# Transesophageal echocardiography-guided device occlusion of ventricular septal defects: a propensity score matching analysis of left anterior mini-thoracotomy *vs.* lower partial median sternotomy

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*To the Editor*: Ventricular septal defect (VSD), as the most common congenital heart defect, accounts for up to 40% of all congenital cardiac malformations.[1] Traditional surgical repair on cardiopulmonary bypass produces substantial trauma and has a long recovery time, and percutaneous device closure is not suitable for all types of VSDs. As minimally invasive procedures have become more common in cardiac surgery, minimally invasive occluder device closure of VSDs under transesophageal echocardiography (TEE) guidance is widely used with excellent preliminary, midterm, and long-term results.[2-4] A small subxiphoid incision and the third/fourth left intercostal space beside the sternum are the two major incisions for device closure of VSDs. However, the differences between the two incisions are unknown. This report describes our experience with two incisions for device closure of VSDs.

The study was approved by the Lanzhou University Second Hospital Institutional Review Board. Between January 2013 and December 2018, 156 patients with VSD were enrolled retrospectively, with individual informed consent obtained from the patients' guardians, and eight patients were converted to heart surgery from failed device occlusion of VSD. All patients were reexamined by TEE (PHILIPS IE33, Andover, MA, USA) before surgery. Left anterior minithoracotomy (LAMT) or lower partial median sternotomy (LPMS) was used, which were both performed under general anesthesia.

There are two methods of occluder delivery. The first is the one-step method, where the occluder is loaded directly into the delivery sheath, with the end of the occluder 2 to 3 mm over the sheath. After full venting, sheath punctures were delivered directly into the cardiac chambers through purse-string sutures in the epicardium. Under the guidance of TEE, it is important to directly point the head of the delivery sheath to the defect, ensure that the plane of the sheath has completely passed the left ventricular surface of the VSD, and then complete the release of the occluder. The second is the step-by-step method: The delivery sheath with a guidewire or hollow probe [Figure 1A, 1B, 1E, 1F] punctures into the cardiac chambers through the minor thoracic incision [Figure 1C and 1D]. Under the guidance of TEE, the head of the delivery sheath or hollow probe is delivered to the left ventricle through the VSD. If the hollow probe is used, keep the guidewire and remove the hollow probe, then the delivery sheath is delivered along the guidewire; if the delivery sheath is used, remove the guidewire and keep the delivery sheath. Then, the occluder is sent through the sheath and released. The other detailed implantation steps of this technique were basically the same as those described previously.[2]

The patients' characteristics are listed in Supplementary Table 1, http://links.lww.com/CM9/A548. Before propensity score matching (PSM), there were 80 patients in the LPMS group and 76 patients in the LAMT group. Patients in the LAMT group were older than patients in the LPMS group (1–5 *vs.* 2–21 years, $P < 0.001$). The weight of patients in the LAMT group was heavier than that of patients in the LPMS group (11.75–49.25 *vs.* 8.38–17.63 kg, $P < 0.001$). There were no significant differences in the other characteristics between the two groups. PSM yielded well-balanced cohorts of 66 patients with device closure from 156 patients (33 patients in the LPMS group and 33 patients in the LAMT group) [Supplementary Table 1, http://links.lww.com/CM9/A548].

VSD was successfully closed in 148 patients (94.9%) in the device closure group, and only eight patients were converted to surgical closure. Among the eight patients,

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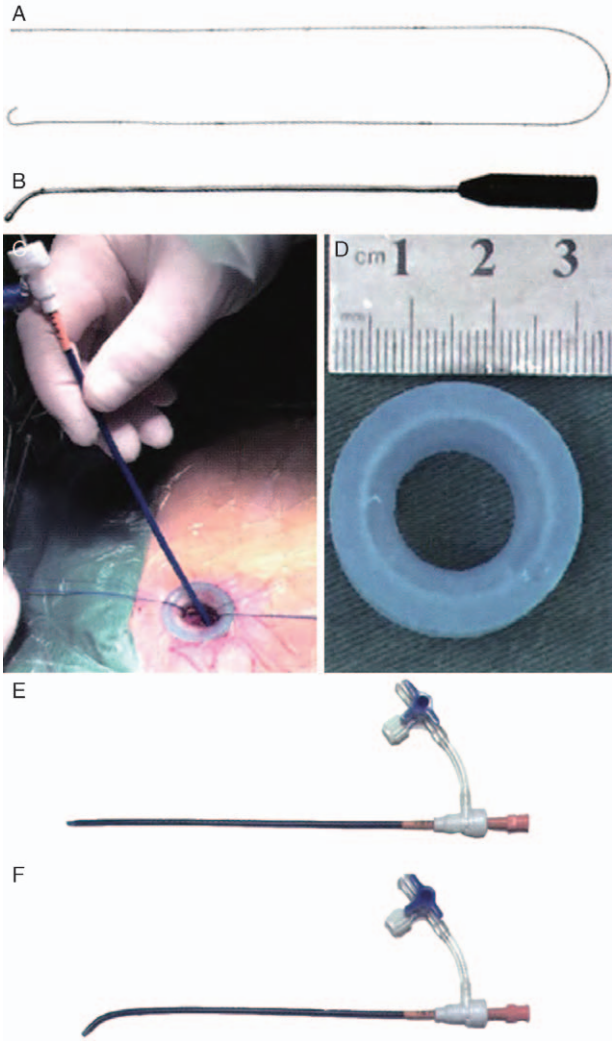


**Figure 1:** (A) A guidewire is used for establishing a conveying track. (B) "L" shape hollow probe. (C) A delivery sheath or hollow probe with the guidewire is inserted through the puncture point into the heart cavity. (D) Built-in silicone protective cover. (E) Straight delivery sheath. (F) "L" shape elbow delivery sheath.

five were in the LPMS group and three were in the LAMT group, including three patients with complete atrioventricular block occurring immediately after the occluder was deployed and five patients with a displacement of the occluder. Before PSM, the intracardiac operation time was not different between the LPMS group and LAMT group ($8.588 \pm 4.133$ *vs.* $9.987 \pm 5.805$ min, $P = 0.087$); the incision and suture time of LPMS was longer than that of LAMT ($57.263 \pm 15.117$ *vs.* $40.355 \pm 8.322$ min, $P < 0.001$). After PSM, the intracardiac operation time of the LPMS group was similar to that of the LAMT group ($8.061 \pm 4.138$ *vs.* $9.061 \pm 5.607$ min, $P = 0.087$); incision and suture time of LPMS was still longer than LAMT ($57.576 \pm 14.031$ *vs.* $41.030 \pm 8.991$ min, $P < 0.001$).

There were no major complications in both groups of device closures. Only one patient with infective endocarditis was converted to surgical closure and died 3 days after the operation. There was no significant difference in arrhythmias after surgery between the LPMS group and LAMT group, regardless of PSM status. The rate of valvular regurgitation (tricuspid regurgitation/aortic regurgitation) after surgery was similar in the two groups. The rate of residual shunts during hospitalization or 3 months after discharge was also similar in the two groups. The early post-operative results of the two groups are summarized and compared in Supplementary Table 2, http://links.lww.com/CM9/A548.

Before PSM, the hospital stay of the LAMT group was shorter than that of the LPMS group ($11.829 \pm 5.335$ *vs.* $14.550 \pm 7.890$ days, $P = 0.012$). The hospital cost of the LAMT group was not different compared to that of the LPMS group ($49{,}527 \pm 24{,}673$ *vs.* $49{,}316 \pm 15{,}203$ RMB yuan, $P = 0.949$). The cost-effectiveness suggested that the cost/average (C/E) of the LPMS group was 528.01, compared with that of the LAMT group, which was not cost-effective. After PSM, neither hospital stay nor cost differed between the two groups. However, the C/E in the LPMS group was more cost-effective than that in the LAMT group (454.57 *vs.* 519.80), as shown in Supplementary Table 2, http://links.lww.com/CM9/A548.

LPMS (limited sternotomy to the right ventricle) is widely used for various types of VSDs. LPMS makes it easy to choose the most appropriate puncture point of the right ventricular surface and avoid the coronary arteries. The angle of the delivery sheath into the VSD is often perpendicular to the plane of the VSD, which is conducive to the release of the occluder and makes it uniformly attach to the VSD. LPMS is especially suitable for VSDs with a large left ventricular surface diameter (8–15 mm), and the delivery sheath more easily passes a smaller defect (2–3 mm). However, LPMS requires splitting the midline of the sternum, which causes a much larger incision of the sternum than the skin incision, with more exudates, a longer time of incision and suture, leading to a greater operative wound. In addition, this method punctures through the right ventricular surface, which might damage the epicardium and myocardium.

LAMT (third/fourth left intercostal space beside the sternum to the right ventricle) is used later than LPMS. The incision for LAMT is approximately 1 cm, causing fewer operative wounds and shorter incision and suture time than LPMS. A small curved forceps are usually used to clamp on the epicardium of the puncture point of the right ventricle, and the selected puncture point is pulled to the incision for easy operation. The incision of the third left intercostal space beside the sternum is suitable for supracristal VSDs and perimembranous outflow-direction VSDs; the incision of the fourth intercostal space is suitable for muscular VSDs and perimembranous inflow-direction VSDs. The angle of the delivery sheath into the VSDs is often not perpendicular to the plane of the VSD, which makes it difficult for a straight delivery sheath to pass through the defect, especially for small VSDs and VSDs with a shunt of deviating from the puncture direction. It is often necessary to appropriately bend the head end of the delivery sheath into an "L" shape to easily pass through the defect.

The surgical approach should be selected individually based on the characteristics of the VSD, such as the size,

location, operating pathway, and direction of the left to right shunt. Under TEE real-time monitoring, transesophageal device occlusion of VSDs can avoid damage to the valves and subvalvular structure. The methods of occluder delivery (one-step/step-by-step) used in our study have their own advantages. The one-step method is suitable for simple and straightforward puncture routes. Although the step-by-step method has more steps, it is suitable for tortuous puncture routes. The elbow delivery sheath and hollow probe increase manoeuverability and contribute to completing complex occlusions of VSDs.

In conclusion, transthoracic device closure through LAMT or LPMS is an effective intervention with excellent short-term results for treating VSD in children and adults. LAMT avoids sternal injury and provides less trauma and faster recovery. In contrast, LPMS is suitable for patients of younger age or low weight, and LPMS is easier for beginners to master. The one-step method is more suitable for LPMS, and the step-by-step method is more suitable for LAMT. More prospective studies are mandatory to assess the two methods of transthoracic device closure of VSDs.

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### Conflicts of interest

None.

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