

## EVALUATION OF TREATMENT OUTCOMES IN VENTRICULAR SEPTAL DEFECT CLOSURE THROUGH MINIMALLY INVASIVE RIGHT AXILLARY THORACOTOMY

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### ABSTRACT

**Background:** Ventricular septal defect (VSD) is the most common congenital heart anomaly requiring surgical intervention. While median sternotomy remains the conventional approach, minimally invasive techniques through right axillary thoracotomy have emerged as viable alternatives offering superior cosmetic outcomes. This study aimed to evaluate the safety, feasibility, and early outcomes of VSD closure through minimally invasive right vertical axillary thoracotomy at our institution.

**Methods:** A prospective descriptive study was conducted on 33 consecutive pediatric patients who underwent VSD closure through right vertical axillary thoracotomy at Hue Central Hospital from January 2025 to December 2025. Patients with isolated VSD (diameter  $\geq 4$  mm) were included. Patient demographics, operative parameters, postoperative outcomes, and echocardiographic follow-up data were collected and analyzed.

**Results:** The study included 33 patients with a mean age of  $28.0 \pm 30.0$  months (range: 1-97 months). VSD types were perimembranous (48.5%) and infundibular (51.5%). All procedures were completed without conversion to sternotomy. Mean cardiopulmonary bypass and aortic cross-clamp times were  $49.2 \pm 9.1$  and  $31.7 \pm 7.9$  minutes, respectively. There was no mortality, no complete heart block, and minimal complications (pneumonia 3.0%, pneumothorax 3.0%). Complete VSD closure was achieved in 87.9% at discharge, improving to 90.6% at one-month follow-up. Pulmonary artery pressure significantly decreased from  $39.7 \pm 18.5$  mmHg preoperatively to 25.6 mmHg at follow-up.

**Conclusion:** Minimally invasive VSD closure through right vertical axillary thoracotomy is a safe and effective approach with excellent early outcomes. The technique is applicable across a wide age spectrum and for both perimembranous and infundibular VSDs, offering substantial cosmetic advantages for pediatric patients.

**Keywords:** Ventricular septal defect, minimally invasive cardiac surgery, right axillary thoracotomy, congenital heart disease, pediatric cardiac surgery.

### I. INTRODUCTION

Ventricular septal defect (VSD) represents one of the most prevalent congenital cardiac anomalies, often necessitating surgical intervention to prevent complications such as heart failure or pulmonary hypertension [1]. Conventional repair through

median sternotomy has been the gold standard, offering direct access but at the cost of a prominent scar and potential long-term skeletal deformities [2]. In recent years, minimally invasive techniques have gained traction, aiming to minimize trauma while maintaining repair efficacy [3, 4].

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The right axillary thoracotomy approach, in particular, has emerged as a promising alternative, providing superior cosmetic results by concealing the incision under the arm and avoiding interference with breast development [2, 5]. Initial applications were limited to atrial septal defects, but extensions to VSD closure have demonstrated feasibility across various defect types, including perimembranous and infundibular [4, 6]. Studies have reported reduced hospital stays, faster recovery, and comparable hemodynamic outcomes to traditional methods [7, 8]. However, concerns persist regarding visualization in small infants, potential phrenic nerve injury, and residual shunts [9].

This study evaluates early outcomes of VSD closure via right vertical axillary thoracotomy at a Vietnamese tertiary center, synthesizing local data with global evidence to assess safety and effectiveness [10, 11].

## **II. SUBJECTS AND METHODS**

### **2.1. Study Population**

The study population comprised pediatric patients diagnosed with VSD who underwent VSD closure through minimally invasive right axillary thoracotomy at the Department of Thoracic and Cardiovascular Surgery, Hue Central Hospital from January to November 2025

**Inclusion criteria:** Pediatric patients with isolated ventricular septal defect; Moderate to large VSD with diameter  $\geq 4$  mm confirmed by transthoracic echocardiography. Complete medical records and research documentation.

**Exclusion criteria:** Patients with other complex congenital heart diseases; Patients with suspected Eisenmenger syndrome; Previous surgical history involving the right thoracic

region; Patients or guardians who did not consent to participate in the study or refused to cooperate with the research

### **2.2. Study Design and Data Collection**

This was a descriptive cross-sectional study. A convenience sampling method was employed. All consecutive patients meeting the inclusion criteria during the study period were enrolled in the study. Data were collected prospectively from medical records, operative reports, and echocardiographic databases. Variables included demographic characteristics, preoperative clinical status, echocardiographic parameters, operative details, and postoperative outcomes.

### **2.3. Surgical Technique**

Patients were positioned in left lateral decubitus with the right arm elevated. A 5-cm vertical skin incision was made along the right axillary line, dissecting through latissimus dorsi and serratus anterior to enter the fourth intercostal space. Central cannulation (aortic and bicaval) was performed via the operative field. Antegrade cold blood cardioplegia was administered. VSD closure used bovine pericardial patches via right atriotomy (trans-tricuspid) or ventriculotomy, depending on location. Tricuspid annular detachment was employed for enhanced exposure in select cases.

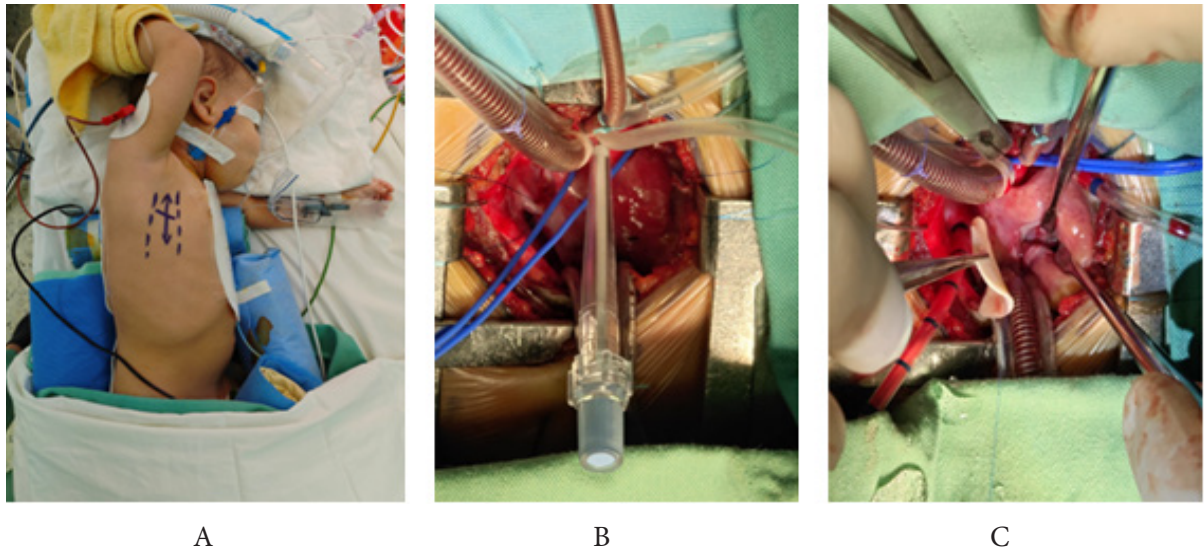
### **2.4. Statistical Analysis**

Data analysis utilized SPSS version 22.0. Categorical variables were expressed as frequencies and percentages; continuous variables as means  $\pm$  standard deviations.

### **2.5. Ethical Considerations**

The study complied with institutional and international ethical standards. Approval was obtained from the Institutional Scientific Committee of Hue Central Hospital in June 2025.

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**Figure 1:** Images of VSD closure through right axillary thoracotomy.

A. Patient positioning: Patients were positioned in the left lateral decubitus position with the right arm elevated and secured above the head; B. Establish extracorporeal circulation between the ascending aorta and 2 vena cava, cardioplegia needle placed in ascending aorta; C. VSD closure using bovine pericardial patch.

**III. RESULTS**

A significant proportion (42.4%) were infants under 6 months, highlighting the approach’s use in young patients. Elective cases were most common, reflecting early detection and planned intervention. Most patients were in compensated states, with few severe cases. Defects were evenly distributed by type, with good ventricular function overall (Table 1).

**Table 1:** Patient Demographics and Preoperative Characteristics

	<b>Variable</b>	<b>Value</b>
Age (months)	< 6 months	14 (42.4%)
	6-12 months	3 (9.1%)
	≥ 12 months	16 (48.5%)
	Mean ± SD	28.0 ± 30.0
	Range	1 - 97
Sex	Male	23 (69.7%)
Reasons for admission	Dyspnea with exertion/feeding	6 (18.2%)
	Failure to thrive	1 (3.0%)
	Poor feeding	2 (6.1%)
	Recurrent pneumonia	8 (24.2%)
	Known VSD (elective)	16 (48.5%)
Medical history	Down syndrome	2 (6.1%)

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Variable		Value
Heart Failure Classification	Class I	21 (63.6%)
	Class II	10 (30.3%)
	Class III	2 (6.1%)
	Class IV	0 (0%)
Preoperative Echocardiographic Parameters		
VSD anatomical type	Perimembranous	16 (48.5%)
	Infundibular (outlet)	17 (51.5%)
Number of defects	Single	33 (100%)
VSD diameter (mm)	Mean $\pm$ SD	6.2 $\pm$ 2.3
	Range	3.0-12.0
Left ventricular ejection fraction (%)	Mean $\pm$ SD	64.2 $\pm$ 2.6
	Range	56 - 68
Pulmonary artery systolic pressure (mmHg)	Mean $\pm$ SD	39.7 $\pm$ 18.5
	Range	25 - 90

Patch closure was performed as standard, with no major intraoperative issues. No patient required conversion to median sternotomy (Table 2).

Low complication rates and short ventilation times indicate good recovery (Table 3).

**Table 2:** Surgical Approach and Intraoperative Parameters

Variable		Value
Closure technique	Direct closure	0 (0%)
	Bovine pericardial patch	33 (100%)
VSD exposure approach	Trans-tricuspid (right atriotomy)	19
	Right ventriculotomy	11
	Tricuspid annular detachment	3
Cardiopulmonary bypass time (min)	Mean $\pm$ SD	49.2 $\pm$ 9.1
	Range	31.0 - 70.0
Aortic cross-clamp time (min)	Mean $\pm$ SD	31.7 $\pm$ 7.9
	Range	20 - 50

**Table 3:** Postoperative Outcomes and Complications

Variable		Value
Mechanical ventilation (hours)	Median	6
	Range	1 - 61
Postoperative complications	Pneumonia	1 (3.0%)
	Pneumothorax	1 (3.0%)
Inotropic support	Adrenaline only	1 (3.0%)
	Milrinone only	3 (9.1%)
	Adrenaline + Milrinone	2 (6.1%)

High rates of complete closure and function recovery at follow-up (Table 4).

**Table 4:** Postoperative Echocardiographic Results

Variable		Discharge	1-Month Follow-up
Residual shunt (mm)	None	29 (87.9%)	29 (90.6%)*
	≤ 2 mm	4 (12.1%)	3 (9.4%)*
	> 2 mm	0 (0%)	0 (0%)
LVEF (%)	Mean ± SD	58.7 ± 5.5	64.1 ± 3.0
	Range	40 - 65	55- 69
PAPs (mmHg)	Mean	27.6	25.6
	Range	25.0 - 40.0	25 - 35
*Follow-up data for 32 patients			

#### IV. DISCUSSION

The pursuit of minimally invasive strategies in pediatric cardiac surgery seeks to balance surgical precision with reduced physical and psychological impact on young patients [3, 12]. Our series illustrates that the right vertical axillary thoracotomy enables robust VSD repair across varied ages, including a substantial infant cohort (42.4% under 6 months), without elevating operative risks. This method leverages a concealed incision to enhance aesthetics, potentially alleviating long-term body image concerns common with midline scars [2].

The most direct way to appreciate the benefits of this approach is to contrast our outcomes with

prior institutional experience using conventional median sternotomy. In our previous institutional study conducted several years earlier, Trần Hoài Ân et al. reviewed 235 children weighing under 5 kg who underwent open cardiac surgery via median sternotomy, of whom 80.5% had VSD as the primary lesion. The authors reported a mean cardiopulmonary bypass time of 75.0 ± 42.0 minutes, mean aortic cross-clamp time of 44.0 ± 29.1 minutes, a mean intensive care stay of 6.0 ± 7.9 days, and an overall in-hospital mortality of 6.8%, with low cardiac output syndrome accounting for 73.3% of deaths [13]. Acknowledging that the earlier cohort was younger and more heterogeneous

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in lesion complexity, the comparative figures in our current minimally invasive series are consistently more favorable. Cardiopulmonary bypass time was  $49.2 \pm 9.1$  minutes. Cross-clamp time was  $31.7 \pm 7.9$  minutes. Median ventilation time was 6 hours. There was no mortality. Only two minor pulmonary complications were observed, including pneumonia 3.0% and pneumothorax 3.0%. Beyond these perioperative metrics, median sternotomy carries the well-described risks of sternal wound infection, sternal dehiscence, and long-term pectus deformities, none of which were encountered in our cohort. Combined with the cosmetic advantage of a 5-cm scar concealed under the arm and away from breast tissue, these data suggest that the right vertical axillary thoracotomy is not merely a cosmetic alternative but offers tangible perioperative gains over conventional sternotomy at our center.

International literature reinforces these observations and helps situate our results within the broader experience. Kadner et al., who pioneered restrictive VSD closure through right axillary thoracotomy, reported median cross-clamp and bypass times of 46 and 104 minutes in 22 older children, with no mortality and no residual defects on follow-up [4]. Aydin et al. closed 24 VSDs through right lateral minithoracotomy with median bypass and cross-clamp times of 81 and 65 minutes, no perioperative death, and only one minimal (2 mm) residual shunt [7]. Heinisch et al. directly compared 15 VRAMT cases with 35 median sternotomy cases for VSD repair. Cross-clamp times were comparable (41 vs 36 minutes,  $p=0.182$ ). Bypass time was modestly longer in the VRAMT group (77 vs 63 minutes,  $p=0.015$ ). Median ventilation time was nearly halved (24 vs 43 hours,  $p=0.043$ ). Neither wound infection nor thoracic deformity was observed in either group [14]. Lee et al., in the largest series to date with 358 patients undergoing right transverse axillary repair for 24 different congenital lesions, reported no intraoperative deaths, no conversion to sternotomy, an in-hospital mortality of 0.3%, and a median postoperative stay of 3 days, supporting the proposition that the axillary incision can serve as a standard of care for selected defects [12]. For the technically more demanding doubly committed

subtype, Nguyen UH et al. likewise demonstrated in a matched comparison of 37 versus 37 patients that closure through the pulmonary trunk via right vertical infra-axillary thoracotomy was associated with significantly shorter mechanical ventilation than median sternotomy ( $11.9 \pm 8.2$  vs  $15.4 \pm 6.3$  hours,  $p = 0.006$ ), with no mortality and no need for conversion [6]. Our bypass and cross-clamp times fall at the shorter end of these published ranges, plausibly reflecting the predominantly isolated VSD anatomy in our cohort, the use of central cannulation through the same incision, and the standardized surgical workflow at our center.

Within Vietnam, two recent series provide directly comparable benchmarks. Trần Thiện Đạt et al., reporting 106 children operated via right anterolateral thoracotomy at the E Hospital Cardiovascular Center, recorded mean bypass and cross-clamp times of  $70.2 \pm 28.0$  and  $45.7 \pm 26.0$  minutes, a residual shunt rate of 5.7% (all < 2 mm), normalization of pulmonary artery pressure in 89.1% of patients, and family satisfaction reaching 95.7% at 3 - 12-month follow-up [10]. Đỗ Anh Tiên et al., focusing on the more challenging subgroup of 62 infants under 6 months at the same center, reported mean bypass and cross-clamp times of 68 and 46 minutes, an 88.7% complete closure rate, no mortality, and resolution of pulmonary hypertension in all but one patient [11]. Our series with 14 of 33 patients (42.4%) younger than 6 months achieves comparable safety with zero mortality and 87.9% complete closure at discharge rising to 90.6% at one month, with shorter bypass and cross-clamp times. These findings suggest that this technique can be replicated effectively across Vietnamese centers. The drop in mean systolic pulmonary artery pressure from  $39.7 \pm 18.5$  mmHg preoperatively to 25.6 mmHg at follow-up echoes the favorable hemodynamic remodeling described in these reports and aligns with the broader principle that timely closure of a sizeable left-to-right shunt prevents progression toward fixed pulmonary vascular disease.

Several operative considerations deserve specific mention. Tricuspid annular detachment, employed in 3 of our 33 patients to improve VSD exposure, has been shown by Koshy et al. to be a safe maneuver with negligible incremental regurgitation

risk when meticulously reapproximated [15]. The risk of phrenic nerve injury, formally documented at approximately 31% in older children undergoing right thoracotomy for ASD repair by Helps et al. [9], reinforces our routine practice of opening the pericardium 1-2 cm anterior to the phrenic nerve and avoiding diathermy in its vicinity. No diaphragmatic palsy was observed in our cohort. The persistence of small ( $\leq 2$  mm) residual shunts in 9.4% of our patients at one month should be interpreted in light of the work of Dodge-Khatami et al., who demonstrated that 83% of post-surgical residual VSDs  $< 2$  mm close spontaneously within a median of 3.1 years and remain hemodynamically and clinically irrelevant in the interim [16]. The apparent reduction from 12.1% at discharge to 9.4% at one month in our series is consistent with this natural course. Finally, vertical mini-thoracotomy for VSD and atrioventricular septal variants has been shown by Heinisch et al. to provide cross-clamp times and length of stay equivalent to sternotomy without thoracic deformities at follow-up [14]. Dave et al.'s mid-term data confirm that the right axillary incision preserves chest-wall integrity over years [8].

Our findings align with this body of evidence. There were zero conversions to sternotomy, rare and minor complications, and 90.6% complete closure at one-month follow-up with no haemodynamically significant residuals. Limitations include the modest cohort size, the single-center, single-team design with convenience sampling, and a follow-up window confined to one month. This precludes conclusions about late residual shunts, long-term thoracic morphology, neurodevelopmental outcomes, and family-reported aesthetic satisfaction. Multicenter prospective studies with longer follow-up and ideally including formal cosmetic and quality-of-life assessments would help define the durability of these benefits and establish the right vertical axillary thoracotomy as a routine alternative to sternotomy for isolated VSD in Vietnamese children. Within these constraints, our experience supports the view that this approach merges technical adequacy with the perioperative and cosmetic advantages that families increasingly expect from contemporary congenital heart surgery.

## V. CONCLUSION

Minimally invasive VSD closure through right vertical axillary thoracotomy is safe and effective, with zero mortality, minimal complications, and high closure rates. Applicable across ages and VSD types, it provides substantial cosmetic and psychological advantages for pediatric patients.

## Conflict of interest

The authors declare that they have no conflict of interest.

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