Pseudoaneurysms of the Heart
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**Case 1**: An 85-year-old man with a history of ischemic cardiomyopathy and recent reoperation coronary bypass surgery was noted on a routine follow-up echocardiogram to have a 25×25-mm fluid-filled extracardiac mass adjacent to the basal inferolateral wall of the left ventricle (Figure 1). Cardiac computed tomography (CT) identified the structure to be a pseudoaneurysm of a saphenous vein graft to an obtuse marginal branch of the left circumflex coronary artery. How should this patient be managed?

**Case 2**: A 27-year-old man with prior homograft aortic valve replacement developed recurrent endocarditis (Figure 2). Echocardiography noted a periaortic valvular fluid collection concerning for abscess or valvular dehiscence. However, Doppler signal to and from the fluid collection connecting to the left ventricular outflow tract also raised concern for pseudoaneurysm. Cardiac CT confirmed the structure to be a 37×32-mm pseudoaneurysm involving the left coronary cusp of a trileaflet homograft prosthetic aortic valve just below the takeoff of the implanted left main coronary artery. How should this patient be managed?

**Case 3**: An 85-year-old woman with ischemic cardiomyopathy and myocardial infarction presented in cardiogenic shock (Figure 3). Angiography noted a chronically occluded right coronary artery. Echocardiogram identified a left ventricular ejection fraction of 25% with a basal inferior pseudoaneurysm. Cardiac magnetic resonance imaging (MRI) confirmed the presence of a transmural myocardial infarction with a pseudoaneurysm of the basal inferior and inferolateral wall. How should this patient be managed?

**Background**
A pseudoaneurysm is a contained rupture of a blood vessel or of the myocardial wall. Typically, pseudoaneurysms will have to-and-fro blood flow into a cavity contained by pericardium, thrombus, or adhesions. This contrasts with a true aneurysm that forms as a result of a weakness rather than a rupture of the wall that typically bulges outward during systole, is thin, and has an outer layer that contains all layers of the myocardium or vessel wall. A pseudoaneurysm will typically have a narrow neck, with a ratio of the breach in the wall to the maximal diameter of the pseudoaneurysm of <50%. In contrast, a true aneurysm has a broad base. Although distinguishing true from false aneurysms often proves challenging, differentiating these 2 entities has clinical relevance because a patient with pseudoaneurysm will have a greater risk of rupture and should thus be considered for immediate repair.

The natural history of surgically treated and untreated left ventricular pseudoaneurysms is not clearly defined and is based largely on retrospective single-center case series. Table 1 lists the location and potential predisposing conditions for various cardiac pseudoaneurysms. The most common cardiac pseudoaneurysm is of the left ventricular myocardium after a myocardial infarction. Other cardiac sites include the mitral-aortic intervalvular fibrosa, the right ventricular outflow tract, native and grafted coronary arteries, and the atria. Although myocardial infarction is the most common cause of left ventricular pseudoaneurysms, prior aortic valvular surgery and endocarditis most often precede pseudoaneurysms at the mitral-aortic intervalvular fibrosa. Less commonly, blunt or penetrating trauma may cause pseudoaneurysm. Pseudoaneurysms of the native coronary arteries tend to occur after stenting or after spontane-
ous coronary arterial dissection, whereas pseudoaneurysms of bypass grafts tend to occur at suture line sites or after stenting. Finally, although rare, reported complications of radiofrequency ablation procedures have included both atrial and ventricular pseudoaneurysms.

Diagnosis

Patients with cardiac pseudoaneurysm often present with symptoms of chest pain or heart failure. If the rupture is not entirely contained or a previously contained pseudoaneurysm ruptures, a patient may present with tamponade, shock, or sudden death. Examination may reveal volume overload indicative of congestive heart failure, and a murmur is often present. However, among the population at risk (who often have a history of prior cardiac procedures, valvular heart disease, or myocardial infarction), these signs and symptoms are neither sensitive nor specific for pseudoaneurysm. Therefore, imaging is usually required to diagnose a pseudoaneurysm or to identify the presence of other pathology accounting for the patient’s signs and symptoms. Initial evaluation with transthoracic echocardiography may be unrevealing, but in suspected cases, angiography, transesophageal echocardiography, cardiac CT, and cardiac MRI will have a higher diagnostic yield.

In clinical practice, distinguishing true from false aneurysms of the heart often proves difficult because a true aneurysm may present with a narrow neck and false aneurysm at times may have a rather broad base. Thus, autopsy or surgical evaluation of tissue layers remains the gold standard for diagnosis. Although angiography had historically been recommended as the imaging modality of choice for cardiac pseudoaneurysms, advances in noninvasive imaging during the past decade have improved the ability to accurately identify this condition. Echocardiography is often the first test performed because of its wide availability and routine use during the initial assessment of patients with signs and symptoms such as chest pain, murmur, and heart failure. In addition to structural assessment with 2-dimensional echocardiography and more recently 3-dimensional echocardiography, one may assess for vascularity of a suspected pseudoaneurysm by detecting to-and-fro Doppler flow or by using echocardiographic contrast. Although transthoracic echocardiography has a low sensitivity to detect pseudoaneurysms, transesophageal echocardiography may allow improved detection of ventricular pseudoaneurysms diagnosed by left ventriculography. Unlike echocardiography, cardiac MRI
and cardiac CT allow visualization of any plane of the heart and can thus visualize segments that are difficult to see on echocardiography. The high spatial resolution and superb tissue characterization of cardiac MRI make it ideal for evaluation of pseudoaneurysm of the left or right ventricles and for distinguishing pseudoaneurysm from true aneurysms. In such cases, the use of late gadolinium enhancement to identify the location and transmural extent of prior infarcts is particularly valuable. Nevertheless, not all patients can undergo cardiac MRI because of either patient contraindications (eg, implanted cardiac devices, severe claustrophobia) or lack of availability. Cardiac CT offers high spatial resolution and provides an excellent visualization of the left ventricular myocardium, coronary arteries, and bypass grafts. Although cardiac CT is more widely available than cardiac MRI, it involves radiation and requires the use of intravenous dye exposure.

After diagnosis, no guidelines address whether to pursue follow-up imaging. For select patients managed nonsurgically, follow-up imaging to assess for expansion may be reasonable if it could affect management. However, the timing for such serial imaging must be individualized on the basis of whether the defect is acute or chronic, whether signs and symptoms associated with potential complications are present, and what the overall goals of care are.

**Complications**

Untreated pseudoaneurysm may cause complications such as rupture, thromboembolism, compression of nearby structures, and infection. Ventricular pseudoaneurysm may also serve as a focus for arrhythmia and result in decreased cardiac output. Historically, ventricular pseudoaneurysm was considered to confer a high risk of rupture, with estimates as high as 30% to 45%. However, in part because of increased use of imaging, there is likely to be increased detection of chronic “incidental” pseudoaneurysm in patients who are asymptomatic. In addition, improvements in reperfusion and post–myocardial infarction medical therapy may have decreased the incidence of rupture. Supporting the finding that not all pseudoaneurysms have a high risk of rupture, in a series of 52 patients with ventricular pseudoaneurysm followed up for a median of 4 years, 42 patients underwent surgery, but notably 10 patients managed nonsurgically did not have any occurrence of rupture. Although randomized controlled data are lacking, these data suggest that not all cardiac pseudoaneurysms—especially small or chronic ones—require immediate surgery. In contrast, acute or large pseudoaneurysms after myocardial infarction are more likely to require repair. Thrombi within the lumen of cardiac pseudoaneurysms may embolize. Finally, pseudoaneurysms may increase the risk of arrhythmia, although whether the arrhythmia risk is related to infarction and whether repair decreases this risk is unclear.

**Treatments**

The main goal of therapy is to reduce the risk of expansion or rupture. The location, type, and size of pseudoaneurysm will guide treatment options, but ultimately clinicians must consider surgical or percutaneous closure. Notably, because of the rarity of pseudoaneurysms, no randomized controlled trial exists to guide treatment decision. In patients with ventricular pseudoaneurysms, it is also
prudent to attain good blood pressure control based on the Laplace law: wall stress = (pressure/2) × (radius/wall thickness).

Repair of left ventricular pseudoaneurysm is traditionally performed with primary repair or patch closure. Although a high operative mortality has been reported, improvements in cardiac surgery techniques have led to lower perioperative mortality (eg, 10%). Nevertheless, the surgical team must be prepared for emergency cardiopulmonary bypass in the case of sudden rupture.

The management of patients with cardiac pseudoaneurysm is frequently complicated by comorbidities such as obstructive coronary artery disease and heart failure. Adverse prognosis has been described in pseudoaneurysms caused by myocardial infarction and in patients requiring more complex surgery (eg, concomitant pseudoaneurysm and valvular replacement). On the other hand, patients with other predisposing conditions as a cause of pseudoaneurysm (eg, valve surgery) are younger, have fewer comorbidities, and often have a better prognosis.

Open surgical repair of vein graft aneurysm and pseudoaneurysm has been reported in 1 case series of 16 patients to have an associated mortality of 6%, likely reflecting that most patients required redo sternotomy, were older, and had multiple comorbidities. More recently, covered stents have been used to occlude aneurysm and pseudoaneurysm in coronary arteries and vein grafts. Similarly, as a recent alternative to open surgical closure of pseudoaneurysms of the cardiac chambers, there are reports of successful interventional percutaneous techniques of implanting septal occluder devices in atria and ventricles.

In some instances, treatment with anticoagulation may be required to reduce the risk of thromboembolism. When considering the use of anticoagulation, clinicians must weigh the benefit of reduced thromboembolism related to therapeutic anticoagulation against the risk of bleeding or pseudoaneurysm rupture. In patients who cannot tolerate anticoagulation therapy, antiplatelet medications such as aspirin or clopidogrel can be considered, although they are probably less effective in preventing thromboembolism and are associated with an increased risk of bleeding. Because there is insufficient evidence to recommend for or against anticoagulation or antiplatelet therapies, these decisions must be individualized with clinical judgment.

Although comparative outcomes data are lacking, the available data suggest that ventricular pseudoaneurysms are more likely to rupture when they are relatively acute (<3 months), large, or located within the anterior or lateral ventricular wall. Similarly, saphenous vein graft pseudoaneurysm should be considered for repair if large (eg, >1 cm) or if associated with symptoms.
Case Resolution

Case 1
Treatment options for a saphenous vein graft pseudoaneurysm include observation, surgery, and percutaneous coronary intervention. Despite the patient being asymptomatic, imaging identified active flow of arterial blood into the pseudoaneurysmal sac (Figure 1A). Subsequently, the decision was made to pursue percutaneous coronary intervention to reduce the risk of rupture. The pseudoaneurysm was treated with a 4.0-mm covered stent without complications. The patient continued to do well at 5-month follow-up.

Case 2
Pseudoaneurysm of the aortic valve is rare, and the optimal treatment is not well defined. In the case presented, a percutaneous closure was not technically possible; thus, surgery was recommended. The patient was treated with 6 weeks of intravenous antibiotics followed by mechanical aortic valve placement with a bovine pericardial patch repair of the pseudoaneurysm. The explanted aortic root did not show gross evidence of abscess. He recovered and had no further complications at 18-month follow-up.

Case 3
Management options in this case included surgery versus observation. The location and size of the pseudoaneurysm precluded the option of a percutaneous closure. Because the patient was a high-risk surgical candidate, she was treated medically for recent myocardial infarction and congestive heart failure. At 2-year follow-up, her left ventricular ejection fraction had improved to 35%, her functional capacity had improved, and she had no complications from her pseudoaneurysm.

Table 1. Key Articles Describing Cardiac Pseudoaneurysm

<table>
<thead>
<tr>
<th>Population/Study Type</th>
<th>n</th>
<th>Age, y</th>
<th>Cause of Pseudoaneurysm, %</th>
<th>Symptoms, %</th>
<th>Diagnosis</th>
<th>Noteworthy Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayo Clinic, Minnesota, Arizona, Florida (case series)</td>
<td>52</td>
<td>48</td>
<td>Surgery, 58</td>
<td>None, 48</td>
<td>LHC</td>
<td>Surgical mortality, 7% immediate and 31% long term (median, 2.3 y)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MI, 42</td>
<td>MI, 42</td>
<td>MRI</td>
<td>Medically treated mortality, 60% long term (median, 2.3 y) but no pseudoaneurysm rupture</td>
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<td></td>
<td></td>
<td></td>
<td>CHF, 15</td>
<td></td>
<td>CCT</td>
<td>After surgery, 2 pseudoaneurysm recurrences requiring reoperation</td>
</tr>
<tr>
<td>Cleveland Clinic (case series)</td>
<td>30</td>
<td>68</td>
<td>CABG, 100; (16 of 28 603 CABG patients over 30 y)</td>
<td>Angina, 69</td>
<td>LHC</td>
<td>Surgical mortality, 6% immediate and 17% and 28% at 5 and 10 y 81% Had thrombus; pseudoaneurysm diagnosed 13 y after initial CABG</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MI, 100</td>
<td>Angina, 41</td>
<td>TTE or LHC</td>
<td>Surgical mortality, 23% immediate</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MRI</td>
<td>Medically treated mortality, 48% at median of &lt;1 wk Neck-to-body ratio &gt;0.5 in 18%</td>
</tr>
<tr>
<td>Systematic literature review (case series)</td>
<td>290</td>
<td>60</td>
<td>MI, 55</td>
<td>CHF, 36</td>
<td>LHC</td>
<td>Surgical mortality, 23% immediate</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Surgery, 33</td>
<td>Angina, 30</td>
<td>TTE</td>
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<td></td>
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<td>Trauma, 7</td>
<td>CVA, 6</td>
<td>MRI</td>
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<td>Infection, 5</td>
<td>Murmur, 70</td>
<td>CCT</td>
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<td>Radionuclide</td>
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</table>

LHC indicates left heart catheterization; MI, myocardial infarction; MV, mitral valve; RVOT, right ventricular outflow tract; CHF, congestive heart failure; TTE, transthoracic echocardiogram; MRI, magnetic resonance imaging; CCT, cardiac computed tomography; TEE, transesophageal echocardiogram; SVG, saphenous vein graft; LAD, left anterior descending; RCA, right coronary artery; LCx, left circumflex; CABG, coronary artery bypass graft surgery; and CVA, cerebrovascular accident.

Table 2. Pseudoaneurysms of the Heart

<table>
<thead>
<tr>
<th>Location</th>
<th>Common Predisposing Conditions</th>
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</thead>
<tbody>
<tr>
<td>Left ventricle</td>
<td>Myocardial infarction; ablation procedures; trauma</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>After surgery to repair congenital heart disease</td>
</tr>
<tr>
<td>Mitral aortic</td>
<td>Prior valvular surgery; endocarditis; abscess</td>
</tr>
<tr>
<td>Interventricular fibrosa; valves</td>
<td>Prior PCI; spontaneous dissection; vasculitis</td>
</tr>
<tr>
<td>Coronary arteries</td>
<td>Prior PCI; spontaneous dissection; vasculitis</td>
</tr>
<tr>
<td>Bypass grafts</td>
<td>Infection; suture sites; prior PCI</td>
</tr>
<tr>
<td>Atria</td>
<td>Ablation procedures; trauma</td>
</tr>
</tbody>
</table>

PCI indicates percutaneous coronary intervention.
Conclusions
Cardiac pseudoaneurysms are rare but clinically significant lesions. Although often challenging to diagnose, advances in noninvasive imaging have improved our ability to distinguish cardiac pseudoaneurysms from other pathologies. Most pseudoaneurysms, particularly if acute or associated with symptoms, require surgical repair or percutaneous exclusion to reduce the risk of rupture and potential for thromboembolism. In patients who have a high risk for surgical (or percutaneous) intervention, particularly when a pseudoaneurysm is chronic in nature, conservative management may be prudent.

Disclosures
None.

References
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