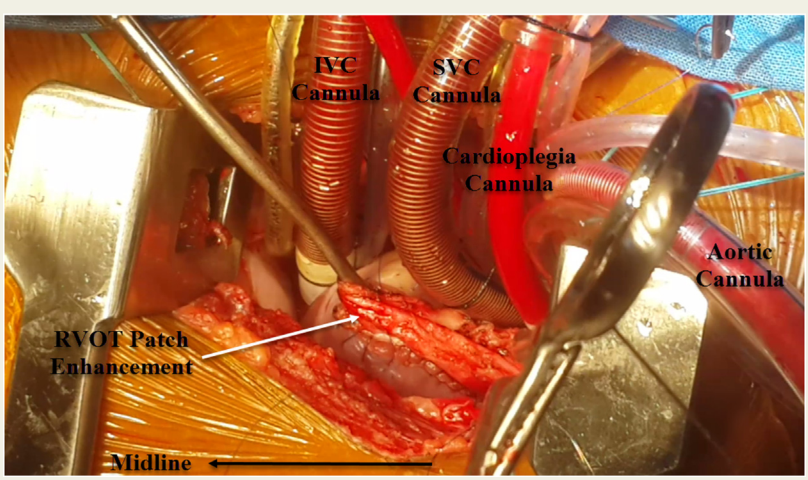

Figure 4 Right anterior minithoracotomy with right ventricular outflow tract patch enhancement.
Abbreviations: IVC, inferior venacava; SVC, superior venacava; RVOT, right ventricular outflow tract.

pain control before extubation. Pain control in the postoperative period consisted of intravenous administration of paracetamol (10 mg/kg every 6 hours) and ibuprofen in syrup (10 mg/kg/dose every 8 hours).

Results

There were no deaths in this series of 145 consecutive patients and no patient required conversion to full sternotomy. The mean CPB time was 64.75 ± 22.28 minutes (range 30–175) and the mean aortic cross-clamp time was 37.53 ± 18.23 minutes (range 14–135). The repair was concluded with one cardioplegia dose in 120 cases [Table 2]. Fifty-five (55) patients were extubated in the operating room and the remaining 90 patients were extubated within 3 hours. Transfusion requirement was minimal (10 patients). The drains along with all invasive lines were removed the next morning and the patient ambulated. All patients maintained normal sinus rhythm in the postoperative period and 11 VSD patients showed tiny residual shunts at discharge. There were no neurological events. The average hospital stay was about 4 days. De-airing and cardioversion present special problems in MICS and can be minimised with continuous carbon-dioxide insufflation of the operative field. Neonatal internal defibrillators can be used in larger children as well and was useful in 15 of our cases to convert ventricular arrhythmias. There was no phrenic nerve injury in our series. Peripheral cannulation to establish CPB was not required in any of our cases and we think it to be an unnecessary addition to the procedure that can add to the overall morbidity. Initially, in three consecutive cases, the right internal mammary artery had to be sacrificed due to injury and later on more focus was placed on the wider lateral aspect of the intercostal space.

One ASD patient with directly closed ASD was re-explored through a median sternotomy on day 1 after routine bedside transthoracic echocardiogram before transferring to the ward showed a large ASD. This patient had a large new septal defect due to excessive stretch on the directly closed thin septum and was repaired with a pericardial patch. Two patients required secondary suturing for superficial wound infection. All other wounds healed well [Figure 5]. There was no incidence of pericardial effusion in this series. At the time of writing, the study group patients were doing well on first follow-up at the end of first year. Five cases continued to show residual VSD (2 mm in size) on follow-up and are asymptomatic. No patients complained of breast deformity or loss of sensation in the right breast or nipple area. There was no evidence of chest deformity at this stage of follow-up.

Table 2 Operative Data.

Variable	Mean	Range
Cardiopulmonary bypass time	64.78 ± 22.22	30–175
Aortic cross clamp time	37.64 ± 18.30	14–135
Body surface area	0.97 ± 0.62	0.5–1.7

Discussion

Minimally invasive surgical techniques, with or without cardioscopy, have received much attention in the surgical community over the last decade. The stated goal has been to improve the cosmetic results, reduce pain and recovery time and to reduce the length of hospitalisation. Of all these factors, improved cosmetic results have proven to be the most objective outcome of these surgical approaches. While there have been some studies to evaluate the differences in pain and hospital or intensive care unit length of stay, no objective differences between the various approaches have been noted in children, even in comparison to full sternotomy [6]. A wide variety of minimal access approaches have been described including lower sternotomy [7], trans-xyphoid approach [8], anterior or lateral thoracotomy [9]

Figure 5 Right anterior mini thoracotomy scar at the time of discharge.

and transaxillary incisions [10]. An array of techniques for management of cardiopulmonary bypass, cardiac arrest and de-airing procedures have also been described. Extracorporeal circulation is used in all cases either with cardioplegic or fibrillatory arrest of the heart and manoeuvres to remove air from the left side of the heart are required prior to resuming ejection. With advancing technology, more and more of these types of defects are closed using a catheter-based device, with improving results. For the surgeon, the choices for incision are many and in experienced hands, the risks and results should be the same as for a full sternotomy approach. However, awareness of the potential pitfalls with each of the alternative approaches is mandatory since each one has different limitations for exposure to the heart and intracardiac structures, and potential for injury to adjacent structures.

Chest scars have significant adverse psychological consequences and social impact on growing boys and girls especially in this part of the world where a visible scar may make one's prospect of advancing in life difficult. Minimally invasive surgery is a good alternative but is limited to a small percentage of surgeons. Several authors have used RAMT similar to our approach but with larger incisions [11,12]. This study lists wider indications for a limited RAMT approach than for only ASD closure. This incision is preferable in most of the straightforward and non-syndromic cases and results in a small and obscure scar that is invisible. We applied this technique to ASDs in the initial phases, became comfortable and later extended the same technique to address other defects including RVOT obstructions and subpulmonary VSDs. Despite earlier reports of breast mal-development and loss of sensation in the right breast and nipple area [13,14], lifting the breast tissue along with the pectoralis muscle avoids its distortion and mal-development. In prepubescent girls, the anterior thoracotomy incision is placed below the future development of the breast tissue and the intercostal space entered at a higher level after retracting the pectoralis muscle and breast tissue. The intercostal space is widest laterally and extension of the incision anteriorly is required only to expose the MPA and RVOT. This can be achieved without subluxation of the chondrosternal junction which may result in chest wall deformity [15]. The extra room anteriorly allows the play of instruments and makes easy the placement of an RVOT and MPA patch. Extensive thoracotomies defeat the purpose of surgery and may lead to scoliosis [16]. Traction on stay sutures placed at the pericardial reflection near the aorta and pulmonary artery brings the aorta closer to the incision and makes cannulation easy. The pliability of the chest wall in children and the inner pleural incision facilitates the chest to be opened widely and allows for placing the cannulae ergonomically, providing enough room to affect a good repair. Inferior venacava snaring and cannulation is made remarkably easy with the lung being down and the heart on partial CPB. Persistent left superior venacava is not a contraindication to this approach and is managed by passing a cannula through the coronary sinus and securing it by a suture at the opening of the sinus. In the current series, the incision ranged from 6 to 7 cms. There has been no compromise in intracardiac technique or precision of repair in this series. The de-cannulation process is the reverse of initial cannulation and all surgical sites are suture enhanced for safety. The pericardium is closed fully along its line of opening and only a small part left open to drain near the IVC. This approach has now been used to cover a wider range of congenital cardiac lesions involving the MPA and RVOT.

Limitations of this Study

The main limitation of this study is its retrospective nature with limited follow-up. All the patients are under medical supervision by family doctors with no reported mortality after discharge from hospital. The effects of RAMT after skeletal maturation of the thoracic cage have to be watched though the operative surgical trauma is small.

Conclusion

Our study shows the feasibility of RAMT without peripheral cannulation in treating wider congenital cardiac lesions in a safe and reproducible way without compromising on the quality of the outcome. An additional benefit of RAMT was the less visible scar that provides good cosmesis and psychosocial satisfaction. The long-term morbidities of extensive thoracotomy and sternotomy are avoided with better pain control and rapid return to normal activities. Multidisciplinary coordinated team-work comprising cardiac surgeons, perfusionists, intensivists, anaesthesiologists, cardiologists, nurses, and psychologists are needed at all stages of treatment with the goal to treat more and hurt less.

Disclosures

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