Percutaneous Perventricular Device Closure of Ventricular Septal Defect: From Incision to Pinhole

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Background. As an alternative to open surgical repair, perventricular device closure provides minimally invasive treatment for doubly committed subarterial ventricular septal defects. However, unlike percutaneous transcatheter access, mini-thoracotomy is still needed. This report describes the percutaneous perventricular device closure technique and its short-term results for this type of heart defect.

Methods. Sixteen patients who had isolated doubly committed subarterial ventricular septal defects underwent percutaneous perventricular device closure. By puncture of the chest wall and subsequently the infundibulum of the right ventricle under continuous guidance of transesophageal echocardiography, the guidewire and the delivery sheath were advanced into the heart to complete the perventricular closure. Closure outcomes and possible complications were measured in the hospital and during 1-year follow-up.

Results. Closure was successful in 15 patients (93.8%). No deaths, residual shunting, new valve regurgitation, or arrhythmias occurred either perioperatively or during the entire follow-up period. One patient had pericardial effusion and tamponade, and the procedure was converted to mini-thoracotomy perventricular closure. The mean hospital stay was 3.5 ± 2.0 days (range, 3.0 to 6.0 days), and only 1 patient required a blood transfusion (6.3%).

Conclusions. Percutaneous perventricular device closure of isolated doubly committed subarterial ventricular septal defects appeared to be safe and efficacious, with acceptable short-term outcomes. Larger studies and long-term follow-up are needed for further evaluation.

(Ann Thorac Surg 2017;103:172–7)

Perventricular device closure has been introduced as an alternative to surgical repair and percutaneous transcatheter closure in the treatment of ventricular septal defects (VSDs) [1–3]. Particularly in the treatment of doubly committed subarterial VSD, which has been a contraindication to percutaneous transcatheter device closure because of the challenging geometry of the upper edge of the defect and the aortic valve, perventricular device closure has provided encouraging initial results and a good cosmetic outcome [3, 4]. Although the technique of perventricular device closure offers selected patients another chance to receive minimally invasive treatment compared with the percutaneous transfemoral approach, it still requires a small incision and mini-thoracotomy. Recently, the percutaneous transapical approach has been applied to cardiac interventions such as closure of paravalvular leaks, treatment of left ventricular pseudoaneurysms, and mitral valve-in-valve implantation [5, 6]. With a puncture roughly the size of a pinhole, the degree of minimal invasiveness for this maneuver is comparable to percutaneous transcatheter device closure. Using a combination of perventricular device closure and the percutaneous transapical approach, we present a case series of percutaneous perventricular device closures of doubly committed subarterial VSD.

Accepted for publication Sept 12, 2016.

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The Video can be viewed in the online version of this article [http://dx.doi.org/10.1016/j.athoracsur.2016.09.061] on http://www.annalsthoracicsurgery.org.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2016.09.061

Patients and Methods

Patients

Between January and May 2015, patients with isolated doubly committed subarterial VSDs diagnosed by transthoracic echocardiography (TTE) were enrolled for the study at the West China Hospital, Sichuan University, Chengdu, Sichuan, China. Our selection criteria for percutaneous perventricular device closure included the following: (1) age 3 months or older, (2) diameter of defect 10 mm or smaller, and (3) no obvious aortic valve prolapse. Exclusion criteria included the following: (1) obvious aortic valve prolapse with or without aortic valve regurgitation, (2) a greater than mild degree of aortic regurgitation, (3) a major coronary branch crossing the infundibulum of the right ventricle, (4) evidence of severe pulmonary hypertension (systolic pulmonary arterial pressure $\geq$75 mm Hg), (5) other coexisting cardiac anomalies, (6) infective endocarditis, (7) coagulation disorders, and (8) chest wall deformity or infection close to the puncture site. This study was approved by the hospital ethics committee. Individual informed consent was obtained from all adult patients and from both parents of all pediatric patients. Alternative treatment options were given to patients or their parents before decision making. Only patients who consented to the study were enrolled; otherwise, they were referred for standard surgical closure. Preoperatively, all patients underwent 12-lead electrocardiography and, under general anesthesia, detailed transesophageal echocardiography (TEE) performed by the same echocardiographer. The following data were recorded: (1) the maximum diameter of the defect as assessed by multiple views, (2) the presence of any aortic or pulmonary regurgitation, (3) the presence of any tricuspid regurgitation, (4) the presence of any major coronary branch crossing the infundibulum of the right ventricle, and (5) any preoperative arrhythmia. Angiography was not performed in any of the patients.

Percutaneous Perventricular Device Closure

The procedure was performed with the patient under general anesthesia and with cardiopulmonary bypass on standby. In our previously established perventricular device closure technique [3], a doubly committed subarterial VSD was occluded through a mini-thoracotomy in the left third intercostal space. The infundibulum of the right ventricle is always located beneath the incision. Therefore, we chose the same space as in the percutaneous perventricular device closure technique. Before the puncture, the chest wall at the puncture site was compressed with the surgeon's index finger. This compression was visualized by TEE to confirm its spatial relationship with the right ventricular (RV) outflow tract (RVOT) (Video). The puncture point was located adjacent to the left border of the sternum to avoid injury to the internal mammary vessels.

After systemic heparinization (1 mg/kg) and transient left lung deflation, a 20-gauge needle was directed perpendicularly from the identified point into the chest. The tip of the needle was identified under TEE when approaching the heart so that the actual epicardial puncture site and neighboring structures (pulmonary artery, pulmonary annulus, and RV infundibular cavity) could be confirmed again before the needle was advanced into the right ventricle. With the tip of the needle in the right ventricle, a guidewire was then introduced into the right and left ventricles through the defect under continuous TEE guidance. The needle was then replaced by a delivery sheath that was advanced through the chest wall into the left ventricle (Fig 1). After removal of the guidewire, an eccentric occluder (Shanghai Shape Memory Alloy Material Co, Ltd, Shanghai, China) was delivered by a loading sheath to close the defect, with technical details as described by us earlier [3]. The position of the device, the presence or absence of residual shunting, the valvular status, and the patency of RVOT were checked again before the device was released.

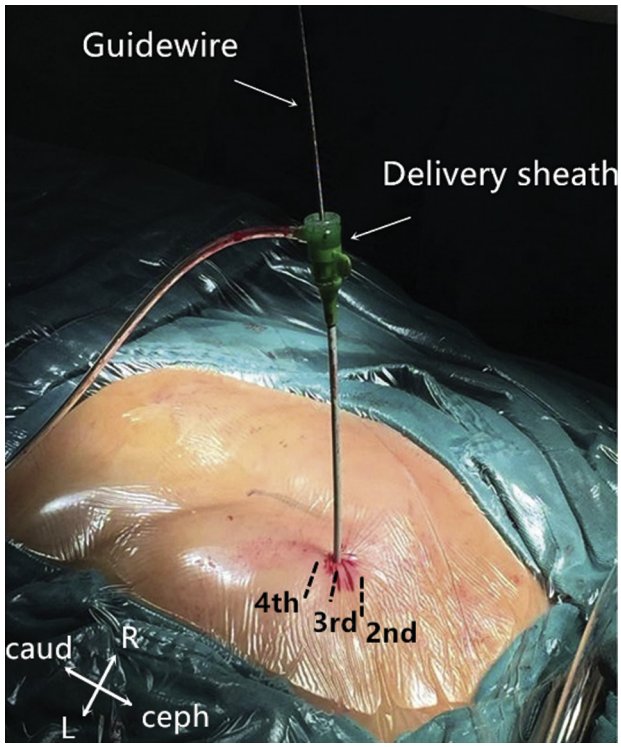

Fig 1. A delivery sheath was advanced through the guidewire into the heart through the chest wall at the third intercostal space. (caud = caudal; ceph = cephalic; L = left; R = right.)

In contrast to the perventricular device closure technique, the delivery sheath was not removed immediately after the eccentric device was released. Instead, after the cable and the loading sheath were retrieved, the delivery sheath was kept inside the right ventricle (Fig 2A). Similar to the technique used in the percutaneous transapical approach [5, 6], another concentric occluder was loaded into the delivery sheath and sent into the right ventricle. The left disc was deployed in the RVOT (Fig 2B), and the whole system (cable and sheath) was then pulled back so that the underside of the left disc lay tightly against the RV free wall (Fig 2C). The sheath was then withdrawn