Transcatheter closure of perimembranous ventricular septal defects with Amplatzer occluder assessed by real-time three-dimensional echocardiography

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Abstract
We report our initial experience in two patients using real-time three-dimensional echocardiography to assess perimembranous ventricular septal defect and device morphology and their relation with contiguous cardiac structure. Defect size and rims as well as device position and profile were displayed from the three-dimensional "en face" views. We think that real-time three-dimensional echocardiography could be a complementary approach to angiography and transesophageal echocardiography in performing transcatheter closure of perimembranous ventricular septal defect.

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Introduction
The isolated perimembranous ventricular septal defect (PM VSD) is one of the most common congenital heart malformations. Treatment has been indicated in the presence of significant left-to-right shunt, resulting in left ventricular overload. Surgical closure has been performed with a very low mortality rate, although complications, such as residual leaks, atrioventricular block, postpericardiotomy syndrome and arrhythmias have been well described. Transcatheter closure PM VSD has been attempted as an alternative approach to surgery. The specific device has to be positioned very closely to the aortic and tricuspid valve. The device closure procedure is performed using in a combination of fluoroscopic and transesophageal echocardiography (TEE). Since two-dimensional (2D) echocardiography approaches the ventricular septum from multiple...
orthogonal planes, it requires a mental three-dimensional (3D) construct to comprehend the relation between the defect and the surrounding structures. Three-dimensional echocardiography (3D echo) provides unique “en face” views of the atrial and ventricular septum.\(^5\),\(^6\) We report our initial experience in two patients using 3D echo to assess PM VSD and device morphology, and their relation with contiguous cardiac structure.

Case report

Population

Two consecutive patients were referred for device closure of their PM VSD. Age and weight were respectively 2 years and 11 kg (patient 1), 3.5 years and 12 kg (patient 2). Each patient underwent 2D transthoracic echocardiography. Size of PM VSD, QP/QS ratio and left ventricular diastolic diameter were respectively 7 mm, 2.2 and 38 mm (patient 1), 9 mm, 2.4 and 40 mm (patient 2).

3D echocardiography

Live 3D echo was performed the day before and after the transcatheter procedure using a Sonos 7500 system (Philips, Andover, MA). The 2–4 MHz matrix probe has a beam-former connecting 3000 piezoelectric elements allowing 3D images. The system acquired 3D data using a 40° × 20° pyramidal imaging volume (live 3D). Cardiac cycles were also acquired using the “full-volume” mode that consists of the acquisition of a larger single pyramid of data (120° × 60°) recorded during four consecutive cardiac cycles. Navigation by cropping inside the volume allowed surface rendering of the intracardiac structures. Measurement of VSD diameter was obtained using the Q-Lab system (Philips).

Transcatheter procedure

The procedure was performed under general anesthesia and TEE. Angiography in single plane (50° LAO/15° cranial) was performed to define the location and size of the PM VSD. The VSD was crossed from the left ventricle and a guidewire advanced into the pulmonary artery. A floppy exchange guidewire was advanced through the arterial catheter, snared and withdrawn from the femoral vein, establishing through-and-through access. A 9-F dilator and delivery Mullins sheath was advanced from the femoral vein across the ventricular septal defect into the ascending aorta.

Device selection

The PM VSD size was measured by TEE, 3D echo and angiography. Maximal diameter of the defect was measured on the left ventricular side in diastole as required.\(^7\) The data in two patients are reported in Table 1. The Amplatzer membranous VSD occluder (AGA, MN, USA) designed specifically for PM VSD has a diameter ranging from 4 to 18 mm with 2 mm increments. The device was selected to be 1–2 mm larger than the VSD size estimated by both TEE and angiography without taking account of 3D data. The device size was respectively 10 in patient 1 and 14 in patient 2.

Device delivery

In patient 2, the sheath tip was withdrawn to the left ventricular outflow tract and the guidewire was advanced to the LV apex with the arterial catheter. The sheath and dilator were advanced to the LV apex. In patient 1, the sheath could not be positioned in the LV apex; therefore, it was left in the ascending aorta and the device was deployed just adjacent to the aortic valve. The left ventricular disc was deployed under fluoroscopic control. Inferior direction of the platinum disc marker was confirmed. Under TEE guidance, the left ventricular disc was withdrawn to the septum. Good position was confirmed by left ventriculography. Absence of aortic insufficiency was confirmed by color flow Doppler. Keeping a steady traction on the delivery rod, the right side of the device was then deployed on the right ventricular side of the defect. Good position was confirmed by TEE and angiography. Tricuspid, mitral, and aortic insufficiency were sought on color flow Doppler. Any arrhythmia or conduction defects were noted.

<table>
<thead>
<tr>
<th>Patient data</th>
<th>Patient 1</th>
<th>Patient 2</th>
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<tbody>
<tr>
<td><strong>Age</strong></td>
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<td>3 years</td>
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<tr>
<td><strong>Weight (kg)</strong></td>
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<td>12</td>
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<tr>
<td><strong>QP/QS</strong></td>
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<td>2.4</td>
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<td><strong>LV diameter (mm)</strong></td>
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<tr>
<td><strong>PM VSD size (mm)</strong></td>
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<td>12</td>
</tr>
<tr>
<td>Occluder size</td>
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device was released by unscrewing the micro-
screw. A left ventriculogram and aortogram were
performed and showed a small shunt through the
device.

Follow-up

Device position was assessed by 2D and 3D echo-
cardiography the day after the procedure. Any
residual shunt and aortic regurgitation was
observed. In patient 1, the profile of the device
was flat. In patient 2, probably due to a slight
oversizing, the device had a mild "mushroom"
profile without left ventricular outflow Doppler
gradient. The patients recovered in an appropriate
setting and were discharged home the following
day. Patients received 100 mg aspirin daily for
6 months. During a follow-up of 3 months after de-
vice release, any arrhythmia or conduction defects
were noted.

Discussion

Real-time 3D echocardiography is a complementary
tool to assess anatomy of PM VSD. Size of the
defect and relation with contiguous cardiac struc-
ture are two crucial parameters to evaluate prior

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**Figure 1** 3D view of PM VSD in patient 1. The defect (arrow) viewed from the left ventricle (LV) has an oval shape. Maximal diameter of the defect could be appreciated accurately.

**Figure 2** 3D view of PM VSD in patient 2. The defect (arrow) viewed from the left ventricle (LV) is larger. The eccentric shape could explain the difference to measure PM VSD maximal diameter by 2D and 3D echo.

**Figure 3** 3D view of PM VSD in patient 1. The defect (arrow) is viewed from the right side. The close relation between PM VSD and the septal leaflet of the tricuspid valve is clearly displayed. RA, right atrium; RV, right ventricle; PA, pulmonary artery.
Device selection is based on VSD diameter measurements. Conventional methods such as angiography and 2D echocardiography do not integrate the complex and three-dimensional structure of the ventricular septum, which could explain the differences in VSD measurement between these methods. We found in the two patients that PM VSD diameter by 3D echo was 2 mm superior to diameter by TEE. Such a finding is explained by the asymmetric shape of the defects (Figs. 1 and 2). We reported

Figure 4  3D view of PM VSD in patient 2. The defect (arrow) is viewed from the left ventricle (LV). The tiny rim between the PM VSD and the aortic leaflets (AO) requires a specific profile of the device. The Amplatzer membranous VSD occluder has an eccentric left disc with minimal subaortic rim.

Figure 5  3D view after device implantation in patient 1. The Amplatzer PM VSD occluder (arrow) has a flat profile. The left disc does not protrude in the left ventricular outflow. LA, left atrium; AO, aorta.

Figure 6  3D view after device implantation in patient 2. The Amplatzer PM VSD occluder (arrow) has a mushroom profile due to oversizing. The left disc protrudes in the left ventricular outflow without Doppler gradient. LA, left atrium; AO, aorta.

Figure 7  3D view after device implantation in patient 1. The Amplatzer PM VSD occluder is viewed from the right side. The right disc (arrow) is well positioned close to the septum and far from the pulmonary artery valve (PA).
in a previous study the accuracy of 3D echo in measuring muscular VSD compared to surgery. However, 3D echo was limited, with off-line reconstructions and variable image quality. The introduction of the 3D matrix array probe allows real-time 3D rendering with higher resolution. Cheng et al. recently reported a real-time 3D echo study in assessing VSD. They found an excellent correlation in measuring size of VSD by 3D echo compared to surgery.

The 3D “en face” views allowed better comprehension of the VSD and its relation with adjacent structures (Figs. 3 and 4). Aortic valve and tricuspid valve competence have to be evaluated during all the procedures. The location of the defect in the membranous septum explains the risk for the valves. The PM VSD is located in the outlet portion of the left ventricle immediately beneath the aortic valve. The presence of a 2 mm or more rim of tissue between the defect and the aortic valve is generally required for device closure of PM VSDs. Septal leaflet of the tricuspid valve is in continuity with the aortic leaflets. Moreover, extra septal leaflet tissue can partially occlude the defect. Such a narrow relation between the PM VSD and the aortic and tricuspid leaflets could be displayed by 3D views from the left and the right side. A recent study showed the ability of 3D echo to guide right ventricular biopsy in children. The 3D views precisely described the attachment of the tricuspid valve chordae to the right ventricular wall.

The geometric profile of the device has to be specifically designed for PM VSD closure. A variety of occluding devices, such as the Rashkind double umbrella, the buttoned device, or coils, were unsuccessfully used to close PM VSD. The Amplatzer membranous VSD occluder has a specific profile consisting of two parallel discs with minimal sub-aortic rim. The left disc is eccentric, 0.5 mm larger than the waist at its superior rim and 5.5 mm at its inferior rim. The right disc is centric, being 4 mm round the waist. Authors focused on the volume of the Amplatzer device in the atrial cavity and its potential obstruction. We presently report the two first PM VSD occluders assessed by 3D echo. The 3D views illustrated the geometric profile of the Amplatzer device in both patients (Figs. 5–8).

McKendrick et al. reported the use of real-time 3D echo to guide device closure of atrial septal defect. They concluded that this method was a feasible, safe and effective alternative to the standard practice of TEE. Higher spatial resolution and frequency probe are required to improve 3D image quality. The freeze 3D images dampened partially the strength of 3D echo study, which needs to be displayed in dynamic format. However, we think that real-time 3D echo could be a complementary approach in planning for and performing transcatheter closure of PM VSD. Further studies with a larger number of patients are required to assess the place of each imaging modality.

References