Mattress Stitch—A Modified Shallow Stitching in the Surgical Closure of Large Perimembranous Ventricular Septal Defect in Infants

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Objectives: The purpose of this study was to assess the feasibility of the mattress suturing technique in repairing large perimembranous ventricular septal defects (VSDs) in infants.

Methods: This was a retrospective review of 120 patients undergoing surgical closure of perimembranous VSD between 2010 and 2012. The mattress suturing technique was performed to close the infero-posterior rim of the perimembranous VSD in 60 patients (Group I) while the conventional shallow suturing method was used in the others (Group II). Propensity-score matching was performed to adjust for potential baseline confounders, which resulted in 120 patients matched to 95 patients. Perioperative outcomes were compared.

Results: Postoperative mortality in both groups was zero. Two patients in Group II developed atrioventricular block (1 complete heart block and 1 temporal II-degree atrioventricular block) compared with none in Group I (p > 0.05). Complete right bundle branch block was found in four patients in Group I and 12 patients in Group II (p = 0.035). Mean follow-up time was 26.6 ± 8.9 months. Three patients in Group II developed a small residual VSD while only one patient in Group I did during the follow-up period (p > 0.05).

Conclusions: The mattress suturing technique produced results comparable with the conventional shallow suturing method and seems to be of value in reducing the incidence of complete right bundle branch block. It appears to provide an optional method for surgical closure of large perimembranous VSDs in infants.

Keywords: Congential heart disease, perimembranous ventricular septal defect, surgical closure, infants

Introduction

Ventricular septal defect (VSD) is one of the most frequent congenital heart malformations, accounting for 40% of all congenital heart diseases. Among these, perimembranous VSD is the commonest hemodynamically significant one. They can be isolated, or be an intrinsic component of other simple or complex cardiac abnormalities. Since Lillehei first repaired the VSD in 1954, techniques have progressed considerably such that surgical closure is now performed with minimal morbidity.
and mortality. Complications are rare but still include injury of conduction system, residual shunt, emergent reoperation, and postoperative death, mainly in malnourished infants suffering from large perimembranous VSDs. Since 2011, we have adopted the mattress suturing technique to close the infero-posterior margin of large perimembranous VSDs. In the current series, we retrospectively reviewed 120 infants with poor weight suffering from large perimembranous VSDs to assess this new method and evaluate its effectiveness.

Material and Methods

Patients were identified by review of the institutional cardiothoracic surgical database after obtaining approval from Ethics Committee of Shanghai Children’s Medical Center. Between February 2010 and November 2012, 120 consecutive infants (51 males, 69 females) underwent surgical closure of perimembranous VSDs. Indications for operative intervention that were taken from the referring surgeon’s preoperative note included congestive heart failure, poor weight gain, failure to thrive, and pulmonary overcirculation. All operations were performed by one surgeon. Conventional shallow suturing was performed in the 60 patients (Group II) before 2011 while mattress suturing has been employed in the others (Group I) since then. The preoperative demographics are summarized in Table 1. Echocardiography was performed in all patients. Patients with associated intra-cardiac and extracardiac lesions included patent ductus arteriosus (n = 14), patent foramen ovale (n = 12), and Down’s syndrome (n = 11).

| Table 1: Distribution of potential confounders used in the propensity-score model in patients before and after matching |
|---|
| | Entire sample | Propensity-score matched groups |
| | Group I | Group II | p value | Group I | Group II | p value |
| Number of patients | 60 | 60 | - | 45 | 50 | - |
| VSD (cm) | 0.95 ± 0.34 | 0.94 ± 0.38 | 0.322 | 0.87 ± 0.42 | 0.93 ± 0.50 | 0.229 |
| Type of VSD: outlet | 36 (60%) | 33 (55%) | 0.891 | 30 (67%) | 31 (62%) | 0.673 |
| trabecular | 18 (30%) | 20 (33%) | 0.695 | 12 (27%) | 15 (30%) | 0.821 |
| inlet | 6 (10%) | 7 (12%) | 0.769 | 3 (6%) | 4 (8%) | 1.000 |
| Weight (kg) | 4.9 ± 2.3 | 5.3 ± 3.1 | 0.127 | 5.1 ± 2.7 | 4.9 ± 1.9 | 0.659 |
| Height (cm) | 50.5 ± 8.35 | 52.37 ± 7.68 | 0.231 | 49.3 ± 10.7 | 50.7 ± 9.8 | 0.433 |
| Surgical age (m) | 4.2 ± 2.6 | 4.8 ± 1.9 | 0.103 | 4.9 ± 3.7 | 5.2 ± 2.9 | 0.264 |
| Patent ductus arteriosus | 6 (10%) | 8 (13%) | 0.579 | 5 (11%) | 7 (14%) | 0.763 |
| Patent foramen ovale | 6 (10%) | 6 (10%) | 1.000 | 3 (7%) | 5 (10%) | 0.718 |
| Unremitting congestive heart failure | 57 (95%) | 56 (93%) | 0.697 | 39 (87%) | 41 (82%) | 0.584 |
| Downs syndrome | 5 (8%) | 6 (10%) | 0.974 | 5 (11%) | 6 (12%) | 1.000 |

VSD: ventricular septal defect

The relationship among the defect, conduction axis and medial papillary muscle in perimembranous VSDs

Medial papillary muscle originates from the trabecula septomarginalis and is near the region of the triangle of Koch apex. What’s of surgical importance is that the conduction axis passes postero-inferiorly from the Koch apex towards the medial papillary muscle (Fig. 1). Part of the defect rim abuts on the central fibrous body where the penetrating bundle is located. Immediately, the penetrating bundle continues as a segment of non-branching bundle before it bifurcates into right and left bundle branch. Owing to the precise subgroups of the perimembranous VSD (trabecular, inlet or outlet type), the different distance between the infero-posterior rim of the defect and the conduction axis, including the penetrating bundle and non-branching bundle, ranges from 0 mm–5 mm. The proximal segment of right bundle branch runs intramurally between the posterior limb of the trabecula septomarginalis and the underlying muscular septum. Then it veers away from the defect and runs in the subendocardial position. The distance between the defect rim and subendocardial portion is about 5 mm and the maximal depth of the intramural segment from the right surface of the septum measures 1 mm–1.5 mm.

Operative data

After standard aorto-bicaval cardiopulmonary bypass was established, the perimembranous VSD was visualized through a right atriotomy. Glutaraldehyde-perserved autologous pericardium was prepared to close the defect. Only single suture was used in closing VSD. A double-armed 6-0 polypropylene suture with buttressing pledget...
Stitches should be placed through the leaflet of tricuspid valve instead of the fibrous rim. Finally, the two limbs met at the atrial side of the nearby annulus of the tricuspid valve so that both arms of the suture can be snugly tied to each other. If retraction of the tricuspid valve cannot provide a satisfactory exposure, a radial incision was performed at the septal leaflet near the anterior-septal commissure. After closing the VSD, interrupted suture was used to close the incision on tricuspid valve tissue.

Conventional shallow suturing way

All of the procedures were same as stated above except for the surgical closure of the infero-posterior rim of the defect. At the inferior rim, traditionally, the shallow superficial stitches were taken vertically between the patch and the margin of the defect, and 3 mm–5 mm from the defect rim. At the posterior rim, a more conservative way was adopted that shallow sutures were moved outward to a distance of 5 mm from the defect rim in case of damage to the His bundle.

Statistical Analysis

Data was collected on standardized forms, entered in a computerized database, and analyzed with a statistical software package (Statistical Package for Social Sciences [SPSS], Chicago, Illinois, USA—version 18.0). Continuous values were expressed as mean ± standard deviations for normally distributed variables. Groups were compared with Fisher’s exact test and Student’s t-test. A p-value

Mattress stitch

The first stitch (point “a”) on the patch was placed 0.5 mm away from the starting point and the subsequent stitch (point “b”) placed on the defect rim was close to the starting point. Then the suture, which was parallel to the edge of the defect, was passed through the rim at a distance of 2 mm, reaching point “c”. Next, the entrance on the patch was chosen 1 mm upstream (point “d”) and was also parallel to the margin of the patch, arriving at point “e”. The subsequent stitch on the defect rim (point “c”) was very close to the previous site of point “c” (Fig. 2). Additionally, the distance of “bc” (2 mm) should be equal to the distance of “ad” (1 mm) plus the distance of “de” (1 mm). Around the whole inferior and posterior rim, the suture was kept in such a backtracking pattern and shallow superficial bites (less than 1.5 mm in depth) were taken that include only the whitish endocardium close to the defect rim (2 mm–4 mm from the rim). If there existed a membranous flap, it could be safely used for suturing. When approaching the “penetrating bundle” area, the stitches should be placed through the leaflet of tricuspid valve instead of the fibrous rim. Finally, the two limbs met at the atrial side of the nearby annulus of the tricuspid valve so that both arms of the suture can be snugly tied to each other. If retraction of the tricuspid valve cannot provide a satisfactory exposure, a radial incision was performed at the septal leaflet near the anterior-septal commissure. After closing the VSD, interrupted suture was used to close the incision on tricuspid valve tissue.

was started at the position of 12:00 h of the defect (starting point), placed deep on the right side of the septal and 2 mm–4 mm away from the defect rim. The stitch was then passed through the tricuspid annulus in a counterclockwise direction toward the leaflet of tricuspid valve, terminating at the right atrial surface. Next, we employed the mattress suturing technique for the other limb in a clockwise direction.
<0.05 was considered statistically significant. Due to inherent differences between patients in different groups, we performed a propensity score matched analysis to adjust for these differences.

Results

There was no difference in the myocardial ischemic and cardiopulmonary bypass times between the two groups (bypass time: 44.4 ± 9.7 min vs. 47.6 ± 123 min, p = 0.872; ischemic time: 28.4 ± 10.9 min vs. 30.5 ± 9.5 min, p = 0.664). Inotropic support with dopamine hydrochloride was required in most patients (n = 78, 82%). There was no difference in the duration of ventilatory support time (15.3 ± 9.3h vs. 16.3 ± 10.8h, p = 0.215) and the length of intensive care unit stay (6.5 ± 4.9 days vs 7.3 ± 5.6 days, p = 0.336). Postoperative mortality in both groups was zero. No immediate residual VSDs and tricuspid valve incompetence were found in all patients.

Patients in both groups underwent electrocardiogram preoperatively and all showed regular sinus rhythm and normal duration of the QRS complex. One patient (Downs Syndrome, 4.2 kg/3 month) in Group II developed complete heart block (with a narrow QRS complex escape rhythm at 54 beats/min) 5h after operation during cardiac care unit stay and temporary pacing wires were placed. Finally, the patient’s rhythm recovered to 1st-degree atrioventricular block by postoperative day 4. Another one patient (inlet type perimembranous VSD) in Group II had temporal II-degree atrioventricular block with the duration of 3-day epicardial pacing catheter. No patients developed atrioventricular block in Group I. There were four patients developing complete right bundle branch block and eight patients developing incomplete right bundle branch block in Group II compared with 12 developing complete right bundle branch block and 13 having incomplete right bundle branch block in Group II (Table 2).

Mean follow-up time was 26.6 ± 8.9 months and the follow-up was available in 75 of the 95 survivors (79%). Echocardiography (every 6 months to 1 year) and electrocardiogram (every 3 to 6 months) were performed routinely. All patients thus far had echocardiography examination showing three patients in Group II and one patient in Group I that developed small residual left-to-right interventricular shunt during the follow-up period (p >0.05) (Table 3). Considering that the relatively small residual shunt may close spontaneously, we continually follow these cases.

Discussion

The outcomes after surgical closure of VSD have significantly evolved over time with the advance in techniques, cardiopulmonary bypass, anaesthesia and postoperative...
care. However, the disturbance of conduction system, residual ventricular shunt, neurologic injury, and postoperative mortality are still major postoperative complications, especially in infants with malnutrition. Our current series reported excellent postoperative outcomes using mattress suturing technique: there was no incidence of complete heart block, reoperation for residual VSD and postoperative mortality. Some may argue that the results can be attributed simply to a learning curve of the surgeon but the comparatively good outcomes are encouraging, and the new technique can be an addition to the armamentarium of pediatric cardiac surgeons.

Although complete heart block occurred in less than 1% after surgical closure of VSD, it still remains a complication especially in patients who develop pulmonary hypertension and right ventricle hypertrophy which make the relationship between the conduction branches and the margin of the defect more intimate. Right bundle branch block, which may be associated with diastolic dysfunction in late follow-up, remains another common conduction disturbance with a reported prevalence of 20%–62%. Both are unequivocally linked to the surgical maneuvers. Precise identification of the conduction bundle including the penetrating bundle, non-branching bundle, and right bundle branch is of surgical importance. In mattress suturing technique, stitches are kept parallel to the inferior and posterior rim of the defect, as well as nearly parallel to the route of the conduction bundle. Besides, the stitches are placed superficially (less than 1.5 mm) and 2 mm–3 mm away from the infero-posterior rim. When coming to the penetrating bundle site, sutures are placed safely through the leaflet of tricuspid valve. Such suturing method can decrease the risk of jeopardizing the main conduction bundles in both “danger zone-1” and “danger zone-2” (Fig. 1). This is also in accordance with the principle employed by Sirak that sutures parallel to the free margin of the defect can avoid injury to the conduction system. No patient develops complete heart block in the mattress suturing group, which convince us that this new technique appears to offer an attractive approach. Complete right bundle branch block can not be eliminated probably because of edema or scar formation. However, in our current series, this new procedure contributes to the statistical lower incidence of complete right branch bundle block in Group I (8.9%) than in Group II (24%) (p = 0.035).

Residual ventricular communication is another common finding after surgical closure of perimembranous VSDs. Although the significant hemodynamic residual shunt is less than 1%, the global rate of small residual shunt still ranges from 15% to 25% on intraoperative transesophageal echocardiography and 30% to 46% on postoperative transthoracic echocardiography. Low weight at operation is a predictive factor for a residual shunt because of the difficulty in balancing prosthesis compliance with tissue friability in such patients. Using the new technique, the suture is routed in a flask-bottom way. When tightening the suture, the patch is subjected to two forces: one is parallel to the patch and the other is perpendicular to the patch. Thus, the backtracking pattern can hold the sutured edge in a more stable way. Besides, the stitches stand by each other like a “lock” that is more secure against dehiscence. Furthermore, the shallow stitches have an equal distance from the infero-posterior margin so that it is liable to equilibrate the force between patch and defect, which is helpful for lowering the incidence

| Table 2 | Prevalence of various postoperative conduction disturbances during follow-up |
|---------|--------------------------------------------------------------------------|
| Group I (n = 45) | Group II (n = 50) | p value |
| Complete right bundle branch block | 4 (9%) | 12 (24%) | 0.035 |
| Incomplete right bundle branch block | 8 (17.8%) | 13 (26%) | 0.458 |
| Complete atrioventricular block | 0 (0%) | 1 (2%) | 1.000 |

| Table 3 | Four patients developed residual ventricular septal defects |
|---------|----------------------------------------------------------|
| Group | Surgical weight | VSD size (preoperative) | Residual VSD size | Down’s syndrome | Treatment |
| II | 4.2 kg | 0.89 cm | 0.1cm/Po-6 mon | yes | Follow up |
| II | 5.1 kg | 0.96 cm | 0.12cm/Po-7 mon | yes | Follow up |
| II | 3.9 kg | 0.94 cm | 0.18cm/Po-9 mon | no | Follow up |
| I | 4.3 kg | 0.85 cm | 0.1cm/Po-7 mon | yes | Follow up |

Po: postoperative; mon: months
of residual shunt and retaining the competence of the tricuspid valve.

**Limitations**

First of all, most patients in the current study are outlet and trabecular type perimembranous VSDs. These two types usually have membranous flaps and well developed posterior extension of the TSM both of which can be safely used for suture. Whereas, there is absent or tiny membranous flap and poorly developed posterior extension of the trabecula septomarginalis in a perimembranous inlet VSD. Whether this new technique can be safely employed in these patients remains discussion and further observation. Secondly, this new technique is performed in a single institute and the results will be more persuasive if it can be used in multi-center sites. Thirdly, the statistical power with which to make certain comparisons may be limited by its retrospective, nonrandomized nature, and relatively small study population. A larger series with a randomized design would be considered more scientifically rigorous. In addition, 20 patients (21%) were not seen after their first postoperative clinic visit which makes surveillance challenging. A further observation of these patients would have been favorable to evaluate this new surgical technique.

**Conclusion**

Mattress suturing technique for surgical closure of large perimembranous VSDs can be performed with no incidence of heart block, reoperation for residual VSD and postoperative mortality. Besides, this technique is also of value in reducing the incidence of complete right bundle branch block. Although further observation and other surgeons’ reconfirmation are needed, this new method merits consideration for surgical repair of large perimembranous VSDs in infants.

**Financial Support**

This study was supported by grants 20134026 (Shanghai Hygiene Science Research) and YG2012MS17 (Shanghai Jiaotong University Biomedical Engineering Research).

**Disclosure Statement**

None.

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