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Analysis of the therapeutic effect of right mid-axillary approach in the surgical treatment of ASD and VSD in children

Fuqiang Li[1], Tian Cheng[1], Mingliang Yan[1], Tao Li[1], Tianchen Zhang[1], Yaoxuan Huang[1] and Jian Tang[1*]

Abstract

Background To compare the therapeutic effects of right vertical infra-axillary thoracotomy (RVIAT) and Standard Median Sternotomy (SMS) in the repair of atrial septal defect (ASD) and ventricular septal defect (VSD), and to evaluate the safety and effectiveness of right subaxillary incision technique in the surgical treatment of common congenital heart disease (CHD) in children.

Methods Data of children diagnosed with ASD repair or VSD repair at our center from September 2019 to September 2022 were collected. Based on propensity score matching, 214 children (107 in the RVIAT group and 107 in the SMS group) who completed ASD repair surgery and 242 children (121 in the RVIAT group and 121 in the SMS group) who completed VSD repair surgery were selected for the study. The perioperative and follow-up data of the two surgical approaches were compared to evaluate clinical efficacy.

Results There was no statistically significant difference ($p > 0.05$) between the two surgical approaches in terms of surgical time, aortic occlusion time, total amount of ultrafiltration fluid, ICU stay time, and hospital stay; The intraoperative blood loss and total postoperative drainage fluid in the RVIAT group were lower than those in the SMS group ($p < 0.05$); The incidence of postoperative thoracic deformities in the SMS group is higher than that in the RVIAT group.

Conclusion The safety and effectiveness of the two approaches are similar, but RVIAT has less intraoperative bleeding, less postoperative drainage fluid and tube time, and better concealment and cosmetic effects, which is worthy of further clinical promotion and application.

Keywords Right mid-axillary approach, Median sternotomy, Repair of atrial septal defect, Repair of ventricular septal defect, Clinical effect

Background

Congenital heart disease (CHD) refers to the abnormal formation or development of the heart and large blood vessels during embryonic development. This results in an abnormal anatomical structure or the failure to close the channels that should be automatically closed with age after the birth of children [1]. CHD accounts for 28% of all congenital diseases and is the most common congenital disease [2]. It is estimated that approximately 8 in 1000 live births are affected by CHD [3]. Among all CHD in children, atrial septal defect (ASD) and ventricular septal defect (VSD) are the most common, occurring either as isolated conditions or in conjunction with other complex cardiac malformations. ASD is a type of CHD caused by abnormalities of the left and right atrial channels due to dysplasia of the atrial septum. The estimated incidence of ASD is 56 children with ASD per 100,000 newborns [4]. The most common type of ASD is the

*Correspondence:
Jian Tang
13759170643@163.com
[1] Department of Cardiac Vascular Surgery, Yan An Hospital of Kunming City, Kunming 65000, Yunnan, China

secundum defect, which can be further subdivided into four categories based on the specific defect site: central, inferior, superior and mixed. Similarly, VSD is a form of CHD characterized by a left-to-right shunt. Simple VSD has the highest incidence in CHD. The size of the shunt is dependent upon the size of the defect and the pressure level difference on both sides of the defect mouth [5]. In the majority of cases, children with large VSD will experience irreversible obstructive lesions of the pulmonary vessels within a relatively short time frame. This is due to the significant volume blood that is shunted through the defect, which ultimately results in the loss of the optimal surgical window for intervention [6].

For the surgical treatment of common CHD in children, such as ASD and VSD, the median sternotomy approach is the standard method for correcting simple heart defects [7]. This approach is undoubtedly the most commonly used and mature. However, with the improvement of the overall level of cardiac surgery and the further development of minimally invasive cardiac surgery techniques, the traditional transsternal median incision approach is no longer able to meet the needs of children and their families for "the smallest possible incision and the least visible incision". In recent years, due to the unsatisfactory cosmetic results and the prevalence of complications associated with sternotomy, an increasing number of surgeons have been disinclined to use this method in common congenital heart surgery [8].

The purpose of this study was to compare and analyze the relevant data of right mid-axillary approach and the standard median sternotomy in pediatric ASD repair and VSD repair, and to further explore the effectiveness and safety of right mid-axillary approach in surgical treatment of common CHD in children.

Methods

General information

A total of 810 children with ASD or VSD diagnosed and treated by the same group of surgeons at the Department of Cardiac Macrovascular Surgery, Yan 'an Hospital Affiliated to Kunming Medical University from September 2019 to September 2022 were selected. The patients' age, weight, combined with other cardiac malformation were matched with propensity scores (matching tolerance 0.05), and 456 children were finally included in the study, of which 214 were first diagnosed with ASD and 242 were first diagnosed with VSD.

Inclusion criteria: (1) Secondary ASD or perimembranous septal defect was confirmed by echocardiography; (2) < 18 years old at the time of operation; (3) No obvious symptoms of cardiac insufficiency or changes in laboratory indicators; (4) No blood system diseases or functional abnormalities. Exclusion criteria: (1) Complicated intracardiac malformation with the exception of patent foramen ovale, patent ductus arteriosus, sub-moderate tricuspid valve insufficiency and sub-moderate pulmonary valve stenosis; (2) Concurrent correction of thoracic malformations or recent history of other thoracic operations; (3) The perioperative data were not perfect.

According to the method of operation, the patients were divided into the right mid-axillary approach ASD repair group and the median sternotomy ASD repair group, 107 cases each. There were 121 cases of VSD repair through right mid-axillary approach and 121 cases of VSD repair through median sternotomy.

Surgical method

The right vertical infra-axillary thoracotomy (RVIAT) group: After satisfactory anesthesia, the children were positioned in the left lateral decubitus position at 90°, with arms extended forward perpendicular to the chest. A position pad of appropriate size was selected and placed successively between the left underarm, back, chest, and arms to fix the position. The surgical approach was selected to be the fourth intercostal space of the right midaxillary line, with a skin incision of about 3–4 cm was made along the midaxillary line at this point (Fig. 1).

Once the chest cavity had been accessed via the fourth intercostal space, the anesthesiologist initiates low tidal volume, high-frequency ventilation. Concurrently, the right lung underwent slight collapse, facilitating visual exposure, while maintaining a finger pulse oxygen saturation of at least 95%. Systemic heparinization was then performed. A parallel incision of the open pericardium was made, approximately 2 cm in front of the phrenic nerve, upward to the pericardial fold, and downward to the front of the diaphragm. The pericardium was then lifted and lifted in sequence near the inferior vena cava, superior vena cava, and aorta, fully exposing each operating point while pulling and lifting the entire pericardial cavity. The right atrial appendage was then ligated and suspended to expose the aortic root. The purse strings

Fig. 1 RVIAT Surgical Position

and catheterization at the ascending aorta, aortic root, superior vena cava, and inferior vena cava were sutured to establish extracorporeal circulation, right angle catheterization was employed; the inferior vena cava drainage tube was inserted through the skin from the 7th intercostal space of the midaxillary line in order to avoid obstructing the surgical field (Fig. 2).

The upper and lower vena cava were released, the ascending aorta were blocked, and the ventilator were ceased. The right atrium was incised in a longitudinal manner, the cardiac arrest protective fluid was injected through the aortic root, and the defect was subsequently repaired once the cardiac arrest had been satisfactorily achieved. Following the intracardiac procedure, the incision in the right atrium was closed, the aorta was opened after complete deflation, and the ultrafiltration was terminated once the heart had resumed automatic beating and circulation was stable. Protamine was neutralized with heparin. Subsequent to achieving hemostasis, drains were placed through the incision sites of inferior vena cava cannula and the intercostal space, subcutaneous tissue, and skin were then sutured in sequence. After the operation, the patient was transferred to the intensive care unit (ICU) for further observation and nursing care.

Standard Median Sternotomy (SMS) group: Once satisfactory anesthesia had been administered, a median sternotomy was taken to open the chest, and the whole body was heparinized. The pericardium was incised and suspended in order to fully expose the operative field. Cardiopulmonary bypass (CPB) was established at the ascending aorta, aortic root, right atrial appendage and inferior vena cava. The the upper and lower vena cava were released, the ascending aorta was blocked, and the ventilator was ceased. The right atrium was incised in a longitudinal manner, cardioplegia was injected through the aortic root, and the defect was repaired following the attainment of satisfactory cardiac arrest. After the intracardiac procedure, the incision in the right atrium was closed, the aorta was opened after complete deflation, and ultrafiltration was terminated once the heart had resumed automatic beating and circulation was stable. Heparin was then neutralized with protamine. After proper hemostasis, a pericardial drainage tube was placed at the lower edge of the operative mouth. The sternum was fixed with absorbable PDS suture (stainless steel wire with a body weight greater than 35 kg), and periosteum, subcutaneous tissue, and skin were subsequently sutured in turn. After the operation, the patient was transferred to the ICU for further observation and nursing care.

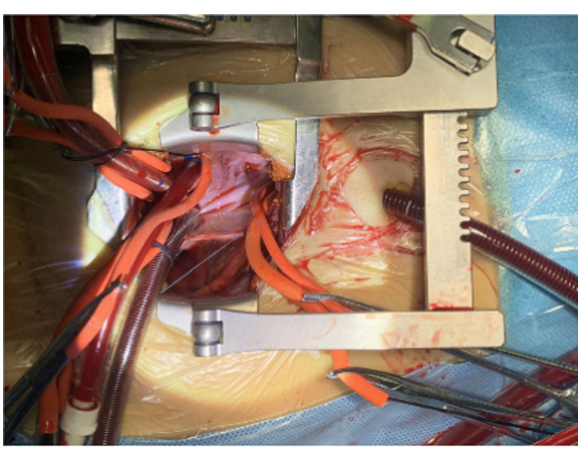

Fig. 2 Establishment of RVIAT cardiopulmonary bypass

Comparison of therapeutic effects

Intraoperative data: surgical time, blood loss, cardiopulmonary bypass time, aortic occlusion time, the amount of blood in and out of cardiopulmonary bypass, total ultrafiltration volume, etc.;

Postoperative data: ventilator-assisted ventilation time, ICU stay time, total amount of drainage fluid, total length of hospital stay, etc.;

Follow-up information: results of echocardiogram re-examination, chest X-ray re-examination, and the occurrence of complications, etc.

Statistical analysis

Perform statistical analysis on the collected data using IBM SPSS 26.0. Measurement data are expressed as mean ± standard deviation (in accordance with normal distribution) or median (interquartile range) [M (P25, P75)] (not in accordance with normal distribution), while count data are expressed as use cases (percentage) [n (%)]; Measurement data are analyzed using t-test or analysis of variance, grade data are tested using non parametric tests, and inter group comparison of count data is tested using chi square or Fisher's test. A p-value less than 0.05 indicates a statistically significant difference. All enrolled children underwent propensity score matching (PSM), and the two groups of children who underwent ASD repair surgery were matched with predictive variables such as age, weight, presence of PDA, and presence of PS; The matched predictive variables for two groups of children undergoing VSD repair surgery were age, weight, gender, pulmonary artery systolic pressure, and heart function grade. The matching tolerance is 0.05 and the matching ratio is 1:1.

Results

Comparison of preoperative characteristics between RVIAT and SMS for ASD and VSD repairs

The general preoperative data for ASD repair and VSD repair were compared between the RVIAT group and the

Standard Median Sternotomy (SMS) group. The results are shown in Tables 1 and 2. There was no statistically significant difference ($P > 0.05$) in gender, age, weight, New York Heart Association (NYHA) Heart Function Classification, defect size, and Pulmonary Art Systolic Pressure (PASP) between the two groups.

Both groups of children underwent repair of ASD were cured and discharged from hospital. Further analysis of perioperative data of the two groups showed that compared with SMS group, RVIAT group had lower ventilator-assisted ventilation time, intraoperative blood loss and postoperative drainage volume, and the difference was statistically significant. However, there was no statistically significant difference between the two groups in terms of surgical time, cardiopulmonary bypass time, aortic occlusion time, the amount of blood in and out of cardiopulmonary bypass, total ultrafiltration volume, ICU stay time, and hospitalization time (Table 3).

Both groups of children underwent VSD repair were cured and discharged from hospital. Further analysis of perioperative data of the two groups showed that the blood loss, the amount of blood in and out of cardiopulmonary bypass, the time of cardiopulmonary bypass and the total amount of postoperative drainage in the RVIAT group were lower than those in the SMS group, and the differences were statistically significant. There were no statistical differences in terms of surgical time, aortic occlusion time, ventilator-assisted ventilation time, total ultrafiltration volume, ICU stay time, and hospitalization time between the two groups (Table 4).

Comparison of postoperative complications.

Among the children who underwent ASD repair surgery, there was 1 case of pleural effusion, 1 case of moderate to severe pneumothorax, 7 cases of subcutaneous emphysema, 2 cases of right diaphragm elevation, and 1 case of chylothorax in the RVIAT group after surgery; There was 1 case of pleural effusion, 1 case of

Table 1 General preoperative information of the ASD group

Variable	RVIAT (*n* = 107)		SMS (*n* = 107)		χ2/t/Z	*p*
Sex	Male Female	36 71	Male Female	37 70	0.021	0.885
Age (years)	4.371 ± 2.933		4.713 ± 3.397		− 0.789	0.431
Weight (Kg)	16.353 ± 6.552		16.611 ± 7.594		− 0.266	0.790
New York Heart Association Heart Function Classification	I	60	I	63	− 0.409	0.683
	II	46	II	43		
	III	1	III	1		
	IV	0	IV	0		
Defect size (cm)	1.546 ± 0.567		1.577 ± 0.604		− 0.385	0.700
PASP (mmHg)	39.896 ± 8.142		41.770 ± 9.871		− 1.503	0.134

Table 2 Preoperative general data of VSD group

Variable	RVIAT (*n* = 121)		SMS (*n* = 121)		χ2/t/Z	*p*
Sex	Male Female	63 58	Male Female	65 56	0.066	0.797
Age (years)	3.014 ± 2.159		3.119 ± 2.810		− 0.327	0.744
Weight (Kg)	13.763 ± 5.063		13.721 ± 8.205		0.048	0.962
New York Heart Association Heart Function Classification	I	50	I	55	− 0.416	0.677
	II	71	II	73		
	III	0	III	2		
	IV	0	IV	1		
Defect size (cm)	0.790 ± 0.220		0.778 ± 0.340		0.326	0.745
PASP (mmHg)	37.770 ± 9.397		39.680 ± 11.157		− 0.686	0.494

Comparison of intraoperative and postoperative indexes

Table 3 Perioperative related data of the ASD group

Variable	RVIAT (*n* = 107)	SMS (*n* = 107)	t	*p*
Surgical time (h)	1.960 ± 0.297	1.867 ± 0.383	1.954	0.052
Blood loss (ml)	23.460 ± 6.566	36.400 ± 30.965	− 6.095	0
Circulating blood inflow and outflow (ml)	89.240 ± 102.912	75.400 ± 146.286	− 0.597	0.551
Ultrafiltration (ml)	538.882 ± 237.992	607.941 ± 302.439	− 1.856	0.065
Aortic cross clamp time (min)	19.412 ± 6.237	20.307 ± 6.946	− 0.984	0.362
Transfer time (min)	42.564 ± 10.449	40.522 ± 9.560	1.488	0.138
Respirator usage time (h)	5.439 ± 5.958	8.125 ± 12.431	− 2.028	0.044
ICU stay time (d)	2.110 ± 0.538	2.120 ± 1.323	0.068	0.946
Postoperative drainage fluid volume (ml)	127.421 ± 74.476	155.853 ± 64.553	− 2.965	0.003
Hospitalization time (d)	16.213 ± 4.272	16.288 ± 3.660	− 0.120	0.904

Table 4 Perioperative related data of the VSD group

Variable	RVIAT (*n* = 121)	SMS (*n* = 121)	t	*p*
Surgical time (h)	2.198 ± 0.537	2.183 ± 0.495	0.227	0.820
Blood loss (ml)	23.350 ± 7.053	33.601 ± 21.892	–4.901	0
Circulating blood inflow and outflow (ml)	103.260 ± 81.781	136.280 ± 105.150	–2.727	0.007
Ultrafiltration (ml)	659.920 ± 178.958	678.260 ± 222.318	–2.727	0.007
Aortic cross clamp time (min)	34.500 ± 14.234	32.980 ± 12.508	–0.886	0.376
Transfer time (min)	60.980 ± 19.651	55.820 ± 15.535	2.256	0.025
Respirator usage time (h)	7.190 ± 7.210	9.479 ± 16.919	–1.369	0.173
ICU stay time (d)	2.180 ± 0.632	2.310 ± 0.956	–1.190	0.235
Postoperative drainage fluid volume (ml)	127.312 ± 49.148	141.825 ± 60.793	–2.042	0.042
Hospitalization time (d)	16.180 ± 4.242	16.370 ± 4.217	–0.358	0.721

Table 5 Postoperative complications in the ASD group

Postoperative complications	RVIAT (*n* = 107)	SMS (*n* = 107)	χ^2	*p*
Pleural effusion	1 (0.9)	1 (0.9)	10.198	0.087
Moderate to severe pneumothorax	1 (0.9)	0		
Pneumopericardium	0	1 (0.9)		
Subcutaneous emphysema	7 (6.5)	0		
Diaphragm elevation	2 (1.8)	0		
Chylothorax	1 (0.9)	0		
Closed thoracic drainage	0	1 (0.9)		

Table 6 Postoperative complications in the VSD group

Postoperative complications	RVIAT (*n* = 121)	SMS (*n* = 121)	χ2	*p*
Pneumopericardium	1 (0.8)	1 (0.8)	7.611	0.060
Subcutaneous emphysema	5 (4.1)	0		
Diaphragm elevation	2 (1.7)	0		
Secondary thoracotomy for hemostasis	0	1 (0.8)	7.611	0.060
Residual shunt	2 (1.7)	4 (3.3)		

pneumopericardium, and 1 case of closed thoracic drainage in the SMS group. Numerically speaking, the incidence of postoperative complications in the RVIAT group was higher than that in the SMS group, but after testing ($\chi^2 = 10.198$, $p = 0.087 > 0.05$), the difference was not statistically significant (Table 5).

In the RVIAT group, pneumopericardium occurred in 1 case, subcutaneous emphysema in 5 cases, right diaphragm elevation in 2 cases and residual shunt in 2 cases. In SMS group, there were 1 case of pneumopericardium, 1 case of secondary thoracotomy for hemostasis and 4 cases of residual shunt. After examination ($\chi^2 = 7.611$, $p = 0.06 > 0.05$), there was no statistical difference in the occurrence of postoperative complications between the two groups, and all complications were cured before discharge, except for residual postoperative shunt (Table 6).

Discussion

In light of the ongoing advancement of cardiac surgery technology and the enhancement of surgical abilities among surgeons, minimally invasive techniques and postoperative aesthetic outcomes have increasingly become focal points of investigation in recent years. The objective of an increasing number of cardiac surgeons is to identify methods that will minimize surgical trauma and improve postoperative aesthetics [9–14].

As early as 1996, Liu et al. attempted to perform open-heart surgery for intracardiac malformations from the fourth intercostal thoracotomy through an oblique incision from the right anterior axillary line to the posterior axillary line. This procedure opened the door for heart surgery through small underarm incisions in China [15]. In the following years, open-heart surgery such as CHD correction and valve replacement was also reported in various centers by making curved incisions from the axillary posterior line down to the 6th intercostal space [16] and from the 3rd intercostal space from the midaxillary line to the 4th intercostal space [17]. Until 2001, Wang et al. proposed the concept of open heart surgery through right armpit straight incision and completed the follow-up of 1,126 patients after surgery. They concluded that RVIAT did not need to segment or cut muscles other than the intercostal muscles, and retained the long thoracic nerve and the normal space between the ribs, which would not hinder the symmetrical development of the breast and the sensitivity of the nipple. In addition, the limited vertical skin incision in the armpit can better meet the aesthetic needs of patients and avoid the damage caused by femoral arterivenous intubation [18]. In recent years, as more and more heart centers have carried out minimally invasive heart surgery, many advantages of RVIAT have gradually emerged, including greatly reducing the psychological burden of patients from the social level, reducing the treatment cost caused by special surgical instruments, and being easy to master by surgeons [9, 19–21].

Early studies on small or straight incisions in the right axilla have achieved satisfactory results, but most of them are small samples with a wide age range, and still lack certain credibility and specificity. This study included 456 cases of CHD in children, with a relatively single diagnosis and a concentrated age. PSM was used in case screening to ensure that there were no statistically significant differences in preoperative data of the children.

In this study, no matter ASD repair or VSD repair was performed, the RVIAT group had less intraoperative blood loss and total postoperative drainage than the SMS group, which was consistent with the results of relevant foreign studies [22, 23]. This may be related to the fact that RVIAT does not require sternal sawing and has a smaller surgical wound. In terms of operation time, aortic occlusion time, total amount of ultrafiltrate, ICU stay time and hospital stay, there was no statistical significance between the two groups after data comparison. It can be considered that there was no significant difference between the two approaches in terms of intraoperative procedures and postoperative recovery. In the cases of VSD repair, the cardiopulmonary bypass time was longer in the RVIAT group than in the SMS group, which was considered to be caused by waiting for the shutdown of cardiopulmonary bypass during the routine transesophageal echocardiography in the RVIAT group.

In terms of postoperative complications observation and follow-up, although the incidence of subcutaneous emphysema and pneumothorax in the RVIAT group was higher than that in the SMS group, most of them did not require special intervention, and all of them had healed themselves upon discharge. In the telephone follow-up after surgery, none of the children in the RVIAT group had thoracic malformations, and their families were satisfied with the aesthetic appearance and recovery of the operation (Fig. 3). In the SMS group, 24.83% of the children had thoracic malformation (mainly chicken breast), and some family members were worried about the future effects on the thoracic cavity and operative mouth. In a comparison of the three surgical incisions performed by Zhi-nuan Hong et al. [19], postoperative thoracic deformity was observed in seven of the 56 patients included in the study who underwent median chest opening. Five of these patients developed chicken chest and two developed funnel chest, with an incidence of 12.5%. In contrast, no patients with postoperative thoracic deformity

Fig. 3 Anterior and lateral views of the chest at 3 months after RVIAT surgery

were seen in the submammary thoracotomy and right axillary thoracotomy groups. Zeng-rong Luo et al. found that the median sternotomy group showed an 8.9% incidence of postoperative thoracic deformity. Among 45 patients, 3 patients showed postoperative chicken breast, 1 patient showed postoperative funnel chest, and the incidence of postoperative thoracic deformity was 0 in both groups of inframammary thoracotomy and right axillary thoracotomy [24]. It can be seen that RVIAT has better cosmetic effects than SMS.

Conclusion

For the surgical treatment of common CHD in children, the right mid-axillary approach and the median sternotomy approach have good safety and effectiveness. In contrast, the right axillary direct incision approach has less blood loss, less postoperative drainage and tube time, and has better concealment and cosmetic effects, which is worthy of further clinical application.

Limitations

There are still some shortcomings in this study. Firstly, the selected cases were all from the same cardiac center, which was a single-center study with limited representativeness. Secondly, the surgical time span of the selected cases is relatively large, and with the continuous improvement of the surgeon's skills, there may be some deviation in the surgical data in different periods. In addition, the study was a retrospective study with a short follow-up time, and the reliability of the conclusions still needs to be further proved by relevant prospective studies and long-term follow-up data.

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Author contributions
Fuqiang Li, Tian Cheng and Jian Tang conceived and designed the study. Fuqiang Li, Tian Cheng and Jian Tang conducted the study. Mingliang Yan, and Tao Li contributed to data acquisition. Tianchen Zhang and Yaoxuan Huang analyzed the data. Mingliang Yan, and Tao Li interpreted the data. Fuqiang Li, Tian Cheng and Jian Tang edited the manuscript draft. Fuqiang Li, Tian Cheng and Jian Tang reviewed and edited the manuscript. All authors have read and approved the manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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