

Original Research Article

Intraoperative Device Closure of Perimembranous Ventricular septal defects with Transthoracic Minimal Invasion

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Abstract: Intraoperative device closure of perimembranous ventricular septal defects with transthoracic minimal invasion is one of the alternative methods to reduce the trauma of the conventional operation through a median sternotomy. We summarized our early experience of intraoperative device closure of perimembranous ventricular septal defects. Between September 2012 and December 2015, we performed transthoracic ventricular septal defect occlusion for 17 patients via a minimally invasive incision. A domestic delivery sheath and occluder were used during surgery. Inpatients data were reviewed. Procedure success was achieved in 17 cases. The deployment of the occluder was failed or terminated in 0 patients. During 9- 47 months of follow-up, there was one residual shunt. There was no occluder dislocation or thrombus-related complications. Intraoperative device closure of perimembranous ventricular septal defects using a minimally invasive incision is a feasible choice in selected patients.

Keywords: Congenital heart disease, Ventricular septal defects, Cardiac intervention

INTRODUCTION

Ventricular septal defect is one of the most common congenital cardiac diseases. Based on the study by Soto and colleagues [1], the ventricular septum is considered to have four components. Perimembranous ventricular septal defect represents the most common congenital cardiac defects, accounting for almost one-fifth of all heart defects, and it is more frequent in Asian population [2]. Conventional surgical repair can achieve excellent treatment outcomes, but it is also associated with morbidity and mortality, patient discomfort, sternotomy and skin scarring. [2,3]. Many efforts have been made to minimize the trauma of the incision during the surgical ventricular septal defect closure, thus developing transthoracic minimal invasion, whose advantages are better cosmetic appearance and pain reduction.

Intraoperative device closure of perimembranous ventricular septal defects was first presented in 2004 [4]. Compared with open-heart surgery, Intraoperative device closure of perimembranous ventricular septal defects avoid

cardiopulmonary bypass and significantly reduce mortality rates. Compared with transcatheter closure, it does not require radiography or contrast agents. The success rate is higher because the short surgical approach tends to facilitate operation of the device. In the present study, we summarized our experience and outcomes of intraoperative device closure of perimembranous ventricular septal defects.

MATERIAL AND METHODS

After approval by the Institutional Review Board at Affiliated Hospital of Guilin Medical University, we searched the electronic database of the patients in whom intraoperative device closure for perimembranous ventricular septal defect had been attempted between September 2012 and December 2015. The exclusion criteria were significant cardiac and noncardiac comorbidities that could affect the clinical outcome of defect closure, evidence of significant heart failure at admission, and perimembranous ventricular septal defect with right to left shunting due to severe pulmonary hypertension.

Informed consent was obtained from each patient or the legal guardian before the procedure.

Telephone conversations were done by 2 physicians using a standard questionnaire containing questions on symptoms and signs, physical development, laboratory reports made elsewhere, and hospitalizations for such problems as device dislocation, cardiac arrhythmia, endocarditis and reoperation. To collect the information regarding electrocardiography and echocardiography performed elsewhere, we recorded the diagnostic results and asked the patient or guardian to read the reports for details if the diagnostic results showed some abnormality.

Clinical data were carefully calculated as follows: demographic and baseline clinical data, mortality and morbidity, operating room time, duration of postoperative mechanical ventilation, and hospitalization, defined as the period from the procedure to discharge. Patients were considered to have successful ventricular septal defect closure if they had no large residual shunt as assessed by postoperative echocardiography.

Complications were divided into major and minor groups. Major complications referred to repeat operation, thromboembolism, endocarditis, death due to the procedure, complete atrioventricular block requiring a permanent pacemaker, new-onset valvular regurgitation requiring surgical repair, or device embolization requiring surgical removal. Minor complications were adverse effects such as cardiac arrhythmia, wound complication requiring intervention, device embolization with transcatheter removal, new or increased valvular regurgitation of 2 grades or less, hemolysis requiring only medication, pericardial/pleural effusion, pneumopericardium, pneumothorax, and pneumonia requiring aspiration or chest tube.

Surgical technique

The patient was placed in the supine position while under general anesthesia, and the entire chest was exposed. Intraoperative transthoracic echocardiography was performed to evaluate the ventricular septal defect size and morphology, the adjacent aortic valve and the pulmonary valve. The size of the selected occluder was 2mm larger than the maximum diameter of the measured ventricular septal defect.

A 3-4cm midline lower sternal incision was made and a partial sternotomy was performed. A small sternal retractor was inserted. The pericardium was incised and suspended to expose the right ventricle. The incision in the pericardium was located on the right side and on the cephalic aspect as much as possible to expose the pulmonary artery and right ventricular outflow tract. Intravenous heparin injection (1 mg/kg)

was titrated to maintain the activated clotting time at >250 seconds. The site of the parallel purse-string sutures of 4-0 Prolene (Ethicon, Inc) were placed on the surface of the right ventricular outflow tract. After inserting a fine needle through the center of the purse-string suture, the inner core was withdrawn, and a guidewire was inserted. Under the guidance of transesophageal echocardiography, the guidewire was passed through the ventricular septal defect into the left ventricle. The occluder was connected to the delivery system and was prepared in a small segment of the sheath. Under the guidance of echocardiography, the delivery sheath was inserted along the guidewire. After the sheath was placed into the left heart, the guidewire and the inner core were withdrawn. The small segment of sheath containing the occluder was connected to the delivery system, and was slowly pushed. The left disc was opened first. The sheath was delivered by rotating and pushing it, and the marked end of the left disc was delivered to a site distant from the aortic valve. The end without the marking was placed beneath the aortic valve and was pulled back until the disc was closely adherent to the interventricular septum. The aortic valve was observed opening and closing, and residual shunt was assessed by echocardiography. Next, the right disc was opened on the other side of the ventricular septal defect. When echocardiography showed no significant residual fistula or aortic regurgitation, the delivery system was removed and the purse-string suture was tied. In some cases, we placed a suture to the disc and fixed it to the incision to prevent the occluder from dislodging into the pulmonary or systemic circulation. A chest tube was routinely placed and removed on the first or second postoperative day in most patients.

All patients were transported to the intensive care unit and then to the general ward at least 6 to 8 hours later after extubation. Before discharge, ECG and transthoracic echocardiography were performed. A follow-up assessment was done approximately 3 months later and repeated on a year. An anticoagulant such as dipyridamole or aspirin was administered orally for at least three months.

RESULTS

Perimembranous ventricular septal defects with transthoracic minimal invasion were attempted in 17 patients. The deployment of the occluder was failed or terminated in 0 patients. 17 patients (100 %) had a successful ventricular septal defect closure according to our definition. Median follow-up duration for the percutaneous group was range 9 to 47 months.

Perimembranous ventricular septal defect was successfully closed with a device size range of 5–18 mm. The duration of the procedure was 20–136 min. All patients were extubated on the table. The intensive care unit stay was less than 4 days, and hospital stay

was 6-16 days. There was no postoperative mortality. On follow-up of 9–47 months, there was no major morbidity. Pleural effusion was noted on echocardiography in 3 patients (mild in 2, moderate in 1). No patient had a minimal residual shunt until the end of the follow-up (December 2015). At a mean follow-up, there was no hemolysis, device embolization or failure and other abnormalities. There were no wound problems.

DISCUSSION

Ventricular septal defect is one of the most common congenital cardiac defects. Open-heart repair with midline sternotomy and cardiopulmonary bypass has been considered as the golden standard for the closure of the perimembranous ventricular septal defect. Although surgical closure has been proved safe and effective, it is still associated with midline sternotomy and cardiopulmonary bypass in a longer hospital stay. Although surgical closure is a straightforward and safe procedure in the current era, it is associated with morbidity and postoperative discomfort, and the midline incisions would reserve the physical and psychological trauma for patients in the future [5, 6]. As an alternative to surgical closure, transcatheter closure of ventricular septal defects has been employed increasingly in the past decade, especially in perimembranous ventricular septal defects, which have become more amenable to closure since the introduction of the Amplatzer, occluder.

Compared with those surgical approaches, percutaneous transcatheter device closure has the advantage of bringing less discomfort to patients and leaving no incisional scar. It can also avoid cardiopulmonary bypass, which could prevent a myocardial reperfusion injury. However, percutaneous approach may cause potential vascular injury and the patient must be exposed to the X-rays. Furthermore, due to expensive equipments and the high cost it requires, many hospitals in the low-income nations have no resources to develop this technology. We use a hybrid method as Zhang GC and his colleagues have reported to close the perimembranous ventricular septal defect [7], which includes an intraoperative device and a minimal invasion. Our study shows that minimally invasive surgical closure of ventricular septal defect s under transthoracic echocardiographic monitoring is feasible and effective. Although some reports have been performed in the operating theatre with a hybrid approach [6, 8]. Detailed transesophageal echocardiography guidance of the entire procedure is important for the success of minimally invasive intracardiac surgery [9]. The relationships of those defects with surrounding tissues, spatial positions and shapes of defects, and the, should be carefully considered with the aid of transesophageal echocardiography before a treatment plan is chosen.

Transesophageal echocardiography can also help surgeons to exclude inappropriate patients, judge when and where to release the occluder, and evaluate the effects of closure. Zhang GC and his colleagues' study shows that transthoracic echocardiography can also be used to as an alternative to guide the ventricular septal defect device implantation, with caution and in experienced hands, it may be safe and feasible to perform transthoracic echocardiographic guided ventricular septal defect closure.

During our experiences, the occluder size chosen is usually 1 to 2 mm larger than the maximal dimension of the defect. Choosing an occluder of appropriate size and type is important in closing the defect completely and avoiding harmful sequelae. Oversize devices are prone to causing valvular regurgitation and atrioventricular block, while smaller ones tend to cause residual shunting and occluder displacement. A perimembranous ventricular septal defect with a rim ≥ 2 mm from the aortic valve responds best. A ventricular septal defect with a rim < 2 mm from the aortic valve or pulmonary valve requires the use of an asymmetric occluder. But we have no experience about an asymmetric occluder. Large ventricular septal defect size (> 10 mm) were also not eligible for this procedure [10].

Bai and his colleagues' study show that transthoracic echocardiographic measurement usually underestimates the defect's maximal dimension; also, transthoracic echocardiographic cannot display structures adjacent to the defect as well as transesophageal echocardiographic can. Therefore, choosing occluder size with the aid of transesophageal echocardiography enables more precision [11]. Our initial experiences in performing minimally invasive surgical closure of ventricular septal defect with the assistance of transesophageal echocardiography have been encouraging. However, larger sample sizes and longer-term follow-up are necessary for the accurate evaluation of this procedure's safety and effectiveness as an alternative to cardiopulmonary bypass surgery and transcatheter closure of congenital cardiac defects.

Perimembranous ventricular device closure provides a potentially safe and effective option for selected patients with isolated perimembranous ventricular septal defect s and for hybrid surgery. However, this new technique should be applied with caution in some subtypes of ventricular septal defect s like sub pulmonary ventricular septal defects, because of the potential risks of and valve regurgitation. Controlled studies with long-term follow-up are needed to confirm the full potential of this technique as the new gold standard of treatment in ventricular septal defect patients [12].

CONFLICT OF INTERESTS

None declared.

AUTHOR'S CONTRIBUTION

Haiyong Wang and Xianzhu Liang wrote the paper. Tianci Qian, Xingxing Peng, Fugui Ruan, Jiangbin Sun, Jianfei Song and Zhenzong Du supervised the composition of the paper. All authors read and approved the final paper.

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REFERENCES

1. Soto B, Becker AE, Moulart AJ, Lie JT, Anderson RH. Classification of ventricular septal defects. *British heart journal*. 1980 Mar 1; 43(3):332-43.
2. Butera G, Chessa M, Carminati M. Percutaneous closure of ventricular septal defects. *Cardiol Young*. 2007; 17(3):243-53.
3. Cao H, Chen Q, Zhang GC, Chen LW, Qiu ZH, Xu F. Transthoracic Subarterial Ventricular Septal Defect Occlusion Using a Minimally Invasive Incision. *Journal of cardiac surgery*. 2016 Jun 1; 31(6):398-402.
4. Amin Z, Danford DA, Lof J, Duncan KF, Froemming S. Intraoperative device closure of perimembranous ventricular septal defects without cardiopulmonary bypass: preliminary results with the periventricular technique. *The Journal of thoracic and cardiovascular surgery*. 2004 Jan 31; 127(1):234-41.
5. Mavroudis C, Baker CL, Idriss FS. Ventricular septal defect. In: Mavroudis C, Baker CL, eds. *Pediatric cardiac surgery*. 3rd ed. Philadelphia, PA: Mosby; 2003:298–320.
6. Kirklin JW, Barrott Boyes BG. Post infarction ventricular septal defect in cardiac surgery 2nd Ed: Kirklin JW. Barratt Boyes BG, Churchill Livingstone New York, Edinburg, London, Melbourne, Tokyo p. 1993; 404.
7. Zhang GC, Chen Q, Chen LW, Cao H, Yang LP, Wu XJ, Dai XF, Chen DZ. Transthoracic echocardiographic guidance of minimally invasive periventricular device closure of perimembranous ventricular septal defect without cardiopulmonary bypass: initial experience. *European Heart Journal-Cardiovascular Imaging*. 2012 Feb 9;jes028.
8. Li J, Zhang J, Shi J, Zhou XD, Duan YY, Zhu T, Yao ZY. Choice of occluder in different shape, size of membranous ventricular septal defect. *Chinese Journal of Medical Imaging Technology*. 2005; 5.
9. Holzer R, Hijazi ZM. Interventional approach to congenital heart disease. *Current opinion in cardiology*. 2004 Mar 1; 19(2):84-90.
10. Lin K, Zhu D, Tao K, Gan C, Tang H, Feng Y, An Q. Hybrid periventricular device closure of doubly committed subarterial ventricular septal defects: Mid-term results. *Catheterization and Cardiovascular Interventions*. 2013 Sep 1; 82(3):E225-32.
11. Bai W, An Q, Tang H. Application of Transesophageal Echocardiography in Minimally Invasive Surgical Closure of Ventricular Septal Defects. *Texas Heart Institute Journal*. 2012; 39(2):211.
12. Yin S, Zhu D, Lin K, An Q. Periventricular device closure of congenital ventricular septal defects. *Journal of cardiac surgery*. 2014 May 1; 29(3):390-400.