Radiological tests in investigations of atypical chest pain

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BACKGROUND
Atypical chest pain (ACP) is a diagnostic challenge that often requires multiple laboratory and radiological investigations. While radiological procedures may not be the first line of investigation in most cases, they are invaluable when appropriately applied. Physicians need to have a good understanding of the capabilities and limitations of these constantly evolving imaging modalities.

OBJECTIVE
This article provides an overview of radiological modalities as they relate to the investigation of ACP. The focus is on radiological procedures that general practitioners may come across when investigating their patients. A brief outline is provided of specialist radiological investigations. The nature of the procedures, their diagnostic yield and appropriateness are addressed. Nonradiological procedures such as coronary angiography, stress tests, ventilation/perfusion scan, resting myocardial perfusion scan, echocardiography and gastroscopies are not discussed.

DISCUSSION
While a thorough history and careful physical examination is paramount, diagnostic imaging is indispensable in patients presenting with ACP. Chest X-ray is almost universally obtained. Other modalities are of value only when appropriately applied.

In a patient with chest pain, acute myocardial infarction (AMI) is among the most vital conditions requiring urgent diagnosis and treatment. It is typically diagnosed by a detailed history confirmed by electrocardiograph (ECG) and serum marker changes. In this article, we define 'atypical chest pain' (ACP) as chest pain that does not have a clinical presentation characteristic of a specific diagnosis or when the typical history of AMI is not supported by investigation results.

Table 1 lists the causes of ACP in their approximate order of frequency,[1,2] and with their most relevant radiological investigations (some, such as gastroesophageal reflux and peptic ulcer, are also commonly investigated endoscopically; and ECG plays a major role in the assessment of ischaemic heart disease and pericarditis).

Initial imaging

Initial radiological study in ACP (if imaging is indicated by history and examination) is usually a chest X-ray to exclude conditions such as pneumonia, rib fracture, pneumothorax, or cardiovascular complications such as congestive heart failure. Further imaging studies will be dictated by the specific circumstances of each case, availability of specialist services, financial considerations, and preference of both the patient and their general practitioner.

Gastroesophageal conditions

Gastroesophageal reflux

Gastroesophageal reflux is the most common cause of ACP. It can usually be diagnosed on history and if there is an appropriate response to treatment, often there is no need for further investigation. If required, the investigation

Table 1. Causes of atypical chest pain with relevant radiological investigations

Condition	Radiological investigations	
	First line	Second line
Gastroesophageal conditions		
Gastroesophageal reflux		Barium swallow
Hiatus hernia		Chest X-ray/barium swallow
Oesophageal motility disorders		Barium swallow/chest X-ray
Spasm		Barium swallow
Peptic ulcer		Barium meal
Gallstones/cholecystitis	Ultrasound	CT or MRI cholangiogram
Pancreatitis	CT	MRI
Rupture/Mallory Weiss syndrome	Chest X-ray	Gastrographin swallow
Ischaemic heart disease	Chest X-ray	CT calcium scoring Functional CT and MRI
Other cardiovascular conditions		
Pericarditis	Chest X-ray	Ultrasound/CT/MRI
Aortic dissection	CT	MRI
Pulmonary conditions		
Pneumonia	Chest X-ray/CT	
Pneumothorax	Chest X-ray/CT	
Pulmonary embolus	Chest X-ray/CTPA/VQ scan	
Tumours	Chest X-ray	CT
Hemorrhagic conditions	Chest X-ray/CT	
Pleuritis		
Musculoskeletal		
Disc space disorder	CT	MRI
Nerve compression	X-ray/CT	MRI
Muscle tears/strains	Ultrasound	MRI
Chest wall fractures	Chest X-ray	CT/bone scan
Costochondritis		Nuclear medicine
Chest wall syndromes/conditions		
Breast conditions	Mammography	
Herpes zoster		
Other		
Trauma	Chest X-ray	CT
Psychosomatic		
Referred pain		
Medication related pain[3]		

of choice is gastroscopy.[3]

Reflux can also be demonstrated on barium studies, as well as nuclear medicine studies. Nuclear medicine is most commonly used in infants and children as it has a lower dose of radiation, is less invasive, and structural abnormalities are less likely in this age group.

Motility disorders

Motility disorders such as achalasia, presbyesophagus and diffuse spasm as a cause of oesophagus related ACP are diagnosed by a dynamic barium swallow study.

Ordering barium studies

There are three different types of barium studies and a different commercial barium suspension is used to optimise each type of study. The request for a 'barium swallow and follow through' is an oxymoron as barium swallow looks at the oesophagus and gastroesophageal junction; barium meal looks at the stomach and the first part of the duodenum; barium follow through looks at the small bowel. Because of the different physical properties of the suspensions, mixing them results in nondiagnostic studies.

Hiatus hernia

Hiatus hernia is usually asymptomatic, but can cause symptoms such as ACP. It is seen on many modalities including chest X-ray (*Figure 1*), barium studies and computerised tomography (CT) scans.

Peptic ulcer

Peptic ulcer is often clinically suspected and investigated successfully with gastroscopy. The main role of radiology is in the investigation of complications, mainly perforation. Chest X-ray is the modality of choice as the first step when looking for free gas under the hemidiaphragm. Computerised tomography is more sensitive but is mainly done in an emergency department setting.

Acute cholecystitis

Ultrasound is the investigation of choice with both a positive and negative predictive value approaching 99%.[4,5] Acute cholecystitis is indicated by:

- a positive sonographic Murphy sign (reproduction of clinical Murphy sign but on direct pressure on gall bladder as visualised on ultrasound)
- thickening of the gall bladder wall by >3 mm
- pericholecystic fluid
- the presence of gallstones (whether impacted or not).

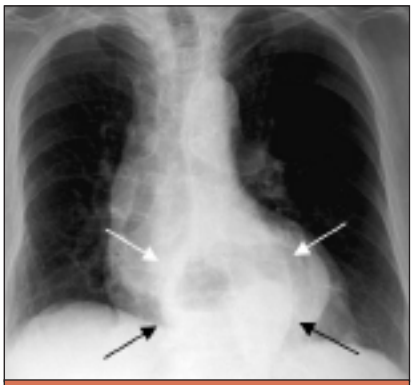

Figure 1. Hiatus hernia seen behind the heart as a soft tissue density with a gas/fluid level

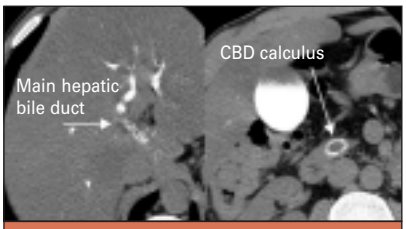

Figure 2. CT IVC: axial liver images with main hepatic duct and common bile duct (CBD) calculi outlined by contrast

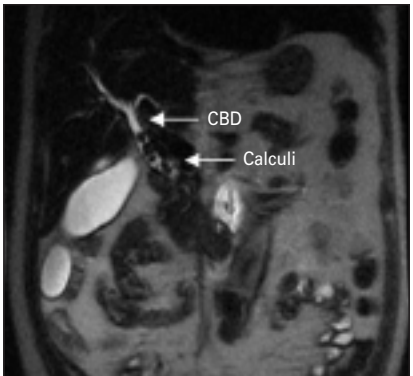

Figure 3. MRCP: coronal image demonstrating calculi in common bile duct

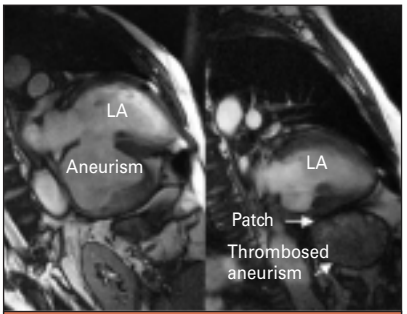

Figure 4. Sagital cardiac MR: left ventricular aneurism pre- and post-repair

Cholangitis

Cholangitis is diagnosed clinically and cannot be diagnosed with ultrasound. Ultrasound is also of a limited value in obese patients and is operator dependent.

Disorders of intra and extra hepatic bile ducts

Disorders of intra and extra hepatic bile ducts are best assessed with CT intravenous cholangiogram (CTIVC) (*Figure 2*) and magnetic resonance cholangio-pancreatography (MRCP) (*Figure 3*). Computerised tomography intravenous cholangiogram requires injection of intravenous contrast. Biliscopin is used at most institutions around Australia and involves the risk of contrast reactions; bilirubin levels should be no greater than twice the normal values. Magnetic resonance cholangio-pancreatography does not require contrast injection, but has the usual limitations of MRI such as contraindication to a pacemaker. Both modalities have an advantage over ERCP of: not having surgical complications (most notably pancreatitis), detecting lesions beyond endoscopically seen mucosal surface, no requirement for sedation or anaesthesia, and are less expensive. The limitation of these modalities is the inability to immediately treat or perform a biopsy. They are most commonly used to investigate patients who are suspected to have more than just simple cholecystitis and to exclude conditions such as malignancy, strictures, and intraductal calculi.

Pancreatitis

Pancreatitis is clinically rated as mild to severe based on clinical indicators and numerical scoring. Computerised tomography based scoring is also available and recent studies indicate that it is more sensitive than clinical scoring for prediction of mortality and morbidity.[6]

In clinically mild pancreatitis (which is a self limiting condition) ultrasound should be performed to identify biliary calculi as their prompt removal reduces morbidity.[7]

In clinically acute pancreatitis, CT scanning is the investigation of choice to assess the severity of pancreatitis including the extent of pancreatic necrosis. Follow up CT scans are useful in the assessment of subacute and late complications such as pseudocyst formation, splenic artery pseudoaneurysm and abscess formation.[8]

Oesophageal rupture

Oesophageal rupture has many causes, mainly traumatic or from foreign body impaction such as chicken or fish bones, dentures and tablets. There are other rare but classic causes of ruptured oesophagus.

Mallory Weiss syndrome, a tear of mucosa and submucosa (but not transmural) with involvement of venous plexus and massive painless haematemesis after

repeated vomiting, is seen typically in alcoholics. There are no findings on a plain film. Contrast study is not done as the diagnosis is made clinically.

Boerhaave syndrome is a complete transmural disruption of the oesophageal wall with extrusion of gastric content into pleural cavity with sudden chest/epigastric pain but without hematemesis. Chest X-ray will demonstrate a hydropneumothorax and a contrast study can confirm the diagnosis.

Both of these conditions need to be managed in the emergency department setting.

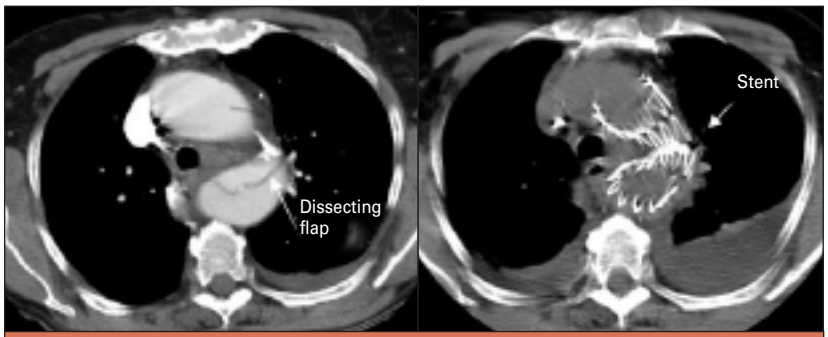

Figure 5a, b. Axial CTPA: thoracic aortic dissection pre- and post-successful endoluminal stenting

Ischaemic heart disease

Chest X-ray will diagnose complications such as cardiac failure and occasionally underlying or related cardiac and pulmonary conditions such as cardiomyopathy or late stages of valvular disease.

Coronary angiography is the gold standard for evaluation of coronary artery stenosis and delineation of vascular anatomy[9] and allows balloon angioplasty and stenting. However, it does not provide functional information and is associated with one in 1400 mortality.[9]

The current role of MRI is structural evaluation of atria, ventricles (*Figure 4*) and pericardium, myocardial ischaemia and assessment of wall motion abnormality. The emerging roles include visualisation of coronary arteries and evaluation of myocardial viability utilising perfusion techniques[10] (see the article by Alex Pitman this issue).

Multidetector CT (MDCT) allows evaluation of structural abnormalities such as cardiomyopathy, indirect diagnosis of pulmonary hypertension and complications such as ventricular aneurysms. Recent studies suggest that 16 and higher detector MDCT coronary angiography (performed with administration of contrast and using cardiac gating) is both sensitive and specific in diagnosing significant coronary artery stenosis in patients with ACP.[11,12]

Electron beam tomography (EBT) is a highly specialised CT scanner, where instead of an X-ray tube and opposing detectors moving around the patient, an electron beam is directed at a donut of X-ray producing material with another donut of receptors surrounding it, the patient being inside the 'imaging donut'. Thus, very fast imaging of a patient inside these donuts can be obtained by moving the electron beam around the patient in microseconds. Obviously, this equipment is far more expensive than usual scanners and is only used in specialised centres.

Both MDCT and EBT have been used for coronary artery calcium scoring.[10,12] The amount of coronary artery calcium directly correlates with plaque burden and presence of severe coronary arterial stenosis. However, it is only a statistical correlation and this modality does not provide information on whether the plaque is in a critical location, or whether it is stable or ulcerated, and absence of calcium does not exclude a plaque.

We have limited our discussion of these modalities as they are in a process of rapid evolution and the future will see wider clinical applications as the techniques become more robust.

Other cardiovascular conditions

Pericarditis, when associated with a pericardial effusion in acute stages, can be detected with ultrasound, CT and MRI. Chest X-ray is suggestive but not diagnostic.

Aortic dissection is best examined with contrast enhanced MDCT (*Figure 5a, b*) to assess whether the dissection is above or below the left subclavian artery, which determines whether thoracotomy and repair or endoluminal repair are used. Catheter angiography however, is the gold standard, as well as allowing management with endoluminal stents at the same time.

Chest wall syndromes/conditions

Breast conditions such as mastitis, abscesses and malignancy occasionally present with ACP. They are detected clinically and may be investigated further with mammography and ultrasound. The role of imaging is well recognised and well described elsewhere. Costochondritis rarely requires (or is seen by) radiography.

Pulmonary conditions

Pneumonia

Pneumonia is often easily diagnosed on chest X-ray. However, there is a well recognised delay of up to 2 days between onset or resolution of clinical symptoms and changes on chest X-ray. Some chest X-ray patterns are said to be specific to particular pathogens, such as bulging of a horizontal fissure in Klebsiella pneumonia. However, these are statistical correlations and should not guide the choice of antibiotics.

In children and young adults there is no need

for follow up chest X-ray after treatment unless there is poor response to treatment or complications are suspected. In more mature individuals and those at risk of an endobronchial malignancy, follow up chest X-ray is appropriate. It should be ordered shortly after symptoms have clinically resolved, or if there is no response to appropriate treatment.

Chest X-ray is widely available and is the least expensive modality of choice to screen for or to diagnose suspected pulmonary tuberculosis.

In all types of pneumonia however, CT is more sensitive and specific than chest X-ray (while also being more expensive and less available), and allows better visualisation of lymph nodes, bronchial walls and other thoracic structures. It is not necessary to order CT in most cases unless complications or malignancy are suspected. Once again, imaging is complementary to clinical judgment and it is the patient who should be treated, not their X-ray.

Pulmonary embolus

Pulmonary embolus (PE) is difficult to diagnose clinically. Imaging is usually required to decide on the need for anticoagulation. The question most commonly asked is: 'Which to order: ventilation/perfusion (V/Q) or CT pulmonary angiogram (CTPA)?' Despite a multitude of studies to address this issue, there is still controversy and few standard protocols regarding the best modality.[13] This reflects continuous evolution of technology, different protocols employed, different levels of expertise, different clinical threshold for ordering the investigations, competing financial interests, and different population biases in the studies.

In the opinion of the authors, MDCT pulmonary angiogram (MDCTPA), where available, is the investigation of choice for PE (*Figure 6a, b*). In technically adequate studies, MDCTPA allows visualisation far beyond the clinically significant segmental pulmonary arteries.[14] In addition, other causes of chest pain can be diagnosed, there is no limitation of underlying lung conditions encountered with V/Q scan, and venous thrombosis (DVT) can be diagnosed if CT venogram protocol is added, comparable in accuracy to a Doppler ultrasound.[15]

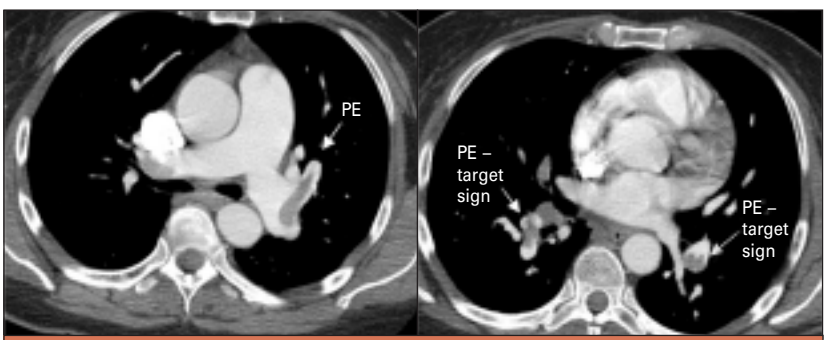

Figure 6a, b. CTPA: pulmonary emboli (PE)

The limitations of MDCT are contrast reactions, renal impairment, inadequate opacification of pulmonary arteries due to poor cardiac function, respiratory motion artefacts in tachypnoeic patients and other technical factors. This excludes about 2–10% of patients depending on the selected population, and certainly will be at the lower end of the spectrum in a GP setting as compared to hospital patients.

Of importance, CTPA has a lower radiation dose to the fetus in pregnant women than V/Q scan.[16]

MDCTPA and V/Q costs are comparable; MDCTPA is faster, has less limitations, higher sensitivity and specificity for PE and a higher diagnostic yield if other pathologies are present.

Doppler ultrasound of the lower limb deep veins is a complementary test when an imaging diagnosis is uncertain but there is a high clinical suspicion of PE that may warrant anticoagulation.[8,14] However, in isolation this test is of limited value as it is of low specificity and absence of DVT does not exclude PE.[17,18] Blood tests such as D dimer and L Dimer can also contribute to diagnostic considerations, especially when negative.

Pneumothorax

Pneumothorax when suspected clinically is confirmed on chest X-ray. Its size and any life threatening tension can be identified with implications for treatment choice. Computerised tomography is more sensitive, but is used predominantly in trauma and complicated cases.

Hemorrhagic conditions

Hemorrhagic conditions of the lung parenchyma are rare, and causes include vasculitidies (such as Goodpasture syndrome), drug reactions, and trauma. The reason for mentioning these is to highlight the importance of a relevant clinical history. The pattern of pulmonary haemorrhage on chest X-ray and CT is often that of nonspecific alveolar opacities, and the diagnosis can only be made in the clinical context.

Pleuritis

Pleuritis imaging is noncontributory unless there is a pleural effusion. Computerised tomography may be useful to diagnose empyema. Magnetic resonance imaging can detect inflammatory changes in the pleura by detecting fluid and enhancement in the inflamed tissues.

Musculoskeletal

Disc space disorders in the thoracic and cervical spine are uncommon causes of ACP. The most serious disorder to consider is discitis. Plain film and CT changes are only present in late stages. Magnetic resonance imaging is the gold standard and has very high specificity and sensitivity even in early stages and allows detection of complications, specifically epidural abscess or cord compression. Biopsy can be done under CT.

Muscle tears and sprains of the chest wall, common in athletes or elderly people, are diagnosed clinically. Ultrasound can confirm the diagnosis.[19]

Chest wall fractures, mainly of the ribs, either traumatic or pathological due to osteoporosis or metastatic malignancy, are initially investigated with plain films. In the setting of osteoporosis, loss of vertebral body height by more than 20% is sufficient for the Pharmaceutical Benefits Scheme to subsidise the relevant medications. Dual energy X-ray absorption spectrometry (DEXA) – also rebated based on specific guidelines – is the most useful modality to assess osteoporosis. When pathological crush fractures are symptomatic, vertebroplasty is a useful treatment option (see the article by Murali Guduguntla this issue).

When pathological fractures are caused by metastasis, MRI is the investigation of choice.

Conclusion

Diagnostic imaging is indispensable in patients presenting with ACP in whom the diagnosis is not apparent following careful history taking, physical examination, and any appropriate other investigations. This article has presented those radiological investigations that GPs are likely to find most useful to complement their clinical assessment. Chest X-ray is almost universally obtained as part of the initial work up. Other modalities are of value only when appropriately applied.

Summary of important points

- The initial study in investigation of ACP is almost always a chest X-ray.
- Ultrasound has a sensitivity and specificity for cholecystitis of >95%. It is however, difficult in patients with large body habitus, is operator dependant, and cannot diagnose cholangitis.
- In acute pancreatitis, CT based scoring is available and likely to be more sensitive than clinical scoring for prediction of mortality and morbidity
- MDCT angiography when available is now an established modality in the evaluation of vascular abnormalities, particularly for conditions such as aortic dissection and pulmonary embolism.

Conflict of interest: none declared.

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