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Conduction Disorders in Continuous Versus Interrupted Suturing Technique in Ventricular Septal Defect Surgical Repair

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Background: Ventricular septal defects (VSD) is one of the most frequent congenital cardiac malformations and cardiac conduction disorders are still one of the serious postoperative complications in this surgery.
Objectives: This study aimed to compare the incidence of conduction disorders with the use of continuous compared to interrupted suturing techniques in VSD surgical repair.
Patients and Methods: Previously recorded data of 231 patients who underwent surgical closure of VSD between January 2009 and January 2012 at the Rajaie cardiovascular medical and research center were retrospectively reviewed. VSD surgical repair was performed using continues suturing technique in group A patients (n = 163, 70.6%) and interrupted suturing technique in group B patients (n = 68, 29.4%).
Results: The most common concomitant congenital anomaly was Tetralogy of Fallot (27.3%). Twenty-four (10.4%) patients had intraoperative cardiac arrhythmia, including 19 (8.2%) transient and 5 (2.2 %) permanent arrhythmia. During their ICU stay, ventricular arrhythmia and complete heart block were observed in 34 (14.7%) and 5 patients (2.2%), respectively. At the time of the last follow-up, incomplete right bundle branch block (RBBB), complete RBBB, RBBB with left anterior hemi-block, and complete heart block were identified in 84 (36.4%), 42 (18.2%), 29 (12.6%), and 5 patients (2.2%), respectively. The results revealed that group A patients were most likely to have had cardiac arrhythmias during their ICU stay and at the time of last follow-up ($P < 0.001$), while the intraoperative incidence of cardiac arrhythmia during surgery was not statistically significant between the two groups ($P = 0.06$).
Conclusions: In the absence of any statistical differences in the other risk factors between the two groups, the difference in the incidence of conduction disorders can be attributed to the type of suturing used during the procedure.

Keywords: Ventricular Septal Defect Repair; Defect; Cardiac Arrhythmia

1. Background

Ventricular septal defects (VSDs) are the most frequent congenital cardiac malformations. One of the serious post-surgical complications remains the development of a complete heart block. Closure of VSD is usually achieved by anchoring a patch using either a continuous or an interrupted suture. During this maneuver, traction and tension are needed in order to obtain good surgical exposure. The conduction system, specifically the bundle of His and its branches, is usually closely related to some part of the border of the defect, and is at risk for damage during the insertion of the individual stitches. If heart block occurs during or after the procedure, it is most often an indication for permanent pacemaker insertion. This is performed through partial or complete sternotomy, which has been demonstrated to increase the risk of late death in patients with postsurgical complete heart block (1).

Large single center studies report a 0% to 3% incidence of atrioventricular (AV) block after the operative repair of VSDs (2, 3). Recent studies have reported a 2% to 3.6% incidence of AV block requiring immediate and late permanent pacemaker placement after transcatheter device closure of perimembranous VSD (4, 5).

2. Objectives

The aim of this study was to compare the incidence of AV block between the continuous and interrupted suture groups, respectively.

3. Patients and Methods

Patients who underwent surgical closure of VSD between January 2009 and January 2012 were identified from our databases at the Rajaie cardiovascular, medical and research center. Patients who were ≤ 18 years old at the time of surgery were included in this study while those with an atrioventricular canal were excluded from participation. The local ethics committee, faculty of medicine, Iran University of Medical Sciences, Tehran, Iran approved the protocol for this study.

A total of 239 patients underwent congenital VSD repair between January 2009 and January 2012. Data from 8 patients were excluded due to either atrioventricular canal or incomplete information. Details about the patients' past medical and surgical history, intracardiac hemodynamics, ventricular function, associated cardiac anomalies, New York heart association functional class, surgical indication and postoperative complications, and patient outcomes, were retrospectively reviewed from clinical notes, surgical protocols, and imaging study reports, respectively.

3.1. Surgical Technique

Standard cardiopulmonary bypass with cold potassium and blood cardioplegic solution was used in all surgeries. The use of the suture or patch closing technique, the approach to the ventricular septum, and the type of suturing that was used, were noted. The largest VSD diameter at surgical inspection was used for determining the defect size. The diameter reported in preoperative echocardiography was used when the VSD diameter was not reported in the operative notes.

3.2. Statistical Analysis

Multivariable logistic regression was performed in order to develop a parsimonious model for identifying factors that were associated with separated suture techniques. A directed stepwise approach using the criteria of $P \leq 0.05$ for retention of variables was utilized for the initial model. The factors that demonstrated the greatest association with the separated suture techniques included the preoperative treatment (Odds ratio = 0.32, P = 0.013) and positional anomaly (Odds ratio = 0.005, P < 0.0001), which were not statistically different between the two groups (Tables 1 and 2).

Table 1. Comparison of the Continuous Demographic Characteristics of the Patients in the Two Suture Groups [a]

Variables	Total	Continuous	Interrupted	P Value
Age, mo	50.53 ± 38.38	49.42 ± 36.46	53.25 ± 42.92	0.98
Height, cm	98.03 ± 22.73	97.37 ± 22.51	99.64 ± 23.36	0.89
Weight , Kg	15.40 ± 10.63	14.91 ± 8.69	16.59 ± 14.29	0.69
BSA	0.61 ± 0.24	0.61 ± 0.21	0.63 ± 0.29	0.68
Age of PA banding, mo	2.26 ± 4.57	2.55 ± 5.05	1.56 ± 3.06	0.15
Weight of PA banding, Kg	1.89 ± 3.07	2.11 ± 3.26	1.37 ± 2.49	0.13
Preoperative LVEF	61.60 ± 6.32	61.54 ± 6.94	61.74 ± 4.51	0.82
Postoperative LVEF	60.35 ± 5.24	60.30 ± 5.50	60.54 ± 4.35	0.84
Preoperative LV-RV gradient	26.23 ± 25.17	25.81 ± 27.39	27.27 ± 18.86	0.28
Preoperative QP/QS	2.11 ± 0.82	2.05 ± 0.89	2.24 ± 0.65	0.70
VSD/BSA	1.91 ± 0.98	1.90 ± 1.07	1.92 ± 0.75	0.29
Pump time, min	110 ± 42.42	93.01 ± 37.62	118.15 ± 65.17	0.001
ACC time, min	67.50 ± 38.89	58.52 ± 35.24	66.49 ± 23.41	0.001
Temp	2.26 ± 0.45	2.30 ± 0.48	2.17 ± 0.37	0.07
ICU stay, d	2.85 ± 1.18	2.88 ± 1.16	2.78 ± 1.24	0.175
Intubation duration, d	1.20 ± 0.49	1.22 ± 0.49	1.17 ± 0.49	0.38
PR interval, cm	0.11 ± 0.07	0.11 ± 0.06	0.11 ± 0.09	0.001
QRS duration, cm	0.13 ± 0.05	0.14 ± 0.06	0.12 ± 0.03	0.001
Follow-Up, mo	13.28 ± 12.93	13.64 ± 14.04	12.26 ± 9.13	0.84

[a] The values are presented as mean ± SD.

Table 2. Comparison of the Categorical Characteristics of the Patients in the Two Suture Groups [a]

Variables	Total	Continuous	Interrupted	P value
Gender				0.14
Male	130 (56.3)	90 (55.2)	40 (58.8)	
Female	101 (43.7)	73 (44.8)	28 (41.2)	
Preoperative medical treatment	162 (70.1)	108 (33.6)	54 (79.4)	0.058
PA banding	70 (30.3)	55 (33.7)	15 (22.1)	0.086
PDA	55 (22.1)	35 (21.5)	20 (29.4)	0.73
Coarctation of the aorta	3 (1.3)	2 (1.2)	1 (1.5)	0.88
Congenital AS	4 (1.7)	1 (0.6)	3 (4.4)	0.04
Subvalvular stenosis	10 (4.3)	4 (2.5)	6 (8.8)	0.068
Congenital MS	1 (0.4)	0 (0)	1 (1.5)	0.12
Congenital MR	8 (3.5)	6 (3.7)	2 (2.9)	0.78
Absence of PA	2 (0.9)	2 (1.2)	0	0.36
Stenosis of PA	31 (13.4)	20 (12.3)	11 (16.2)	0.52
ASD	49 (21.2)	38 (23.3)	11 (16.2)	0.29
Positional Anomaly	9 (3.9)	4 (2.5)	5 (7.4)	0.08
TOF	63 (27.3)	45 (27.6)	18 (26.5)	0.86
Malposition of the great arteries	10 (4.3)	10 (6.1)	0.(0)	0.04
Truncus arteriosus	2 (0.9)	2 (1.2)	0 (0)	0.36
Tricuspid atresia	0 (0)	0 (0)	0 (0)	
Sinus of valsalva aneurysm	0 (0)	0 (0)	0 (0)	
Interrupted aortic arch	0 (0)	0 (0)	0 (0)	
Dexterocardia	1 (0.4)	1 (0.6)	0	0.52
Situs inversus totalis	0 (0)	0 (0)	0 (0)	-
Type of VSD				0.8
Perimembranous	194 (84)	135 (58.4)	59 (86.80)	
Muscular				
Anterior	4 (1.7)	3 (1.8)	1 (1.5)	
Apical	2 (0.9)	2 (1.2)	0	
Trabecular	4 (1.7)	4 (2.5)	0	
Inlet	14 (6)	11 (6.7)	3 (4.4)	
Doubly committed	7 (3)	5 (3.1)	2 (2.9)	
Subarterial	3 (1.3)	2 (1.2)	1 (1.5)	
Inlet	4 (1.7)	1 (0.6)	3 (4.4)	
TR				0.10
Mild	104 (45)	77 (47.2)	27 (39.7)	
Moderate	33 (14.3)	16 (9.8)	17 (25)	
Severe	3 (1.3)	3 (1.8)	0	
AI				0.26

Mild	11 (4.8)	10 (6.1)	1 (1.5)	
Moderate	9 (3.9)	6 (3.7)	3 (4.4)	
Severe	3 (1.3)	3 (1.8)	0	
VSD Diameter				0.46
Small	20 (8.7)	13 (8)	7 (10.3)	
Moderate	34 (14.7)	23 (14.1)	11 (16.2)	
Large	177 (77.6)	127 (77.9)	50 (73.5)	
VSD Shunt				0.46
Left to right	185 (80.1)	128 (78.5)	57 (83.8)	
Right to left	24 (10.4)	19 (11.7)	5 (7.4)	
Both	22 (9.5)	15 (9.2)	7 (10.3)	
Technique				0.03
Atrial	201 (87)	135 (82.8)	66 (97.1)	
Ventricular	26 (11.3)	26 (16)	0	
Aorta	4 (1.7)	2 (1.2)	2 (2.9)	
Suture type				
Continuous	163 (70.6)			
Interrupted	68 (29.4)			
Patch type				0.03
Pericard	15 (6.5)	12 (7.4)	3 (4.4)	
Goretex	200 (86.5)	140 (86)	60 (88.2)	
Dacron	16 (7)	11 (6.6)	5 (7.4)	
Aortic repair				0.63
Direct	7 (3)	5 (3.1)	2 (2.9)	
Patch	9 (3.9)	7 (4.3)	2 (2.9)	
Tricuspid repair	42 (18.2)	19 (11.7)	23 (33.8)	< 0.001
PA debanding				0.19
Direct	39 (16.9)	30 (18.4)	9 (13.2)	
With patch	15 (6.5)	12 (7.4)	3 (4.4)	
Inotrope dose				0.59
Low (< 0.02)	121 (52.4)	83 (50.9)	38 (55.9)	
Mod dose (0.05 - 0.1)	32 (13.9)	27 (16.6)	5 (7.4)	
High (> 0.2)	4 (1.7)	4 (2.5)	0	
None	74 (32)	49 (30.1)	25 (36.8)	
Reoperation	9 (3.9)	9 (5.5)	0	0.049
Defective growth	4 (1.7)	3 (1.8)	1 (1.2)	0.84
Residual Shunt				< 0.001
Small (1 - 2.3)	118 (51.1)	101 (62)	17 (25)	
Moderate	10 (4.3)	10 (6.1)	0	
Severe	0	0	0	

Residual PS				0.81
Mild	48 (20.8)	33 (19.6)	15 (22.1)	
Moderate	2 (0.9)	1 (0.6)	1 (1.2)	
Severe	1 (0.4)	1 (0.6)	0	
Post-operative TR				0.45
Mild	132 (57.1)	89 (54.6)	43 (63.2)	
Moderate	19 (8.2)	18 (11)	1 (1.2)	
Severe	1 (0.4)	1 (0.6)	0	
Postoperative AI				0.26
Mild	74 (32)	48 (29.4)	26 (38.2)	
Moderate	3 (1.3)	3 (1.8)	0	
Severe	1 (0.4)	1 (0.6)	0	
Rhythm (OR)				0.06
Sinus	207 (89.6)	141 (86.5)	66 (97.1)	
Transient pace maker	19 (8.2)	17 (10.5)	2 (2.9)	
Permanent pace maker	5 (2.2)	5 (3.0)	0	
Rhythm (ICU)				< 0.001
Sinus	192 (83.1)	126 (77.3)	66 (97.1)	
CHB	5 (2.2)	5 (3.0)	0	
AVB	34 (14.7)	32 (19.7)	2 (2.9)	
Rhythm (Follow-up)				< 0.001
Sinus	71 (30.6)	25 (15.3)	46 (67.6)	
Incomplete RBBB	84 (36.4)	69 (42.3)	15 (22.1)	
Complete RBBB	42 (18.2)	39 (24)	3 (4.4)	
RBBB + left ant Hemi-block	29 (12.6)	25 (15.4)	4 (5.9)	
CHB	5 (2.2)	5 (3.0)	0	
Complication				0.33
Bleeding	5 (2.2)	5 (3.1)	0	
PH crisis	2 (0.9)	2 (1.2)	0	
Death	1 (0.4)	1 (0.6)	0	0.52

[a] The values are presented as No. (%).

Furthermore, stepwise logistic regression models were used to find multivariate predictors for postoperative cardiac arrhythmia in order to detect confounding variables. The multivariable model included all the significant variables that were identified during univariate analysis ($P < 0.05$). Model selection was performed using the stepwise method (backward and forward methods resulted in the same model). The factors that were most associated with postoperative cardiac arrhythmia are exhibited in Table 3. There were no significant differences in the confounding variables between the two suture type groups. Therefore, the two groups were already well matched and did not require propensity match analysis (6).

Categorical variables were reported as frequency and percentage while continuous variables were reported as the mean with standard deviation, respectively. Categorical baseline characteristics and outcomes were compared between groups using the chi-square or Fisher exact tests (where appropriate), while continuous variables were compared using analysis of variance or Kruskal-Wallis tests (where appropriate). All statistical tests were 2 sided with the alpha level set at 0.05 for statistical significance.

Table 3. Comparison of The Variables Identified By Multivariate Logistic Regression According To The Timing of Arrhythmia Occurrence (Operating Room, Icu, After Discharge)

Variables	Cardiac Arrhythmia (Operating Room)	Cardiac Arrhythmia (ICU)	Cardiac Arrhythmia (Discharge)
Age	■		■
Gender		■	
Height	■		■
Weight	■		■
Body surface area (BSA)	■		■
Preoperative treatment		■	■
Congenital mitral regurgitation			■
Absence of pulmonary artery	■	■	
Atrial septal defect		■	
Position anomaly		■	
Type of ventricular septal defect (VSD)	■		
VSD/BSA	■		
Suture technique			■
Aortic repair		■	
Inotrope use	■		
ICU stay	■		■
Intubation period	■		■
Postoperative Tricuspid regurgitation		■	
Residual VSD shunt			■
PR Interval		■	■
QRS duration	■	■	■

4. Results

Two hundred and thirty-one patients, including 130 (56.3%) male subjects, with a mean age of 50.53 ± 38.38 months, were included in the study. The mean follow-up time was 13.28 ± 12.93 months. The most common concomitant congenital anomaly was Tetralogy of Fallot (27.3%) followed by persistent ductus arteriosus (22.1%), atrial septal defect (21.2%), and stenosis of the pulmonary artery (13.4%). The continues variables are described in Table 1, while categorical variables are exhibited in Table 2. One hundred and sixty-three (70.6%) and 68 (29.4%) patients with VSD underwent surgical repair using the continuous (group A) and interrupted (group B) suture types, respectively. The patients in group B had longer pump and aortic cross clamp times ($P < 0.001$ and $P = 0.001$, respectively) while group A patients had longer PR-Intervals and QRS durations at the time of discharge ($P = 0.001$ and $P < 0.001$, respectively). However, the differences in the other risk factors for postoperative cardiac arrhythmia (Table 3) were not statistically significant between the two groups (Table 1 and Table 2). Twenty-four (10.4%) patients had intraoperative cardiac arrhythmias, 19 (8.2%) had transient and 5 (2.2 %) had permanent cardiac arrhythmia. During their ICU stay, 34 (14.7%) patients had ventricular arrhythmias while 5 patients (2.2%) had complete heart blocks. At the time of last follow-up, 84 (36.4%), 42 (18.2%), 29 (12.6%), and 5 patients (2.2%) had incomplete right bundle branch block (RBBB), complete RBBB, RBBB with left anterior hemi-block and complete heart block, respectively. The results indicate that the group A patients most likely had cardiac arrhythmia during their ICU stay, and at the time of last follow-up ($P < 0.001$) while the incidence of cardiac arrhythmia at the operation room was not statistically significant between the two groups ($P = 0.06$). The mean age and body mass index (BMI) were 53.45 ± 53.84 and 15.63 ± 2.30, respectively, in patients with cardiac arrhythmia at the time of last follow-up, and were 56.21 ± 47.83 and 15.30 ± 3.89 in patients with sinus rhythm, respectively. There were no statistical differences in age and BMI between these groups ($P = 0.052$ and 0.77, respectively).

Complications that were considered included postoperative bleeding, sepsis, neurological accidents, and pulmonary hypertensive (PH) crisis. Among 231 patients, postoperative bleeding and PH crisis occurred in 5 (2.2%) and 2 (0.9%) patients, respectively. One patient (0.4%) in group A died during follow-up because of severe pneumonia.

5. Discussion

Our study has some limitations including the lack of long-term follow-up. Therefore, the incidence of late permanent AV block requiring pacemaker implantation is not defined in our study. However, the follow-up duration was not statistically different between groups.

In conclusion, our study demonstrated that although the prevalence of conduction disorders in both continuous and interrupted suturing for VSD surgical repair is around 1%, it is significantly less common with the interrupted compared to the continuous method.

Ventricular septal defect (VSD) is one of the most common defects requiring surgical intervention (7, 8). Lillehei and associates performed the first surgical closure of the VSD in 1955 (9, 10). Several subsequent improvements in surgical repair, including improved techniques in cardiopulmonary bypass, myocardial preservation, anesthesia, and postoperative care, have greatly reduced operative mortality. Complications are rare, but can include residual VSD, conduction disorder, emergent reoperation, neurologic injury, and death (9, 10). For infants who undergo surgical closure of VSD, long-term results are similarly positive. Meijboom and associates (11) reported normal growth in all survivors with a good quality of life after more than 10 years postoperatively. Other recent studies report similar outcomes, with the risk of mortality, major morbidity, emergent reoperation, and significant residual VSD of approximately 1% (10).

Conduction system injury continues to be a leading cause of long-term postoperative cardiac morbidity, especially with the performance of more surgical procedures in increasingly younger patients. Complete heart block has been a serious complication of VSD closure which is associated with an increased risk of late death (1, 12). Because of the close anatomic relationship of the atrioventricular node and the bundle of His to the inferoposterior wall, the conduction system is particularly at risk during closure of perimembranous VSDs (13, 14). Increasing knowledge of the anatomy of the conduction system has greatly decreased the incidence of intraoperative injury (2, 15, 16). In fact, numerous studies have reported the absence of complete heart block after VSD closure (11, 17, 18). Andersen et al. (2) recently reviewed the results of a large series of patients undergoing VSD repair at the Great Ormond Street Hospital for Children during a 26-year period. Based on the results of their study, they suggest that the risk of iatrogenic complete heart block with VSD closure should be less than 1% and the expected mortality rates for these patients should be approaching 0%.

The results of our study exhibited a higher rate of CHB compared to that previously reported by Andersen et al (2). The incidence of complete heart block and an operative mortality were 2.2% and 0.4%, respectively. Furthermore, overall morbidity was minimal, with 9 (3.9%) patients requiring reoperation for residual VSD, the absence of valve-related complications, and preservation of left ventricular function postoperatively.

Right bundle branch block is a recognized finding after VSD closure, and this was also observed in our study, with 84 (36.4%) incomplete RBBB, 42 (18.2%) complete RBBB and 29 (12.6%) RBBB with left anterior hemi-block cases, respectively. The significance of long-standing right bundle branch block has been debated, and a recent report by Pederson et al. (19) studied the long-term significance of right bundle branch block on left ventricular function after surgical closure of VSD. They noted that right bundle branch block continues to be a common finding after surgical repair, which in long term follow up, does not appear to affect systolic ventricular function but may be associated with diastolic dysfunction. Right bundle branch block after surgical closure of VSD remains a common finding that warrants long term evaluation.

Previous studies have detected potential risk factors for atrioventricular block after surgical repair of VSD. Some studies have suggested an association between surgical heart block and small size, but these were inadequately powered to provide definitive data (20, 21). Siehr et al. (22) have demonstrated that patients weighing less than 4 kilograms were at significantly higher risk for surgical AV block. Our results could not find such a difference. Moreover, Anderson et al. (23) has substantiated that VSD location and type of repair were also important in predicting the risk of heart block. They reported that patients with atrioventricular canal repair were more likely to develop postoperative heart block compared to those with isolated VSD and TOF repair. Additionally, the majority of patients with surgical heart block had inlet VSDs. This likely relates to the proximity of the AV node and the posterior-inferior margin of the inlet VSD. Our study demonstrated that the prevalence of inlet VSD was higher in patients with sinus rhythm at the last follow-up (7.8% versus 11.7%), which was not statistically significant ($P = 0.13$). Malalignment VSDs were detected in 21.1% of patients with sinus rhythm and 18.7% of patients with cardiac arrhythmia ($P = 0.15$), respectively; these results were not similar to results from previous studies (2).

Another difference in VSD repair involves the use of either the continuous or interrupted stitch. Tanveer et al. (24) previously compared the incidence of residual VSD after the use of the continuous and interrupted types of stitches in patients with TOF. Their results demonstrated that residual VSD is more common with the continuous compared to the interrupted suturing technique of VSD closure. No postoperative heart blocks were detected in any of their patients (24). Although our results were consistent with theirs while incidence of residual shunt was higher in continuous suture type group than interrupted one ($P < 0.01$). Residual VSD may result from insufficient intraoperative exposure or suture disruption with patch dehiscence (24-26). Significant residual shunting is most commonly observed in muscular defects. It has been suggested that trabeculations decrease the visualization of the full extent of the VSD (24). Our results also demonstrated that 67% (6 out of 9) of the moderate residual VSD shunt occurred in either the muscular or inlet type of VSD.

Multivariate analysis on our data resulted in the selection of AVB risk factors including age, height, weight, and BSA at the time of surgery, preoperative treatment, congenital mitral regurgitation, VSD/BSA, suture type, temperature during operation, duration of ICU stay and intubation, postoperative and discharge residual VSD as well as the PR and QRS durations at the time of discharge. There were no statistical differences in these risk factors between continuous and interrupted suture groups except for the PR and QRS durations, respectively, at the time of discharge. Therefore, the differences in the incidence of AVB can be attributed to the type of suturing. This was the first time that type of suturing has been evaluated as a risk factor for AVB.

Authors' Contributions

Study concept and design: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki. Acquisition of data: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki. Analysis and interpretation of data: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki. Drafting of the manuscript: Maziar Gholampour Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki. Critical revision of the manuscript for important intellectual content: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zare, Solmaz Babaki. Statistical analysis: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki. Study supervision: Maziar Gholampour-Dehaki, Hoda Javadikasgari, Asghar Zareh, Solmaz Babaki.

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