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Original article

Percutaneous closure of postinfarct muscular ventricular septal defects: A multicenter study in China

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ABSTRACT

Background: Surgical repair is an effective method to treat ventricular septal defect (VSD) complicating acute myocardial infarction (AMI). However, the mortality rate remains high. This study was designed to assess the immediate and mid-term results of transcatheter closure of postinfarct muscular VSDs.
Methods: Data were retrospectively collected from 42 AMI patients who underwent attempted transcatheter VSD closure between 2008 and 2012 in seven heart centers of China.
Results: Nine patients underwent emergent VSD closure in the acute phase (within two weeks from VSD) while the others underwent elective closure. The time between VSD occurrence and closure in emergency group and elective group was 7.7 ± 2.3 days and 35 ± 14.5 days, respectively ($p < 0.01$). The percentage of procedure success in the emergency group and elective group was 77.8% (7/9) and 97% (32/33), respectively ($p = 0.048$). The hospital mortality was higher for emergent closure in comparison to elective closure (66.7% vs. 6.1%, $p < 0.01$). During a median follow-up of 25 months (0–58 months), two patients died at 8 and 29 months, respectively, and no serious complications occurred in other patients.
Conclusion: Interventional postinfarct VSD closure is a safe and effective approach that can be performed with a high procedural success rate, with favorable outcomes if it can be undertaken >14 days postinfarct.

Introduction

Ventricular septal defect (VSD) complicating acute myocardial infarction (AMI) is a rare but fatal complication, occurring in 1–3% of patients in the pre-reperfusion era [1,2]. VSD after AMI was associated with extremely poor outcome, with in-hospital mortality rates in two studies of about 42.9% ($n = 2876$) [3] and 47% ($n = 41021$) [4] for surgically treated patients and 90% for those treated medically [5,6]. With the development of reperfusion therapies such as thrombolysis and percutaneous coronary intervention (PCI), there was a significant decrease in incidence (0.2–0.5%) and mortality of postinfarction VSD [4,7]. Although this decrease is encouraging, both early and long-term prognoses after AMI-related VSD remain unsatisfactory. Surgical repair is a traditional and effective method and favorable for survival [3,8]. However, the mortality rate remains high [3,9], and the incidence of a large residual shunt and re-rupture after surgery reaches up to 10–20% [10,11]. Among the patients who survived the perioperative period the five-year survival rates reported in two studies were only 57.1% ($n = 1235$) and 38% ($n = 189$) [3,12]. With advances in cardiac interventional techniques and devices, transcatheter closure of VSD had become an alternative or a bridge to surgical

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repair for patients with postinfarction VSD, mainly as anecdotal single case reports [13] or as small series [14–17]. We evaluated the immediate- and mid-term safety and efficacy of transcatheter VSD closure in 42 cases of AMI patients with the additional complication of postinfarction VSD from seven Chinese heart centers.

Materials and methods

We conducted a retrospective chart review of all patients who underwent transcatheter closure of postinfarction VSD at seven Chinese heart centers from 2008 to 2012. Patients with congenital muscular VSD or who could not undergo closure because of too big size and other reasons were excluded. Primary data were abstracted from the electronic medical record or archived records. Demographic information was collected from the time of procedure. Transthoracic echocardiography (TTE) measurements were collected before procedure and at latest follow-up focusing on location of occluder, residual shunt, and cardiac function. Invasive hemodynamic measurements and procedural information were collected from catheterization records. All patients who survived the procedures were called to hospital for follow-up by TTE, echocardiography (ECG), and clinical examination between March and May 2013. The degree of residual shunt was assessed by measuring the width of the color jet as it exited through the ventricular septum by TTE. It was classified as trivial for a width <1 mm, mild for a width between 1 and 2 mm, moderate for a width between 2 and 4 mm, and severe for a width >4 mm. Clinical data were collected concerning patient symptoms prior to procedure and at the most recent follow-up. Furthermore, patients were identified by change in symptoms (improved/worse/no change) based upon their explicit description of significant change in symptoms as documented in the medical record. Before intervention, informed written consent was obtained from all patients or their parents. The study was approved by the Ethics Committee of Changhai Hospital, and was carried out in accordance with the Declaration of Helsinki (1996) and all relevant Chinese laws. Two types of occluders were used in the study: the Amplatzer occluder (AGA Medical, Golden Valley, MN, USA) and the domestic SHSMA occluders (Shape Memory Alloy Ltd, Shanghai, China). The SHSMA occluder used was a modified double-disk occluder, which was designed based on the Amplatzer occluder. The only difference between these two occluders is the size of the left disk and the maximum diameter of the waist. The diameter of the left disk is 14 mm larger than that of the waist in SHSMA occluder, while 10 mm larger in Amplatzer occluders. The maximum diameter of the waist is 32 mm in SHSMA occluder, while 24 mm in Amplatzer occluders. The waist length of both SHSMA and Amplatzer occluders is 10 mm (Fig. 1).

Statistical analysis

All continuous variables are expressed as mean ± standard deviation (SD) or median with range as appropriate, and discrete variables are presented as frequencies and/or percentages. Comparisons of baseline data were performed using the chi-square test or Fisher's exact test (categorical variables) and Student's *t*-test or Wilcoxon rank-sum test as appropriate (continuous variables). All tests were two-sided, and *p*-values <0.05 were considered as indicating statistical significance.

Results

Demographic data and clinical characteristics

A total of 42 patients qualified for inclusion. The mean age of patients was 65 ± 4.1 years and 43% (18/42) were female. The AMI preceding the VSD was anterior in 19 and inferior/posterior in 23 patients. At the time of presentation, cardiogenic shock was present in 16 patients (38.1%), and 18 patients (42.9%) had a history of angina. Standard comorbidities were hypertension in 29 (69%), hypercholesterolemia in 21 (50%), diabetes mellitus in 11 (26.2%), active smoking in 17 (40.1%), and history of revascularization in two (4.8%). The time from infarction to VSD occurrence was 2.5 ± 1.4 days and the time from VSD occurrence to percutaneous device closure was 29 ± 17.2 days. Demographic and clinical findings of patients are summarized in Table 1. In these patients, nine (21.4%) underwent emergent closure (within two weeks) of a post-MI VSD. All patients presenting with hypotension and heart failure were supported by intra-aortic balloon pump (IABP).

Interventional VSD closure procedure and periprocedural complications

Coronary angiography was performed prior to VSD closure in all patients with 47.6%, 33.3%, and 19.1% having single-, double-, and triple-vessel diseases. Successful device deployment was performed in 39 of the 42 patients and 34 of them survived until discharge. The VSDs were located apically in 26 patients and basally in 16 patients. Thirty-nine patients underwent successful transcatheter VSD closure including four patients with two defects and one patient with three defects each which were closed by using two separate devices except one patient with two defects was closed

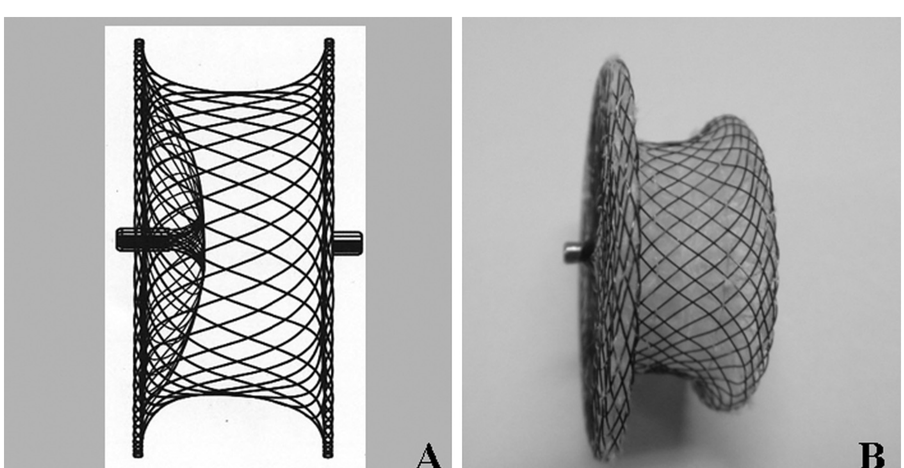

Fig. 1. Lateral views of the Amplatzer (A) and SHSMA (B) muscular ventricular septal defect occluders.

Table 1
Demographic data and clinical characteristic of the two groups (median with range, frequencies, and percentages).

	Emergency	Elective	*p* value
Patients (*n*)	9	33	–
Gender (female), *n*%	5 (55.6)	13 (39.4)	0.385
Age (years)	64 (58–72)	65 (55–74)	0.871
Comorbidities			
Hypertension	6 (66.7%)	23 (69.7%)	0.862
Hypercholesterolemia	5 (55.6%)	16 (48.5%)	0.707
Diabetes mellitus	2 (22.2%)	9 (27.3%)	0.760
Medical history			
Smoking	3 (33.3%)	14 (42.4%)	0.622
Stroke	1 (11.1%)	3 (9.1%)	0.855
Revascularization	0 (0%)	2 (6.1%)	0.449
Region of MI			
Anterior	5 (55.6%)	14 (42.4%)	0.483
Inferior/posterior	4 (44.4%)	19 (57.6%)	0.483
Unstable angina	4 (44.4%)	14 (42.4%)	0.914
Cardiogenic shock	5 (55.6%)	11 (33.3%)	0.224
Occurrence VSD after MI, days	2 (1–5)	2 (1–7)	0.303
Occurrence VSD-closure, days	7 (5–12)	30 (18–86)	<0.001

MI, myocardial infarction; VSD, ventricular septal defect.

by using one occluder on the account of occurrence of acute left ventricular failure and another occluder could not be implanted. The patient with three defects had a failed VSD closure in one of his triple ventricular defects. The device success rate was 89.6% (43/48) and procedure success was 92.9% (39/42). The mean diameter of the occluders is 18.0 ± 3.1 mm. A residual shunt was noted at the time of procedure in 32 patients. Twenty-six patients had mild residual shunts and eight of these disappeared at the time of discharge, while four had moderate residual shunts and two had a failed closure in one of their multi-defects had severe residual shunts. Hemolysis was found in one of these patients 10 h after procedure. Outcomes of transcatheter VSD closure are summarized in Table 2.

Altogether, three patients (7.1%) died during the study due to procedure-related complications. Two (acute phase) of these three patients had a left ventricular rupture related to the manipulation of the VSD positioning, resulting in a sudden cardiac death. In the third patient (elective phase), ventricular fibrillation occurred after crossing the VSD with the delivery sheath. The patient died despite electrical conversion and chest compression.

Details of the five patients, four closed in acute phase and one closed in elective phase, who died in the intensive care unit after transcatheter therapy are as follows: the status of patient one was good after successful transcatheter VSD closure; however, one day later, the patient died of another new-onset septal perforation and cardiogenic shock. Patient 2 was an old female (72 years) who died of refractory heart failure and multiorgan failure. The third patient who had two defects died of refractory heart failure and failed to undergo the transcatheter VSD closure for the second ventricular defect. The fourth patient who had a 20-mm defect measured from the left ventriculogram was implanted a 30-mm ASD occluder successfully. Unfortunately, hemolysis occurred 10 h after the procedure and this patient died of renal failure. The status of patient five was good after successful transcatheter VSD closure; however, a week later, the patient died of another myocardial infarction despite the application of dual antiplatelet therapy.

Follow-up data

We attempted to contact all the patients who survived the procedures for follow-up. Thirty patients were contacted and the remaining four were lost to follow-up. Twenty-five patients went to their respective hospital for follow-up by TTE, ECG, and clinical examination between March and May 2013. The median follow-up time was 25 months (0–58 months). At the latest follow-up, there were two cardiac deaths, which occurred at 8 and 29 months after discharge, respectively. The TTE showed that the VSD devices were placed in their appropriate position and VSD to be completely closed in seven patients. Their functional capacity had improved to New York Heart Association class I or II for 22 and class III for six patients according to their explicit description. The follow-up data are summarized in Table 3.

Discussion

VSD is one of the most serious complications of AMI that generally produces progressive circulatory failure and death within a short time. Compared to patients with AMI without VSD, patients with VSD were older, more likely to be women, had increased rate of chronic renal disease, congestive heart failure, and cardiogenic

Table 2
Catheterization data of the two groups (median with range, frequencies, and percentages).

	Emergency	Elective	*p* value
Invasive hemodynamic data			
Mean systolic BP	108 (94–122)	124 (106–155)	0.001
Qp/Qs	3.1 (2.3–3.6)	2.8 (2.2–3.4)	0.015
Coronary angiography			
One-vessel disease	5 (55.6%)	15 (45.5%)	0.591
Two-vessel disease	3 (33.3%)	11 (33.3%)	1
Three-vessel disease	1 (11.1%)	7 (21.2%)	0.494
Number of defects			
One	8 (88.9%)	29 (87.9%)	0.934
Two	1 (11.1%)	3 (9.1%)	0.855
≥Three	0 (0%)	1 (3.0%)	0.597
VSD location			
Apical	6 (66.7%)	20 (60.6%)	0.740
Basal	3 (33.3%)	13 (39.4%)	0.740
Occluder size (mm)	20 (14–30)	17 (14–24)	0.030
Procedure success	7 (77.8%)	32 (97.0%)	0.048

Qp/Qs, pulmonary to systemic flow ratio; BP, blood pressure; VSD, ventricular septal defect.

Table 3
Data of post-procedure and follow-up of the two groups (median with range, frequencies, and percentages).

	Emergency	Elective	*p* value
Residual shunt: immediate result			
Mild	3 (33.3%)	23 (69.7%)	0.046
Moderate	2 (22.2%)	2 (6.1%)	0.143
Severe	1(11.1%)	1 (3.0%)	0.313
Residual shunt: before discharge			
Mild	2 (22.2%)	18 (54.5%)	0.085
Moderate	0 (0%)	1 (3.0%)	0.597
Severe	0 (0%)	1 (3.0%)	0.597
Residual shunt: latest follow-up			
Mild	2 (22.2%)	11 (33.3%)	0.523
Moderate	0 (0%)	1 (3.0%)	0.597
Severe	0 (0%)	1 (3.0%)	0.597
Complications			
Death			
On table	2 (22.2%)	1 (3.0%)	0.048
During hospitalization	4 (44.4%)	1 (3.0%)	0.001
After discharge	0 (0%)	2 (6.1%)	0.449
Hemolysis	1 (11.1%)	0 (0%)	0.053
Follow-up time, months	36 (27–44)	24 (0–58)	0.349

shock, the absence of a history of angina or myocardial infarction (MI), and severe coronary stenosis or total occlusion without compensatory collateral circulation and were less likely to be hypertensive or diabetic [4,9,18,19]. Optimized medical treatment including inotropic support, vasopressor drugs, and diuretic therapy for these patients is essential. However, attempts to stabilize the patient's condition with medical therapy often fail because most patients have a rapid deterioration and subsequently die. Current guidelines of the American College of Cardiology–American Heart Association for the treatment of postinfarction VSD recommend immediate surgical repair, regardless of clinical status (class I recommendation) [20]. However, mortality rates in surgical closure remain high at about 20–77% in current series to date. The interventional approach is a less invasive option and might allow for immediate complete VSD closure and stabilize the hemodynamics enough to function as an alternative or a bridge to surgical repair, especially in patients with multi-organ failure [16].

This retrospective study described the experience of 42 patients from seven Chinese heart centers who underwent attempted transcatheter VSD closure for the purpose of treating postinfarction VSD. We reported our experience with the percutaneous treatment of postinfarction VSD using the Amplatzer or domestic SHSMA occluder device. The median length of time from infarction to VSD occurrence was two days [interquartile range (IQR) 1–3] and time from VSD to closure was 28 days (IQR: 21–36). The in-hospital mortality rate (8/42) is concordant with data already published from other groups (6/29) [17]. But the mortality of urgent transcatheter VSD closure in our study was significantly higher than the previously reported mortality [21]. The majority of the patients (6/9) who underwent urgent percutaneous VSD closure died in the catheterization laboratory or during hospitalization. However, among the 33 patients who underwent elective VSD closure about three weeks after VSD, only two died and the status of the other 31 patients was good at the latest follow-up. Such a high survival rate was perhaps attributed to the long time from VSD occurrence to percutaneous device closure (median 30 days, IQR: 26–39 days). From our experience, it is responsible for improving outcomes to close the VSDs after a 2–3 weeks delay to allow the surrounding tissue to develop a firm scar which can be firmly anchored with occluders. It is not safe to deliver a sheath and close the defect shortly after AMI because the surrounding myocardium is too fragile. Therefore, the options for treatment depend on the hemodynamic status of the patient. When the patient is hemodynamically stable or has become stable after medication or mechanical support with IABP, transcatheter closure or surgical repair should be delayed until the margins of infarcted muscle have developed a relatively firm scar. When the patient is hemodynamically unstable, transcatheter closure is not a principal choice and perhaps an urgent surgical repair is favorable for survival.

The difficulty of transcatheter closure of ventricular septal rupture is how to push the catheter through the septum defect. According to our experience on transcatheter closure of congenital muscular VSD, we firstly push right coronary angiography catheter through the right femoral artery retrograde into the left ventricle. Then we let the catheter tip point to left ventricular surface of septum at left anterior oblique 45–60°and cranial 25° and the super-smooth guidewire is used to pass through the defect and the arteriovenous wire loop is established. If the defect is located in the front upper of the septal, it is difficult to pass through the defect to the arterial side. Then transvenous (femoral or jugular vein) approach is a preferred choice and the guide wire can be inserted directly into the descending aorta (Fig. 2). Except four patients, all other patients underwent transcatheter closure through the femoral vein due to operational convenience. In order to avoid the ventricular rupture, we should let the catheter tip point to left ventricular outflow tract but not apical to avoid damaging the left ventricular free wall when we push the catheter through the defect into the left ventricle. And we should pull back the delivery catheter but not push the occluder to release the right disc. In addition, the occluders are usually difficult to fix because of

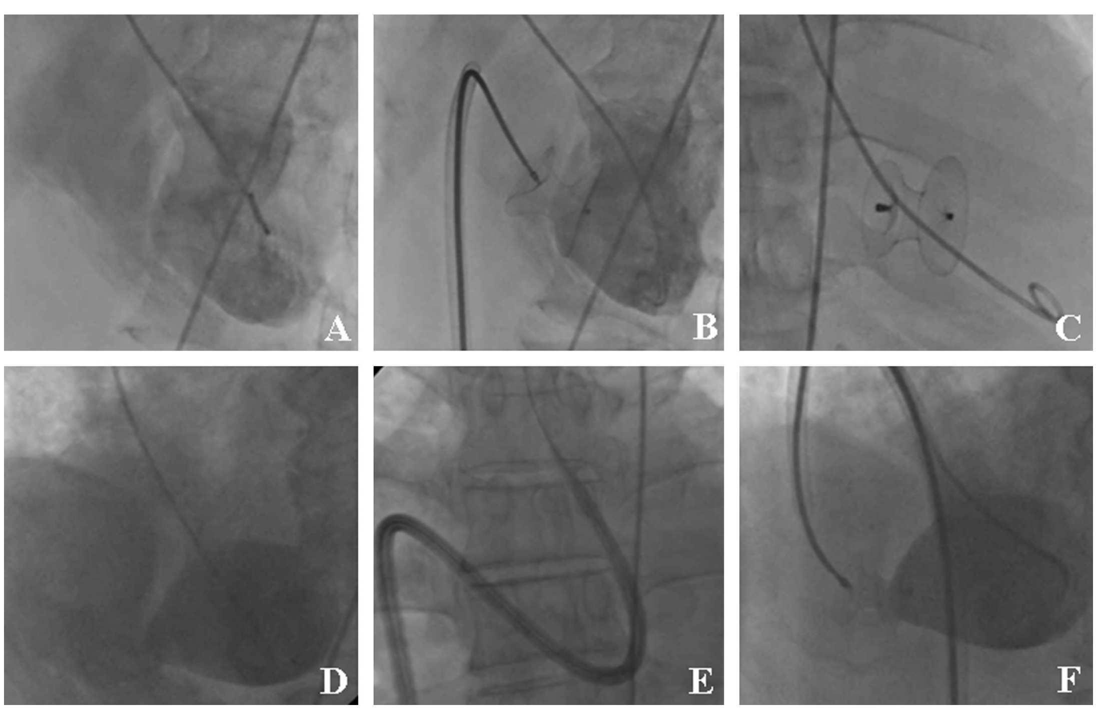

Fig. 2. Transcatheter postinfarction VSD closure in two patients without (A–C) and with arteriovenous wire loop (D–F). (A) LV angiogram delineating the mid muscular VSD (arrow). (B) Occluder was deployed, and mild residual shunt was found by angiography. (C) Occluder was released. (D) LV angiogram showed a muscular VSD (arrow). (E) Arteriovenous wire loop was established and the rigid delivery sheath was advanced. (F) Occluder was deployed, and mild residual shunt was found by angiography. LV, left ventricular; VSD, ventricular septal defect.

the presence of the friable necrotic myocardial tissue around the defect. For this reason, the design of SHSMA occluder was made for better fixation and the avoidance of disc displacement.

The study has some limitations. The first limitation is the relatively small patient population. Second, because of the retrospective study design, non-randomized study in hospitals in China, the experience may not be universally representative. On the other hand, we are unable to certify that all potential confounders have been examined. Third, follow-up in our study was relatively short and a few patients were not seen after discharge, and thus, these data do not provide information on the durability of surgical closure of post-MI VSD.

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