Surgical management of multiple ventricular septal defects: The role of the felt sandwich technique

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Objective: Recently, the felt sandwich technique has been widely used to close muscular ventricular septal defects. We evaluated the early and midterm results of our strategy (a combination of the sandwich technique and direct closures) and assessed the role of the sandwich technique in the treatment of multiple ventricular septal defects.

Methods: Twenty-nine consecutive patients underwent an operation for multiple ventricular septal defects and associated cardiac malformations. They included 17 boys and 12 girls with a median age of 6.0 months. Thirteen patients had 4 or more ventricular septal defects (Swiss cheese septum).

Results: There was no surgical or follow-up mortality, and no reoperations were required. There were no cases of heart block and no significant residual shunts in the latest follow-up study. Two patients with Swiss cheese septum had postoperative congestive heart failure. Three muscular ventricular septal defects were closed with the sandwich technique in these 2 patients, whereas 1 or fewer ventricular septal defects were closed with the sandwich technique in the other 27 patients. Seven (77.8%) of 9 patients who underwent the sandwich procedure had septal dysfunction, whereas 5 (25.0%) of the other 20 patients showed septal dysfunction ($P < .05$).

Conclusions: The outcome of the surgical repair of multiple ventricular septal defects was satisfactory. Although the sandwich technique is simple and effective, the use of numerous felt patches disturbed the movement of the interventricular septum. An effort should be made to close the muscular ventricular septal defect directly to avoid postoperative cardiac dysfunction. Large apical ventricular septal defects, especially those located just underneath the moderator band, are considered suitable for the sandwich technique.

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The surgical management of multiple ventricular septal defects (VSDs) remains controversial and a challenge. It is frequently associated with operative mortality and complications, including residual VSDs, ventricular dysfunction, and complete heart block.[1-4] Several techniques that avoid performance of a left ventriculotomy have been described to prevent these complications.[4-6] Recently, a novel technique was introduced for the closure of muscular VSDs by sandwiching the septum between 2 felt patches placed in the left and right ventricles (the felt sandwich technique). This simple technique does not require any special devices, a prolonged surgical time, or a left ventriculotomy.[7-10]

We have developed a treatment strategy that uses the felt sandwich technique and direct closure of VSDs. The aim of this strategy was to close all VSDs without either a left ventriculotomy or sectioning of the major trabeculae, including the moderator band. The present study evaluated the early and midterm results of this strategy and assessed the role of the felt sandwich technique in the treatment of multiple VSDs.

MATERIALS AND METHODS

Patients

Twenty-nine consecutive patients underwent surgical intervention for multiple VSDs and associated cardiac malformations during a 38-month period from February 2005 to March 2008 in our institution. Parents of the patients provided written informed consent before the operations. There were 17 boys and 12 girls with a median age of 6.0 months (range, 8 days–8 years). The patients ranged in body surface area (BSA) from 0.20 to 0.76 m^2 (median, 0.30 m^2) and weighed 3.0 to 18.0 kg (median, 5.7 kg). The associated cardiac malformations included double-outlet right ventricle in 7 patients, tetralogy of Fallot in 4 patients, transposition of the great arteries in 2 patients, coarctation of the aorta in 1 patient, and atrioventricular septal defect in 1 patient. Fourteen patients had isolated multiple VSDs. Nine of 29 patients had undergone previous cardiac operations (Table 1). The interventricular septum was analyzed by means of preoperative cineangiographic analysis in 17 patients. Preoperative cineangiographic analysis demonstrated the presence of multiple VSDs in 11 patients. Five other patients were given a diagnosis of multiple VSDs based on preoperative echocardiographic analysis. Thereafter, the presence of multiple VSDs was preoperatively diagnosed in 16 (55.2%) patients and intraoperatively diagnosed in 13 patients. Twelve patients had 2 VSDs, 4 had 3 VSDs, and 13 had 4 or more VSDs (Swiss cheese septum).

Surgical Technique for Closure of Muscular VSDs

The details of the surgical technique have been described in previous reports.[7,10] After achievement of mild-to-moderate hypothermic cardiopulmonary bypass, the aorta was crossclamped, and myocardial protection was achieved with cold blood cardioplegia.[11,12] A longitudinal right atriotomy was performed, and the interventricular septum was exposed through

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Abbreviations and Acronyms
BSA = body surface area
VSD = ventricular septal defect

the tricuspid valve. A ventriculotomy was not used to access VSDs unless it was required for other repairs, such as a right ventricular outflow tract reconstruction. A combination of different techniques was used to close multiple VSDs. The perimembranous VSD was closed with a Dacron polyester fabric patch. If the patient did not undergo preoperative cineangiographic analysis, meticulous analysis was required to avoid missing muscular VSDs. Muscular VSDs were sometimes found in the malaligned interventricular septum. In these cases blood oozed into the right ventricle, despite adequate left ventricular venting. Identification of muscular VSDs was done by means of gentle probing of the trabeculations with a fine hemostatic forceps to delineate the connection with the left ventricle. The location, number, and size of muscular VSDs were estimated by the meticulous analysis from the right ventricle. Initially, an attempt was made to close the muscular VSDs with mattress sutures reinforced with pledgets or endocardial running sutures by using 6–0 polypropylene sutures (re-endocardialization techniques). When the VSD was located just underneath the moderator band or apex of the heart, where it was difficult to place the exact sutures, it was considered unsuitable for direct closure. The VSD was then closed with the felt sandwich technique. The tip of the right-angled forceps placed in the VSD could be seen in the left ventricle through a perimembranous VSD or through the longitudinal atrioseptostomy. A 3F Nelaton catheter (Bard, Haverhill, Mass) was grasped and pulled back into the right ventricle. The Nelaton catheter led an oversized (2–4 mm larger than the estimated size of the VSD) circular polyester felt patch mounted on a 4–0 braided polyester suture. The suture ends were then passed through a slightly smaller (1–2 mm larger than the estimated size of the VSD) polyester felt patch on the right ventricular side of the septum. The braided polyester suture was then tied, thereby sandwiching the septum between the 2 polyester felt patches.

Echocardiographic Analysis and Follow-up

Postoperative echocardiograms were performed before hospital discharge to evaluate the residual shunts and cardiac functions. Because patches occupying the interventricular septum might cause left ventricular dysfunction, the relationship between the motion of the interventricular septum and the calculated total patch area/BSA ratio[10] was evaluated based on the following equation: Total patch area/BSA = the sum total patch area of patches used for closure of all VSDs (in square centimeters)/BSA (in square meters). Follow-up echocardiograms were performed a mean of 7.6 months (range, 1–32 months) after the operation.

Statistical Analysis

Normally distributed data are expressed as the mean ± standard deviation, and data not normally distributed are expressed as medians with ranges. The differences between the 2 groups were analyzed by using the Student's unpaired *t* test for means of continuous variables and the Fisher's exact test for categorical variables.

RESULTS

Early and Midterm Results

There were no early deaths. Electrocardiographic analysis showed sinus rhythm in all patients, with a complete right bundle branch block in 13 patients. Two patients with Swiss cheese septum had postoperative congestive heart failure. One patient with double-outlet right ventricle underwent an arterial switch operation, with intraventricular rerouting at 6 months of age and a weight of 6.2 kg. Postoperatively, marked cardiomegaly and severe pulmonary congestion developed, and the patient could not be weaned from ventilatory support. Fourteen days after the operation, cardiac catheterization revealed a large amount of residual shunt, with a Qp/Qs ratio of 6.67. At the time of the second emergency operation, 5 muscular VSDs (10, 6, 5, 5, and 3 mm in diameter, respectively) were identified. Three muscular VSDs were closed by using the sandwich technique, and 2 VSDs were closed directly. Although the pulmonary blood flow decreased, severe left ventricular dysfunction with moderate mitral valve insufficiency developed postoperatively. The patient required prolonged ventilatory support. The left ventricular function was gradually improved by the medical treatment. The postoperative catheterization study, performed at 5 months after the operation, showed a decrease in the volume of the residual shunt (Qp/Qs ratio of 1.10) and mitral valve insufficiency. At the 18-month follow-up, the patient was doing well.

Another patient had postoperative congestive heart failure after a Rastelli-type procedure and closure of 3 muscular VSDs (6, 4, and 4 mm in diameter, respectively) by using the sandwich technique. Echocardiographic analysis revealed the reduced wall motion of the interventricular septum. Cardiac dysfunction was thought to be caused by a standard VSD patch and the felt patches disturbing the movement of the interventricular septum. The left ventricular function was gradually improved in response to the

TABLE 1. Characteristics of the 29 patients

Age (mo), median (range)	6 (0–104)
BSA (m^2), median (range)	0.30 (0.20–0.76)
Associated cardiac anomalies	
Double-outlet right ventricle	7
Tetralogy of Fallot	4
Transposition of the great arteries	2
Coarctation of the aorta	1
Atrioventricular septal defect	1
Previous cardiac interventions	
Pulmonary artery banding	5
Blalock–Taussig shunt	3
Ligation of arterial duct	2
Unifocalization	2
Extended aortic arch anastomosis	1
Arterial switch operation	1
Tetralogy of Fallot repair	1
Additional procedures	
Double-outlet right ventricle repair	6
Debanding	3
Arterial switch operation	2
Rastelli procedure	2
Tetralogy of Fallot repair	1
Atrioventricular septal defect repair	1

BSA, Body surface area.

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