It has long been an axiom of mine that the little things are infinitely the most important.1
—Sherlock Holmes to Dr Watson
Arthur Conan Doyle,
The Adventures of Sherlock Holmes: A Case of Identity.

**Case Presentation:**
A 70-year-old woman with hypertension presents for evaluation of a single episode of nonexertional chest pain of moderate intensity, atypical for myocardial infarction. Clinical signs of acute aortic dissection and cardiac tamponade are absent. A 12-lead ECG and blood test for troponin are negative for acute myocardial infarction. M-mode transthoracic echocardiogram of the aortic root shows dense echoes anteriorly and posteriorly at the level of the aortic valve and a large pericardial effusion (Figure 1A). After discussing a diagnosis of acute aortic syndrome, she asks, “What other tests will I need to confirm the diagnosis? Will I undergo surgery?”

Intramural hematoma (IMH) is a life-threatening aortic disease included within acute aortic syndrome, together with aortic dissection and penetrating aortic ulcer (PAU).2,3 IMH is a contained aortic wall hematoma with bleeding within the media but without initial intimal flap formation (Figure 2). Its natural history is variable; it may be reabsorbed without any intervention, or it may progress to classic aortic dissection, with outward aortic rupture observed in 15% to 20% of patients. Approximately 10% to 30% of patients with acute aortic syndrome have IMH. Similar to acute aortic dissection, it is classified as Stanford type A (ascending aorta) or B (exclusive involvement of the descending aorta). Most patients with IMH have Stanford type B (50% to 85%). IMH converts to acute aortic dissection in 3% to 14% of patients with involvement of the descending aorta and in 88% of those with involvement of the ascending aorta, with high mortality rates. It is generally recommended that patients with type A IMH undergo early surgery, whereas patients with type B IMH can be managed conservatively in the absence of complications.

It is difficult to reliably distinguish IMH from acute aortic dissection and PAU, but clues from patient characteristics, clinical presentation, and noninvasive cardiac diagnostic techniques, including M-mode echocardiography, can facilitate the diagnosis of IMH. The major complications of acute aortic syndrome, periaortic hematoma and hemorrhagic pericardial effusion, occur more frequently in IMH than in acute aortic dissection and can be fatal unless treated on an emergency basis.2,3

**Pathology and Pathogenesis of IMH and Its Complications**
Computed tomography (CT) and transesophageal echocardiography have been used increasingly to diagnose patients with aortic IMH. These methods have advanced our understanding of the pathogenesis of IMH. Although the initiating event leading to the formation of IMH remains unknown, hypertension and atherosclerosis play a major role in most patients.4 The most common initial event leading to IMH formation is hemorrhage within the media (intramural) of the aortic wall, which results in weakening of the aortic wall, without rupture of the intima and without formation of the classic intimal flap of aortic dissection. These events result in a circumferentially oriented blood-containing space without intimal discontinuity. Because there is no intimal break, the space does not communicate directly with the aortic lumen. Hemorrhage in the media may...
be caused by spontaneous rupture of the aortic vasa vasorum, which initiates IMH formation, causing aortic wall weakening and subsequently leading to dissection (Figure 3). Other mechanisms include pathological neovascularization, with an increase in microvessels and spontaneous bleeding in the arterial plaque. This mechanism is similar to both the rupture of coronary atherosclerotic plaque, which results in myocardial infarction, and to intimal fracture of an atheromatous plaque, which results in intramedial propagation of blood and IMH formation. IMH can also be caused by microscopic tears in the aortic intima or from a PAU. PAU contributes to a small proportion of IMHs, and although rare, thoracic trauma may cause IMH. PAU, an uncommon cause of type A IMH, is a condition in which ulceration of an aortic atheromatous plaque is initially confined to the intimal layer. This ulceration subsequently progresses, penetrating the internal elastic lamina and rupturing into the media, which results in hematoma formation, defined as secondary IMH. PAUs usually involve the descending thoracic aorta and are very uncommon in the ascending aorta. Overall, nontraumatic causes, including PAU, account for >90% of IMHs, and, among the IMHs with a

![Figure 1. A and B. M-mode echocardiogram at the level of the aortic valve. Dense echoes along right and noncoronary sinuses caused by periaortic hematoma from a perforated aortic ulcer (white arrows, A) compared with a normal echo (B). C. Cardiac computed tomography angiography orthogonal view equivalent to transthoracic echocardiographic parasternal long-axis view. This view is optimized to visualize (white arrow) perforated ulcer in the ascending aorta, hemorrhagic pericardial effusion with blood collection along right and noncoronary aortic sinuses correlating with M mode echo at the level of the aortic valve. AV indicates aortic valve; LA, left atrium; LV, left ventricle; PA, pulmonary artery; and RV, right ventricle.](http://circ.ahajournals.org/figtext/10.1161/CIRCULATIONAHA.113.005624)
Aortic dissection, intramural hematoma, and penetrating atherosclerotic ulcer. Note the distinct intimal flap separating the true and false lumens in aortic dissection. An intramural hematoma, possibly caused by rupture of the vasa vasorum, leads to a concentric hematoma within the media and has no intimal tear. Penetrating atherosclerotic ulcers burrow deeply through the intima, which precipitates a localized intramural dissection associated with a variable amount of hematoma. Adapted with permission from Coady et al. Authorization for this adaptation has been obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

clinical manifestations and complications: symptoms and physical examination

The Table summarizes the demographic, clinical presentation, and imaging characteristics of type A IMH and acute aortic dissection from the International Registry of Acute Aortic Dissection (IRAD), which consists of 2830 patients evaluated from 1996 to 2011. IMH was identified in 178 patients (6.3%); the incidence of IMH among IRAD sites in patients with acute aortic syndrome varied from 0% to 25%. Clinical presentation and 1-year outcome of patients with IMH did not differ significantly from those of acute aortic dissection. Results of IRAD and from previous studies showed that patients with IMH are older than those with types A and B aortic dissection. IMH is essentially a disease of the seventh, eighth, and ninth decades of life, with 80% of patients with IMH being hypertensive. Approximately 80% of IMH patients present with chest pain similar to classic aortic dissection. This chest pain, referred to as “aortic pain,” is acute and excruciating and may or may not radiate to the back, which suggests an acute cardiac or vascular event. In one meta-analysis, 80% of patients reported chest pain, back pain, or both. Rarely, patients have experienced syncope, anterior spinal pain syndrome, hoarseness, or acute renal insufficiency or have been asymptomatic.

The symptoms and signs can also be caused by complications of IMH, including classic aortic dissection, pericardial effusion with tamponade, acute aortic regurgitation, hemothorax/pleural effusion, acute neurological deficits, pulse deficits, acute myocardial infarction, and rupture or dissection.

Patients with IMH are at higher risk than patients with acute aortic dissection for developing peri-aortic hematoma and hemorrhagic pericardial effusion but are less likely than patients with acute aortic dissection to develop aortic regurgitation and acute coronary insufficiency. The likely mechanisms of acute aortic syndrome, with a rupture rate as high as 38% in patients with PAUs presenting as acute aortic syndrome.

Pathogenesis of Complications

Blood in IMH collects at a superficial location, close to the adventitia. Consequently, these patients have high rates of peri-aortic hematoma, pericardial effusion, and rupture in the mediastinum. Peri-aortic hematoma can be caused by oozing of blood or frank rupture in the pericardial sac or mediastinum. Bleeding from the intrapericardial portion of the ascending aorta will immediately result in a hemorrhagic pericardial effusion, whereas bleeding from the extrapericardial portion of the aorta will result initially in bleeding in the mediastinum and pleural cavity, leading to hemorrhagic pleural effusion.

Figure 1A shows an M-mode echocardiogram of our patient, exhibiting dense echoes emanating from the clotted blood that resulted from a leaking IMH. The location of the blood, anterior and posterior to the ascending aorta at the level of the aortic valve, is consistent with leakage of blood from the IMH in the ascending aorta. Subsequent echocardiographic examinations showed a large hemorrhagic pericardial effusion with signs of tamponade. Cardiac tamponade, which occurs in 19% of patients with acute type A dissection, is one of the most common causes of death in patients with this disorder. Patients with tamponade are more likely to present with hypotension, syncope, or altered mental status. The in-hospital mortality rate is 2-fold higher among patients with than without cardiac tamponade (54% versus 25%, respectively).

Patients with IMH caused by PAU are also prone to complications of PAUs, including pseudoaneurysm formation, rupture into the pericardial sac (hemorrhagic pericardial effusion), hemorrhagic pleural effusion, and aortic dissection. PAU accounts for 2% to 7% of acute aortic syndromes, with a rupture rate as high as 38% in patients with PAUs presenting as acute aortic syndrome.
of aortic regurgitation, which may be similar to acute aortic dissection, include disruption of annular support and incomplete diastolic coaptation of the aortic valve. There is progression to acute aortic dissection with development of a large intimal flap, which may prolapse into the left ventricular outflow tract during diastole, preventing coaptation of the cusps, which results in the development of severe aortic regurgitation. Acute aortic regurgitation, a cause of severe heart failure and death, should be suspected when a patient with IMH develops acute heart failure, when first and second heart sounds are soft, when a soft to-and-fro murmur is present, and when heart size and ECG are nearly normal. Acute severe aortic regurgitation imposes a sudden excessive volume load on an unprepared left ventricle that is normal in size, which results in a dramatic extreme rise in left ventricular diastolic pressure, which may approach or equal the aortic diastolic pressure. Because left ventricular pressure exceeds left atrial pressure in diastole, the resulting rapid ventriculoatrial (V-A) gradient causes the mitral valve to close prematurely before the onset of the next systole. Premature mitral valve closure is present when aortic regurgitation is both acute and severe and is best demonstrated by M-mode transthoracic echocardiography with a simultaneous ECG. This method has been shown to be a specific and sensitive noninvasive indicator of acute severe aortic regurgitation. The degree of premature mitral valve closure has been correlated with the degree of increase in the left ventricular diastolic pressure. Normally, the mitral valve does not close until shortly after the onset of left ventricular contraction, with leaflet closure occurring 40 ms after the onset of the QRS complex. Premature mitral valve closure is mild when there is complete coaptation of the anterior and posterior mitral leaflets at or before the initial inscription of the QRS (up to 50 ms before the Q wave and after the P wave). Premature mitral valve closure is more severe when the mitral valve closes very prematurely, up to 200 ms before the Q wave (Figure 4). Compared with patients with mild premature mitral valve closure, those with more severe premature mitral valve closure show greater elevations in left ventricular diastolic pressure and volume and may be marginally compensated.

IMH caused by PAU is also susceptible to complications of PAUs, including overt aortic dissection, pseudoaneurysm formation, and rupture into the pericardial sac leading to hemorrhagic pericardial or pleural effusion. PAU is responsible for 2% to 7% of patients with acute aortic syndromes, and the rupture rate has been reported as high as 38% for PAUs presenting as acute aortic syndrome.

ST-segment elevation myocardial infarction occurred in 3.3% of patients with IMH in the IRAD database and was attributable to direct coronary involvement. The possible mechanisms of myocardial infarction in IMH, which may be similar to acute dissection, include type A, coronary compression; type B, retrograde dissection; type C, coronary artery detachment; in situ thrombosis.

Recognition of acute coronary syndrome in IMH is important, because primary coronary intervention and thrombolytic therapy are contraindicated in these patients.
Selecting an Imaging Modality for Diagnosis and Management

When IMH is suspected, the diagnosis should be confirmed quickly to proceed with treatment. Because of the significant risks of complications and death associated with type A IMH in patients receiving medical treatment alone, immediate surgery should be performed in patients with IMH that involves the ascending aorta. Details regarding the location of the IMH and its complications, along with aortic root size, are obtained by use of noninvasive imaging modalities, such as echocardiography (both transthoracic and transesophageal), CT angiography, and magnetic resonance imaging (MRI).

The echocardiographic criteria diagnostic of IMH include a wall thickness >7 mm and an echolucent zone in the aortic wall, which leads to compression of the aortic lumen. An echoluent zone has been reported in 70% to 80% of patients, but there is considerable overlap between atherosclerotic wall thickening and the 7-mm criterion for diffuse IMH. Furthermore, echolucency is not present in all patients with IMH. The appearance and continuity of the intima and the presence of an intimal flap may help distinguish acute aortic dissection from IMH and PAU. However, a thrombosed false lumen of acute aortic dissection, with intimal calcification or atherosclerotic plaque in the aortic wall, can be difficult to differentiate from IMH. Furthermore, reverberations and other artifacts can cause linear densities and shadows within the aortic lumen, mimicking IMH or acute aortic dissection. Because of these limitations of echocardiography and CT, as well as the high risks of developing a periaortic hematoma, hemorrhagic pericardial effusion, and tamponade, recent studies recommend MRI as a first-line test for diagnosis and follow-up of patients with IMH (Figure 5). MRI has the advantage of very high signal to noise ratio and high contrast resolution with the ability to characterize the vascular wall far better than CT or transthoracic echocardiography/transesophageal echocardiography. However, it should not be used as a first-line modality. In the situation of an acutely sick patient with IMH, the MRI study takes longer to obtain data than the CT scan. However, if transthoracic echocardiography or CT is equivocal, MRI should be used as a confirmatory test. For the stable patient with IMH, the use of MRI may have important advantages over CT. Typical benefits of MRI include the presence of methemoglobin, which produces a brighter signal on T1-weighted images, and the fact that the patient is not subjected to radiation exposure.

American College of Cardiology/American Heart Association guidelines for thoracic aortic disease recommend that transthoracic echocardiography, along with M-mode echocardiography, be performed for initial and follow-up imaging in patients admitted for surveillance of aortic disease limited to the aortic root. Transthoracic echocardiography accurately images the aortic root and the aortic valve. The advantages of M-mode echocardiography include high temporal resolution and high spatial resolution along the single line of interrogation. Because of its high resolution and high sampling rate, M-mode permits optimal recording of subtle and high-frequency motions of cardiac structures. This method is therefore of diagnostic value in cardiac conditions that result in (1) pericardial effusion and tamponade imaged as diastolic collapse of the right ventricular free wall, and (2) pseudocontrast from hemorrhagic pericardial effusion with precise anatomic localization.

The abnormalities observed in M-mode electrocardiograms of our patient were diagnostic for a periaortic hematoma and tamponade from hemorrhagic pericardial effusion. M-mode echocardiography will also be useful in guiding the type of aortic valve surgery in IMH patients with acute aortic regurgitation, as shown in type A aortic dissection.

Figure 4. Transthoracic echocardiogram with M-mode ultrasound of the mitral valve. Premature mitral valve closure was caused by acute severe aortic regurgitation. Adapted from Hamirani et al.33

Figure 5. Subacute aortic intramural hematoma. A, Axial T2-weighted gradient-echo (white blood) magnetic resonance image depicts intramural fluid collection with intermediate hyperintensity of signal compared with signal intensity of intraluminal blood. B, Axial T1-weighted spin-echo (black blood) magnetic resonance image shows hyperintensity of signal in intramural blood collection compared with that in intraluminal blood. Adapted with permission from Chao et al.6 Authorization for this adaptation has been obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.
Therefore, we propose a management plan for patients under surveillance for acute aortic syndrome (Figure 6).

Our patient underwent chest CT angiography, which showed a PAU of the posterior wall of the proximal ascending aorta with IMH from the sinotubular junction to the origin of the innominate artery, hemorrhagic pericardial effusion, and bilateral pleural effusions. Emergency surgery was performed to replace the affected aortic segment with a graft. The patient was discharged home 10 days after surgery.

Disclosures
None.

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Aortic Intramural Hematoma and Its Complications
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