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Article

Relative Factor Analysis of Postoperative Complications in Infants Below 1 Year Undergoing Repair of Ventricular Septal Defect Combined with Other Procedures through a Right Axillary Incision

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Abstract

Background: Compared to the traditional surgical repair of isolated ventricular septal defects, the proportion of complex congenital heart diseases has been increasing due to advancements in diagnostic capabilities and surgical techniques. Concomitant surgeries to correct multiple congenital heart diseases have become the preferred choice. Therefore, the evaluation of the safety of the combined correction of ventricular septal defects with other cardiac anomalies in young children through a right axillary incision and the analysis of related factors of perioperative complications needs to be investigated. **Methods**: A retrospective study was conducted on a single-center patient sample from January 2018 to December 2022 to compare outcomes between infants undergoing isolated ventricular septal defect (VSD) repair via a right axillary thoracotomy (control group) and those undergoing VSD repair combined with other cardiac procedures (experimental group). **Results**: A total of 397 eligible infants were included. After baseline data were matched using propensity score matching, the experimental group (n = 181) and the control group (n = 107) showed no significant differences in intraoperative blood loss, postoperative total drainage, length of hospital stay, duration of ICU monitoring, Vasoactive-Inotropic Score (VIS), predischarge left ventricular ejection fraction, fractional shortening (FS), postoperative severe pulmonary infection, reoperation, mortality, postoperative atrioventricular block, chylothorax, cardiac arrest, pericardial effusion, pneumothorax, pulmonary atelectasis, tricuspid regurgitation, myocardial injury, abdominal effusion, and metabolic acidosis. However, the control group had shorter surgical time [28.00 (90.00, 196.00) *vs*. 140.00 (95.00, 658.00) min, $p < 0.05$], shorter cardiopulmonary bypass time [58.00 (24.00, 114.00) *vs*. 66.00 (33.00, 422.00) min, $p < 0.05$], shorter aortic cross-clamp time [32.00 (17.00, 62.00) *vs*. 37.00 (15.00, 142.00) min, $p < 0.05$], and shorter postoperative mechanical ventilation time [22.00 (0, 99.00) *vs*. 23.00 (3.00, 193.00) h, $p < 0.05$]. The rate of abdominal effusion was lower in the experimental group than in the control group ($p = 0.044$). In the analysis of postoperative complication-related factors, the preoperative grade of tricuspid regurgitation, postoperative mechanical ventilation time, and VIS were positively correlated with abdominal effusion and satisfied the variable ($p < 0.05$) in each of three established models. In the single-factor analysis, both VIS and preoperative lymphocyte count were ($p < 0.1$) related to pericardial effusion; however, in the multi-factor analysis, only VIS met the threshold ($p < 0.05$). Gender, height, and VIS were each associated with pleural effusion ($p < 0.05$). **Conclusion**: The combination of ventricular septal defect repair with other cardiac procedures via a right axillary thoracotomy did not significantly differ from isolated VSD repair in terms of postoperative complications, monitoring, and length of hospital stay. However, increased surgical complexity was associated with longer surgical and mechanical ventilation times. Factors such as tricuspid regurgitation severity, duration of postoperative mechanical ventilation, and VIS were identified as relative factors for postoperative effusion. Additionally, the risk of postoperative pericardial effusion increased with higher VIS, while gender, height, and VIS were identified as relative factors for postoperative chylothorax.

Keywords

right axillary incision; ventricular septal defect repair; congenital heart disease; infant; relative factors

Introduction

With the development of medical advancements over the past twenty years, the right axillary thoracotomy has not only the advantages of preserving aesthetics, avoiding damage to the breast, preventing sunken chest or scoliosis [1], but also its safety is increasing year by year. Initially, it was only applicable to repair simple atrioventricular septal defects. Currently, the incision can be used for effectively correcting complex congenital heart diseases, such as partial or total anomalous pulmonary venous drainage, double-chambered right ventricle, valvuloplasty, persistent

left superior vena cava, and tetralogy of Fallot. The age restriction is gradually being relaxed with advancements in surgical techniques. Initially, surgery was contraindicated for children under 2 years old [2], but now the safety of right axillary incisions for infants aged 3 months is comparable to that of a median sternotomy. Currently, our center has accumulated a certain number of cases involving right axillary incision repair for simple congenital heart disease in young children, with ventricular septal defects being a significant component of our research focus. Compared to traditional surgical repair of simple ventricular septal defects, the proportion of complex congenital heart disease has been increasing due to advancements in diagnostic capabilities and surgical techniques. Similarly, combined surgeries for correcting multiple congenital heart defects have become the preferred choice for most cardiac centers. In addition to reducing the cost of hospitalization by avoiding secondary surgical repair of other intracardiac malformations, combined surgery can also reduce the risk associated with secondary thoracotomy. The aim of this study is to evaluate the safety of the combined correction of ventricular septal defects with other cardiac anomalies in young children and to analyze related factors of perioperative complications, utilizing a right axillary incision.

Material and Methods

Data Source

The data was extracted from the information center database of Beijing Anzhen Hospital, affiliated with Capital Medical University. This database is a comprehensive medical data storage system within the hospital, encompassing all information recordable in the field of cardiovascular disease diagnosis and treatment. This includes patient demographics, diagnostic records, and examination results. The collection and storage of medical information is conducted in a manner that adheres to relevant privacy guidelines, ensuring patient privacy rights are safeguarded. It supports medical personnel in accelerating clinical decision-making, scientific research statistics, and the construction of a medical information platform, thereby promoting the digital transformation of the hospital. The information center continually optimizes the database structure and management mechanisms to enhance data query efficiency and security, and aiding medical personnel in analyzing the progress of disease treatment and prognostic outcomes. This study has been approved by the Ethics Committee of Beijing Anzhen Hospital.

Study Population and Patient Selection

By querying the database from January 2018 to December 2022, 397 cases of infants under 1 year of age who underwent right axillary small incision repair of ventricular septal defects by the same primary surgeon during hospitalization were identified. The specific procedure can be seen in (Fig. 1). Inclusion criteria: (1) Confirmed diagnosis of ventricular septal defect by echocardiography; (2) Other concurrent cardiac malformations in combination with ventricular septal defect meeting the conditions for correction via right axillary incision (excluding coarctation of the aorta, double outlet right ventricle, transposition of the great arteries, and other congenital heart diseases). Since in clinical practice, for the above more complex congenital heart diseases, a mid-sternotomy incision is often chosen, and most of these children have a poor baseline condition, this will affect the authenticity of the inclusion of children undergoing correction through a right axillary incision and the results of propensity score matching; (3) All selected infants are under 1 year of age (excluding 1 year), due to the prevailing viewpoint that children under 2 years old are contraindicated for a right axillary incision, with advancements in medical technology, age restrictions are gradually being relaxed. In order to demonstrate the perioperative efficacy of right axillary incision repair for ventricular septal defects in our center, we chose to analyze pediatric patients under 1 year of age; (4) No history of prior surgery for ventricular septal defect repair in all infants; (5) Infants are free from symptoms of heart failure; (6) No malignant lesions in the liver, kidneys, brain, or lungs; (7) No immune system abnormalities; (8) No missing relevant data; (9) Surgery performed by the same primary surgeon. The purpose of including 45,679 points in the inclusion criteria is to minimize the baseline data differences between the experimental and control groups as much as possible before matching, which is beneficial for obtaining more favorable matched results. This will facilitate the comparison of the impact of the complexity of the surgical repair for congenital heart disease on perioperative efficacy. Based on whether there are other concurrent cardiac malformations requiring surgery, the patients were divided into two groups. Cases of readmission for correction of heart malformations were excluded, resulting in the division of patients into the isolated ventricular septal defect repair group and the ventricular septal defect combined with other cardiac surgery group. The study covers a total of 16 additional cardiac malformation corrective surgeries, including atrial septal defect repair, closure of patent foramen ovale, tricuspid valvuloplasty, mitral valvuloplasty, pulmonary valve repair, closure or ligation of the patent ductus arteriosus, right ventricular outflow tract reconstruction, resection of abnormal muscle bundles in the right ventricle, correction of double-chambered right ventricle (these three surgical operations were collectively classified as right ventricular outflow tract reconstruction due to their similar nature of intervention), subaortic membrane resection, correction of pulmonary vein stenosis, mitral annuloplasty, repair of coronary artery fistula, correction of

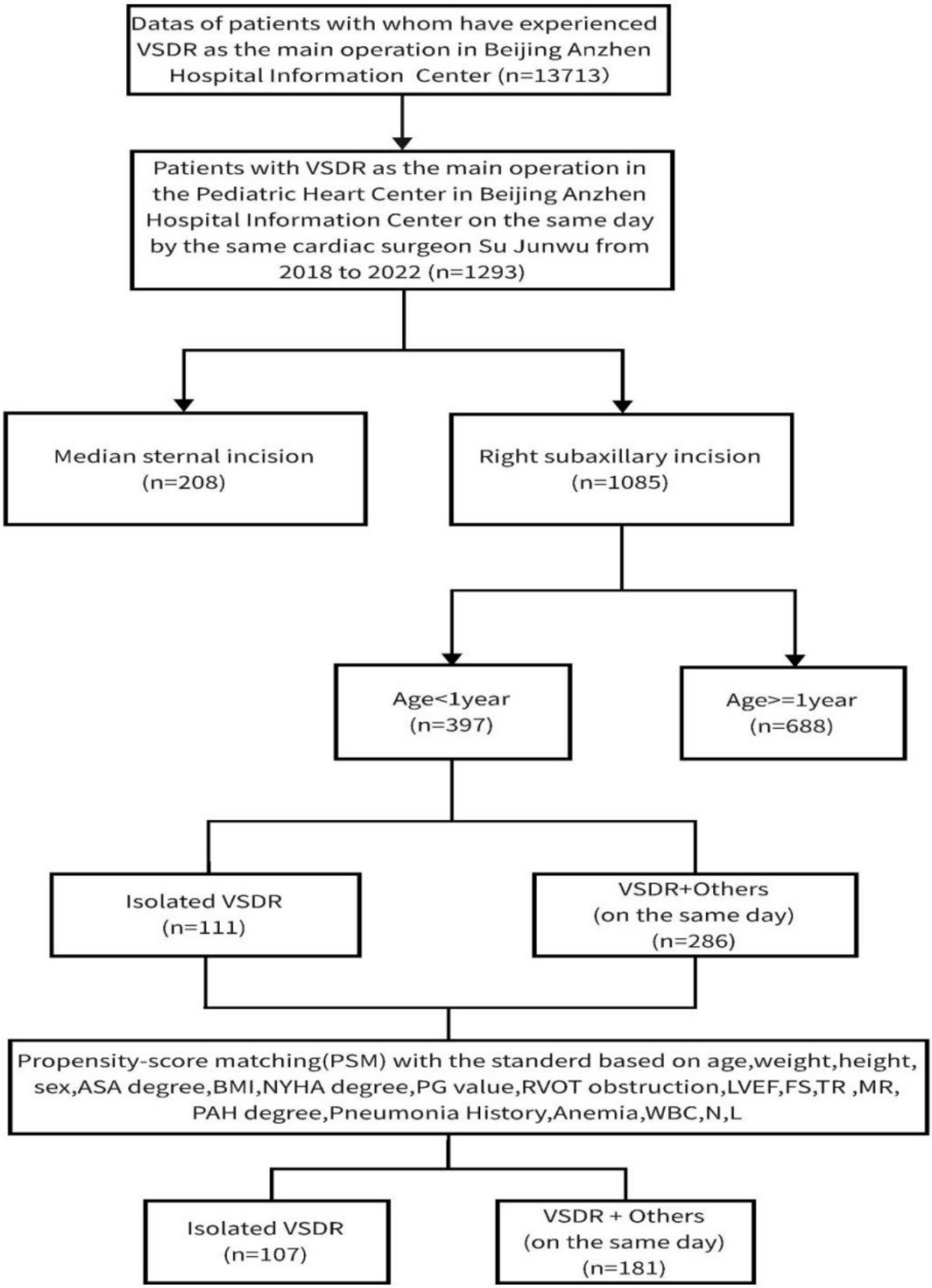

Fig. 1. Study Flow Diagram. BMI, Body Mass Index; ASA, American Society of Anesthesiologists; NYHA, New York Heart Association; RVOT, Right Ventricular Outflow Tract; LVEF, Left Ventricular Ejection Fraction; FS, Fractional Shortening; TR, Tricuspid Regurgitation; MR, Mitral Regurgitation; PAH, Pulmonary Artery Hypertension; WBC, White Blood Cell; N, Neutrophil Count; L, Lymphocyte Count; VSDR, Ventricular Septal Defect Repair.

Table 1. Classification and Number of Pre-matched Cardiac Malformations and Treatment Methods.

Malformation Name		Number of Cases	VSDR				Correction Of Combined Deformities															Non-correction Number
							ASDR		PFOS	RVOTP		PDA		MVP	TVP	SMR	SMR		PLSVC		Others	
			DS	PS1	TTV	TRV	DS	PS1	DS	TTV	VI T NT	DL	S				TTV	TAV	DL	D		
Main Malformation	VSD	397		397	397																	0
Minor Malformation	ASD	50					37	12														1
	PFO	144							142													2
	MI	45												40								5
	TI	28													28							0
	SM	50															47					3
	PDA	40										37	3									0
	PLSVC	20																				20
	DCRV	8								8												0
	AMBRVOT	30								26												4
	SRVOT	2								2												0
	PS	10														6						4
	Others	9																			8	1

VSD, Ventricular Septal Defect; ASD, Atrial Septal Defect; PFO, Patent Foramen Ovale; MI, Mirtal Insufficiency; TI, Tricuspid Insufficiency; SM, Subaortic Menbrane; PDA, Patent Ductus Arteriosus; PLSVC, Persistent Left Superior Vena Cava; DCRV, Double Chamber Right Ventricle; AMBRVOT, Abnormal Muscle Bundles of Right Ventricular Outflow Tract; SRVOT, Stenosis of Right Ventricular Outflow Tract; PS, Pulmonary Stenosis; VSDR, Ventricular Septal Defect Repair; ASDR, Atrial Septal Defect Repair; PFOS, Patent Foramen Ovale Suture; PS1, Patch Suture; DS, Direct Suture; TTV, Trough Tricuspid Valve; RVOTP, Right Ventricular Outflow Tract Patency; VI, Ventricular Incision; T, Transannular; NT, Non-Transannular; DL, Direct Ligation; S, Suture; MVP, Mirtal Valvuloplasty; TVP, Tricuspid Valvuloplasty; PVR, Pulmonary Valvuloplasty; SMR, Subaortic Menbrane Resection; TAV, Through Aortic Valve; D, Drainage.

triatrial heart, repair of persistent truncus arteriosus, and cases that combine multiple procedures. The specific cardiac malformations and their correction methods are outlined in detail in Table 1.

Study Outcome

The study results cover preoperative data, perioperative data (including postoperative echocardiography results), and the incidence of postoperative complications, and evaluation of the surgical outcomes and safety through these three categories of indicators:

Preoperative data: age at admission, gender, height, weight, and classification (≤5 kg low weight; 5–20 kg normal weight), Body Mass Index (BMI), body surface area (calculated using the DuBois formula [3]), preoperative New York Heart Association (NYHA) functional classification (I; II; III; IV), preoperative left ventricular ejection fraction (LVEF), preoperative pulmonary artery valve pressure difference (PAP), length of ventricular septal defect, left-to-right shunt pressure gradient at the ventricular level (PG) and classification (PG ≤30 mmHg defaults to non-restrictive ventricular septal defect; PG >30 mmHg indicates restrictive ventricular septal defect (Vaidyanathan *et al*., 2002 [4]), presence of preoperative right ventricular outflow tract obstruction, preoperative left ventricular fractional shortening (FS), tricuspid regurgitation (<moderate default is non-influential; ≥moderate is influential), mitral regurgitation (<moderate default is non-influential; ≥moderate is influential), aortic valve regurgitation (all less than moderate defaults to non-influential), history of pneumonia, history of anemia, white blood cell and neutrophil gender, lymphocyte level in blood routine examination performed within three days before surgery. Left ventricular fractional shortening (FS) = [(left ventricular end-diastolic diameter LVEDD – left ventricular end-systolic diameter LVESD)/left ventricular end-diastolic diameter LVEDD] × 100%, normal range 25–45% [5].

Perioperative data: Intraoperative information: operation time, cardiopulmonary bypass time, aortic cross-clamp time, intraoperative blood loss, occurrence of cardiac arrest, delayed sternal closure. Postoperative information: duration of mechanical ventilation, length of ICU stay, postoperative hospital stay, total postoperative drainage amount, vasoactive-inotropic score (VIS), postoperative left ventricular ejection fraction, postoperative fractional shortening (FS), postoperative aortic valve regurgitation, degree of postoperative mitral valve regurgitation, degree of postoperative tricuspid valve regurgitation. The vasoactive-inotropic score is used to indirectly evaluate the stability of the child's circulatory system during the intensive care unit (ICU) special nursing period by assessing the use of vasoactive medications. Some researchers have determined through prospective studies that, to a certain extent, this score can be used as a predictor of postoperative low cardiac output syndrome [6]. Additionally, related research indicates that the maximum value of the vasoactive-inotropic score per hour within the first 48 hours after entering the cardiac intensive care unit can serve as a good predictor for common postoperative complications and mortality [7]. The vasoactive-inotropic score is calculated according to the formula of Tóth *et al*. [8]: VIS = dopamine (μg/kg/min) + dobutamine (μg/kg/min) + 100 × epinephrine (μg/kg/min) + 100 × norepinephrine (μg/kg/min) + 20 × milrinone (μg/kg/min).

Based on postoperative complications, the outcomes are categorized as major and minor outcomes. Major outcomes are defined as predefined major adverse cardiovascular events (MACEs) [9], which include in-hospital outcomes such as death, heart failure (NYHA functional classification ≥III), cardiac arrest. Minor outcomes include severe pulmonary infection, reoperation, postoperative atrioventricular conduction block, chylothorax, pneumothorax, pericardial effusion, pleural effusion (both effusions confirmed by echocardiography after removal of the drainage tube), abdominal effusion (assessed by abdominal ultrasound, with effusion volume evaluated by abdominal puncture), tricuspid regurgitation, myocardial injury, metabolic acidosis. Additionally, we assessed the correlation between the high postoperative complication rates and baseline data levels.

Statistical Analysis

For continuous variables, it was determined whether they follow a normal distribution. If the data are normally distributed, a *t*-test is chosen. If the data are not normally distributed and the sample size for both groups falls between 50 and 300, the two independent sample Kolmogorov-Smirnov test will be employed. Categorical variable results were presented as percentages, and the normal distribution of continuous variables was assessed using skewness and kurtosis. Normally distributed continuous variable results were presented as means ± standard deviations, while non-normally distributed continuous variable results were presented as medians and ranges. All tests were two-tailed, with $p < 0.05$, and analyzed using SPSS V.27 software (27.0.1.0, Manufacturer: IBM Corp, Amonk, NY, USA).

Initially, potential confounding factors were adjusted using PS Matching, a sequential propensity score matching method [10]. Factors adjusted for included age at admission, gender, height, weight, American Society of Anesthesiologists (ASA) classification, length of ventricular septal defect, presence of restrictive ventricular septal defect, presence of right ventricular outflow tract obstruction, preoperative left ventricular ejection fraction (LVEF), preoperative pulmonary artery valve pressure difference (PAP), preoperative left ventricular fractional shortening (FS), history of anemia, history of pneumonia, presence and clas-

sification of pulmonary artery hypertension, and presence of left heart enlargement. The variables of age at admission, weight, size of the cardiac defect, classification of pulmonary artery hypertension, and preoperative cardiac function are key variables that need to be matched to ensure that there no significant differences between the two groups, in order to compare the perioperative efficacy and enhance the credibility. Patients undergoing isolated ventricular septal defect repair were matched with those undergoing combined ventricular septal defect repair and other congenital heart malformation correction at a ratio of 1:1.7, using the nearest neighbor matching technique with a caliper width of 0.2.

To further explore the relative factors affecting postoperative complications, we conducted binary unconditional logistic regression analysis on the original data before matching and performed preliminary single-factor analysis for each variable. Factors to be included in the analysis consisted of preoperative data such as age, weight, and size of the cardiac defect, intraoperative data including operation time, cardiopulmonary bypass time, intraoperative blood loss, and postoperative data such as mechanical ventilation time, ICU monitoring time, and Vasoactive-Inotropic Score (VIS). All relevant variables were ensured to occur before the onset of complications. A univariate analysis was initially carried out for each variable, with a significance level set at $p < 0.1$. Variables meeting the criteria were included in the multivariate analysis, with results expressed as adjusted odds ratios (OR) and 95% confidence intervals (CI).

Results

Preoperative Baseline Features of Isolated VSDR and Combined Procedure Groups

We extracted the information of 397 patients who met the inclusion criteria from the database of Beijing Anzhen Hospital, Capital Medical University. Among them, 286 cases (72.5%) underwent ventricular septal defect repair combined with corrective surgery for other congenital heart abnormalities (experimental group), while the remaining 111 cases (27.5%) underwent isolated ventricular septal defect repair (control group) (Fig. 1). Table 1 presents the specific cardiac malformations and their corrective methods.

Most baseline characteristics showed statistically significant differences before matching. Among them, height, BMI, and preoperative FS data were normally distributed. In the experimental group, the height was lower than the control group (66.98 ± 5.06 *vs.* 68.70 ± 4.72 cm, $p < 0.05$), and the BMI was smaller than the control group (15.16 ± 1.98 *vs.* 15.85 ± 1.90, $p < 0.05$). However, there was no statistical difference in preoperative FS compared to the control group ($p > 0.05$). Apart from these three variables, all other continuous variables in the preoperative baseline data were non-normally distributed. The age at admission in the experimental group was lower than in the control group ($p < 0.05$), and the weight and body surface area were smaller in the experimental group compared to the control group ($p < 0.05$). Additionally, the length of the ventricular septal defect was larger in the experimental group compared to the control group ($p < 0.05$), and the PG value was lower in the experimental group ($p < 0.05$). The proportion of non-restrictive ventricular septal defects was lower in the experimental group compared to the control group ($p < 0.05$). Considering the high proportion of statistical differences in the initial preoperative baseline data between the two groups, and to control for confounding bias in the analysis of intraoperative and postoperative data, we used propensity score matching. The pre-match and post-match baseline characteristics are displayed in Table 2. Stratified analysis was conducted based on the presence of combined corrective surgery for other congenital heart abnormalities.

Perioperative Data of Isolated VSDR and Combined Procedure Groups

The intraoperative data for both groups were non-normally distributed before and after matching. As shown in Table 3, statistically significant differences are described as follows: before matching, the operative time in the experimental group was longer than in the control group ($p < 0.05$), as well as the cardiopulmonary bypass time, which was longer than in the control group ($p < 0.05$). The aortic cross-clamp time was also longer in the experimental group compared to the control group ($p < 0.05$). After matching, the operative time in the experimental group remained longer than in the control group ($p < 0.05$), along with the cardiopulmonary bypass time and the aortic cross-clamp time, which were both longer in the experimental group compared to the control group ($p < 0.05$).

For postoperative data, except for postoperative fractional shortening (FS), which followed a normal distribution in both groups before and after matching, all other variables were non-normally distributed both before and after matching. Pre-match, the experimental group exhibited a longer duration of mechanical ventilation, ICU stay, and postoperative hospital stay compared to the control group ($p < 0.05$). The vasoactive-inotropic score (VIS) and postoperative left ventricular ejection fraction were lower in the experimental group compared to the control group ($p < 0.05$), and postoperative FS was lower than in the control group ($36.04\% \pm 5.52\%$ *vs.* $37.72\% \pm 4.97\%$, $p < 0.05$). After matching, the experimental group still had a longer duration of mechanical ventilation compared to the control group ($p < 0.05$).

In-Hospital Outcomes after Cardiopulmonary Bypass

The postoperative complications for the two groups before and after matching were assessed as categorical vari-

Table 2. Preoperative baseline features of isolated VSDR and combined procedure groups.

	Unmatched			Propensity-Matched		
	Isolated VSDR (n = 111)	VSDR+Other (n = 286)	*p* value	Isolated VSDR (n = 107)	VSDR+Other (n = 181)	*p* value
Preoperative Data						
Age, y	0.59 (0.17, 0.99)	0.52 (0.13, 0.98)	<0.05	0.58 (0.17, 0.99)	0.56 (0.15, 0.97)	>0.05
Sex						
Male	52.3	48.6	0.514	53.3	50.8	0.689
Female	47.7	51.4		46.7	49.2	
Height, cm	68.70 ± 4.72	66.98 ± 5.06	<0.05	69.00 (57.00, 79.00)	68.00 (56.00, 81.00)	>0.05
Weight, kg	7.40 (4.70, 11.0)	6.70 (4.20, 12.30)	<0.001	7.40 (4.70, 10.50)	7.00 (4.20, 12.30)	<0.001
≤5	4.5	9.1	0.126	4.7	5.5	0.753
5–20	95.5	90.9		95.3	94.5	
BMI	15.85 ± 1.90	15.16 ± 1.98	0.002	15.61 (10.82, 21.00)	15.39 (9.94, 22.17)	0.412
BSA, m^2	0.36 (0.27, 0.45)	0.34 (0.24, 0.50)	<0.001	0.36 (0.27, 0.45)	0.35 (0.25, 0.50)	0.383
ASA Classification						
I	NR	0.3	0.692	NR	NR	0.891
II	45.9	42.3		43.9	43.1	
≥III	54.1	57.3		56.1	56.9	
NYHA Classification						
I	10.8	8.7	0.687	10.3	8.3	0.637
II	89.2	90.9		89.7	91.2	
≥III	NR	0.30%		NR	0.6	
Long Diameter of VSD, mm	7.00 (2.50, 15.00)	9.00 (2.50, 18.00)	<0.001	7.00 (2.50, 15.00)	8.00 (2.50, 18.00)	0.368
PG value, mmHg						
≤30	77.5	54.2	<0.001	76.6	75.7	0.856
>30	22.5	45.8		23.4	24.3	
RVOT obstruction	NR	0.7	-	NR	NR	-
LVEF, %	69.00 (60.00, 80.00)	70.00 (55.00, 82.00)	0.632	69.19 ± 4.99	69.86 ± 5.12	0.276
FS, %	38.53 ± 4.24	39.20 ± 4.44	0.171	38.55 ± 4.23	39.13 ± 4.32	0.266
Left Heart Enlargement	92.8	92.3	0.870	92.5	92.3	0.936
TR						
<Moderate	100	96.9	0.130	100	96.7	0.140
≥Moderate	NR	3.1		NR	3.3	
MR						
<Moderate	100	95.8	0.062	100	94.5	0.032
≥Moderate	NR	4.2		NR	5.5	
PAH	36	55.2	<0.001	37.4	38.7	0.828
0	64	44.8	0.005	62.6	61.3	0.834
1	9	5.9		9.3	6.6	
2	2.7	3.5		2.8	3.9	
3	6.3	11.9		6.5	9.9	
4	2.7	7.3		2.8	3.9	
5	15.3	26.6		15.9	14.4	
Pneumonia History	23.4	31.8	0.100	24.3	25.4	0.833
Anemia	80.2	80.1	0.980	82.2	79.6	0.578
WBC, $\times 10^9$/L	9.13 (3.95, 14.60)	8.45 (3.39, 20.14)	0.236	9.11 ± 2.11	8.71 ± 2.53	0.162
N, $\times 10^9$/L	2.11 (0.58, 6.34)	2.04 (0.42, 10.63)	0.743	2.00 (0.58, 6.34)	1.93 (0.42, 10.63)	0.518
L, $\times 10^9$/L	5.81 (1.93, 10.31)	5.54 (1.12, 12.35)	0.194	5.81 (1.93, 10.31)	5.54 (1.32, 12.01)	0.205

Values are median (IQR), mean or %. BMI, Body Mass Index; BSA, Body Surface Area; ASA, American Society of Anesthesiologists; NYHA, New York Heart Association; VSD, Ventricular Septal Defect; PG, Pressure Gradient; RVOT, Right Ventricular Outflow Tract; LVEF, Left Ventricular Ejection Fraction; FS, Fractional Shortening; TR, Tricuspid Regurgitation; MR, Mitral Regurgitation; PAH, Pulmonary Artery Hypertension; WBC, White Blood Cell; N, Neutrophil Count; L, Lymphocyte Count; VSDR, Ventricular Septal Defect Repair; NR, Not Reported.

Table 3. Perioperative data of isolated VSDR and combined procedure groups.

	Unmatched			Propensity-Matched		
	Isolated VSDR (n = 111)	VSDR+Other (n = 286)	*p* value	Isolated VSDR (n = 107)	VSDR+Other (n = 181)	*p* value
Perioperative data						
Operation Time (min)	128.00 (90.00, 196.00)	140.00 (92.00, 658.00)	<0.05	28.00 (90.00, 196.00)	140.00 (95.00, 658.00)	0.001
CPB Time (min)	58.00 (24.00, 114.00)	68.50 (33.00, 422.00)	<0.05	58.00 (24.00, 114.00)	66.00 (33.00, 422.00)	<0.05
Aortic Occlusion Time (min)	32.00 (15.00, 62.00)	38.50 (15.00, 142.00)	<0.05	32.00 (17.00, 62.00)	37.00 (15.00, 142.00)	<0.05
Intraoperative Bleeding (mL)	60.00 (20.00, 100.00)	60.00 (20.00, 300.00)	0.978	60.00 (20.00, 100.00)	60.00 (20.00, 300.00)	0.987
Postoperative Mechanical Ventilation Time (h)	22.00 (0, 99.00)	24.00 (3.00, 193.00)	<0.05	22.00 (0, 99.00)	23.00 (3.00, 193.00)	0.031
ICU Stay (d)	3.75 (0.56, 12.15)	3.99 (0.71, 54.54)	0.174	3.74 (0.56, 12.15)	3.93 (0.71, 54.54)	0.184
Postoperative Hospital Stay (d)	6.83 (4.56, 17.98)	7.75 (4.53, 70.62)	0.002	6.85 (4.56, 17.98)	6.93 (4.53, 70.62)	0.244
Postoperative Drainage (mL)	175.00 (40.00, 345.00)	170.00 (40.00, 5190.00)	0.499	175.00 (40.00, 345.00)	170.00 (40.00, 5190.00)	0.843
Vasoactive-Inotropic Score	6.30 (1.00, 25.00)	8.45 (1.08, 59.10)	0.02	6.30 (1.00, 25.00)	6.30 (1.08, 33.80)	0.607
Postoperative LVEF (%)	69.00 (45.00, 85.00)	66.00 (32.00, 84.00)	0.024	69.00 (45.00, 85.00)	66.00 (45.00, 84.00)	0.053
Postoperative FS (%)	37.54 ± 4.97	36.04 ± 5.32	0.013	37.50 (22.22, 50.00)	35.71 (21.43, 50.00)	0.002

CPB, Cardiopulmonary Bypass; ICU, Intensive Care Unit; LVEF, Left Ventricular Ejection Fraction; FS, Fractional Shortening; VSDR, Ventricular Septal Defect Repair.

Table 4. In-hospital outcomes in isolated VSDR and combined procedure groups after cardiopulmonary bypass.

	Unmatched			Propensity-Matched		
	Isolated VSDR (n = 111)	VSDR+Other (n = 286)	*p* value	Isolated VSDR (n = 107)	VSDR+Other (n = 181)	*p* value
Complications						
MACE	0	3	1.000	0	1	1.000
Death	0	1	1.000	0	0	1.000
Heart Arrest	0	1	1.000	0	0	1.000
Heart Failure	0	1	1.000	0	1	1.000
Severe Pulmonary Infection	0	1	1.000	0	0	1.000
Second Thoracotomy	0	5	0.369	0	3	0.460
Chylothorax	0	1	1.000	0	1	1.000
Residual Shunt	0	4	0.489	0	2	0.531
Hypoalbuminemia	0	1	1.000	0	1	1.000
Aerothorax	0	2	1.000	0	1	1.000
Atelectasis	0	2	1.000	0	1	1.000
II AVB	1	0	0.280	1	0	0.372
TR	1	8	0.445	1	2	1.000
Myocardial Damage	0	2	1.000	0	2	0.531
Hydropericardium	5	3	0.072	5	3	0.257
Hydrothorax	25	38	**0.024**	24	24	**0.044**
Seroperitoneum	4	5	0.460	4	2	0.278
Metabolic Acidosis	1	0	0.280	1	0	0.372

MACE, Major Adverse Cardiovascular Event; Heart Failure, NYHA class ≥3; II AVB, II Atrial Ventricular Block; TR, Tricuspid Regurgitation; VSDR, Ventricular Septal Defect Repair. Bolded numbers in the table indicate that the *p*-value for related complications between groups is less than 0.05.

ables using the chi-square test, and the results are presented in Table 4. Before matching, the major adverse cardiac events (MACE) rate in the experimental group was 0.70%, with one death (0.35%), one cardiac arrest (0.35%), and one case of grade III heart failure (0.35%). The primary cause of death was severe postoperative lung infection leading to severe pneumonia and resulting in sudden respiratory and cardiac arrest. No MACEs occurred in the control group, and there were no significant statistical differences between the two groups ($p > 0.05$). Aside from MACE, the occurrence of other secondary adverse events is as follows: The experimental group had one case of severe lung infection, five cases of reoperation (four for residual shunts after surgery for residual ventricular septal defects and one for chylothorax with chest tube ligation), four cases of residual shunts requiring corrective reoperation, one case of chylothorax, one case of hypoalbuminemia, two cases of pneumothorax, two cases of atelectasis, one case of transient paroxysmal supraventricular tachycardia, eight cases of tricuspid regurgitation (newly developed after surgery, all with minimal or less regurgitation), two cases of myocardial injury, five cases of abdominal fluid, and three cases of pericardial effusion. In the control group, there was one case of transient paroxysmal supraventricular tachycardia, one case of tricuspid regurgitation (newly developed after surgery, with minimal regurgitation), one case of metabolic acidosis, four cases of abdominal fluid, and five cases of pericardial effusion. The incidence of secondary adverse events did not differ significantly between the two groups ($p > 0.05$). However, pleural effusion, being the only secondary adverse event, showed a statistically significant difference, with a lower incidence of pleural effusion in the experimental group compared to the control group ($p = 0.024$): the experimental group had 38 cases of hydrothorax, while the control group had 25 cases. Twenty-two cases were found to have residual shunts less than 2 mm. Previous studies indicate that 83% of such residual shunts less than 2 mm can close spontaneously without affecting the patient's hemodynamics, daily activities or requiring further surgery, with the vast majority closing within one year after surgery [11], therefore, they were not considered postoperative complications. After matching, there was no statistical difference in MACE between the two groups regarding postoperative complications. As the unique secondary adverse event, the incidence of pleural effusion was lower in the experimental group compared to the control group ($p = 0.044$).

Univariate and Multivariate Logistic Regression for the Prediction of In-Hospital Complications After Cardiopulmonary Bypass

Based on the comparison of postoperative complications between the experimental and control groups before matching, we selected pleural effusion, pericardial effu-

sion, and ascites as the three leading complications for the analysis of influencing factors. The other complications had a small proportion and showed no significant statistical differences between the groups. Consequently, including them in the analysis would significantly reduce the reliability of the conclusions, so they were not included as analysis options. This study used univariate and multivariate logistic regression analyses to assess the influencing factors, and the results are presented in Tables 5,6.

In the univariate analysis, the degree of tricuspid regurgitation (p = 0.002), operative time (p = 0.007), cardiopulmonary bypass time (p = 0.001), aortic cross-clamp time (p = 0.001), intraoperative blood loss (p = 0.026), duration of postoperative mechanical ventilation (<0.001), length of ICU stay (p = 0.011), and Vasoactive-Inotropic Score (VIS) (p = 0.012) were found to be associated with abdominal fluid, as their p-values were all less than 0.1 and the Odds Ratio (OR) was greater than 1. Therefore, these variables were further included in the multivariate analysis, and three models were constructed. Model 1 consists of preoperative tricuspid regurgitation, postoperative mechanical ventilation time, and VIS, while operative time, aortic cross-clamp time, intraoperative blood loss, cardiopulmonary bypass time, and postoperative ICU stay were not included. Model 2 includes two variables, tricuspid regurgitation degree and postoperative mechanical ventilation time. Model 3 includes tricuspid regurgitation degree and VIS. Table 6 presents the sensitivity, specificity, and Youden's index from the ROC curves predicting abdominal fluid for the three models.

According to the univariate analysis, preoperative lymphocyte count (p = 0.061), duration of postoperative mechanical ventilation (p = 0.094) and postoperative Vasoactive-Inotropic Score (VIS) (p = 0.007) were found to be associated with pericardial effusion, meeting the criteria of $p < 0.1$ and OR >1, as shown in Table 5. These two variables were included in the multivariate analysis, which indicated that the preoperative lymphocyte count did not show a significant association with pericardial effusion in the multivariable analysis ($p > 0.05$). Thus, a predictive model for pericardial effusion was not constructed.

Based on the univariate analysis, gender (p = 0.048), height (p = 0.092), intraoperative blood loss (p = 0.089), postoperative hospital stays (p = 0.049) and postoperative Vasoactive-Inotropic Score (VIS) (p = 0.020) were found to be associated with chest fluid, meeting the criteria of $p < 0.1$ and OR >1. The three variables were included in the multivariate analysis, which indicated that gender, height, and VIS were all associated with chest fluid ($p < 0.05$), leading to the construction of Model 4. To further assess the magnitude of the relationship between complications and various factors for more accurate prediction of their occurrence, we chose to analyze the area under the ROC curve (AUC) of each factor in each complication to compare the diagnostic value of each relevant factor. The AUC for postoperative mechanical ventilation time in the ascites group was the highest at 0.901, the AUC for the VIS in the pleural effusion group was the highest at 0.604, and the AUC for the preoperative blood routine lymphocyte count in the pericardial effusion group was the highest at 0.734 (Table 5).

Considering that all three types of postoperative complications belong to postoperative edema and effusion (POEE) [12], a total of 71 cases of POEE were observed among 397 pediatric patients before matching. Based on the results of the individual multivariable regression analyses for each complication, it was found that the three types of effusion were positively correlated with the postoperative Vasoactive-Inotropic Score (VIS) ($p < 0.05$, OR >1). Therefore, it is reasonable to conjecture that VIS may also be a risk factor for POEE. The ROC curves for the four predictive models are displayed in (Fig. 2).

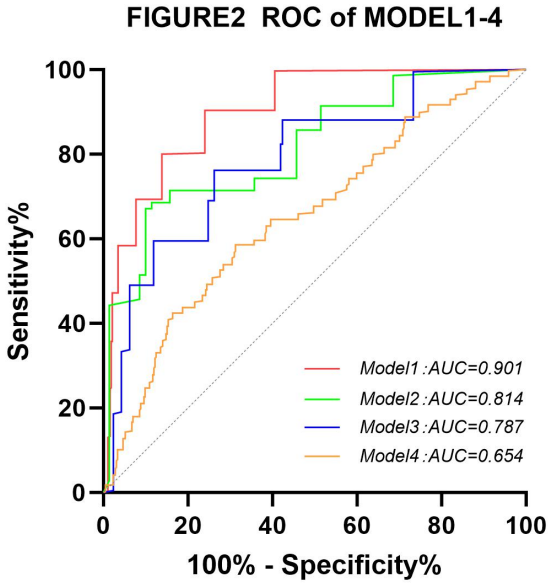

Fig. 2. ROC of MODEL1-4. AUC, Area Under the Curve.

Discussion

Since the first ventricular septal defect repair in 1956, after nearly seventy years of development, the surgical approach to correcting simple congenital heart disease has transitioned from the traditional median sternotomy to the right axillary small incision, video-assisted thoracoscopic surgery for congenital heart disease, and robot-assisted cardiac surgery. Through data analysis and long-term follow-up by various centers, good treatment outcomes for correcting simple congenital heart disease have been achieved using different methods. In this study, the use of the right axillary incision for correcting simple congenital heart disease has gradually become widely adopted [13]. Our cen-

Table 5. Univariate regression for the prediction of three complications after cardiopulmonary bypass.

Prognostic Factor	Univariate Analysis							
	Seroperitoneum		Hydrothorax		Hydropericardium		POEE	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Group (test group)	0.476 (0.125, 1.806)	0.275	0.527 (0.301, 0.924)	0.025	0.225 (0.053, 0.957)	0.043	0.487 (0.285, 0.831)	0.008
Age, y	0.007 (0, 0.492)	0.022	2.350 (0.610, 9.056)	0.214	0.069 (0.001, 3.481)	0.181	0.975 (0.267, 3.556)	0.969
Sex (female)	3.636 (0.725, 17.238)	0.118	1.746 (1.005, 3.032)	0.048	1.658 (0.391, 7.034)	0.493	1.776 (1.049, 3.005)	0.032
Height, cm	0.838 (0.734, 0.958)	0.009	1.048 (0.992, 1.107)	0.092	0.910 (0.792, 1.046)	0.184	1.007 (0.957, 1.060)	0.792
Weight, kg	0.651 (0.376, 1.127)	0.126	1.102 (0.917, 1.325)	0.300	0.886 (0.532, 1.475)	0.642	1.033 (0.865, 1.233)	0.723
ASA Degree	0.975 (0.262, 3.637)	0.970	1.220 (0.708, 2.102)	0.475	5.529 (0.675, 45.252)	0.111	1.241 (0.738, 2.085)	0.416
NYHA Degree	6.547 (0.140, 305.607)	0.338	2.034 (0.663, 6.246)	0.215	0.703 (0.087, 5.689)	0.741	2.319 (0.767, 7.014)	0.136
PG Value	0.990 (0.967, 1.012)	0.372	1.002 (0.993, 1.010)	0.721	1.003 (0.981, 1.027)	0.764	1.000 (0.992, 1.009)	0.957
LVEF, %	0.975 (0.858, 1.108)	0.699	1.018 (0.966, 1.072)	0.514	0.961 (0.839, 1.100)	0.563	1.001 (0.953, 1.052)	0.956
PAP, mmHg	1.011 (0.956, 1.068)	0.712	0.994 (0.965, 10.24)	0.686	0.917 (0.788, 1.067)	0.261	1.000 (0.974, 1.026)	0.993
FS, %	0.966 (0.829, 1.126)	0.658	1.021 (0.961, 1.086)	0.498	0.935 (0.793, 1.103)	0.425	1.005 (0.948, 1.065)	0.877
TR Degree	15.551 (2.729, 88.619)	0.002	0	0.999	0	0.999	1.321 (0.269, 6.496)	0.732
MR Degree	0	0.999	1.062 (0.227, 4.968)	0.939	4.909 (0.555, 43.400)	0.152	0.916 (0.196, 4.274)	0.911
History of Pneumonia (Yes)	0	0.997	1.139 (0.565, 2.297)	0.715	1.000 (0.197, 5.068)	1.000	0.779 (0.434, 1.397)	0.402
Anemia (Yes)	1.211 (0.139, 10.580)	0.862	0.515 (0.0.254, 1.043)	0.066	1.711 (0.206, 14.198)	0.619	0.617 (0.340, 1.120)	0.112
WBC, $\times 10^9$/L	1.071 (0.765, 1.498)	0.690	0.921 (0.807, 1.052)	0.226	1.235 (0.921, 1.656)	0.159	0.918 (0.824, 1.022)	0.118
N, $\times 10^9$/L	1.234 (0.757, 2.011)	0.399	0.857 (0.638, 1.152)	0.307	0.745 (0.343, 1.617)	0.465	0.816 (0.634, 1.050)	0.114
L, $\times 10^9$/L	0.982 (0.645, 1.495)	0.932	0.954 (0.811, 1.122)	0.567	1.389 (0.985, 1.960)	0.061	0.953 (0.834, 1.090)	0.481
PAH (Yes)	0.806 (0.145, 4.473)	0.805	0.867 (0.454, 1.654)	0.665	1.642 (0.402, 6.702)	0.490	0.688 (0.410, 1.156)	0.158
Operation Time, min	1.012 (1.003, 1.020)	0.007	1.001 (0.995, 1.008)	0.725	0.956 (0.914, 1.001)	0.057	1.001 (0.995, 1.007)	0.736
CPB Time, min	1.015 (1.006, 1.024)	0.001	1.003 (0.995, 1.010)	0.491	1.003 (0.986, 1.020)	0.756	1.005 (0.998, 1.012)	0.130
Aortic Occlusion Time, min	1.042 (1.017, 1.069)	0.001	1.006 (0.990, 1.022)	0.469	1.011 (0.974, 1.049)	0.577	1.012 (0.998, 1.027)	0.103
Intraoperative Bleeding Volume, mL	1.024 (1.003, 1.045)	0.026	1.013 (0.998, 1.028)	0.089	0.989 (0.946, 1.035)	0.634	1.007 (0.997, 1.016)	0.189
Postoperative Mechanical Ventilation Time, min	1.040 (1.019, 1.062)	<0.001	1.001 (0.988, 1.015)	0.853	1.017 (0.997, 1.038)	0.094	1.004 (0.995, 1.013)	0.394
ICU Stay, d	1.131 (1.029, 1.243)	0.011	0.868 (0.775, 0.973)	0.015	0.806 (0.575, 1.128)	0.208	0.905 (0.819, 1.001)	0.051
Postoperative Hospital Stay, d	1.105 (1.007, 1.213)	0.035	1.018 (0.965, 1.074)	0.518	0.989 (0.830, 1.179)	0.904	0.998 (0.979, 1.016)	0.802
Postoperative Drainage Volume, ml	1.002 (0.996, 1.009)	0.467	1.004 (1.000, 1.007)	0.049	1.000 (0.999, 1.001)	0.511	1.003 (1.000, 1.006)	0.048
VIS	1.128 (1.027, 1.239)	0.012	1.050 (1.008, 1.094)	0.020	1.119 (1.031, 1.214)	0.007	1.046 (1.014, 1.079)	0.004

ASA, American Society of Anesthesiologists; NYHA, New York Heart Association; PG, Pressure Gradient; LVEF, Left Ventricular Ejection Fraction; FS, Fractional Shortening; TR, Tricuspid Regurgitation; M R, Mitral Regurgitation; POEE, Postoperative Edema and Effusion; WBC, White Blood Cell; N, Neutrophil Count; L, Lymphocyte Count; PAH, Pulmonary Artery Hypertension; CPB, Cardiopulmonary Bypass; ICU, Intensive Care Unit; VIS, Vasoactive-inotropic Score; CI, Confidence Interval; OR, Odds Ratio.

Table 6. Multivariate logistic regression for the prediction of three complications after cardiopulmonary bypass.

Prognostic Factor	Multivariate Analysis							
	Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Sex (female)							2.145 (1.196, 3.849)	0.01
Height							1.089 (1.025, 1.156)	0.006
TR Degree	10.356 (1.481, 72.415)	0.018	10.105 (1.428, 71.487)	0.02	12.709 (2.114, 76.404)		0.005	
Postoperative Mechanical Ventilation Time, min	1.029 (1.014, 1.045)	<0.001	1.031 (1.017, 1.045)	<0.001				
VIS	1.022 (0.944, 1.105)	0.595			1.069 (1.006, 1.137	0.033	1.049 (1.015, 1.084)	0.005
Model performance								
AUC	0.901 (0.879, 0.922)	<0.0001	0.814 (0.743, 0.884)	<0.0001	0.787 (0.743, 0.831)	<0.0001	0.654 (0.615, 0.692)	<0.0001
Hosmer-Lemeshow goodness-of-fit test	X^2: 2.713; *p*: 0.951		X^2: 4.224; *p*: 0.834		X^2: 6.873; *p*: 0.550		X^2: 7.245; *p*: 0.510	
Sensibility	0.889		0.889		0.889		0.556	
Specificity	0.784		0.771		0.714		0.734	
Youden's Index	0.672		0.660		0.603		0.289	

TR, Tricuspid Regurgitation; VIS, Vasoactive-inotropic Score; CI, Confidence Interval; OR, Odds Ratio; AUC, Area Under the Curve.

ter, with extensive surgical experience accumulated over many operations, has broken conventions, providing medical technology and compassionate care for more children, while minimizing surgical trauma and avoiding permanent psychological trauma for children to ensure surgical efficacy. With the development of medical advancements over the past twenty years, the technique for correcting isolated ventricular septal defects using the right axillary incision in our center has matured. However, there is currently limited literature on the comparative efficacy and relative factors for perioperative complications associated with ventricular septal defect repair, especially in young patients. This study sought determine whether a small right axillary incision in young patients improves short-term outcomes for VSD repair combined with various cardiac malformations and analyzed the relative factors for common complications.

Perioperative Data

After comparison of perioperative data after matching, it was found that there was a significant statistical difference between the experimental group and the control group in intraoperative data (operation time, cardiopulmonary bypass time, aortic cross-clamp time). This was due to the difference in the number of types of surgical corrections of heart defects between the two groups, resulting in a significantly higher complexity of the surgical procedure in the experimental group than in the control group. Additionally, postoperative data showed a statistical difference in mechanical ventilation time. The baseline indicators were essentially controlled after propensity score matching. We found that the complexity of the cardiac malformation in the preoperative data was an important factor affecting postoperative mechanical ventilation time. Related studies have shown that RACHS-1 can be a good predictor for the duration of postoperative mechanical ventilation [14]. The complexity of pediatric cardiac malformations could increase postoperative morbidity by affecting the RACHS-1 risk score [15], including the duration of postoperative mechanical ventilation. Furthermore, the duration of postoperative mechanical ventilation was to some extent related to significant residual shunts and postoperative complications related to cardiac defects [16]. However, in the matched data of this study, only two children required a second open-chest operation for significant residual shunting after the surgery, which was not statistically significant. The remaining postoperative echocardiograms suggested residual shunts less than 2 mm from left to right, which would not have an impact on the children. Additionally, among the remaining postoperative complications, only pleural effusion showed a statistical difference. The occurrence of pleural effusion in the experimental group was 13.3%, while in the control group, it was 22.4%, with a lower occurrence rate in the experimental group compared to the control group. Therefore, in combination with the higher average mechanical ventilation time in the experimental group, longer mechanical ventilation time was not the cause of pleural effusions. This was consistent with the single-factor analysis in the binary logistic regression, in which postoperative mechanical ventilation time was not found to be a factor affecting the occurrence of pleural effusion.

Relative Factors Affecting the Formation of Seroperitoneum

There was no significant difference in the number of cases of abdominal fluid accumulation in the two groups before and after matching. After combining with propensity score matching, there were no significant statistical differences in baseline data between the experimental and control groups. We conclude that the complexity of the surgery (within the included diseases) is not the main factor influencing the occurrence of ascites. However, there were limitations in the results due to the differences in the technical proficiency of the leading physician in this study. To further investigate potential influencing factors apart from the complexity of the cardiac malformations, binary nonconditional logistic regression analysis was conducted using baseline data from 397 cases before matching to identify potential predictive factors related to abdominal fluid, providing a reference for early prevention of abdominal fluid accumulation. It was found that the three prediction models established by ROC curves covered three factors: degree of tricuspid regurgitation, postoperative mechanical ventilation time, and postoperative vasoactive medication score. When we analyzed the area under the ROC curve (AUC) for each factor concerning ascites, it showed that the AUC for postoperative mechanical ventilation time is 0.901. This indicated a higher diagnostic value for ascites compared to the other two factors.

The degree of tricuspid regurgitation degree before the surgery showed a strong correlation with abdominal fluid after the surgery in all three prediction models. Trivial or mild tricuspid regurgitation had no significant impact on the long-term prognosis of the child and did not meet the surgical intervention criteria for severe functional tricuspid regurgitation with refractory symptoms [17], whereas moderate or severe tricuspid regurgitation significantly increased the risk for poor prognosis. Of the 9 cases with moderate or severe tricuspid regurgitation in this study, all were secondary tricuspid regurgitation, with 6 cases accompanied by moderate or severe pulmonary hypertension, and the remaining 3 cases were secondary to right ventricular volume overload due to atrial septal defect or patent foramen ovale and malformation of the pulmonary valve, resulting in tricuspid regurgitation. In studies by Forado-Benatar *et al.* [18] and others, the physiological mechanism by which moderate to severe tricuspid regurgitation affected the formation of ascites is due to right ventricular volume overload, decreased right ventricular output with an increase in central venous pressure, and increased peripheral vein and

capillary pressure, leading to accelerated ascites formation [18]. This study lacked right heart hemodynamic data post-surgery to definitively verify the above inference. If further validation was needed, a prospective trial could have been designed to match baseline data for children with similar baseline characteristics but significantly different degrees of tricuspid regurgitation preoperatively. These children would have undergone VSD repair by the same operator using the same approach, and after a fixed postoperative period, right heart catheterization would have been performed to measure right ventricular pressure, pulmonary artery pressure, and tricuspid regurgitant volume. The occurrence of ascites would have been compared between the two groups to verify whether preoperative tricuspid regurgitation had an impact on the development of ascites. This would have been of significant value in the future evaluation of whether tricuspid valvuloplasty should be performed in children with moderate or severe tricuspid regurgitation preoperatively to reduce or even prevent the occurrence of ascites.

Postoperative mechanical ventilation time also showed a positive correlation with abdominal fluid. Although there is currently no direct causal relationship between the two, it was observed that prolonged postoperative mechanical ventilation could result in a systemic inflammatory response and release of inflammatory mediators, potentially promoting the formation of ascites.

The postoperative vasoactive medication score also had a positive correlation with abdominal fluid. Gaies *et al.* [19] and others have shown that the vasoactive-inotropic score, especially the maximum score within 48 hours postoperatively, reflects the severity of postoperative complications in infant cardiac surgery [19]. Although there is limited literature on predicting the formation of postoperative ascites based on the vasoactive-inotropic score, it could be inferred from predicting first-time fluid imbalance or renal replacement therapy that the vasoactive-inotropic score serves as an intermediate predictive factor to assess the severity of postoperative complications [20]. To a certain extent, this had not only filled the gap in the lack of predictive factors for ascites complications but also enhanced the clinical value of the VIS score. Additionally, in the univariate analysis of the binary non-conditional logistic regression for ascites, it was found that age, height, and weight categorization all had a $p < 0.05$ and the odds ratio was significantly less than 1, suggesting a potential protective role in postoperative ascites. Ingviya *et al.* [21] and others found that the risk of the occurrence of postoperative ascites was higher in younger children, similar to findings in our study.

Relative Factors Affecting the Formation of Hydropericardium

After propensity score matching, there was no significant statistical difference in the number of occurrences of postoperative pericardial effusion between the group that underwent isolated ventricular septal defect repair and the group that underwent ventricular septal defect repair combined with the correction of other congenital heart defects. Considering that pericardial effusion is a common postoperative complication in cardiac surgery and is one of the important factors leading to rehospitalization or death of children postoperatively [22], especially in the expanding group of infants undergoing right subaxillary minimally invasive surgery, this retrospective study aimed to analyze the risk factors for postoperative pericardial effusion in infants under 1 year of age who underwent ventricular septal defect repair and other routine congenital heart defect correction surgeries via a right subaxillary minimally invasive incision.

Single-factor analysis using binary non-conditional logistic regression found a positive correlation between preoperative lymphocyte count within three days and the vasoactive-inotropic score (VIS) postoperatively, and pericardial effusion. However, further multivariate analysis showed no significant statistical significance for lymphocyte count. The reason for not including the lymphocyte count in the predictive model was twofold: (1) The small number of cases may have resulted in a small database for pericardial effusion complications, leading to insufficient support for the multivariate analysis. (2) Introduction of the VIS in the multivariate analysis may have impacted the significance of the lymphocyte count on pericardial effusion development due to interaction effects between the two factors. Some studies have indicated that preoperative serum levels of lymphocytes and neutrophil percentages can be used to assess the risk of postoperative pericardial effusion, but in comparison with this study, considering that postoperative excessive effusion (POEE) encompasses a wider range than pericardial effusion and has different postoperative occurrence timeframes (not excluding the impact of postpericardiotomy syndrome), as well as differences in preoperative blood routine testing time and baseline vital signs, the predictive capability of preoperative lymphocyte count as a predictor of postoperative pericardial effusion in cardiac surgery requires further prospective research for clarification.

This study found that the VIS could serve as an independent factor for postoperative pericardial effusion. However, considering the lack of a clear definition for postoperative pericardial effusion (only including patients detected by echocardiography in the study), and given the limitations of a small sample size and a relatively short follow-up period, it is possible that some cases that may develop into a pericardial effusion have been overlooked. This conclusion would still need to be verified for its validity by expanding the sample size and extending the observation period. According to the vascular active-inotropic score classification system used in the study by Gaies *et al.* [23] and others, further exploration is needed to determine the maximum

VIS cutoff point for predicting postoperative pericardial effusion [23].

Relative Factors Affecting the Formation of Hydrothorax

The predictive model established through multivariate analysis using pre-matching baseline data for binary nonconditional logistic regression includes gender, height, and vasoactive-inotropic score (VIS).

We observed that male pediatric patients (OR 2.145, 95% CI: 1.196–3.849) had a higher risk of developing Hydrothorax. This finding might be attributed to the higher proportion of female pediatric patients undergoing ventricular septal defect repair combined with the correction of other congenital heart defects among those with Hydrothorax, which was approximately 64.1%, compared to 54.2% in male patients. It also might be related to physiologic and anatomical factors leading to differences in surgical procedures, which had been shown to be influential in the development of Hydrothorax, as indicated in the study by Talwar *et al*. [24]. In addition, the impact of female hormone levels on postoperative inflammation and coagulation could also be a contributing factor for the increased risk of Hydrothorax, as suggested in another study [25]. To fully understand these associations, prospective research is necessary to obtain preoperative hormonal indicators in pediatric patients and postoperative indicators of inflammatory factors and coagulation function levels before the onset of Hydrothorax. By controlling for the similarity of baseline data between the two groups of males and females, we could compare the occurrence rate of pleural effusion within the same period after surgery (upon removal of the pericardial and mediastinal drainage tubes).

There was a positive correlation between pediatric patient height and abdominal fluid, and currently, there was no related research to validate this conclusion. The effectiveness of height as a predictor for Hydrothorax requires further verification.

The vasoactive-inotropic score (VIS) in the predictive model was identified as a relative factor associated with an increased risk of postoperative Hydrothorax. Further sub-group comparative analyses are required to establish the maximum VIS cutoff point for predicting Hydrothorax. It is important to explore and research more effective approaches under lower VIS to support treatments with the aim of reducing the risk of postoperative Hydrothorax.

Limitations

Limitations of Methods

Due to the inclusion of patients primarily concentrated in the period from January 2018 to December 2022, and the fact that the latest follow-up time has a maximum interval of 6 years, we currently lack the conditions for assessing long-term prognosis. Therefore, this study primarily focuses on the analysis of perioperative complications. Although the same lead surgeon performed all surgeries in this study, their technical proficiency may improve over the years, and there are differences in surgical times among the patient groups that meet the selection criteria, which inevitably affects the surgical outcomes. Additionally, the data collected in this study are from a single center, which cannot represent the national average and thus presents regional limitations. The inclusion criteria do not completely cover the impact of factors such as the patients' birth environment and maternal adverse habits on postoperative complications. Future research to determine mid- to long-term postoperative prognosis could include an earlier patient inclusion timeframe, increase the follow-up intervals, and select specific periods to record patient status, thereby reducing bias due to time differences between groups.

Limitations of Research Objectives

The aim of this study is to evaluate the safety of the combined correction of ventricular septal defects with other cardiac anomalies in young children through a right axillary incision and to analyze related factors of perioperative complications. Due to the limited variety of diseases and the various levels of proficiency in right axillary incision techniques among cardiac centers at different levels both domestically and internationally, the positive conclusions of this study are insufficient to represent the average standards. Furthermore, the factors influencing postoperative complications can only be considered in the context of right axillary incisions, as there is not enough evidence to support that complications from other types of incisions, such as median sternotomy or thoracoscopic approaches. Future research should expand the variety of diseases and incision types, and even collect multicenter data to enhance the clinical value of the factors influencing postoperative complications.

Conclusion

Isolated ventricular septal defect repair and ventricular septal defect repair combined with correction of other congenital heart anomalies via a right suaxillary minimally invasive incision resulted in significant differences for infants under 1 year of age in surgical duration, cardiopulmonary bypass time, aortic clamping time, and postoperative mechanical ventilation time. However, no significant differences were observed between the two groups in terms of in-hospital postoperative complications, postoperative echocardiographic assessment of left ventricular ejection fraction, and outcomes following ventricular septal defect repair. Our study revealed that the degree of tricuspid re-

gurgitation, postoperative mechanical ventilation time, and vasoactive-inotropic score (VIS) were identified as relative factors influencing postoperative abdominal fluid accumulation. The risk of postoperative pericardial effusion gradually increased with an increasing VIS. Furthermore, gender, height, and VIS were demonstrated as relative factors influencing postoperative pleural effusion.

Availability of Data and Materials

The study's original contributions are contained within the article/supplementary material. For additional information, please contact the corresponding authors.

Author Contributions

LL, conception, design of the work, acquisition, analysis, interpretation of data for the work. TY, acquisition, analysis, interpretation of data for the work. YL, acquisition, analysis, interpretation of data for the work. YX, acquisition, analysis, interpretation of data for the work. YY, acquisition, analysis, interpretation of data for the work. AL, design of the work. JS, design of the work. Each author contributed to editorial revisions of the manuscript. All authors re- viewed and endorsed the final version of the manuscript. Every author has sufficiently participated in the work to as- sume public responsibility for relevant aspects of the con- tent and has consented to be accountable for all aspects of the work in ensuring accuracy and integrity.

Ethics Approval and Consent to Participate

This study has been approved by the Ethics Committee of Beijing Anzhen Hospital (Approval No.: KCZD202202). All participants included in this study gave informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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