Cardiology in the Young

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Mini right axillary thoracotomy for congenital heart defect repair can become a safe surgical routine

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Abstract

Objective: Owing to its obvious cosmetic appeal, minimal invasive repair of congenital heart defects (CHDs) through the mini right axillary thoracotomy is becoming routine in many centres. Besides cosmesis, and before becoming a new norm, it is important to establish its outcomes as safe compared to repairs through traditional median sternotomy. *Methods:* Between 2013 and 2021, 116 consecutive patients underwent defect repairs through mini right axillary thoracotomy. Patient, operative data, and hospital outcomes were compared to contemporary mini right axillary thoracotomy and sternotomy series. *Results:* There was no mortality or need for approach conversion (mean age 4.3 years, range 0.17–17, mean weight 18.6 kg, range 4.8–74.4) in 118 repairs for atrial septal defect, ventricular septal defect, partial anomalous pulmonary venous return, partial atrioventricular canal with mitral cleft, scimitar syndrome, double-chambered right ventricle, cor triatriatum, and tricuspid valve repair. Protocol included on-table extubation, achieved in 97 children, with 23 outliers leading to 0.7 average hours of mechanical ventilation (range 0–66 hours), indwelling chest drain time of 2.6 days (range 1–9 days), intensive care stay of 1.8 days (range 1–10 days), and hospital stay of 3.9 days (range 2–18 days). Late revisions were required in one patient after scimitar repair for scimitar vein stenosis at 2 weeks, and in another for repair of superior caval vein stenosis after a Warden operation at 2 months; reoperations (5/116 = 4.3%) were successfully performed through the same mini right axillary incision. *Conclusions:* While providing obvious cosmetic advantages, the minimally invasive right axillary thoracotomy approach for the surgical repair of common CHDs yields excellent results and is safe compared to the benchmark median sternotomy approach.

Median sternotomy has long been the primary approach to perform various congenital heart lesions. However, this traditional surgical approach not only results in a longer and very visible scar but also possibly in long-term sternal deformity and psychological burden in children and adolescents with their increasing physical self-awareness.[1,2] With development of better surgical techniques and experience gained from the adult cardiac surgical world,[3] minimally invasive surgery is getting more traction as an alternative approach for the repair of many types of the most common CHDs in the paediatric population.[1–9] Despite initial concerns regarding reduced surgical exposure with minimally invasive cardiothoracic surgery, improvements in perfusion techniques, echocardiography imaging, and the development of necessary and specialised surgical instruments have rendered the operation safer, simpler, reproducible, and adopted by an ever-increasing number of surgeons.[1–9] Various minimally invasive approaches including lower mini-sternotomy, right sub-mammary thoracotomy, right axillary thoracotomy, and the anterolateral mini-thoracotomy have been described in the literature.[1–9] As such, there has been recent growth in the published literature regarding outcomes of various minimally invasive approaches versus median sternotomy with relatively similar outcomes based on safety.[10–14] Due to the obvious cosmetic appeal combined with an ever increasing safety profile, minimal invasive repair of congenital heart defects through a mini right axillary thoracotomy is becoming routine in many centres, and even proposed as standard of care in those with experience.[2,4,5]

We describe our current outcomes of the mini right axillary approach for the repair of common CHDs, and suggest it as a safe surgical routine, as otherwise performed classically through median sternotomy.

Materials and methods

Institutional review board approval was obtained before all data collection at three teaching university hospitals, chronologically being the Children's Heart Center at the University of

Mississippi Medical Center, Jackson, MS, Hermann Memorial Children's Hospital, University of Texas Health Science Center at Houston, TX, and Cohen Children's Hospital, New Hyde Park, NY, USA (UMMC #2021V0523, #HSC-MS-19-1082, N #21-0551).

Surgical technique

The details of the approach and technique have previously been described by our group.[4] Briefly, after appropriate anaesthesia and endotracheal intubation, all defects and anatomy are confirmed to be repairable through mini right axillary thoracotomy by trans-esophageal echocardiography. Following confirmation, the patient is then positioned in a left lateral decubitus, and the approach involves a muscle-sparing incision made under the right arm in the mid-axillary line, on the border of the latissimus dorsi muscle. The right groin vessels are always prepped and draped in case peripheral cannulation becomes necessary for cardio-pulmonary bypass. The third rib or fourth rib is exposed after dividing fibres of the serratus muscle parallel to the rib, and the respective intercostal space entered. In larger adolescents and young adults, aortic cannulation may be difficult as the aorta is very remote, and placing a cross-clamp or inserting a cardioplegia needle is quite challenging. Accordingly, peripheral arterial cannulation (and sometimes venous) is performed using the prepped right groin vessels, and induced ventricular fibrillation is anticipated. In smaller patients, after intravenous heparin, before standard aortic cannulation, a stay suture is placed on the right atrial appendage, which is retracted caudally, giving better exposure to the ascending aorta. The superior caval vein is cannulated with an angled cannula, and partial bypass commenced, followed by inferior caval vein cannulation and establishment of full bypass.

After either aortic cross-clamping or induced ventricular fibrillation, routine right atrial access is achieved, and various repairs are performed as they otherwise would be through a standard median sternotomy. Weaning from bypass, decannulation, and hemostasis are all standard and equivalent to a repair from the front. All repairs are evaluated by transoesophageal echocardiography and deemed satisfactory prior to decannulation and planned extubation before leaving the operating room.

Measured parameters

Our outcome measures included cardiopulmonary bypass time, aortic cross-clamp or induced fibrillation times, intubation time, length of chest tube drainage, length of intensive care, and hospital stay. All data were analysed, and measurement data were expressed as mean and range.

Results

Between 2013 and 2021, 116 consecutive patients (62 females, 54 males) underwent common CHD repairs through mini right axillary thoracotomy in three different institutions, namely at the Children's Heart Center of the University of Mississippi Medical Center, Jackson, MS (2013–2018), Hermann Memorial Children's Hospital, University of Texas Health Science Center at Houston, TX (2018–2020), and Cohen Children's Hospital, New Hyde Park, NY (2020–2021), USA. Ages ranged from 0.17 to 17 years (mean, 4.3 years) and body weights ranged from 4.8 to 74.4 kg (mean, 18.6 kg). There was no mortality. Surgical procedures were completed as planned, without need of conversion to median sternotomy. The diagnoses included ventricular septal defect (n = 44), atrial septal defect (n = 33), partial anomalous pulmonary venous return (n = 17), double-chambered right ventricle (n = 10), partial atrioventricular canal defect (n = 6) with mitral cleft (n = 3), cor triatriatum (n = 2), scimitar syndrome (n = 2), and tricuspid valve repair (n = 1).

Procedural protocol for mini right axillary thoracotomy included on-table extubation achieved in 97 children, with 23 outliers leading to the total group averaging 0.7 hours of mechanical ventilation (range 0–66 hours), induced ventricular fibrillation time of 25.9 minutes (range 7–60 minutes), aortic cross clamp time of 59.4 minutes (range 1–225 minutes), cardiopulmonary bypass time of 104.6 minutes (range 25–386 minutes), indwelling chest drain time of 2.6 days (range 1–9 days), intensive care stay of 1.8 days (range 1–10 days), and hospital stay of 3.9 days (range 2–18 days).

Early complications included one heart block and diaphragmatic paralysis in the same patient with an inlet ventricular septal defect and unknown syndrome with microdeletion, requiring insertion of a pacemaker and diaphragmatic plication during the same admission, and two patients with baffle leaks after low sinus venosus/partial anomalous pulmonary venous return repair also requiring baffle revisions during the same admission. Late revisions during a separate hospital admission were required in one patient after scimitar repair for scimitar vein stenosis at 2 weeks, and in another for repair of superior caval vein stenosis after a Warden operation at 2 months. Importantly, all reoperations (5/116 = 4.3%) were successfully performed through the same mini right axillary incision and did not require an additional incision or scar, including the one patient who needed an epicardial dual chamber pacemaker system. This approach, although through the mirror image left axillary incision, has been extensively described as an elective primary approach for left heart epicardial pacing systems in the senior author's prior experience [15,16] (Table 1).

Discussion

Most congenital cardiac surgery is performed through a traditional median sternotomy, as the approach through this incision provides excellent exposure. However, median sternotomy confers a poorer cosmetic outcome and the possibility of postoperative respiratory dysfunction, chronic pain, and deep sternal wound infections.[3] With the advent of modern surgical techniques and instruments, minimally invasive approaches for common congenital heart lesions are gaining favour. In our experience with minimal invasive incisions, the mini right axillary approach is preferred because it is far from breast tissue with reduced risk of asymmetrical breast growth,[1] it is muscle sparing with the exception of a few fibres of the serratus anterior, is associated with rapid functional recovery of the right shoulder and arm, and the cosmetic results are highly appreciated.[2,4] With gained expertise and surgeon comfort, the same high standards as through a median sternotomy are maintained without compromising repair quality.[2,4]

Our current series cover the consecutive experience with minimally invasive approaches from three different North American centres spanning 8 years. Comparing our results and some of the previously published minimally invasive series,[1–9] with repairs

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Table 1. Perioperative variable description among minimal invasive series.

Study	Year of publication	Number of pts/cases	Approach	Age	Weight (kg)	LOS (days)	Intubation time (hours)	Aortic cross clamp time (minutes)	Cardiopulmonary bypass time (minutes)
Lee	2018	358	Right transverse axillary	5	17	3			49
Chang	1998	60	Right Sub mammary thoracotomy	18.8	36.2	5.1	5.1		42
		58	Median sternotomy	17.3	34.7	8	8.2		27
Beşir	2019	15	Right anterior thoracotomy			3.7	7	35.5	67.1
		29	Median sternotomy			6.3	10.6	41	66.3
Our study		116		4.3	18.6	3.9	0.7	59.4	104.6

done through median sternotomy,[10–14] the most common denominator is the shortened intubation time and length of hospital stay for the minimal invasive series.

The minimally invasive approach often results in one-lung ventilation physiology in order to fully expose the surgical field during the intra-cardiac phase of repair, with atelectasis, and intuitive potential for lung injury. The ventilated lung is exposed to higher strain secondary to large, non-physiologic tidal volumes and the loss of the normal functional residual capacity. Re-expansion of the collapsed lung at the end of repair prior to coming off from cardiopulmonary bypass after one-lung ventilation may invariably induce duration-dependent ischaemia–reperfusion injury.[17] Intuitively, lung injury could be more severe during minimally invasive approaches, leading to longer intubation times and corresponding intensive care stays, compared to median sternotomy group. However, in cardiac surgery, lung damage is mainly ascribed to two factors: cardiopulmonary bypass times and sternotomy.[18] Indeed, the meta-analyses have shown shorter intubation times in the mini-thoracotomy groups versus patients after median sternotomy,[10–14] thereby implying at least no clinically detectable effect from lung injury during minimally invasive procedures that require some portion of procedural time under one lung physiology. All the relevant recent series describing the minimal invasive thoracotomy approaches seem to support this, with shorter to no post-operative intubation times and corresponding shorter intensive care and hospital stays.[5,6,8–14]

In their meta-analysis, Lei et al. compared the anterolateral mini-thoracotomy approach versus median sternotomy for the surgical treatment of atrial septal defects and concluded that they were equally safe and effective in terms of success rates and severe complication rates.[12] The surgical procedures were equally difficult (no significant difference in the operation time between the two groups), but the anterolateral mini-thoracotomy approach was associated with significantly faster functional recovery and a better cosmetic result. Severe complication rates, defined as reoperation for bleeding, severe residual disease, neurological complications, and renal failure, were comparable between the two groups ($p = 0.56$).[12] The intubation time in the mini-thoracotomy group was 1.82 hours less than that in the median sternotomy group ($p = 0.005$). The length of ICU stay was significantly shortened by 0.24 days in the mini-thoracotomy group, compared with the median sternotomy group ($p = 0.02$). The length of postoperative hospital stay was also significantly shortened by 2.45 days in the mini-thoracotomy group ($p < 0.001$). In terms of cosmetic results, the mini-thoracotomy group showed a significantly shortened incision length.

In a meta-analysis and systematic review comparing the mini anterolateral thoracotomy to median sternotomy by Ding et al., 932 patients were included.[13] Despite longer aortic cross-clamp time (2.38 minutes more; $p = 0.06$) and significantly longer cardiopulmonary bypass times with the anterolateral mini-thoracotomy (8 minutes more; $p = 0.04$), the minimal invasive approach showed more benefits compared to median sternotomy, by reducing intubation time and post-operative length of hospital stay.

Lee et al. published their extensive experience ($n = 358$) using the right axillary approach in patients as a safe and effective alternative to the median sternotomy for a diverse array of congenital cardiac defects, including atrial septal defect, ventricular septal defect, subvalvular aortic membrane resection, Tetralogy of Fallot repair, ventricular assist device placement, and mitral valve repair.[5] There were no intraoperative deaths or conversions to sternotomy. In-hospital complications included mortality ($n = 1$; 0.3%), reoperations for bleeding ($n = 5$; 1%), pneumothorax or pleural effusion ($n = 6$; 2%), and permanent pacemaker ($n = 4$; 1%). Successful extubation in the operating room occurred in 342 patients (96%), with 6 patients (2%) requiring reintubation postoperatively. The median postoperative length of stay was 3 days (range 2–44 days), with 254 patients (71%) discharged within 3 days (Table 1).

As with introducing any new technique, during the early development of the minimally invasive right axillary approach, our goal was to demonstrate its safety and reproducibility at or above the gold standard hospital outcomes of median sternotomy. The goal of congenital cardiac surgery is safety with excellent outcomes and providing patients with improved quality of life. Several reports from groups who perform variations of our minimally invasive technique have presented similar if not better data related to the length of tracheal intubation, duration of ICU, and hospital length of stay. These results are consistent with our study. We did not have any mortality; however, one of our patients developed heart block and required pacemaker placement ($n = 1/116$; 0.86%), which is comparable to that experienced and accepted after repairs through median sternotomy.

In contrast to the anterolateral mini-thoracotomy, the vertical mini right axillary thoracotomy preserves the mammary gland

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tissue and breast tissue and thus allows normal breast development.[1,2,4]

Conclusion

While providing clear cosmetic advantages, the minimally invasive right axillary thoracotomy approach for the surgical repair of common congenital heart lesions yields excellent results in the paediatric population. Our data compare well to other contemporary studies using various minimally invasive approaches.[1–9]

For minimal invasive approaches to garner widespread acceptance, popularity and even a push towards becoming the norm, the results must be perfect, or at least as good as through the extant classical median sternotomy. To accomplish this, it must demonstrate comparable or better safety, comparable or lesser need for reoperation on residual lesions, minimal or lesser morbidity, and be reproducible. Additionally, through enhanced comfort for the patient, can an elective and very low risk cardiac repair become commonplace and the new norm, when compared to a more classically established approach.

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Conflicts of interest. None.

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