HVAD continuous flow assist device for ischemic ventricular septal rupture

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A ventricular septal defect (VSD) can occur as a severe complication of extended myocardial infarction (post-MI-VSD) and has been associated with high mortality.¹ According to the Global Registry of Acute Coronary Events database, post-MI-VSD complicates 0.26% of acute MIs. In approximately 60% of cases, post-MI-VSDs will be located in the anteroapical septum as the result of an occlusion of the left anterior descending artery. In 40% of patients, the rupture will occur in the posterior septum after occlusion of a dominant right coronary

artery. Emergency or early surgical intervention has been recommended for post-MI-VSDs, despite the high operative risk. Post-MI-VSD has been a classic indication for the implantation of a total artificial heart (TAH) in patients with extended MI requiring mechanical circulatory support. However, because TAHs have been associated with a markedly reduced quality of life and are limited to bridge-to-transplant patients, modern mechanical circulatory support therapy must rely on continuous flow pumps. We present our surgical strategy for post-MI-VSDs using the HeartWare HVAD (HeartWare Inc, Framingham, Mass).

Three male patients (age 46, 47, and 67 years) were admitted to our institution in cardiogenic shock with post-MI-VSD. All 3 patients were in Interagency Registry for Mechanically Assisted Circulatory Support levels 1 or 2 on arrival. Two patients had an occluded left anterior descending artery with subsequent left ventricular (LV) failure, and the other patient had an occluded right coronary artery with leading right ventricular (RV) failure. Hemodynamically relevant VSDs in the anterior or posterior

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FIGURE 1. Patient with left anterior descending artery occlusion and post-myocardial infarction (MI) ventral septal defect (VSD). A, This patient had an acute MI caused by proximal occlusion of the left anterior descending (arrow). B, An anterior, midseptum VSD was revealed by left ventriculography when the patient went into cardiogenic shock. RV, Right ventricle; LV, left ventricle. C, A transesophageal echocardiogram showed a hemodynamically relevant VSD shunt. D, The patient underwent VSD closure with a modified Dor plasty, carrying the HVAD sewing ring. E, Postoperative chest radiograph showing the HVAD in the typical apical position.

FIGURE 2. A patient with right coronary artery occlusion and post–myocardial infarction (MI) ventral septal defect (VSD). A, This patient experienced an acute MI due to occlusion of the proximal right coronary artery (*arrow*), which could not be revascularized. He developed a posterior, midseptum VSD, documented by (B) left ventriculography and (C) transthoracic echocardiography. RV, Right ventricle; LV, left ventricle. He underwent surgical VSD patch closure and required right ventricular assistance for cardiopulmonary bypass weaning. D, The HVAD was implanted in a right atrium-to-pulmonary artery configuration. E, The discharge chest radiograph showed the intrapericardial HVAD with the inflow pointing toward the tricuspid valve.

septum were documented using echocardiography, and all patients underwent emergency surgery by a single surgeon (T.D.).

Our surgical strategy was as follows. After a median sternotomy and aortic and bicaval cannulation, the heart is arrested using antegrade and retrograde blood cardioplegia. A 6- to 8-cm left ventriculotomy is performed at the LV apex, irrespective of the suspected location of the VSD, and the VSD is evaluated. The defect is closed using a Vascutek patch (Vascutek Terumo, Scotland, UK), secured within vital myocardium using interrupted pledgeted sutures. In patients with left-sided MI, the patch will be used to close the VSD and remodel the apex. With this modified Dor plasty, the LV cavity can be reduced in size (Figure 1). The HVAD sewing ring is attached to the patch and the HVAD pump inserted. The outflow graft is then connected to the ascending aorta.

In patients with RV infarction, the Vascutek patch is only used to close the VSD. The LV apex is closed using horizontal mattress sutures, taking care to limit the trauma to the left ventricle, and no size reduction or Dor plasty is performed. The HVAD is inserted into the right atrium (Figure 2). Although HVAD implantation into the diaphragmatic right ventricle has been previously described,² it can be challenging to place the inflow into a regular size right ventricle without generating suction events. The outflow graft is then anastomosed to the main pulmonary artery.

In LV assist device (LVAD) patients, the pump speed should be set cautiously during cardiopulmonary bypass weaning and the RV function should be closely monitored. We have not experienced any RV failure in our 2 patients. Cardiopulmonary bypass weaning is even simpler in RV assist device (RVAD) patients, because we have never seen LV failure caused by excessive RVAD flow.

Both LVAD patients recovered well and were discharged. One patient accidentally died 12 weeks later of fatal device mishandling. At the last follow-up point, the other patient was still on the device and in good clinical condition. The patient with RVAD support was listed for heart transplantation and successfully underwent transplantation 6 months later. Because it is still an off-label use, an HVAD RVAD will not usually be reimbursed by health insurance companies in Germany and needs to be negotiated on an individual basis.

Post-MI-VSD usually develops within a few days after MI. In-hospital mortality has been 67% to 82% at 2 months in these patients with medical therapy only.¹ The reported mortality after surgical repair has varied and has been approximately 45%. Because of necrotic myocardium and friable tissue, the risk of persistence or recurrence of VSD has been approximately 35%.³

According to the current consensus statement from the International Society for Heart and Lung Transplantation, an LVAD alone in the setting of an unreparable post-MI-VSD is not recommended, and, if possible, permanent

LVAD placement should be delayed in the setting of an acute infarct involving the LV apex.⁴ In the case of post-MI-VSD with extensive infarction and a high risk of biventricular failure, a TAH should be implanted.

In an experienced mechanical circulatory support program, a 30-day survival rate of 74% can be achieved after TAH placement in patients with acute biventricular failure.⁵ However, the long-term results and quality of life will be severely impaired by hemolysis, infections, stroke, noise, and a bulky driver. Our presented technique might supersede the need for TAH placement in patients with post-MI-VSD.

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Bilateral pulmonary artery banding with ligation clips: A novel technique resistant to residual stenosis

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Bilateral pulmonary artery (PA) banding (BPAB) is a less invasive alternative to the Norwood procedure for hypoplastic left heart syndrome (HLHS) and related defects. Conventional BPAB, that is, bilateral PA narrowing achieved with expanded polytetrafluoroethylene tape, has its drawbacks, including high risks of residual PA stenosis after debanding and difficulty in attaining laterally balanced degree of banding.^{1,2} Conventional BPAB, which produces circular narrowing, inevitably reduces PA perimeter significantly. If PA narrowing could be attained with no or minimal reduction in its perimeter, the risk of residual PA stenosis might be reduced.

We have devised a novel BPAB technique whereby ligation clips are halfway closed into a rhombic shape to narrow bilateral PAs. Four ligation clip applicators with small stoppers within the jaws (Hemi Closure; Midoriya Sugiura, Tokyo, Japan) were manufactured to transform a ligation clip (Horizon clip ML; Teleflex Medical Inc,

Research Triangle Park, NC) into a rhombic shape. Each applicator had a different length of stopper to transform the clip into a rhombic shape with an internal diagonal of either 1.0, 1.2, 1.4, or 1.6 mm (Figure 1).

At surgery, bilateral PAs were exposed through a median sternotomy and encircled with heavy threads. By gently pulling the threads, ligation clips were applied around both PAs. When the degree of banding was deemed inappropriate by oximetry or ultrasound, the clip was taken out with a clip remover (Hemoclip remover; Teleflex Medical) and replaced with a different sized clip.²

The novel BPAB technique was used in 8 neonates with HLHS and 7 high-risk neonates with congenital heart defects other than HLHS. Age at operation ranged from 1 to 15 days (median, 3 days). For more precise adjustment of banding, a clip applicator sized 1.3 mm was

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FIGURE 1. A clip applicator with a stopper within the jaw (white arrow) transforms the ligation clip into a rhombus with a shorter internal diagonal of 1.4 mm (indicated by white line).