SECTION ONE
Cardiac Ischemia

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Chest pain

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Section I: Case presentation

A 46-year-old man presented to the emergency department (ED) complaining of chest pain. The pain had begun while he was carrying some heavy boxes at home four hours prior, and had persisted since. He described the pain as a severe ache in the midsternal area, but there were superimposed sharp pains that radiated to the left shoulder when he took a deep breath. It did not appear to change with body or arm position, with walking, or with swallowing. He felt dyspneic and nauseated, and he also reported that he was diaphoretic during the first 20 minutes of the pain. The pain did not improve with ibuprofen, so he decided to come to the ED.

The past medical history was notable for HIV and hypertension. The patient had stated that he had been noncompliant with medications and primary care follow-up during the prior year. The last CD4 count one year ago was approximately 500. He had smoked one pack of cigarettes per day for more than 20 years, and had used crack cocaine regularly for 10 years, although he had not used cocaine for a week. He was uncertain if there was a family history of early cardiac disease or sudden death. He had been admitted for chest pain approximately six months earlier at a nearby hospital, and had a "negative" stress test at that time.

The vital signs were: temperature 37°C, pulse 90 beats/min, respirations 20 breaths/min, blood pressure 180/110 mmHg, pulse oximetry 98%. The cardiac and pulmonary examinations were normal with the exception of mild, sharp, left-sided chest pain with deep inspiration. The chest wall was mildly tender. The pulses and jugular venous pulsations were normal. There was no peripheral edema. The rest of the physical examination was normal. An electrocardiogram (EKG) was obtained, and demonstrated sinus rhythm with voltage criteria for left ventricular hypertrophy and diffuse T-wave flattening across the precordium. The chest X-ray study was normal.

Section II: Case discussion

Dr Peter Rosen: We are always taught that the most important part of the evaluation of ischemic chest pain is the history. Yet, for 30 years I have been trying to find a description of ischemic chest pain that enables me to say, "this chest pain is ischemic, and that is musculoskeletal, and that is gastrointestinal." Do you have any clues for us, or is that just one of the legends of clinical medicine?

Dr David Brown: I don't think there is an answer to your question that is clinically useful. Each of us could probably describe classic chest pain and classic findings for all of the conditions you just mentioned, but there is considerable overlap between these disease presentations such that I don't think the emergency

physician can use the history alone to reliably exclude an acute coronary syndrome in a patient like this one.

PR: Do you think there is any benefit to the patient describing isometric exercise such as shoveling snow or, as in this history, less isometric exercise in that he was carrying boxes? Would a more isometric history, such as if he had said that the pain came on while he was lifting the boxes up onto a shelf, be more useful?

DB: If you have additional history from him regarding whether or not any use of the muscles or movement of his arm might have precipitated the pain, and can fully reproduce it now while he is in the ED, this may be useful. But I don't think there is a lot of utility in differentiating whether this exercise was isometric because one could say that he was walking at the same time, and that there was an aerobic component that precipitated the pain.

PR: The drug abuse history in this case makes me far less suspicious that this is ischemic pain. Once I get a history of cocaine use in a patient who says he hasn't used it in the past week, although time is relative for users, I find it is more likely to be nonspecific chest wall pain rather than ischemia. Is there any way you can distinguish these patients from history alone, or does it require a full workup?

Dr Shamai Grossman: Patients with cocaine chest pain always worry me because I find that they have more atypical presentations. These patients seem to present often, as this one has, with chest pain that can be from multiple different etiologies. Once they tell me that they use cocaine, I tend to not trust them to be telling me the truth when they say they haven't used cocaine in the last week. I would simply assume that the patient has actually used cocaine very recently, likely within the last 24 hours. Once I assume this, I also have to assume that the chest pain is cardiac in etiology until it has been fully proven otherwise.

PR: This patient also has a past history of HIV. I'm not aware of HIV causing ischemic cardiac disease. I have seen cardiac ischemia with pulmonic, oncologic, and gastrointestinal problems, but I don't believe I've ever seen a patient with HIV present with an ischemic coronary syndrome. Is this true?

SG: HIV can cause a dilated cardiomyopathy, although not an ischemic cardiomyopathy. In addition, recent data seem to suggest an increased incidence of coronary artery disease with protease inhibitors, and HIV patients appear to be more likely to have traditional cardiac risk factors then the general population.[1–9] All of this requires one to truly think broadly when trying to sort out a diagnosis in this patient.

PR: What is the utility of that CD4 count that's a year old?

Dr Ted Chan: It suggests that, a year ago, he was not significantly immunosuppressed, and not at risk for many of the atypical infections associated with HIV. It's difficult to say what it might be now, particularly if he has been non-compliant with his medications over the past year.

PR: Would you say the same thing about his "negative" stress test from six months earlier?

SG: The same suspicions that I had about this patient's report that he hadn't used cocaine in a week would make me skeptical about his report of a negative stress test, and I wouldn't accept this at face value. The value of any stress test that is six months old is controversial, although some studies suggest that there is utility in a negative stress test anywhere from one and one-half to three years later.[10–13] However, the utility of a stress test is related to the pre- and post-test probability that this patient's symptoms are ischemic in etiology.

PR: This is the kind of patient who is going to be a significant management problem in the ED because no cardiologist is going to be excited about working him up, and he may be very hard to admit. We become very cynical about these patients because of their social circumstances, and they may have to prove to us that they are experiencing something nefarious before we will listen to their story. What should the extent of his workup in the ED be before you would push for a cardiology consult?

DB: Given an EKG that is nonspecific, a history that is suggestive but nondiagnostic, and no cardiac markers, we have little compelling data to prompt a cardiology consultation at this point. What he does need now is a first set of cardiac markers and a careful look at his electrocardiogram, perhaps obtaining an old EKG if one's available. There are some data to suggest that a rapid rule-out over 6 to 8 hours, including two sets of negative markers followed by some sort of provocative testing, is sufficient to evaluate patients with cocaine-related chest pain.[14]

SG: There are a couple of studies looking at the utility of stress testing in patients with cocaine chest pain, which suggest that they are not useful in the first few weeks following cocaine use.[15–18] In our institution, we tend not to obtain stress tests on these patients while they are in the observation unit or in the hospital. In patients at high risk based on their histories and EKGs suggestive of ischemia, we would likely take them for a cardiac catheterization. If they were a little lower risk, in this day and age, I might consider a cardiac computed tomography (CT) angiogram.

PR: I presume you would get a chest X-ray study to see if there is a noncardiac disease declaring itself as the source of the pleuritic pain. Would you get a repeat CD4 count?

TC: I would most likely not check a CD4 count, as we would probably not get it back in a timely manner. Furthermore, unless he is manifesting some other symptoms suggestive of an opportunistic infection, it probably would not be that helpful in terms of the emergency care.

PR: Since there is a pleuritic component to the history, would you evaluate him up for a pulmonary embolism (PE)?

TC: True, there is a pleuritic component to his pain, but he has minimal respiratory complaints, and the oxygenation is normal. Unless there is additional history of some immobilization, prior trauma, or something similar, I would put him in a low-risk category for PE, and perhaps screen him with a D-dimer.

PR: I was told by one of the county hospital faculty in a high cocaine use neighborhood that, one Saturday night, they did a toxicologic screen on all of the patients in the ED, and 100% of them tested positive for cocaine. Obviously you can't admit 100% of your patients to the observation unit, so can you limit utilizing the unit for the high-risk cocaine user only? I've been perhaps too cavalier in my own practice, because unless they have an enzyme elevation or a significant EKG change, I have not been doing further work-up on them, but maybe I should be treating them more diligently?

SG: Again, in a low-risk patient who had used cocaine (unclear if it was during the previous 24 hours, but within the last week), we would probably do serial enzymes 6 hours apart, and if they were negative, and if the patient were pain free with an unchanged follow-up EKG, we would probably discharge him home. We would arrange a follow-up, and possibly a stress test in the next 1 to 2 weeks. The patient with other risk factors, or a more worrisome story, is more likely to get a stress test as an outpatient 2 weeks later, or a coronary CT while in the ED.

PR: I've read some literature that says that while these patients seem to have an increased incidence of coronary artery disease over the general population, they do not respond to reperfusion when they appear to be having a myocardial infarction (MI) that is induced by cocaine. This leaves me puzzled as to what should the approach be for these patients? Do they require a stent, or are they better off treated with vasodilators like calcium channel blockade?

SG: Even though cocaine accelerates atherosclerosis, if these patients are having infarctions, it is more likely from coronary vasospasm than thrombosis. When the etiology is vasospasm, a stent is not going to be useful. In the acute setting, we generally use benzodiazepines as a first line treatment. Nevertheless, if the patient presents with an EKG suggestive of an acute MI, he would still be a candidate for thrombolytic therapy and coronary intervention, simply because you can't tell definitively, without visualizing the vessels, whether the etiology is vasospasm or atherosclerotic in etiology. For that reason, given a choice between thrombolytic therapy and taking the patient to the catheterization laboratory, I would certainly favor taking them to the catheterization laboratory; if you take them to the catheterization laboratory and it turns out that they have coronary vasospasm, then you could treat the vasospasm without subjecting the patient to the dangers of thrombolytic therapy.

PR: Do you have any different experiences in your institution?

TC: Our cardiologists may be more reticent to go to the catheterization laboratory right away, but I think that's just a function of their own practice.

PR: What about a nonspecific EKG change? It's easy to recognize an abnormality if it is new, but this case is a classic example of a patient who may have had EKG changes for a long time, and we may not be able to prove it because we won't be able to obtain a prior tracing. He also has a history of hypertension, so left ventricular hypertrophy with these changes wouldn't

be unusual. Is this EKG reassuring if his enzymes are not elevated?

SG: In a patient with a nonspecific story, a nonspecific EKG that doesn't evolve when you do serial EKGs concurrent with serial cardiac enzymes tends to be much more useful. If the repeat EKG has changed, which I find is more often the case than that the enzymes have changed, then I become more concerned that this is cardiac ischemia. On the other hand, if the EKG is unchanged, I find myself more reassured that this is likely to be the baseline EKG, and that the presentation less likely to be cardiac ischemia in etiology.

PR: As many of these patients are often not just smoking cocaine but also abusing drugs intravenously, do you think there is any utility here for obtaining an echocardiogram to make sure you are not missing an endocarditis?

SG: Endocarditis should always be in your differential diagnosis, particularly in patients who are likely to engage in intravenous drug abuse. Unless there were other pieces of information suggestive of endocarditis, such as a concomitant fever, a murmur, splinter hemorrhages, or telangiectasias that would point towards endocarditis, I probably wouldn't pursue this diagnosis. Nevertheless, an echocardiogram is not an unreasonable test to do to help differentiate the etiologies of chest pain. One might be able to evaluate the valves and regional wall motion at the same time, and this might make it a very useful test.

PR: Over the years I've been confused about what pharmacotherapy to utilize in a cocaine user. Are aspirin, beta-blockers or anti-coagulants useful?

TC: Aspirin is inexpensive and rarely harmful in any patient, and that would include those with cocaine chest pain. Beta-blockers, depending on whether this patient had just ingested cocaine, might be problematic because of unrestricted alpha agonism. With anticoagulation, it depends on how you categorize this patient in terms of the likelihood of having an acute coronary syndrome (ACS) event. The higher the probability, the more anticoagulation is reasonable. With low-risk patients, cocaine by itself would not push me to start a glycoprotein 2b/3a inhibitor or heparin.

DB: I want to reiterate that cocaine chest pain patients should be approached the same way as other patients who present with chest pain, and should be evaluated like non-cocaine using patients. Their workup and treatment are dictated by the history, EKG and cardiac marker findings, and the persistence of symptoms.

Case resolution

The patient was admitted to a chest pain observation unit adjacent to the ED and ruled out for myocardial infarction based on negative troponin values. The EKG demonstrated no changes. The patient underwent an exercise stress test during which he developed recurrence of the chest tightness, accompanied by frank T-wave inversions in the lateral leads. The patient was then sent for cardiac catheterization that demonstrated mild diffuse atherosclerotic disease and a critical occlusion in the left circumflex artery. He was treated with a stent, and was discharged 2 days later in good condition.

Section III: Concepts

Background

Chest pain is one of the four most-common chief complaints for adult patients presenting to EDs in the United States.[19] While medical professionals and the lay public alike typically associate chest pain with a cardiac source (i.e., cardiac ischemia or infarction), a significant portion of patients with chest pain will have other etiologies of their pain. One study finds that nearly 21% of patients with chest pain have a noncardiac cause of their symptoms.[20] Chest pain may be caused by a variety of serious and life-threatening illnesses. Emergency department evaluation of the patient with chest pain therefore must focus on excluding the most dangerous conditions first. To accomplish this, care should be taken to employ a systematic approach to avoid missing one of these key diagnoses. Dangerous diagnoses associated with chest pain may be distilled down to a few easy to remember diagnoses. Acute coronary syndromes (acute myocardial infarction and unstable angina), aortic dissection, pulmonary embolism, tension pneumothorax, cardiac tamponade, and esophageal rupture are the most rapidly life-threatening diagnoses associated with chest pain symptoms. Evaluation of each chest pain patient should include consideration of each of these diagnoses. A careful clinical history and physical examination and consideration of individual risks versus benefits are

important in determining the ultimate evaluation and treatment course for a specific patient.

Initial chest pain workup

Physicians evaluating a patient with chest pain should have a systematic approach to these patients, and the resulting workup should be based on the etiologies of chest pain, history, and physical examination findings.

Acute coronary syndrome (ACS)

An ACS is a frequent concern for emergency healthcare providers when evaluating patients with chest pain. The prospect of missing the diagnosis of acute myocardial infarction in the ED has been the topic of several papers. The commonly quoted "miss rate" for MI stands at 2.1%, and the consequences are significant, both for patient care and from a medico-legal perspective.[21] Missed MI accounts for 10% of malpractice claims against emergency physicians, but comprise 25% of the total cost of these malpractice claims.[22] Thus, consideration of cardiac ischemia or infarction should always occur when evaluating patients with chest pain.

A careful history and physical examination are the starting points for evaluating patients with possible ACS. Chest pain radiating to the left arm, right shoulder, or both arms is associated with a progressively higher likelihood of MI.[23] A history of a previous MI, diaphoresis, an S3 heart sound on auscultation, nausea and vomiting, hypotension, and pulmonary rales are also factors that increase the likelihood of MI.[23] Chest pain worsened by changes in position or described as sharp or stabbing has been associated with a lower likelihood of an acute MI, as has chest pain of very short duration.[24,25] In previous studies, chest pain of very short or very long duration is associated with a very low risk of acute cardiac events.[26] In addition, reproducible chest wall pain does not exclude a cardiac cause, including acute MI; in one study, up to 7% of patients with acute MI present with fully reproducible chest wall pain.[27]

Coronary artery disease risk factors are often used to help differentiate high- and low-risk patient groups in the ED. While the classic risk factors of diabetes mellitus, hypertension, older age, male gender, hyperlipidemia, smoking, and premature family history of coronary artery disease are useful in determining long-term risk of a patient developing coronary artery disease, the use of risk factors has very limited utility in the ED when trying to determine the *acute* risk of ACS.[28–30] The 2007 American College of Cardiology (ACC)/American Heart Association (AHA) Guidelines have affirmed that the most important factor associated with predicting ACS in a patient presenting with chest pain is the history of the present illness, clearly exceeding the predictive value of cardiac risk factors.[31,32]

Physical examination findings noted above, including diaphoresis, an S3 heart sound, and pulmonary rales, are all nonspecific and, in isolation, not overly helpful for pointing the overall diagnosis to acute MI. However, in conjunction with other historical findings, these may lead to an increased likelihood of MI.[24] The main benefit of the physical examination in patients with an acute MI is to exclude the acute complications of MI (e.g. valvular rupture, acute congestive heart failure), or other non-ACS diagnostic possibilities. Esophageal rupture, cardiac tamponade, tension pneumothorax, and aortic dissection may all have physical examination findings that suggest these entities instead of an acute MI.[33–36]

Aortic dissection

Aortic dissection is much less common than an acute MI or unstable angina, but the emergency physician must still be alert to the possibility of this entity. There is some overlap of clinical findings with those seen with myocardial ischemia, but several factors are helpful in determining the presence of acute aortic dissection. Chest pain is the most common symptom of acute aortic dissection, and though a description of "ripping" or "tearing" pain has been shown to have a significantly increased likelihood of aortic dissection, more recent registry data shows that sharp pain may be even more common.[37] Pain that is sudden in onset and pain which reaches maximal intensity at onset is also associated with aortic dissection. Several factors relating to the location of pain may be helpful. Tearing-type pain in the posterior thoracic or interscapular area may signify dissection involving the descending aorta, while pain in the neck or jaw may mean that the dissection affects the brachiocephalic or common carotid arteries and the aortic arch.[36,37] Typically, anterior chest pain may signify a dissection site at the root or ascending portion of the aorta.[37]

Several other presenting symptoms are well reported and varied, often depending on the location and extension of the dissection, including: neurologic deficits or stroke-like symptoms, flank pain, syncope, and altered mental status.[36] Other historical components include an increased incidence in men compared with women, as well as increased incidence with hypertension, especially following cocaine use. Finally, there are associations of aortic dissection with genetic connective tissue disease such as Marfan syndrome and Ehlers-Danlos syndrome, which may be found in nearly 5% of patients with acute aortic dissection. Pregnancy, syphilis, and bicuspid aortic valves have also been associated with aortic dissection.[37] Physical examination occasionally reveals pulse inequities between the upper and lower extremities. A blood pressure difference of 20 mmHg or more between the upper extremities has been associated specifically with aortic dissection.[38] Hypertension is the classic blood pressure finding with aortic dissection, and is seen in nearly half of all cases (although hypotension may be seen as well).[37,38] Hypotension associated with aortic dissection suggests a poor prognosis, as this typically signifies other complications, such as inferior wall MI, cardiac tamponade, or volume loss/bleeding.[37] Other common findings include neurologic deficits, which can be present in up to 20% of patients, and include stroke-like syndromes with extremity weakness or paresthesias or altered mental status.[37] A variety of other findings including shortness of breath, new diastolic murmur from acute aortic insufficiency, and dysphagia or hoarseness may be seen.[37]

Pulmonary embolism
Because of the difficulties in diagnosing pulmonary embolism (PE), a large body of medical literature exists on this topic, but it is still a most challenging condition to assess. The most commonly seen symptoms of PE include shortness of breath (60–79% of patients) and chest pain (17–64%).[39,40] The classic symptom triad of dyspnea, chest pain, and hemoptysis has been found to have poor sensitivity and specificity. Pleuritic chest pain is found in a significant proportion of patients with PE, though this complaint also has poor specificity for PE.[39,40] Several other symptoms may be seen, but none are very specific for PE; these include: syncope, palpitations, tachycardia, wheezing, cough, seizure, fever, lower extremity edema, diaphoresis, and cyanosis.[40] Unfortunately, no specific symptom is sufficient to diagnose PE. Physical findings with PE are similarly nonspecific and include fever, tachycardia, accentuated second heart sound, rales, tachypnea, and new cardiac murmurs or S3/S4 cardiac gallop. Additionally, cardiac dysrhythmias, especially atrial dysrhythmias such as atrial fibrillation, atrial flutter, and atrial premature contractions, may be present.[41] Given the difficulties in finding specific historical or physical findings for PE, assessment for risk factors for venous thromboembolism should be considered next. There are a wide variety of risks for venous thromboembolism, but a few important risks include: a history of previous deep venous thrombosis (DVT) or PE; hematologic factors such as protein C, protein S, antithrombin III deficiencies, or Factor V Leiden; prothrombin 2010 gene mutation; and a host of miscellaneous less common factors.[42] Additional recognized complications include recent travel or immobilization, history of cancer, recent trauma or surgery, estrogen hormone use, pregnancy, and the post-partum period.[43]

Using risk assessment in conjunction with standard history and physical examination findings, a variety of clinical prediction rules have been developed. While no rule is perfect, these tools may aid initial decision-making. The most well-known scoring system is the Well's score, which assigns points for any of the following findings: clinical signs/symptoms of DVT, heart rate over 100 beats per minute, immobilization, previous history of DVT/PE, hemoptysis, malignancy, and a determination of the likelihood of PE as compared with that of alternative diagnoses.[43] Another popular scoring system is the revised Geneva score (RGS).[44] The RGS is also a point-scoring system, and assigns points for any of the following: age >65, previous DVT or PE, major surgery or lower limb fracture within one month, malignancy within the past year, unilateral lower-limb pain, hemoptysis, rapid heart rate, and pain on lower-limb deep venous palpation or unilateral edema. Both the Well's score and the RGS assign low, intermediate, and high clinical probabilities of thromboembolism based on the point total. The use of these clinical probabilities can be combined with certain testing (e.g. D-dimer assay) to determine how far to progress with the workup.

For very low-risk patients in whom additional testing is being debated, use of the Pulmonary Embolism Rule-out Criteria (PERC) rule may be useful. This rule utilizes eight criteria: age <50 years, pulse <100 bpm,

$SaO_2 > 94\%$, no unilateral leg swelling, no hemoptysis, no recent trauma or surgery, no previous DVT or PE, and no hormone use.[45] In a more recent prospective multicenter evaluation, the PERC rule (PERC negative) in conjunction with a low clinical probability of PE reduced the probability of venous thromboembolism to <2%.[46]

Tension pneumothorax

Tension pneumothorax is a life-threatening cause of chest pain. Clinical history is key with any history of trauma or associated respiratory issues. A recent military-based study shows a prevalence of tension pneumothorax in 3–4% of battlefield casualties.[47] A history of an obstructive airway process (e.g., asthma, chronic obstructive pulmonary disease) or of positive pressure ventilation (e.g., recent intubation, recent surgery, etc.) is very important in determining whether to pursue this diagnosis. A chest X-ray study or other imaging modality should be not be sought until the tension has been relieved, as the time spent in proving the diagnosis with an imaging study may prevent a successful relief of the tension pressures. Clinical findings are often present in support of this, with abnormal breath sounds—decreased breath sounds on the affected side or hyperresonance to percussion over the affected side—and deviation of the trachea away from the affected side representing the most common findings. Rapid imaging is indicated in patients with a suspected pneumothorax, with bedside ultrasound showing excellent sensitivity and specificity.[48] A chest X-ray study is the most common imaging modality utilized, although as stated, it is more prudent to relieve the tension than to prove its presence. In the setting of suspected tension pneumothorax, other imaging is also reserved for evaluation post-intervention, but CT scanning is more sensitive than chest X-ray for finding a small pneumothorax in general.

Cardiac tamponade

Cardiac tamponade is another condition with key historical and physical examination features. General history taking should include consideration of typical causes of pericardial effusion, including uremia, malignancy, HIV, tuberculosis, and other previous medical conditions and surgical procedures.[49,50] Recent pacemaker placement, central venous catheter insertion, cardiac catheterization, trauma, or other thoracic surgical procedures can lead to a very rapid development of pericardial fluid

and tamponade physiology.[50] A careful history including anticoagulant and antiplatelet use is also important, particularly if the presumed pericardial effusion is felt to be hemorrhagic in nature. Additional historical findings include weight loss, fatigue, night sweats, or symptoms suggestive of underlying rheumatologic or connective tissue disorders.[49] Specific symptoms to suggest current or impending cardiac tamponade include shortness of breath, dyspnea on exertion, tachypnea, air hunger, and tachycardia.[51]

The physical examination may demonstrate diaphoresis, tachycardia, and tachypnea, typically with clear lung fields.[49] The classic Beck's Triad consists of increased jugular venous pressure (JVP), hypotension, and diminished heart tones. This triad is typically seen with a significant pericardial effusion, and is more often seen with medical than traumatic etiologies.[49,52] Pulsus paradoxus is often described with cardiac tamponade. In severe tamponade, the pulses may disappear with inspiration. On auscultation, the difference between the first appearance of the first Korotkoff sound while obtaining the systolic blood pressure, and where it becomes steady, is the pulsus paradoxus. Greater than 10 mmHg is usually abnormal.[49] Transthoracic echocardiography at the bedside is probably the quickest way to confirm the presence of an effusion, and tamponade. The normal pathophysiologic response to tamponade is a tachycardia, but immediately prior to arrest, the patient will develop a bradycardia. The intrapericardial pressure must be relieved immediately when this is seen.

Esophageal rupture

The most common cause of esophageal rupture is iatrogenic, due to endoscopic or other procedures. The classic Boerhaave's syndrome, caused by repeated retching or vomiting, is seen in about 15% of cases of esophageal rupture, followed in incidence by toxic ingestions and penetrating trauma.[53] Other historical findings for classic esophageal rupture include a sudden onset of severe epigastric or chest pain following forceful vomiting or retching. Other potential causes include recent childbirth, heavy lifting or straining, blunt trauma, or bouts of severe coughing.[52–55] Some patients will complain of fever or of radiation of pain to the back, shoulder, or neck. Some patients will have difficulty with speech, or trouble swallowing. Previous esophageal conditions, cancer, or radiation treatment may also predispose patients to esophageal rupture.

Physical findings are varied with esophageal rupture, and many are nonspecific. Fever, tachypnea, tachycardia, and subcutaneous emphysema are important considerations. Subcutaneous emphysema is the most specific of these findings, but may take several hours to develop.[53–56] Hypotension may be a sign of septic shock from mediastinitis, and carries a grave prognosis. Hamman's crunch, a friction rub of the pericardium heard when auscultating the heart and occurring with each heart beat, is another useful finding that is fairly specific for mediastinal emphysema.[57] Esophageal rupture is best repaired early after the rupture surgically.

Testing for patients with chest pain

Once an initial differential diagnosis has been created, the next steps in the ED typically involve diagnostic testing. While each of the serious conditions outlined previously generate different workups, the workup for most ED patients with chest pain should start with an EKG and a chest X-ray study.

Electrocardiogram
The EKG is critically important in diagnosing ST-segment elevation MI (STEMI) and acute coronary syndromes, and also has benefit for non-ST-segment elevation MI (NSTEMI) and high-risk unstable angina patients. EKGs showing a STEMI will dictate rapid medical management, with either fibrinolytic therapy or percutaneous coronary intervention (PCI). For this reason, the initial EKG should be obtained and reviewed by the emergency physician within 10 minutes of the patient's arrival in the ED. The EKG can also help steer management toward other key diagnoses during the critical first few minutes of evaluation.

The EKG can be used to localize an acute STEMI to a specific wall or anatomic territory; commonly involved areas include the anterior, anterolateral, inferior, lateral, and septal territories.[58] Additionally, ST depressions in the right precordial leads (leads V1-V3) or ST elevation in specially placed posterior leads may signify an acute posterior wall STEMI.[59–61] Right-sided EKG leads should be obtained in patients with acute inferior STEMI.[62] This special placement of EKG leads can identify concurrent right ventricular infarction, which increases the possibility of complications, including hypotension (especially if nitroglycerin is utilized during treatment).[63–65]

EKGs demonstrating acute ST-segment deviation—ST depression or transient ST elevation—signify the need for rapid, aggressive medical management, or consideration of early invasive (PCI) therapy.[66] T-wave inversions can also be indicative of cardiac ischemia or non-ST-elevation MI, and a need for more aggressive medical management.[66] In addition, several specific findings on EKG may be suggestive of specific acute coronary syndromes or MI. ST elevation in lead aVR in patients with other findings suggestive of an acute coronary syndrome may be indicative of left main coronary artery occlusion.[67] The terminal T inversion and biphasic T wave pattern in precordial leads V2-V4 is sometimes known as Wellens' sign or Wellens' syndrome, indicating proximal occlusion of the left anterior descending coronary artery.[68,69]

Serial EKGs or continuous ST-segment monitoring are often useful in diagnosing an evolving ACS, and increase the sensitivity of the diagnostic process in these patients.[70] These options are especially important when managing ill-appearing patients with an initially unclear diagnostic evaluation, or those with persistent chest pain or other ischemic symptoms.

The EKG can also be a key diagnostic tool for other non-ACS conditions. The classic changes of diffuse ST elevation with PR depression suggest acute pericarditis, while low voltage and electrical alternans should raise suspicion for pericardial effusion and possible cardiac tamponade.[71,72,73] Aortic dissection may be associated with an acute STEMI when the coronary arteries are affected. A STEMI in conjunction with aortic dissection can involve the right coronary artery, and thus presents as an inferior wall STEMI.[74] Pulmonary embolism is associated with a wide variety of EKG changes, although none of these changes are specific enough to enable a diagnosis of PE from the EKG alone. In patients who might have a PE, the S1Q3T3 pattern has been seen with equal rates in patients with and without confirmed PE following testing.[75] Other EKG findings such as sinus tachycardia, nonspecific ST-T changes, right bundle branch block, atrial fibrillation or flutter may occur in the presence of acute PE as well.[76]

Chest X-ray study
The chest X-ray study represents the second test commonly obtained for ED patients presenting with chest pain. This study is useful in determining the presence or absence of a variety of pulmonary conditions,

including pneumothorax, pneumonia, and pleural effusions, or obtaining information about other mediastinal structures. Supine chest X-ray sensitivity and specificity is lower than an upright chest X-ray study, with sensitivity typically listed in the 37–52% range even for those primary pulmonary disorders just mentioned, so reasonable attempts should be made to acquire upright rather than supine X-rays.[77–80]

Esophageal rupture may demonstrate a pleural effusion (usually on the left), pneumomediastinum, and subcutaneous emphysema.[81–83] Cardiac tamponade itself cannot be diagnosed by chest X-ray study, although the presence of a large, globular heart may suggest an underlying pericardial effusion.[84]

The most common manifestation of aortic dissection on chest X-ray (69% in one registry report) is a widened mediastinum, although the classic finding of aortic diameter of >5.5 cm for ascending (Type A) dissections has recently been questioned.[85] Several other chest X-ray findings may be seen with aortic dissection, including abnormal cardiac contour (51%), displacement or calcification of the aorta (7%), and pleural effusion (15%).[85] Most of these findings are seen with ascending aortic dissection, and not with descending aortic dissection. Aortic changes on the chest X-ray study may also be seen with traumatic aortic injury. Several findings may be seen, including left apical pleural cap, irregularity or loss of the aortic knob, tracheal shift to the right, depression of the left main bronchus, opacification of the aorticopulmonary window, and deviation of a nasogastric tube to the right or left as well as widening of the mediastinum.[86,87]

Finally, the chest X-ray study is probably of the lowest utility in evaluation of patients with presumed cardiac ischemia from acute MI or other acute coronary syndromes. In these patients, the primary benefit of a chest X-ray study is to differentiate alternative conditions that might be the cause of a patient's symptoms, or to identify concurrent heart failure.

Other diagnostic imaging studies
Following initial evaluation with EKG and the chest X-ray study, many patients require additional imaging to further delineate their clinical conditions. The mainstays of this imaging are CT scans and ultrasound-based studies (bedside ultrasound, echocardiography, etc.). For those patients with concerns regarding aortic dissection or pulmonary embolism, CT scanning with IV contrast is typically the next diagnostic study to be obtained, and "triple rule out" or other scanning techniques simultaneously evaluate for coronary artery disease, pulmonary embolism, and aortic dissection. These studies are currently being performed with low frequency, but may be more prevalent in the future as technology advances.[88] CT scanning has been shown to be very sensitive for determining the presence and location of acute aortic dissection, and EKG-gated protocols allow more reliable imaging.[89] This can be very helpful for determining the specific location of the dissection and its relation to the renal arteries—important information for surgical colleagues as they plan their management. As noted above, CT imaging can also be of assistance in diagnosing other potential intra-thoracic causes of chest pain, and can be used to assess for pulmonary embolism and coronary atherosclerotic disease.

CT scanning with IV contrast is very useful for diagnosing pulmonary embolism. The sensitivity and specificity for these scans is high, with one systematic review noting an overall negative predictive value following a negative CT scan for PE of 99.1%.[90] CT scans provide a high diagnostic yield, but do not come without potential pitfalls. The most common of these problems include IV contrast reactions and higher radiation exposure, although EKG-gating and reduced CT tube voltage may help to limit increases in radiation dose.[91]

Ultrasound-based studies may be obtained directly at the bedside by the emergency physician, or via colleagues in radiology or cardiology. Most patients requiring urgent ultrasonography for chest pain have time-sensitive clinical presentations or are considerably ill, and studies outside the ED are often not possible to obtain safely. A wide range of studies illustrates the utility of emergency ultrasound for these chest pain-related conditions, and a recent policy statement by the American College of Emergency Physicians emphasizes the increasing role ultrasound has in daily clinical practice.[92] Probably the easiest to perform and most-studied use of ultrasound is in determining the presence of a pericardial effusion. Additionally, more detail can be obtained by evaluating for right ventricular collapse, which is another finding readily seen on bedside ultrasound.[93] Right ventricular collapse points toward tamponade physiology. Several studies have looked at the utility of ultrasound in making the diagnosis of pneumothorax. A variety of

signs can help the emergency physician identify pneumothorax via ultrasound, including the comet tail sign, sliding sign, etc.[48,94,95] While the ultrasonic image can demonstrate the pneumothorax, it cannot tell you the size, or whether there is tension pathophysiology. Ultrasonographic diagnosis of pneumothorax may be most useful in trauma, in the intensive care unit, or in other supine patients where initial chest X-ray imaging may not be sensitive enough to exclude a pneumothorax.[94,95] In addition, ultrasound use allows visualization of an associated hemothorax or pleural effusion.

Bedside echocardiography can be very helpful with diagnosing aortic dissection. For unstable patients who are unable to leave the ED for imaging, bedside echocardiography is the study of choice.[96] If available, transesophageal echocardiography is preferred. In addition, echocardiography can evaluate for associated valvular dysfunction, especially aortic insufficiency, which sometimes accompanies aortic dissection, as well as regional wall motion abnormalities and overall systolic function in patients with concurrent acute MI.

Esophageal rupture may be diagnosed by contrast-enhanced X-ray studies utilizing water-soluble contrast, or via direct endoscopy. Additional imaging may be needed via CT scanning or other studies in order to fully evaluate this condition.

Various other imaging modalities have currently or may have in the future a role in evaluating selected patients with acute chest pain. Chief among these tests, magnetic resonance imaging can be used for aortic dissection and other aortic injuries, formal aortography can also be obtained in appropriate patients, and ventilation-perfusion scans can be useful in specific patients being evaluated for pulmonary embolism. A wide variety of cardiac perfusion and other imaging can be utilized for patients with chest pain suggestive of an ACS.

Laboratory studies
Laboratory studies are not overly helpful for a number of chest pain syndromes. However, the diagnosis of ACS, including acute STEMI and non-STEMI ACS, is largely based on the use of cardiac biomarkers, primarily troponin. There is much in the medical literature regarding the use of cardiac markers in the evaluation of patients with chest pain. Various protocols involving myoglobin, creatine kinase-MB fraction (CK-MB) and troponins are currently in use. The diagnostic benefit of myoglobin involves a trade-off: very high sensitivity balanced by a relatively low specificity for acute MI. Most protocols utilizing myoglobin seek to exploit the high sensitivity in order to perform a rapid "rule-out" of MI.[97] CK-MB was the previously preferred test for evaluating for myocardial necrosis from MI. Troponins (troponin I or troponin T) are now being used as the primary markers for myocardial necrosis and MI, particularly when attempting to "rule in" a diagnosis of acute MI, and the American College of Cardiology and European Society of Cardiology embraced troponins in their 2000 joint statement on the definition of myocardial infarction.[62,97–99] All of these biomarkers are indicative of myocardial necrosis, and therefore they are only reliably elevated in MI, but the failure to detect a rise does not eliminate the presence of cardiac ischemia. Furthermore, because there is a delay in detectable serum levels of these biomarkers after MI, a single laboratory result does not reliably rule out MI if the level is obtained within the first few hours of the MI.[62,97] Serial cardiac markers, especially when obtained 6 hours or more following symptom onset, demonstrate a much improved sensitivity, nearing 98–100%.[100] Even when only one of the markers is elevated (e.g., elevated CK-MB in conjunction with a normal troponin value), patients are still at higher risk for adverse events. Troponin elevation, however, tends to be more reliably predictive of adverse events.[101,102]

Cardiac markers, especially troponin, are also being evaluated for their role in diagnosing aortic dissection and pulmonary embolism. Troponin levels may be elevated above the threshold defining acute myocardial infarction in close to 10–11% of patients with acute aortic dissection, especially with a type A or ascending dissection, but the specificity of troponin testing for aortic dissection is not adequate to differentiate this condition from an acute MI.[103–104] Several studies have examined the role of troponin T or troponin I testing for pulmonary embolism and, while some studies show elevated troponin levels with massive PE/right ventricular dysfunction, the overall specificity of troponin testing in differentiating a primary myocardial infarction remains unclear. Some suggest combined approaches that utilize troponin testing followed by acute echocardiography in appropriate patients.[105]

The other major laboratory test that has utility in the diagnosis of chest pain syndromes is the D-dimer. In one large, prospective observational study, the rate of developing venous thromboembolism at three months after the onset of symptoms in patients with a low clinical probability and negative D-dimer result is only 0.5%.[106] Obtaining D-dimer testing in very low-risk, or in moderate-to-high-risk patients, will result in significant numbers of false positive or false negative tests, respectively. The PIOPED II investigators also recommend clinical evaluation, followed by D-dimer testing in appropriate patients, with CT pulmonary angiography and CT venography for patients in whom further testing is needed.[107]

Other laboratory tests may have roles once a critical chest pain diagnosis is confirmed (e.g., correctable anemia in a patient with cardiac ischemia or acute MI), but there is little diagnostic benefit to most other laboratory tests for acute chest pain syndromes.

Disposition of emergency department patients with chest pain

Most of the critical diagnoses associated with chest pain represent serious conditions where admission to the hospital or directly to the operating room is indicated. This seems straightforward with patients diagnosed with acute MI, acute aortic dissection, pulmonary embolism, esophageal rupture, cardiac tamponade, or tension pneumothorax. Admission of patients with pericarditis is less clear, and often depends upon other co-morbid conditions and current clinical findings, as well as the underlying etiology of the pericarditis. Pneumothorax without tension presents similar challenges. While a large pneumothorax that requires a tube thoracostomy warrants an admission, it is less true for patients with a small pneumothorax. These patients often may be managed with a short-term (i.e., 6 hour) observation and repeat chest X-ray study, followed by discharge with close follow-up; needle aspiration of the pneumothorax in the ED followed by discharge home; or simple outpatient observation with close follow-up and repeat chest X-ray studies.[108] A variety of scoring systems have been used to assist with disposition decisions regarding patients with pneumonia, including the PORT score/pneumonia severity index and the CURB-65 score.[109–111] Some patients with chest pain may have musculoskeletal pain, and may be safely discharged to home, as can the majority of patients with acute herpes zoster-related pain. Patients may also have gastrointestinal-related symptoms such as esophageal spasm, gastroesophageal reflux disease, or other syndromes, and these patients usually can be discharged to home, if the diagnosis can be clearly established.

Unfortunately, there is considerable overlap in the clinical findings for these various conditions, and admission or further testing is warranted to exclude a serious potential cause of the chest pain. In all of these cases, clinical judgment supersedes all testing and guidelines.

Section IV: Decision making

- Careful consideration must be made of the critical chest pain differential diagnoses including:
    acute coronary syndrome
    aortic dissection
    pulmonary embolism
    esophageal rupture
    pericarditis/cardiac tamponade
    tension pneumothorax
- Less critical diagnoses include non-tension pneumothorax, pneumonia, musculoskeletal problems, and herpes zoster.
- Evaluation for all of these entities starts with a focused history and physical examination.
- EKG and chest X-ray study are indicated in most patients with chest pain.
- Further testing and consultations are guided by clinical presentation.
- Cardiac biomarkers and D-dimer testing should be considered.
- Chest pain attributable to one of the critical diagnoses above warrants admission.
- Use of clinical judgment is paramount.

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