Circulation Cardiovascular Case Series

A Constrained Heart
A Case of Sudden Onset Unrelenting Chest Pain

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Foreword
Information about a real patient is presented in stages (boldface type) to expert clinicians (Dr Kronzon, Dr Machnicki, and Dr Ruiz), who respond to the information, sharing their reasoning with the reader (regular type). A discussion by the authors follows.

A 43-year-old athletic black male was awoken from sleep with severe left-sided, nonradiating chest pain. He has no past medical history and denied any recent injury, infection, or drug use. He described the chest pain as nonreproducible on palpation but sharp that increased in severity when laying on his left side. Because of his symptoms the patient went to the local emergency department. On arrival, his temperature was 98.3°F, pulse 79 bpm, blood pressure 170/100 mm Hg, and respiratory rate of 24 breaths per minute with oxygen saturation of 98% on room air. Physical examination revealed a jugular venous pressure of 8 cm H2O, clear lungs on auscultation, regular rate with normal S1 and S2 sounds without murmurs, rubs, or gallops. There was no lateral displacement of the point of maximum impulse. The abdomen was nondistended with normal bowel sounds and was free of bruits. The extremities were warm, with 2+ palpable pulses with no arterial pulse delay. Cardiac enzymes were drawn and an initial ECG (Figure 1) showed normal sinus rhythm with >5-mm ST-segment elevations in the lateral and inferior lead segments.

Dr Ruiz: When a patient presents with chest pain, the 12-lead ECG is 1 of the principal tools used in diagnosis. This test can be performed quickly and helps narrow the differential, especially when the application of timely treatment aimed at coronary reperfusion is warranted in the setting of acute occlusion of a coronary artery. A small proportion of patients with suspected ST-segment–elevation myocardial infarction may have mimicking conditions such as pericarditis, myocarditis, and left ventricular aneurysm. Characteristics such as age, sex, and ethnicity of the patient should be considered. Electrocardiographic features of the ST segment including convexity, bundle-branch block, hypertrophy, reciprocal ST segment depression, along with the morphology of the PR segment and T wave have to be assessed. In this patient, ST-segment elevations in the lateral and inferior leads are seen, suggestive of the hyperacute phase of a ST-elevation myocardial infarction. Additionally, there are horizontal and down sloping reciprocal ST-segment depressions in aVR and V1–V3. These findings may indicate involvement of >1 myocardial territory.

When evaluating the patient with ST-segment elevation it is important to take into account the nature of the patient’s chest pain. A detailed history of the patient’s symptoms can typically differentiate between symptoms ranging from benign musculoskeletal causes to life-threatening cardiac disease. Angina pectoris is typically a retrosternal, vague, heavy, compressive, squeezing sensation that may radiate to the left shoulder, arm, neck, or jaw. Rarely does it last <1 minute or in a persistent manner for >20 minutes, and it can be aggravated by exertion or relieved by rest.

Our patient had an exacerbation of chest pain when lying on his left side. Chest pain influenced by body position may be seen in a variety of conditions, including myocarditis, pericarditis, pleuritis, or musculoskeletal problems. Pericardial and pleuritic chest pain is typically aggravated by deep breathing while musculoskeletal pain may be reproduced by palpation or passive spinal movements. The patient’s chest pain did not improve when leaning forward and he did not present with symptoms, suggestive of myocarditis that may include fevers, sweats, chills or dyspnea. It is especially important to consider alternative diagnoses in young patients who do not have significant coronary risk factors.

Because of the patient’s worrisome ECG and his atypical left-sided nonradiating chest pressure, which did not change in the 2 hours from its onset to his arrival to the emergency department, I would perform an angiogram.

Patient presentation (continued): In the emergency department sublingual nitroglycerin and intravenous morphine was administered for his chest pain along with 325 mg of aspirin and 600 mg of clopidogrel. Coronary angiography revealed severe narrowing and reduced TIMI II flow down the left anterior descending artery, diagonal arteries and obtuse marginal arteries (Figure 2A and 2B and Movie I in the online-only Data Supplement). In the catheterization laboratory he continued to have elevated ST segments and left-sided nonradiating chest pain.
**Dr Ruiz:** Review of the patient’s angiograms demonstrates a very unique appearance of the coronary arteries. The arteries themselves are normal in caliber and flow until an abnormal sharply angulated bend. There are very few processes that can cause an abrupt change in a coronary artery. Such an appearance of a coronary artery has been reported in catheter-induced spasm, replacement of the aortic root or mitral valve surgery (secondary to traction of a purse string suture), and cardiopulmonary support during angioplasty.\(^1\)\(^-\)\(^5\) However, in our patient’s case the kinking of the coronary arteries is widespread, did not occur in the setting of an intervention, and is suggestive of either an intramyocardial process pushing outward or an extracardiac process pushing inward and compressing the coronary circulation.

**Patient presentation (continued):** The patient was given a total of 300 \(\mu\)g of intracoronary nitroglycerin with no change in symptoms or in degree of coronary stenoses. Because of the patient’s persisting chest pain, ST changes, along with his elevated cardiac biomarkers, a balloon angioplasty was performed of the left anterior descending artery, 2nd diagonal artery, and 2nd obtuse marginal artery by the referring cardiologist. After this intervention there was mild improvement in the patient’s clinical symptoms and ECG but no change in the appearance and TIMI flow down the coronary arteries. A left ventriculogram was performed, demonstrating hypokinesis of the apical lateral segments with pooling of blood. At that time the procedure was terminated and he was transferred to our institution for further management and evaluation.

**Dr Kronzon:** Throughout the procedure the patient was never in shock nor did he suffer from refractory unstable angina or experience persistent arrhythmias. Some may argue that at the time of the intervention, consideration for placement of an intra-aortic balloon pump should have been made because of the reduced coronary blood flow. Theoretically, the balloon pump would raise the aortic pressure during diastole and augment coronary blood flow and myocardial oxygen supply. However, the benefit in a patient with what was believed to be extravascular compression is not known. Because of the unclear benefit and the not insignificant risk of complications, including vascular injury, bleeding, and infection, an intra-aortic balloon pump was not inserted.

The administration of nitroglycerin at time of the angioplasty provides valuable information. Although commonly taught, relief of chest pain after nitroglycerin treatment has been shown to not necessarily predict active coronary disease especially in patients with true acute coronary occlusions. Nitroglycerin can relieve chest pain attributable to noncardiac conditions including esophageal or other smooth-muscle spasms. More so, the apparent irreversibility of the stenotic lesions following the administration of a vasodilator agent is unusual in coronary vasospasm in an otherwise angiographically normal coronary artery.

These findings, along with the lack of angiographic improvement after balloon angioplasty and abnormal left ventriculogram, further support the need for additional imaging studies. To help define the pathological process causing the distortion in the coronary arteries a cardiac structural computed tomography (CT) study would be beneficial to evaluate...
for any intra- or extra-cardiac processes. Additionally, a cardiac MRI study may be necessary to assess whether there is any primary disease that is directly involving the myocardium.

**Patient presentation (continued):** On arrival to our facility, the patient continued to experience intense left-sided nonradiating sharp chest pain. His vital signs and physical examination remained unchanged. He has been given intermittent intravenous administrations of morphine. A repeat ECG demonstrated >50% reduction in ST elevations. Complete blood count, electrolytes, and thyroid function studies were within normal limits. His laboratory data were significant for an alanine aminotransferase of 121 U/l, aspartate aminotransferase of 255 U/l, creatine kinase of 2416 U/l, CK-MB fraction 416.7 ng/mL, CK-MB/CK ratio 17.2%, and troponin I of 84 ng/mL.

The transthoracic echocardiogram (TTE) that was completed at the outside institution was reviewed. It was noted that there was marked thickening of the apical left ventricle, which measured 26 mm, and a mildly reduced ejection fraction. To better assess endocardial definition, contrast echocardiography using perflutren lipid microspheres (Definity, Bristol-Myers Squibb Medical Imaging Inc, Billerica, MA; 1.3 mL diluted in 8.7 mL saline) was performed, demonstrating normal basilar segments of the left ventricle with severely hypokinetic apex and adjacent segments. A large irregular apical mass versus clot appeared to be obliterating the apical left ventricular cavity (Figure 4A and 4B; Definity contrast A, double sided arrow; definity contrast 1.3 mL diluted in 8.7 mL saline). There is concern for an irregular mass obliterating the apical left ventricular cavity.

Dr Ruiz: Repeat physical examination can yield much useful information in the assessment and differential of a patient’s condition. Our patient was a physically fit man who up until his hospitalization exercised regularly, did not take any medications, herbs, or supplements, and lived a healthy lifestyle. Despite continuing chest pain he had no signs or stigmata of a systemic or infectious process. Laboratory evaluation revealed elevated cardiac biomarkers with a marked elevation of his troponin I a sensitive marker of irreversible myocardial necrosis. Although troponin elevation is typically associated with coronary obstruction, abnormal values related to other causes including myocarditis, sepsis, aortic dissection, pulmonary embolism, heart failure, septic shock, and cardiotoxic drugs must be entertained.

The following day he continued to have persistent left-sided chest discomfort and ST elevations on his ECG without development of pathological q waves. Because of concern that he may elicit worsening of the pain he limited his movement. His troponin peaked at 96.5 ng/mL.

The patient underwent a cardiac MRI for further evaluation of his abnormal wall thickness and apical abnormality. The cardiac MRI study showed a moderate amount of hyperenhancement involving the midventricular lateral wall and the entire apex, suggestive of a probable transmural myocardial infarction. There continued to be thickening of the apical myocardial walls and a reduced left ventricular ejection fraction of 47%. There were low-signal foci representative of microvascular obstruction (Figure 4A and 4B and Movie IV in the online-only Data Supplement). The global appearance and systolic function of the right ventricle was normal. No myocardial mass was seen in a variety of pathologies including apical hypertrophic cardiomyopathy, endocardial fibrosis, isolated ventricular noncompaction, left ventricular apical tumors, and thrombus. None of these conditions have been associated with kinking of the coronary arteries and acute onset of persistent chest pain. Because of the highly unusual appearance of the coronary arteries and his thickened myocardial wall, suspicion for extravascular compression of the coronary vessels such as congenital partial absence of the left pericardium should be raised.

**Patient presentation (continued):** Inspection of his ECG after transfer shows persistent ST elevation with ≥50% resolution. The continued presence of ST elevation is not surprising in failed reperfusion treatment but it is unusual when considering that an intrinsic or extrinsic process may have acutely compressed the coronary bed. More so, he has not gone on to develop q waves or t-wave inversions a marker for myocardial infarction and jeopardized myocardium, respectively. Close review of his TTE reveals some important findings. During an acute coronary syndrome many changes may be seen, including wall motion abnormalities, reduced ejection fraction, and impaired wall thickening, suggestive of significant obstructive coronary artery disease.

Unlike an acute coronary syndrome event, our patient’s TTE showed dramatic increased thickness and hypokinesis of the apical myocardial wall. Increased apical thickness may be seen in a variety of pathologies including apical hypertrophic cardiomyopathy, endocardial fibrosis, isolated ventricular noncompaction, left ventricular apical tumors, and thrombus. Inspections of his abnormal wall thickness and apical abnormality. The cardiac MRI study showed a moderate amount of hyperenhancement involving the midventricular lateral wall and the entire apex, suggestive of a probable transmural myocardial infarction. There continued to be thickening of the apical myocardial walls and a reduced left ventricular ejection fraction of 47%. There were low-signal foci representative of microvascular obstruction (Figure 4A and 4B and Movie IV in the online-only Data Supplement). The global appearance and systolic function of the right ventricle was normal. No myocardial mass was seen in a variety of pathologies including apical hypertrophic cardiomyopathy, endocardial fibrosis, isolated ventricular noncompaction, left ventricular apical tumors, and thrombus. None of these conditions have been associated with kinking of the coronary arteries and acute onset of persistent chest pain. Because of the highly unusual appearance of the coronary arteries and his thickened myocardial wall, suspicion for extravascular compression of the coronary vessels such as congenital partial absence of the left pericardium should be raised.
seen and no thrombus was present in the left ventricular cavity. A small-appearing pericardial effusion was present. To further assess the left ventricular mass and possible involvement of noncardiac structures a cardiac structural CT scan was performed. The CT scan demonstrated what appeared to be a circumscribed mass extending from the interventricular groove to the posterior aspect of the left ventricular. There was no evidence of lymphadenopathy or metastatic disease. It was suspected that these findings were consistent with an intramyocardial mass with displacement of the left anterior descending and diagonal arteries (Figure 5A and 5B and Movie V in the online-only Data Supplement).

Dr Machnicki: The anatomic details and functional assessment of the cardiac MRI and CT scans are highly indicative that neither a cardiac tumor nor an infiltrative process is the cause of the patient’s symptoms. Primary cardiac neoplasms are very rare. Our patient had no signs or symptoms of a metastatic disease process to suggest a secondary cardiac neoplasm, making a secondary cardiac neoplasm highly unlikely. His presentation of abrupt coronary occlusion would be unusual for a primary cardiac mass. Unless resulting from a genetic disorder, primary cardiac tumors are very rare. Neither the patient nor his family has a history for any Mendelian conditions. When they do occur, they have a similar frequency in all races, sexes, and age groups. Symptoms secondary to a cardiac neoplasm are typically attributable to mass effect causing obstruction of intracavitary blood flow, compromised valvular function, conduction abnormalities, arrhythmias, or symptoms attributable to tumor embolization or inflammation.

Infiltrative cardiac diseases are attributable to the deposition of abnormal substances that lead to progressive diastolic followed by systolic dysfunction. Depending on the disease process, some conditions present with increased left ventricular mass and thick ventricular walls such as cardiac amyloid, Friedreich ataxia, or cardiac oxalosis. Others cause chamber enlargement and thinning of the walls including sarcoidosis, Wegner disease, or hemochromatosis. Our patient does not have the typical findings of an infiltrative cardiomyopathy. He has no history of gait abnormality, skeletal myopathy, congestive heart failure, upper or lower respiratory tract infection, or juvenile urolithiasis or nephrocalcinosis, nor has he received a blood transfusion. His QRS complex amplitude is not decreased. When considering an infiltrative process based on his age, echocardiogram, and cardiac MRI imaging he does not have characteristic findings. There is no symmetrical left and right ventricular wall thickness, dilated atrium, or diffuse late gadolinium enhancement of the subendocardium of cardiac amyloid. Additionally, his left ventricle cavity is not dilated and there is no patchy involvement of the basal and lateral walls on late gadolinium enhancement to suggest sarcoidosis.

Patient presentation (continued): Given the lack of a unifying diagnosis, wide range of nonspecific symptoms, and suspicious diagnostic testing the patient was referred to the structural heart disease team for further
assessments. His history was reviewed in its entirety. Key points were addressed, including (1) abrupt onset of chest pain, (2) persistent chest pain days after initiating event, (3) chest pain exacerbated on changes in position, (4) continued ST-segment elevation, (5) lack of pathological Q waves, (6) kinking of coronary arteries on cardiac catheterization, (7) TTE, cardiac MRI, and CT scans showing focally increased myocardial wall thickness, and (7) no significant past medical history of active systemic process.

It was suspected that an external process was impinging the myocardium and coronary vasculature. Imaging studies were reassessed, and it was further noted on both cardiac MRI and cardiac structural CT scans that the pericardium was partially absent on the left side up to the region of circumscription (Figure 4A and 4B).

Before urgent referral to surgery the team wanted to confirm that the diagnosis was secondary to partial congenital absence of the pericardium. The patient was questioned whether the chest pain changed in particular when shifting from his right to left side. With team at bedside, his chest pain was assessed as he rotated from a left lateral decubitus position, to a supine position, and then right lateral decubitus position. He complained of an increase in the intensity of his chest pain in the left lateral decubitus position. ECGs were performed during positional changes (Figure 6A, 6B, and 6C).

Dr Ruiz: Based on the clinical diagnosis very different treatment strategies would have been approached in the care of this patient. Partial absence of the pericardium is rarely included in the differential diagnosis of an individual presenting with chest pain, even in those with no past medical history of chest pain. Based on the patient’s unusual presentation and findings a high clinical index of suspicion and multimodality imaging was necessary to help lead to the diagnosis and appropriate management strategy.

The diagnosis was further confirmed by cardiac hypermobility (cardiophtosis). Dynamic changes in the V4–V6 ST segments of the ECG along with heightened chest pain were noted when the patient laid in the right lateral decubitus position. The heart occupies no fixed position in the thorax but rather is suspended by its great vessels and its intimate relationship with the thoracic wall, mediastinal tissue, lungs, and diaphragm. Any change in the surrounding structures or position of the body can result in the modified position of the heart. Cardiophtosis may be attributable to a primary condition of the heart, such as congenital absence of the pericardium, or secondary conditions, such as a tumor or a pleural effusion.7

The herniation of the myocardium through the dense fibrous rim of the pericardial defect likely caused dynamic occlusion of the coronary vasculature bed, strangulation of the myocardium along with cardiac contusion which contributed to the patient’s chest pain and myocardial ischemia. The dynamic compression of the heart was also likely intermittent because of the patient’s position and associated degree of edema. The edema was mostly from extrinsic compression of the coronary venous circulation causing severe venous congestion of the myocardium.

After review of imaging studies the clinical diagnosis was confirmed on further history taking and performance of positional ECGs. The patient was urgently brought to the operating room.

Patient presentation (continued): In the operating room a left diagnostic thorascopy was performed. After inflation of CO₂, the myocardium was immediately noted to have a purplish discoloration (Figure 7). A defect in the pericardium was seen through which the heart had herniated, causing congestion. A video-assisted thoracoscopic pericardiotomy was initially attempted but because of the friability of the myocardium...
of the heart and the tight adherence of the pericardium (Movie VI in the online-only Data Supplement), a small 5-cm mini-thoracotomy was performed to allow direct access to the pericardium. The adherent pericardium was incised with immediate improvement in venous congestion and color of the heart.

The patient did well postoperatively and was discharged home 3 days later. On 1-month follow-up the patient was seen in clinic where he is symptom free. He has returned to his normal daily activities. Subsequent echocardiography imaging demonstrated marked improvement in wall motion with a small area of hypokinesis in the apical segment and decreased wall thickening. His ejection fraction was 55%.

Dr Ruiz: When evaluating the dramatic improvement in the patient’s wall motion and appearance a month after his large myocardial necrosis several hypotheses were considered. At time of surgery the myocardium appeared to be incarcerated ruling out the possibility of transient herniation. The kinking of the vessels, which were not totally occluded, was caused by impingement not thrombosis. The myocardial wall was thickened secondary to the edema caused by the venous coronary obstruction.

Myocardial perfusion and resistance is regulated by a close interaction between myogenic, metabolic, humoral, and neurohormonal factors. It can be hypothesized that the constricting pericardium potentially comprised the epicardial coronary arteries creating a physiological coronary stenosis and a decrease in distal coronary perfusion pressure. Despite exhaustion of vasodilator reserve, basal coronary blood flow could not be maintained and myocardial hypoperfusion and necrosis resulted. More importantly, the strangulated pericardium impaired coronary venous outflow raising the intramyocardial pressure and passively compressing the arterial-venous bed. The lack of thrombus formation may be secondary to recirculation of blood through the thebesian vessels with intermittent reoclusion of the coronary vasculature. Furthermore, the small pericardial effusion may be attributable to congestion of the venous and lymph outflow. This has been shown in animal studies of the heart.

Discussion

The pericardium is formed by an outer fibrous layer and an inner serous layer of mesothelial cells. During embryogenesis, the heart grows into and invaginates the inner serous pericardium, resulting in visceral and parietal layers that are in continuity. The pericardial sac is formed from the embryonic coelom, which is separated from the pleura by the right and left pleuropericardial folds. Pericardial agenesis is thought to result from malformation of the transverse septum or pleuropericardial membrane as a result of early premature atrophy of the ducts of Cuvier.

When imaging the pericardium, echocardiography, cardiac CT, and cardiac MRI can be utilized. Although considered the first line in diagnosis, echocardiography may be equivocal secondary to low signal-to-noise ratio of the pericardium, limited tissue characterization and operator dependence.

On cardiac CT and MRI the pericardium appears as a thin curvilinear line surrounded by epicardial fat tissue. In areas with a sparseness of fat (lateral and posterior left ventricular wall) the pericardium may be difficult to visualize. Benefits of cardiac CT and MRI include larger field of view to evaluate extracardiac disease, better anatomic description, and superior soft-tissue contrast.

Congenital absence of the pericardium is a rare cardiac defect that is usually discovered incidentally, on autopsy, or during surgery. Absence of the pericardium can vary from partial to complete and typically involves the left rather than the right pericardium. The most common defects are left total defects which are all asymptomatic, followed by left partial defects. Congenital absence of the pericardium has been associated with other abnormalities including atrial septal defect, patent ductus arteriosus, tetralogy of Fallot, bronchogenic cysts, and pulmonary sequestrations in 30% to 50% of patients. Most patients are asymptomatic and have an excellent prognosis. If symptomatic, patients can present with a wide range of nonspecific symptoms ranging from dyspnea to palpitations and syncope. Visualization or lack thereof of the pericardium is typically made on cardiac MRI and CT. Cardiac MRI and CT allows for delineation of the location and extent of pericardial defect and determination of complications as a result of impingement of its rim. Complications of partial congenital absence of the pericardium include incarcerated cardiac tissue primarily involving the left atrial appendage, torsion of the great vessels, myocardial ischemia, lung interposition between the aorta and pulmonary artery.

In symptomatic patients or those who present with a complication, surgical intervention is recommended. In asymptomatic patients the risk of complications is believed to be dependent on the size of the pericardial defect with total and
large defects carrying little to no risk. Consequently, many would not consider sending a patient with a large defect for surgical correction with a pericardiectomy or pericardioplasty.

Despite its rarity, congenital absence of the pericardium is not without clinical significance and may be increasingly found on cardiac imaging. Patients presenting with congenital deficiency of the pericardial sac may present with a wide spectrum of signs and symptoms. Awareness of this condition in clinically challenging patients being assessed for cardiopulmonary anomalies is necessary to avoid life-threatening complications.

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Dr Ruiz reports receiving research grants and consulting fees from Philips Healthcare. The other authors report no conflicts.

References

KEY WORDS: chest pain ■ congenital heart defect ■ echocardiography ■ magnetic resonance imaging ■ multidetector computed tomography ■ myocardial infarction ■ pericardium
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