Percutaneous Closure of Left Ventricular Pseudoaneurysm

Yuriy Dudiy, MD; Vladimir Jelnin, MD; Bryce N. Einhorn; Itzhak Kronzon, MD; Howard A. Cohen, MD; Carlos E. Ruiz, MD, PhD

Background—Left ventricular pseudoaneurysm is a rare but serious complication from myocardial infarction and cardiac surgery. Although standard treatment is surgical intervention, percutaneous closure of left ventricular pseudoaneurysm has become an option for high-risk surgical candidates. Experience with percutaneous treatment is limited to a few single case reports. This is the first series of percutaneous treatment of the left ventricular pseudoaneurysms.

Methods and Results—This is a retrospective analysis of 9 procedures of percutaneous repair of left ventricular pseudoaneurysm in 7 consecutive patients (ages 51 to 83 years, 6 men) completed in our Structural Heart Disease center from June 2008 to December 2010. All patients were considered as a high risk for surgery because of multiple comorbidities. Multiple imaging modalities were used before, during, and after the procedures to improve success and efficacy. The left ventricular pseudoaneurysms of all 7 patients were successfully repaired. Fluoroscopy time on average was 36.5±24.0 minutes (range, 12.4 to 75.7 minutes). All patients were followed up for a period ranging from 3 to 32 months after the procedure. Each patient improved by at least 1 New York Heart Association functional class, and 4 patients improved by 2 classes.

Conclusions—Transcatheter closure of the left ventricular pseudoaneurysm is a feasible alternative for high-risk surgical candidates. The use of multiple imaging modalities is required for a detail planning and execution of the procedure. (Circ Cardiovasc Interv. 2011;4:322-326.)

Key Words: myocardial infarction ■ aneurysm ■ cardiac tamponade ■ left ventricular pseudoaneurysm

Left ventricular pseudoaneurysm is a rare but serious complication that may occur after acute myocardial infarction or cardiac surgery. Left ventricular pseudoaneurysm is a rupture of the left ventricular wall that is contained by the pericardium. In many cases, cardiac rupture results in cardiac tamponade and death.1 In left ventricular pseudoaneurysm, however, this rupture is contained by pericardial adhesions or a new thrombus, preventing exsanguination.1–6

The true incidence of left ventricular pseudoaneurysms is unknown. In few reports, however, myocardial infarction and previous cardiac surgery accounted for 55% and 33%, respectively, of all causes of left ventricular pseudoaneurysm.7 Mitral valve replacements, in particular, have been associated with causing left ventricular pseudoaneurysms.8 Although the general consensus for initial treatment is surgical intervention,7,9 percutaneous left ventricular pseudoaneurysm closure is a new alternative for high-risk surgical candidates.

Methods

This retrospective study encompasses 7 consecutive patients who underwent 9 procedures of percutaneous repair of left ventricular pseudoaneurysm at the Lenox Hill Hospital Structural Heart Disease center from June 2008 to December 2010. The patients’ demographics are summarized in Table 1. Overall mean age was 70.5±12.1 years, ranging from 51 to 83 years; 6 patients were men. All patients were considered as a high risk for surgery because of multiple comorbidities: All patients had congestive heart failure and systemic hypertension, 5 patients had atrial fibrillation, 3 patients had a permanent pacemaker, 2 patients had prior coronary bypass surgery, and 1 patient had 4 previous mitral valve replacements. Five patients had development of left ventricular pseudoaneurysm as a result of previous mitral valve replacement surgery, and 2 patients had development of left ventricular pseudoaneurysm as a result of myocardial infarction.

Patients were informed about procedural risks, therapeutic alternatives, and “off-label” use of closure devices. Written informed consent was obtained from all patients before the procedure. The study was approved by Lenox Hill Hospital’s Institutional Review Board.

Procedural success was defined as the successful implantation of the closure device, without embolization or migration, at the left ventricular pseudoaneurysm orifice with no flow into the pseudoaneurysm cavity as determined by color-flow Doppler.

Imaging

Computed Tomographic Angiography

All patients underwent computed tomographic angiography (CTA) before the procedure. We used helical acquisition with retrospective

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ECG-gated reconstruction of 16 phases at equally spaced intervals increments. Four-dimensional (4D) (time-factor) volume rendering (using “Aquarius” v 3.7.0.14, workstation, TeraRecon Inc, San Mateo, CA), which simulates actual heart movements, was used to evaluate the dynamic changes of the left ventricular pseudoaneurysm. Size and type of the device, as well as the approach, was selected on the basis of information obtained from the volume rendered CTA (Figure 1). The volume-rendered CTA images were also used for planning of the transapical and left ventricular pseudoaneurysm punctures, as previously described.11

**Echocardiography**

Each patient was examined by transthoracic (TTE) and transesophageal (TEE) echocardiography. In 5 of 7 patients, real-time, 3D TTE and TEE were also performed, using the IE33 system a with the x7-2T probe (Philips, Andover, MA). Images were obtained by using the live 3D, 3D zoom, and full-volume modalities.

Images were obtained and recorded during each stage of the procedure. The operator used the information thus obtained to guide the catheters and devices throughout the procedure (Figure 2). The blood flow from the left ventricle into the left ventricular pseudoaneurysm (during LV systole) and back from the left ventricular pseudoaneurysm into the LV (during LV diastole) were evaluated by spectral and color flow Doppler.

The 2D TTE was used in 1 procedure to guide and monitor percutaneous puncture of the pseudoaneurysm.

**Interventional Techniques**

All the left ventricular pseudoaneurysms were repaired by implantation of the closure device at the orifice of the pseudoaneurysm, preventing the communication between the left ventricle and pseudoaneurysm.

The size and type of occlusive devices were chosen based on the dimensions of the left ventricular pseudoaneurysm orifice(s) measured using the 3D (4D) volume-rendered CTA images.

In 3 procedures, left ventricular pseudoaneurysm closure were accomplished by retrograde approach to the left ventricle, using a Judkin left catheters (Cordis, Miami Lakes, FL) over a Wholey wire (Covidien Imaging, Hazelwood, MO) or a Tiger wire (St Jude Medical, St Paul, MN). In 1 patient, a 7F delivery catheter was used to deliver the Amplatzer Septal Occluder (AGA Medical Corp, Plymouth, MN); in 2 patients, the Amplatzer Vascular Plug II was delivered with guide catheters (AGA Medical Corp).

A transapical approach was used in 6 procedures. It was carefully planned before the procedure with 4D volume-rendered CTA and was monitored by 3D TEE.

Transapical puncture was accomplished by accessing the left ventricle percutaneously with a 21-gauge micropuncture needle (Cook Medical Inc, Bloomington, IN). A 4F or 5F radial artery sheath was then inserted into the left ventricular cavity. A Berenstein catheter was used to guide a Wholey wire (Covidien Imaging, Hazelwood, MO) or an Inoue wire (Toray International America Inc, Houston, TX) through the left ventricular pseudoaneurysm orifice, over which an appropriate-sized delivery sheath was placed. The transapical approach for procedures 5b, 5c, and 6 was accomplished by direct percutaneous puncture of the left ventricular pseudoaneurysm, followed by advancement of the wire through the orifice of the pseudoaneurysm, into the LV cavity.

In procedures 5b and 6, an exchange length 0.035 angled hydrophilic glide wire (Terumo Medical Corp, Somerset, NJ) was snared into the aorta and exteriorized through the right femoral arterial puncture, creating a supporting arterioventricular rail. The delivery sheath was then advanced from the arterial side into the pseudoaneurysm for the retrograde delivery of the closure device. In procedure 5c, after direct left ventricular pseudoaneurysm puncture, a guide wire was ad-

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**Table 1. Patient Demographics**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, y</th>
<th>Sex</th>
<th>NYHA-FC</th>
<th>Etiology</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>59</td>
<td>Female</td>
<td>III</td>
<td>MVR</td>
<td>Paravalvular 51×33×29</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>Male</td>
<td>II</td>
<td>MVR</td>
<td>Paravalvular 25×21×20</td>
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<tr>
<td>3</td>
<td>51</td>
<td>Male</td>
<td>III</td>
<td>MVR</td>
<td>Paravalvular 21×20×15</td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>Male</td>
<td>III</td>
<td>MVR</td>
<td>Paravalvular 14×10×10</td>
</tr>
<tr>
<td>5</td>
<td>73</td>
<td>Male</td>
<td>III</td>
<td>Post-MI</td>
<td>Anteropical a. 61×40×33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b. 29×20×28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>c. 85×33×51</td>
</tr>
<tr>
<td>6</td>
<td>82</td>
<td>Male</td>
<td>III</td>
<td>Post-MI</td>
<td>Anterolateral 45×51×50</td>
</tr>
<tr>
<td>7</td>
<td>79</td>
<td>Male</td>
<td>III</td>
<td>MVR</td>
<td>Paravalvular 37×10×34</td>
</tr>
</tbody>
</table>

NYHA-FC indicates New York Heart Association functional classification; MI, myocardial infarction; MVR, mitral valve replacement; LVPA, left ventricular pseudoaneurysm.
vance into the left atrium and snared by means of the transseptal approach and then exteriorized through the right femoral vein, creating an arterio-venous rail over which a 12F delivery sheath was placed from the pseudoaneurysm side for transthoracic delivery of the closure device.

In 3 patients (1, 3, and 7), the transapical access was closed using a 6-mm to 4-mm Amplatzer Duct Occluder (AGA Medical Corp). In 1 patient (patient 7), after the release of the closure device and after blood flow across the device decreased, thrombin was injected into the left ventricular pseudoaneurysm cavity to expedite the clot formation. Then, Surgiflo (Ethicon Inc, Somerville, NJ) was injected into the delivery sheath to fill the track to the skin.12

Results

The left ventricular pseudoaneurysms of all 7 patients were successfully closed. One patient required 3 procedures to close the pseudoaneurysm because of the device displacement into the left ventricular pseudoaneurysm cavity (details below). Fluoroscopy time on average was 36.5 ± 24.0 minutes and ranged from 12.4 to 75.7 minutes. A total of 10 devices were used for left ventricular pseudoaneurysm closure: 5 Amplatzer Septal Occluders; 2 Amplatzer Vascular Plug II; 2 Amplatzer Muscular VSD Occluders; and 1 Amplatzer Duct Occluder (all from AGA Medical Corp). One patient, with a “donut-shaped” pseudoaneurysm, required 2 occluders: 1 24-mm and 1 32-mm Amplatzer Septal Occluder (AGA Medical Corp). The 24-mm closure device was delivered into the anterior orifice, and the larger posterior left ventricular pseudoaneurysm orifice was then entered with a 12F delivery sheath and the second, 32-mm closure device was deployed, with the distal disc anchored with the first device (Figure 2).

In the patient who required 3 procedures, initially the left ventricular pseudoaneurysm was closed by using the 12-mm Amplatzer Septal Occluder (AGA Medical Corp) device, using a retrograde approach. During a CTA follow-up performed a few hours after the procedure, device migration into the left ventricular pseudoaneurysm cavity was observed. The second procedure was performed through the use of the transapical approach and the Amplatzer Muscular VSD Occluder (AGA Medical Corp) was successfully deployed into the neck of the left ventricular pseudoaneurysm. TTE and TEE confirmed the absence of flow through the device and that communication with left ventricular pseudoaneurysm was discontinued. A postprocedure CTA, however, showed a second device embolization into the left ventricular pseudoaneurysm cavity. The third procedure was performed and a combination of transapical puncture and transseptal technique was performed. After establishing stable support of the guide wire, the 18-mm Amplatzer Septal Occluder (AGA Medical Corp) was delivered in a transseptal manner. The follow-up CTA, 1

Figure 2. Intraprocedural transesophageal echocardiography (modified transgastric view). A, Frame demonstrates the left ventricular pseudoaneurysm with catheter (white arrow) advanced inside the pseudoaneurysm, continuous wave Doppler demonstrates blood flow to the pseudoaneurysm cavity. B, Real-time 3D transesophageal echocardiography demonstrates the pseudoaneurysm with catheter inside. C, Frame demonstrates well-positioned closure device (black arrow) at the neck of the pseudoaneurysm, continuous wave Doppler confirms cessation of the communication between the left ventricle and left ventricular pseudoaneurysm cavity. D, Real-time 3D transesophageal echocardiography shows the en face view of the deployed closure device (black arrow). LV indicates left ventricle; LVPA, left ventricular pseudoaneurysm.

Figure 3. A donut-shaped paravalvular pseudoaneurysm (patient 1), 3D volume-rendered computed tomography angiogram (ventricular side view). A, Donut-shaped left ventricular pseudoaneurysm (LVPA) with 2 orifices (white 2-headed arrow). B, Two Amplatzer Septal Occluders (white arrows) positioned at both pseudoaneurysm orifices. MV indicates mitral valve; AO, aortic valve, LVPA, left ventricular pseudoaneurysm; RV, right ventricle; PA, pulmonary artery.
A week after the procedure, confirmed device position at the left ventricular pseudoaneurysm neck without any evidence of blood extravasation. Previously embolized devices were left inside the left ventricular pseudoaneurysm cavity.

There were no complications observed in any of the patients.

**Follow-Up**

All patients were followed up for a period ranging from 3 to 32 months (mean, 18±12.5 months) after the procedure. Although prevention of left ventricular pseudoaneurysm rupture was the primary goal of repair, 3 patients improved by 1 New York Heart Association functional class, and 4 improved by 2 classes. There were no complications observed during the follow-up period.

**Discussion**

The left ventricular pseudoaneurysm is a rare but potentially lethal complication of myocardial infarction, cardiac surgery, trauma, and infections. Untreated, pseudoaneurysms have a 30% to 45% risk of rupture within the first year. Surgical repair of the left ventricular pseudoaneurysm carries a high risk of morbidity and mortality, mortality rate of 20% to 36%3–5,7,9,13,14; however, is better than medical treatment, which carries an even higher mortality rate of 48%.7

This study is the first reported series of percutaneous closure of the left ventricular pseudoaneurysm to date. Despite the small number of patients, successful closure with no complication in 7 consecutive patients demonstrates feasibility and safety of the percutaneous repair of the left ventricular pseudoaneurysms. This study was limited by the small number of patients. We cannot, therefore, recommend any particular type of device or judge if there is any advantages of one device over another. Moreover, we believe that an individualized approach should be used for every case because of the unique anatomic characteristics of pseudoaneurysms (size and location of the pseudoaneurysm orifice, length of the neck, shape of the pseudoaneurysm cavity, etc) (Figure 4). All these parameters should be accounted when selecting the closure device. For example, for a pseudoaneurysm with a long neck, devices that have a lengthier waist, such as Amplatzer Duct Occluder or muscular VSD Occluder (both from AGA Medical Corp, Plymouth, MN), are warranted. Closure devices used in our study along with orifices size and oversize ratio are presented in Table 2. We think that the 2 device dislodgments in patient 5 were, most likely, caused by the friability of the myocardium after the recent myocardial infarction (10 days) rather than device size mismatch.

Use of the 3D/4D volume-rendered CTA images and, to a lesser extent, 3D echocardiography, allows appreciation of the 3D anatomy of the pseudoaneurysm and neighboring

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### Table 2. Closure Details

<table>
<thead>
<tr>
<th>Patient</th>
<th>Approach</th>
<th>Fluoroscopy Time, min</th>
<th>Orifice Size, mm</th>
<th>Device</th>
<th>Oversize Ratio†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transapical*</td>
<td>12.4</td>
<td>12×10</td>
<td>24 mm ASO</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26×18</td>
<td>32 mm ASO</td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>Retrograde</td>
<td>36.9</td>
<td>4×3</td>
<td>8 mm AVP II</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>Transapical*</td>
<td>19.6</td>
<td>9×8</td>
<td>12 mm AmVSD</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>Retrograde</td>
<td>50.6</td>
<td>8×5</td>
<td>8 mm AVP II</td>
<td>1.0</td>
</tr>
<tr>
<td>5a</td>
<td>Retrograde</td>
<td>75.7</td>
<td>10×8</td>
<td>12 mm AmVSD</td>
<td>1.2</td>
</tr>
<tr>
<td>B</td>
<td>Retrograde/Transapical†</td>
<td>71.4</td>
<td>13×10</td>
<td>14 mm AmVSD</td>
<td>1.1</td>
</tr>
<tr>
<td>C</td>
<td>Transseptal/Transapical†</td>
<td>23.7</td>
<td>13×10</td>
<td>18 mm AmVSD</td>
<td>1.4</td>
</tr>
<tr>
<td>6</td>
<td>Retrograde/Transapical†</td>
<td>17.6</td>
<td>9×7</td>
<td>14 mm AmSO</td>
<td>1.6</td>
</tr>
<tr>
<td>7</td>
<td>Transapical*</td>
<td>20.4</td>
<td>7×3</td>
<td>10×8 mm ADO</td>
<td>1.4</td>
</tr>
</tbody>
</table>

ASO indicates Amplatzer Septal Occluder; AVP, Amplatzer Vascular Plug; AmVSD, Amplatzer Muscular VSD Occluder; and ADO, Amplatzer Duct Occluder (all from AGA Medical Corp, Plymouth, MN).

*Transapical access site closure; †direct puncture of LVPA; ‡ratio between maximal orifice diameter and body of the device.
structures helping to select the appropriate closure device. The TTE, which was used in 1 case of anterolateral left ventricular pseudoaneurysm, was very useful during the transthoracic puncture of the pseudoaneurysm. Pseudoaneurysm wall tenting was clearly seen on the 2D image, confirming the position of the puncture needle. The intraprocedure TEE guidance was also very useful for confirmation of the position of the catheters and closure device.

There is no standardized approach for left ventricular pseudoaneurysm closure, and no standard fluoroscopy views have been defined. Fluoroscopic imaging for left ventricular pseudoaneurysm percutaneous closure, therefore, can be challenging. The 3D echocardiography and 3D volume-rendered CTA can help to quickly interpolate the 2D fluoroscopic view into 3D structures.

Conclusion
Transcatheter closure of the left ventricular pseudoaneurysm is a feasible alternative for high-risk surgical candidates. The use of multiple imaging modalities is required for detailed planning and execution of the procedure.

Disclosures
Dr Ruiz is a consultant and educational grant recipient from Philips Healthcare and is a proctor for AGA Medical Corp. Dr Kronzon has received speaking honoraria from Philips Healthcare and is a research grant recipient from GE.

References

CLINICAL PERSPECTIVE
Left ventricular pseudoaneurysm is a serious complication of cardiac surgery and of acute myocardial infarction. If left untreated, it may be complicated by rupture, bleeding, infection, and death. Until recently, the only effective method to repair pseudoaneurysms has been surgery. Using combined imaging modalities and transcatheter techniques, we were able to close left ventricular pseudoaneurysms percutaneously, by occluding its communication with the ventricular chamber, without major complications. This approach represents a potential alternative to surgical closure, especially in patients at excessive risk for cardiac surgery.
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