

## CLINICAL SCIENCE

# Percutaneous closure of a post-traumatic ventricular septal defect with a patent ductus arteriosus occluder

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**OBJECTIVE:** Ventricular septal defects resulting from post-traumatic cardiac injury are very rare. Percutaneous closure has emerged as a method for treating this disorder. We wish to report our experience in three patients who underwent percutaneous closure of a post-traumatic ventricular septal defect with a patent ductus arteriosus occluder.

**METHODS:** We treated three patients with post-traumatic ventricular septal defects caused by stab wounds with knives. After the heart wound was repaired, patient examinations revealed ventricular septal defects with pulmonary/systemic flow ratios (Qp/Qs) of over 1.7. The post-traumatic ventricular septal defects were closed percutaneously with a patent ductus arteriosus occluder (Lifetech Scientific (Shenzhen) Co., LTD, Guangdong, China) utilizing standard techniques.

**RESULTS:** Post-operative transthoracic echocardiography revealed no residual left-to-right shunt and indicated normal ventricular function. In addition, 320-slice computerized tomography showed that the occluder was well placed and exhibited normal morphology.

**CONCLUSION:** Our experiences indicate that closure of a post-traumatic ventricular septal defect using a patent ductus arteriosus occluder is feasible, safe, and effective.

**KEYWORDS:** Post-Traumatic Ventricular Septal Defect; Cardiac Injury; Percutaneous Closure; Patent Ductus Arteriosus Occlude.

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## INTRODUCTION

Post-traumatic ventricular septal defect (VSD) is an uncommon, if not rare, sequel of penetrating or blunt trauma, post-surgical contusion, and myocardial infarction (1). Open-heart surgery has been the standard method of treatment (2), but percutaneous closure has emerged as a new technique to address this important and challenging surgical problem. In this procedure, an Amplatzer VSD Occluder has usually been employed (3), or occasionally, an Atrial Septal Defect (ASD) Occluder has been used (4). We present our experience with percutaneous closure of post-traumatic VSDs utilizing a PDA Occluder (Lifetech Scientific (Shenzhen) Co., LTD, Guangdong, China). The PDA Occluder is shown in Figure 1A.

## MATERIALS AND METHODS

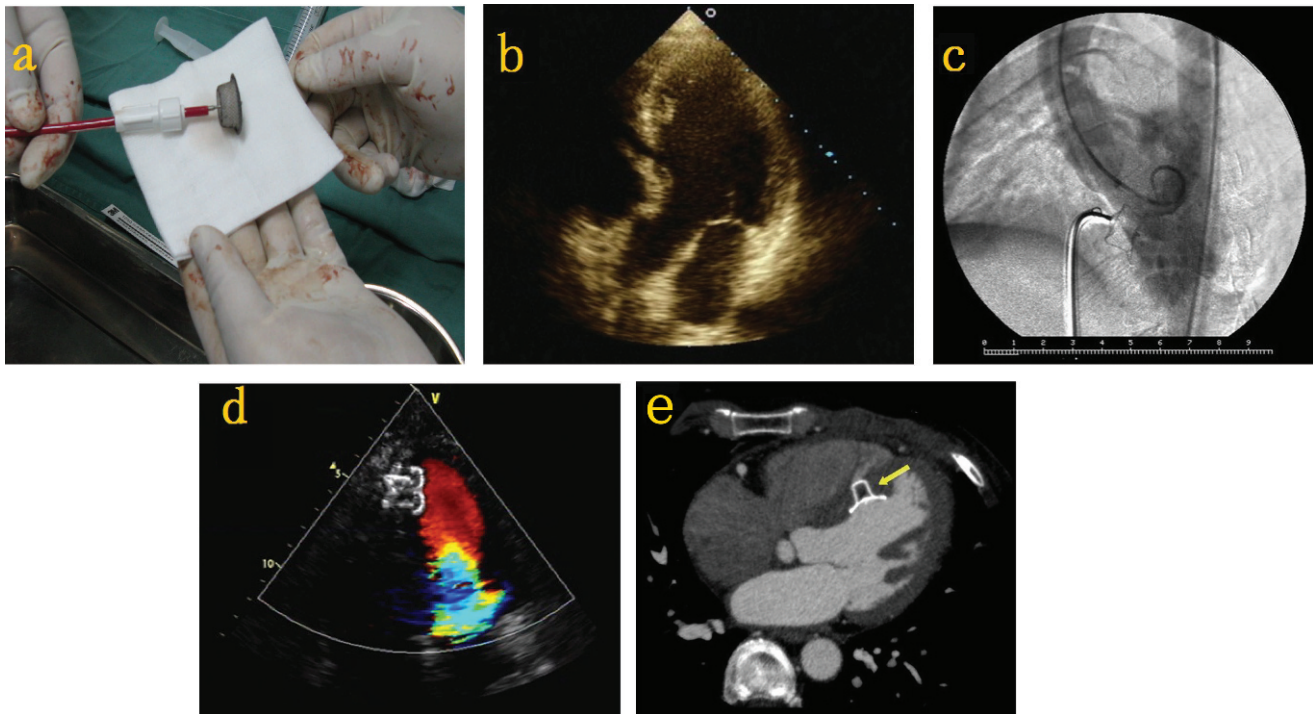
Three previously healthy patients who were stabbed in the left anterior chest presented with knives lodged in the fourth left intercostal space that moved synchronously with the heartbeat. The patients were awake but restless and in severe pain, with cardiac tamponade, dyspnea, hypotension, and elevated central venous pressure. The results of patients' physical examinations are described in Table 1. The knives were surgically removed, and perforations of the right ventricle were repaired with pledgeted-reinforced mattress sutures. On the second post-operative day, a loud holosystolic murmur was detected in all three of the patients. Transthoracic echocardiography revealed a large VSD in the muscular septum of each patient, and their pulmonary/systemic flow ratios (Qp/Qs) were over 1.7. Pulmonary arterial pressure was mildly elevated. The transthoracic echocardiography data are listed in Table 2 and one patient's echocardiography image is shown in Figure 1B.

### Percutaneous closure

Cardiac catheterization with a femoral approach was performed using local anesthesia. A pigtail catheter was

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No potential conflict of interest was reported.



**Figure 1** - A) Picture of the PDA Occluder. B) After initial surgical repair, the transthoracic echocardiography image revealed an angulated defect. C) The angiogram image indicated that the PDA Occluder was well mounted. D) Follow-up postoperative echocardiography showed complete closure of the defects with no residual left-to-right shunt. E) Follow-up postoperative 320-slice computerized tomography showed the Occluder was well placed and had normal morphology.

introduced into the left ventricle. A left ventricular angiogram disclosed a significant left-to-right shunt across a large defect in the muscular ventricular septum. The pigtail was withdrawn, and a multi-purpose catheter was guided from the left ventricle into the right ventricle and advanced through the VSD into the pulmonary artery. A second catheter was introduced into the femoral vein and advanced into the pulmonary artery. The defect in the first patient was closed with a Muscular VSD Occluder. The device became trapped during placement of the occluder because the right plate had an inappropriate configuration. The device was retrieved.

A PDA Occluder was selected to close the defect. The device's size was similar to that of the VSD or ASD Occluder, judged by the maximum diameter viewed by echocardiography and angiography. The delivery sheath was introduced into the left ventricle and ascending aorta in a loop. The PDA Occluder was then mounted and inserted into the delivery sheath (Figure 1C). After release of the device, left ventriculography revealed no left-to-right shunt. In the following two patients, the PDA Occluder was our primary choice.

**Table 1** - Clinical data collected on the day of injury.

Patient	1	2	3
Age (years)	16	22	44
Blood pressure (systolic/diastolic; mmHg)	70/30	82/54	68/45
Heart rate (beats/minute)	132	118	129
Respiratory rate (breaths/minute)	36	32	34
Oxygen saturation (%) on room air	86	90	83

## RESULTS

The transthoracic echocardiogram revealed that the device was in place with no left-to-right shunt. Ventricular size and function were normal. Pulmonary arterial pressure was normal (Figure 1D). In addition, 320-slice computerized tomography showed that the Occluder was well placed and had normal morphology (Figure 1E).

## DISCUSSION

Penetrating cardiac injuries are among the most common causes of violent death (5). Cardiac injury occurs in approximately 20-30% of cases of major chest trauma (6). In the majority of cases, the injuries are fatal. Approximately 20% of patients are alive when they arrive in the hospital, and up to 70% of these patients survive to hospital discharge (7). Survival depends upon rapid diagnosis and immediate treatment.

A VSD due to penetrating cardiac injury can occur directly, due to perforation of the septum, or indirectly, following injury of an epicardial coronary artery with

**Table 2** - Data from transthoracic echocardiography following initial surgical repair of the VSD.

Patient	1	2	3
VSD position	muscular	muscular	muscular
VSD size (mm)	12	8	10
Qp/Qs	1.7	1.9	2.0

necrosis and subsequent rupture. VSD is the most common complication of penetrating heart injuries. There are reports of delayed VSD presentation in which initial echocardiography was normal, but subsequent echocardiograms revealed a defect (8). The most common location of a post-traumatic VSD is at the apex (9). Surgical repair of a traumatic VSD can incur significant morbidity and mortality (10).

Surgical repair may not be feasible immediately after injury because of the patient's poor clinical condition. In addition, an increase in the defect's size can result from progressive tissue necrosis due to injury of the septal coronary arteries after perforation of the interventricular septum. Delay allows time for the development of fibrotic scarring on the rims of the defect, facilitating delineation on transthoracic echocardiography, which is important for optimal device selection and fixation (2).

Percutaneous closure has been successful in children with congenital VSD, approximately 90% of which are in the perimembranous septum (11). In most studies, the Amplatzer Muscular VSD Occluder and ASD Occluder were employed. Complete closure using the Amplatzer Muscular VSD Occluder or ASD Occluder is achieved in 92% of patients with a perimembranous VSD and in 95% of patients with a muscular VSD (11).

In a previous report, an Amplatzer device was successfully implanted in 16 of 18 patients with a post-infarction VSD; however, the 30-day-mortality was as high as 28% (12). In a group of mixed cases, successful VSD closure was reported in 30 of 32 patients (13). Prior our experience, only sporadic cases of successful percutaneous closure of traumatic VSD had been reported (3,9). For repair of post-traumatic VSDs, an Amplatzer Muscular VSD Occluder (3) or an ASD Occluder is usually chosen (4). The use of a PDA Occluder in this type of procedure has not been previously reported. We successfully repaired three post-traumatic VSDs with percutaneous with PDA occluders. A Muscular VSD Occluder initially employed in the first patient failed for two reasons. The post-traumatic VSD is almost angulated (Figure 1B), but the congenital VSD or ASD is straight. The Amplatzer Muscular VSD Occluder or ASD Occluder is designed for congenital heart disease, so the length was insufficient (the perforations in our three patients were more than 9 mm long, while the metal waist length of the Amplatzer Muscular VSD Occluder implant is only 4 mm). The Amplatzer Muscular VSD Occluder and ASD Occluder, which have two discs, are difficult to release in an angulated pathway. However, the PDA Occluder has only one disc. The higher blood pressure in the left ventricle serves the PDA Occluder's left disc; thus, it is safe. During the follow-up periods of the three patients (the longest for five years), the PDA Occluders remained securely implanted in each case.

Use of the PDA Occluder in a VSD closure has several advantages in comparison to the Amplatzer Muscular VSD Occluder or the ASD Occluder. The PDA Occluder cannot cause ventricular outflow tract obstruction because it only has a left disc. In addition, the metal waist of a PDA Occluder is both more flexible and softer than other Occluder implants, so it is more easily released and molded. The implant moves synchronously with the heartbeat. Fatigue damage of the metal material (14) occurs under the action of the dynamic load, and the implant's main

cause of failure is fatigue rupture. The fatigue life of the PDA Occluder is increased in comparison to the other implant types.

Our experiences indicate that percutaneous closure of a post-traumatic VSD using a PDA Occluder device is feasible, safe and effective. However, more experience is warranted before recommending widespread use of the PDA Occluder in this procedure.

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## AUTHOR CONTRIBUTIONS

Zhu J, Zhang Y and Xia F contributed to the written paper. Xi EP, Zhu SB, Yin GL, Liu Y and Dong YQ contributed to patient treatment. Zhu SB conceived the study. Xi EP is the first surgical doctor for these patients. Zhu J was responsible for the manuscript first draft.

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