Despite aggressive emergent revascularization strategies, large myocardial infarction (MI) involving the left anterior descending coronary artery can result in akinesis or aneurysmal dilatation of the anterior wall and left ventricular apex. This in turn can cause progressive, deleterious remodeling of the left ventricle in up to 33% of post MI patients and increased wall stress on the non-infarcted regions of the heart. The management of such patients who consequently develop severe chronic heart failure (HF) can be challenging. Patients in NYHA class III and ambulatory class IV (heart failure symptoms with minimal exertion or at rest) have a poor quality of life, low intermediate and long-term survival (32% 1-year mortality), and frequent admissions to the hospital with decompensated heart failure.

Therapeutic options for such patients include:

a. Intensive therapy with vasodilators, beta-blockers, aldosterone antagonists, and loop diuretics

b. Cardiac resynchronization therapy (CRT) with biventricular pacemakers/Implantable Cardioverter Defibrillators (ICDs)

c. Ventricular assist devices (VAD), either as a permanent treatment modality in patients who are not candidates for heart transplant, or as a “bridge” to eventual heart transplant

d. Cardiac transplant

VAD and transplant are typically reserved for patients with ACC/AHA stage D heart failure (refractory to conventional medical therapy), whereas CRT is useful only in patients with a wide QRS duration on EKG. Drug therapy is also limited in some patients due to low blood pressure and poor kidney function.

Finally, some patients continue to have NYHA class III-IV symptoms despite maximally tolerated drug therapy and/or CRT, and are not candidates for VAD or transplant.

A novel mode of treatment for such patients is to percutaneously implant a device in the left ventricular cavity with the intention of reshaping and improving the compliance of the left ventricle (LV). Since the device partitions the LV and excludes the akinetic or aneurysmal segment, it is referred to as a ventricular partitioning device (VPD). The term “percutaneous ventricular restoration” or PVR has been proposed to differentiate the technique from surgical approaches to ventricular volume reduction.

**Parachute Device**

The Parachute device (Cardiokinetix, Menlo Park, CA) is a catheter-based VPD. The device in its current form consists of a conical nitinol frame covered with ePTFE. A soft radio-opaque “foot” is attached to the apex of this cone, and 2 mm projections at the base of the cone assist in anchoring the device to the LV endocardium (Figure 1). The entire device is constrained in a loader and delivered to the LV cavity via a dedicated and specially shaped guide catheter. The guide is advanced over a wire via 16F sheath in the femoral artery. The device is de-sheathed from the guide in the LV cavity and advanced to the apex until the “foot” abuts the LV apex. Left ventriculography and simultaneous transthoracic echocardiography guide this process. A 20 ml balloon is inflated within the cone of the device to assist in opening the device to its full extent, and then deflated. The device is then released from the delivery cable after ensuring satisfactory position by repeat (Continued on page 6)

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Figure 1
The Parachute device with nitinol frame and anchors, ePTFE covering, and foot composed of polymer material.

Courtesy of CardioKineticx

Figure 2 - Angiographic sequence of a Parachute implantation in the left ventricle (LV). Pigtail in the LV cavity to perform LV angiography (A); device placement with foot exposed and in contact with the antero-apical wall (B); balloon inflation to facilitate self-expansion of the device (C); device fully expanded but still attached to the delivery system (D); final positioning after release of the device (E).

With permission from Wolter Kluwer
angiography and echocardiography (Figure 2). The procedure is typically performed under conscious sedation and local anesthesia with a completely percutaneous approach. Patients are discharged on warfarin for 1 year, followed by aspirin indefinitely. Histopathological studies on devices removed during transplant or autopsy have shown platelet and fibrin-thrombus on both luminal and abluminal aspects of the device. Over time, granulation tissue and neo-endocardium form and incorporate the device surfaces and contact points with the LV wall (Figure 3).

**Mechanism of Action**

The goal of PVR is to lower LV end-diastolic and systolic volumes, which are surrogates for severity of adverse LV remodeling. There are several potential mechanisms of action:

1. Substitution of the rigid apical scar with the more compliant device, coupled with the outward force exerted by the device’s anchors in diastole, improves LV filling by exerting a “trampoline effect.”
2. Improved LV compliance also reduces LV end diastolic pressure.
3. Favorable changes in LV geometry lower wall stress in the unaffected portion of the LV.

**Clinical Studies**

Initial animal studies found that implantation of the device 6 weeks following experimental MI was associated with attenuation of LV remodeling. The device was then successfully implanted in 2 patients in Belgrade, Serbia, with reductions in LV volumes and improvement in LV ejection fraction (LVEF). Since then the device has been evaluated in single-arm clinical trials with prospective follow-up, and more recently in randomized controlled trials. The European, first-in-human cohort A consisted of 18 patients while cohort B had 59 patients. The US Feasibility trial enrolled 20 patients, and 18 had the device implanted.

In one recent series involving 91 patients, successful implantation was achieved in 90%. Five implantations were unsuccessful including one case of device infection, which required removal. One procedural death occurred and 1 patient suffered a stroke. Overall, 89% of patients improved or maintained their functional class.

The PARACHUTE trial (N=15) reported a significant reduction in LV end diastolic and systolic volumes at one year, coupled with an improvement in LVEF from 28% to 33%. Functional capacity and 6-minute walk test improved, with a significant reduction in NYHA class. The device had to be surgically removed in 2 patients and 1 patient died from non-device related infection.

Additional 1-year data from 111 patients from the European cohort A and B, U.S. feasibility, and Parachute III trials have been reported. Baseline LVEF was 27.9%. The device was successfully implanted in 96% of cases. Average length of hospital stay was 2.9 days. At 12 months, a highly significant 14% decline in LV volume was noted despite a modest 2% absolute increase in LVEF. Improvement or maintenance of NYHA class was noted in 54% and 32% of patients, respectively. Major complications were noted in 7.2% and minor complications in 8.2%. One-year stroke, all-cause mortality, and combined mortality and heart failure rehospitalization rates were 2.9%, 5.7%, and 21.7%, respectively.

Three-year data in 23 patients, with post MI LVEF of 15-40% and NYHA class II-IV symptoms, were recently published. These patients underwent device implantation as part of the
Parachute first-in-human study, which was a prospective, single-arm study conducted at 10 centers in the U.S. and Europe. In this study, NYHA class was improved or maintained in 85% of patients (Figure 4). Further, a statistically significant reduction occurred in LV end diastolic volume index by 10% and LV end-systolic volume index by 7% (Figure 5). This was paralleled by significant improvements in quality of life and functional capacity, as assessed by the Minnesota Living with Heart Failure questionnaire and 6-minute walk test. The incidence of heart failure hospitalization or death at 1 year was 16.1%, 32.3% at 2 years, and 38.7% at 3 years. Only 2 out of 31 patients died of cardiac causes over 3-year follow up and no cardiac death occurred after 6 months. No strokes were noted at 1-year follow up. Four strokes were noted by 3 years.

Percutaneous Versus Surgical Ventricular Restoration

Surgical ventricular restoration (SVR) as studied in the STICH and RESTORE trials has provided mixed results and differs significantly from PVR.9, 10 In some studies, the degree of LV end systolic volume reduction appears to be greater with PVR compared with SVR. The Parachute device partitions the LV with a flexible device and results in a conical apex, whereas SVR results in a rigid flat apex due to an inflexible surgical patch. Also, the risk of PVR is considerably lower than SVR.

Pivotal Trial

PARACHUTE IV is the pivotal FDA investigational device exemption trial, which is enrolling 560 post-left anterior descending artery territory MI heart failure patients in the U.S. who have NYHA class III or ambulatory class IV symptoms. Other inclusion criteria include LVEF between 15-35% by echocardiogram, appropriate left ventricular wall motion abnormality (akinesis, dyskinesis, or aneurysm), and anatomy as assessed by cardiac CT and echocardiogram to allow device placement. Individuals with untreated significant coronary artery disease requiring revascularization, cardiogenic shock within 72 hours, stroke or transient ischemic attack within 6 months, pacemaker or ICD within 2 months, creatinine > 2.5 mg/dl, or moderate or severe valvular stenosis or regurgitation will be excluded. The primary endpoint of Parachute IV is all-cause mortality and hospitalization for worsening heart failure. Vanderbilt University Medical Center is one of the U.S. sites participating in Parachute IV. The first implant was performed successfully and without complications in August 2014, with a favorable clinical course post procedure.

Conclusions

Percutaneous ventricular restoration is a novel and potentially effective technique to counteract harmful LV remodeling after an extensive MI. Short and intermediate term data suggest that the procedure reduces LV volume, maintains or improves NYHA functional class in 85% of patients, and lowers heart failure hospitalization, with an acceptable safety profile in experienced centers. Long-term data and data from randomized controlled trials comparing the device to optimal medical therapy are awaited.

References:
5. Thomas M. Presentation at EuroPCR 2013.