Clinical imaging
Skills and techniques
Update 2012 (pdf)

Module Authors (Update 2012)
Brian Daragh Murphy, Ferdia Bolster, Eoin Kavanagh and John Murray
Department of Radiology
Mater Misericordiae University Hospital
Dublin, Ireland

Module Authors (first edition)
Eoin Kavanagh and John Murray
Department of Radiology
Mater Misericordiae University Hospital
Dublin, Ireland

Module Reviewers
Colman O’Loughlin
Ethna Phelan
Janice Zimmerman

Guest Editors
John Bates
Ethna Phelan
# Clinical imaging
## Update 2012

<table>
<thead>
<tr>
<th>Role</th>
<th>Name and Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editor-in-Chief</td>
<td>Dermot Phelan, Dept of Critical Care Medicine, Mater Hospital/University College Dublin, Ireland</td>
</tr>
<tr>
<td>Deputy Editor-in-Chief</td>
<td>Position vacant</td>
</tr>
<tr>
<td>Medical Copy-editor</td>
<td>Charles Hinds, Barts and The London School of Medicine and Dentistry</td>
</tr>
<tr>
<td>Self-assessment Author</td>
<td>Hans Flaatten, Bergen, Norway</td>
</tr>
<tr>
<td>Editorial Manager</td>
<td>Kathleen Brown, Triwords Limited, Tayport, UK</td>
</tr>
<tr>
<td>Business Manager</td>
<td>Estelle Flament, ESICM, Brussels, Belgium</td>
</tr>
<tr>
<td>Chair of Education and Training Committee</td>
<td>Marco Maggiorini, Zurich, Switzerland</td>
</tr>
</tbody>
</table>

## PACT Editorial Board

<table>
<thead>
<tr>
<th>Role</th>
<th>Name and Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editor-in-Chief</td>
<td>Dermot Phelan</td>
</tr>
<tr>
<td>Deputy Editor-in-Chief</td>
<td>Position vacant</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>Anders Larsson</td>
</tr>
<tr>
<td>Cardiovascular critical care</td>
<td>Jan Poelaert/Marco Maggiorini</td>
</tr>
<tr>
<td>Neuro-critical care</td>
<td>Mauro Oddo</td>
</tr>
<tr>
<td>Critical Care informatics, management and outcome</td>
<td>Carl Waldmann</td>
</tr>
<tr>
<td>Trauma and Emergency Medicine</td>
<td>Janice Zimmerman</td>
</tr>
<tr>
<td>Infection/inflammation and Sepsis</td>
<td>Johan Groeneveld</td>
</tr>
<tr>
<td>Kidney Injury and Metabolism.</td>
<td>Charles Hinds</td>
</tr>
<tr>
<td>Abdomen and nutrition</td>
<td></td>
</tr>
<tr>
<td>Peri-operative ICM/surgery and imaging</td>
<td>Torsten Schröder</td>
</tr>
<tr>
<td>Professional development and Ethics</td>
<td>Gavin Lavery</td>
</tr>
<tr>
<td>Education and assessment</td>
<td>Lia Fluit</td>
</tr>
<tr>
<td>Consultant to the PACT Board</td>
<td>Graham Ramsay</td>
</tr>
</tbody>
</table>

Copyright © 2012. European Society of Intensive Care Medicine. All rights reserved.
LEARNING OBJECTIVES
After studying this module on Clinical imaging, you should be able to:

1. Define the role of imaging in intensive care medicine and detail the assessment of everyday, important critical care images – the chest and the cervical spine X-rays.
2. Determine appropriate imaging for the patient with intrathoracic disease.
3. Determine appropriate imaging for the patient with circulatory dysfunction.
4. Determine appropriate imaging for the patient with spinal disease.
5. Determine appropriate imaging for the patient with abdominal disease.

FACULTY DISCLOSURES
The authors of this module have not reported any disclosures.

DURATION
7 hours
# Introduction

1/ Understanding the role of imaging in intensive care medicine

<table>
<thead>
<tr>
<th>Indications for imaging</th>
<th>Choice of imaging modalities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plain radiographs</td>
</tr>
<tr>
<td></td>
<td>Ultrasound</td>
</tr>
<tr>
<td></td>
<td>Computed tomography</td>
</tr>
<tr>
<td></td>
<td>Nuclear medicine</td>
</tr>
<tr>
<td></td>
<td>Magnetic resonance imaging</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazards associated with imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation protection</td>
</tr>
<tr>
<td>Intravenous contrast agents</td>
</tr>
<tr>
<td>MRI safety</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost/benefit of imaging</th>
</tr>
</thead>
</table>

2/ Using imaging – The patient with intrathoracic disease

<table>
<thead>
<tr>
<th>Chest radiography – normal appearances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspiration</td>
</tr>
<tr>
<td>Rotation</td>
</tr>
<tr>
<td>Penetration</td>
</tr>
<tr>
<td>The heart and cardiothoracic ratio</td>
</tr>
<tr>
<td>Diaphragms</td>
</tr>
<tr>
<td>Hila</td>
</tr>
<tr>
<td>Bones</td>
</tr>
<tr>
<td>Lung zones</td>
</tr>
<tr>
<td>Widened mediastinum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Barotrauma</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Imaging of tubes/catheters/circulatory supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ICU chest X-ray</td>
</tr>
<tr>
<td>Tracheal tube position</td>
</tr>
<tr>
<td>Central venous catheters</td>
</tr>
<tr>
<td>Pulmonary arterial catheters</td>
</tr>
<tr>
<td>Enteral tube placement</td>
</tr>
<tr>
<td>Chest drains</td>
</tr>
<tr>
<td>Intra-aortic balloon pump</td>
</tr>
<tr>
<td>Extracorporeal Membrane Oxygenation</td>
</tr>
<tr>
<td>Left ventricular assist device</td>
</tr>
<tr>
<td>Cardiac pacemakers</td>
</tr>
<tr>
<td>Thoracic trauma</td>
</tr>
<tr>
<td>Thoracic skeletal injuries</td>
</tr>
</tbody>
</table>
Aortic and great vessel injuries ........................................................................................................ 22
Pulmonary contusion and pulmonary laceration ........................................................................ 22
Tracheobronchial injury ............................................................................................................... 23
Cardiac injuries ............................................................................................................................. 23
Diaphragmatic injury ................................................................................................................... 23

3/ Using imaging – The patient with circulatory disease or dysfunction .......................................... 25
Pulmonary embolic disease ............................................................................................................. 25
Deep venous thrombosis .................................................................................................................. 25
Indications for placement of inferior vena caval filters .............................................................. 26
Aortic dissection ........................................................................................................................... 27
Aortic aneurysms .......................................................................................................................... 28
Endovascular treatment of abdominal aortic aneurysms ........................................................... 29
Imaging of pulmonary oedema ........................................................................................................ 29
CT in ARDS .................................................................................................................................... 31

4/ Using imaging – The patient with spinal disease .......................................................................... 32
Spinal trauma ................................................................................................................................... 32
Cervical spine assessment ................................................................................................................ 32
Bony alignment ............................................................................................................................. 32
Vertebral body height .................................................................................................................... 32
Intervertebral disc height ............................................................................................................. 32
Prevertebral soft tissues ................................................................................................................. 32
Posterior elements ........................................................................................................................ 32
CT scanning/screening ................................................................................................................... 33
Magnetic resonance imaging ....................................................................................................... 34
Spinal cord injury without radiographic abnormality ................................................................ 35
Spinal cord compression ................................................................................................................ 36
Spinal infection – discitis and epidural abscess ........................................................................... 37

5/ Using imaging – The patient with abdominal disease ................................................................... 38
Bowel obstruction, ileus and perforation ........................................................................................ 38
Obstruction ................................................................................................................................... 38
Ileus ............................................................................................................................................... 39
Perforation .................................................................................................................................... 39
Intestinal ischaemia ....................................................................................................................... 39
Acalculous cholecystitis ............................................................................................................... 40
Intra-abdominal collections, abscesses and pancreatitis ............................................................ 41
Trochar technique ........................................................................................................................ 44
Seldinger technique ...................................................................................................................... 45
Upper urinary tract ........................................................................................................................ 46
Percutaneous nephrostomy ......................................................................................................... 46
**INTRODUCTION**

Every patient admitted to the intensive care unit (ICU) will require imaging. Imaging modalities range from the straightforward and relatively inexpensive plain radiograph to more sophisticated and complex investigations such as magnetic resonance (MR) and positron emission tomography (PET) scans. The availability of more complex investigations typically depends upon hospital size and local economic factors.

This module addresses areas of clinical imaging that are particularly relevant to the critical care practitioner especially the chest X-ray; also the cervical spine X-ray. It is not intended to be all encompassing, as imaging is incorporated directly into many other modules. This new update of the module focuses on the continuum of communication between the critical care team and the radiologist with particular reference to the choice of imaging modality and role of interventional radiology.
1/ UNDERSTANDING THE ROLE OF IMAGING IN INTENSIVE CARE MEDICINE

**Indications for imaging**

The ultimate decision regarding the appropriateness of a specific radiological examination or treatment must be made by the referring physician and radiologist in light of individual patient circumstances. However, there are guidelines available from both the American College of Radiology (ACR) and the Royal College of Radiologists (RCR) UK, to help the referring physician choose the most appropriate imaging modality.

The ACR has published sets of ‘Appropriateness Criteria’ which allow for the fact that certain scans may not be available on site. These very useful criteria are available on the ACR website and make a handy reference guide when ordering more complex investigations as frequently occurs in the ICU.


Also available for reference are the RCR Referral Guidelines; the most recent seventh edition of these guidelines has been renamed iRefer and is available from the RCR website at the link below:

http://www.rcr.ac.uk/content.aspx?PageID=995

**Note** It is important to remember that referral of a patient for a radiological examination is a consult to a radiologist. It is important that the reasons for the investigation should be clearly stated, along with the appropriate clinical information. This helps the radiologist decide on the most appropriate investigation, which in some cases may be an alternative imaging modality. Consultation with radiologists can be particularly useful in complex ICU patients when multiple imaging modalities may be needed to reach a specific diagnosis.

**Choice of imaging modalities**

*Plain radiographs*

Chest radiographs are the most frequently performed radiological investigation in the ICU. They are an extremely useful clinical tool, and commonly alter patient management. In addition to assessing heart or lung disease, they are used to assess placement of tubes and intravascular catheters, and to exclude complications from same. Many patients have routine daily chest radiographs. This practice is controversial and increasing evidence suggests it is not cost-effective nor does it improve patient morbidity, mortality or length of stay.
Occasionally other plain radiographs are performed in the ICU. These include plain radiographs of the abdomen or, following trauma, cervical spine, facial bones, or extremities. Lateral decubitus chest radiographs help differentiate pleural fluid from other causes of lower zone opacification based on layering of pleural fluid to a dependent position. A lateral shoot through view can also be helpful in detecting pneumothoraces in patients who cannot be moved from the supine position. Lateral decubitus views of the chest can be useful in verifying pulmonary artery catheter position (i.e. above or below left atrium). Similarly a lateral decubitus view of the abdomen can be helpful in detecting free intraperitoneal air which is seen to collect over the right lobe of liver in the left lateral position.

Review the chest radiographs performed over a one-week period in your ICU. Write a report on each radiograph and compare your report with the radiologist’s report. Discuss any discrepancies with a radiology colleague.

**Ultrasound**

Ultrasound is an extremely useful and versatile imaging modality particularly suited to the ICU setting. The use of bedside ultrasound by intensivists is increasingly common for a wide variety of clinical problems.

The major advantages of real time imaging by ultrasound are: the lack of ionising radiation; the ability to perform scans in the ICU; the facilitation of bedside
interventional procedures including drainage of abdominal, pelvic or pleural collections and the placement of arterial and (usually central) venous catheters.

Transthoracic and/or transoesophageal echocardiography is often used in the ICU to assess left and right ventricular function in critically ill and postoperative patients. Furthermore bedside echocardiography may facilitate diagnosis of postoperative complications such as acute valvular dysfunction, aortic dissection and pericardial or pleural effusions.

Chest ultrasound has been shown to be more useful than supine radiography for the detection of pneumothorax, equalling the diagnostic accuracy of computed tomography (CT) in one study.

Other uses for bedside ultrasound in the ICU include the assessment of patient fluid status and the assessment of PEEP induced lung recruitment.

The addition of Doppler enables assessment of perfusion of renal and liver transplants, and assessment of lower limbs for deep venous thrombosis. Focused Assessment with Sonography for Trauma (FAST) is a limited ultrasound examination directed at identifying free fluid in the pelvis, peritoneum and pericardium. The use of the FAST assessment has become widespread practice both in the ICU and the emergency room. FAST assessment is indicated in patients who have a history of abdominal trauma, are hypotensive or in those who are unable to provide a reliable history due to impaired consciousness.


**Computed tomography**

Computed tomography (CT) is a commonly requested investigation on patients in the ICU and a wide range of traumatic and non-traumatic emergency conditions can be
diagnosed quickly and accurately with spiral or multislice CT. Since its introduction in the early nineties, spiral CT scanning with a single row of detectors has revolutionised imaging e.g. of thoracic trauma. Today multidetector CT scanners can quickly and accurately diagnose and display a wide range of injury and pathology.

Many traditional emergency imaging procedures have been replaced with newer helical CT techniques that can be performed in less time and with greater accuracy, less patient discomfort, and decreased cost. The speed of helical technology permits CT examination of seriously ill patients who might not have been taken to CT previously because of long scan times. Also, helical technology permits multiple, sequential CT scans to be quickly obtained in the same patient, a great advance for the ICU patient. Higher quality CT examinations result from decreased respiratory artefact, enhanced intravenous contrast opacification of vascular structures and parenchymal organs, greater flexibility in image reconstruction, and improved multiplanar and three-dimensional reconstructions.

Specific indications commonly include: CT diagnosis of thoracic aortic trauma; aortic dissection; CT pulmonary angiography; abdominal trauma; urinary tract stones; appendicitis; pancreatitis, diverticulitis, colitis; abdominal aortic aneurysm; fractures of the face, spine, and extremities; and acute stroke.

Q. What is multislice CT and how does it confer advantage over regular spiral CT scanning?

A. Multislice CT uses a bank of up to 16 detectors as opposed to a single bank of detectors offered by regular spiral scanning. This allows the acquisition of an isotropic data set, which allows multiplanar and three-dimensional reconstructions.

Q. What practical, clinical advantages does multislice CT confer over regular spiral CT scanning?

A. Multislice scanners also allow for more rapid scanning at a higher resolution with the need for less intravenous contrast agents.


Nuclear medicine

Nuclear medicine studies are rarely requested on ICU patients. One of the reasons for this is that many nuclear medicine examinations require the patient to be in the radiology department for long periods of time. Bedside scanning can be performed with a mobile gamma camera, but is not widely available. Traditionally V/Q scanning
was the most frequently requested nuclear medicine scan, but with the availability of multislice CT, CT pulmonary angiography has become the test of choice for the ICU patient with a suspected pulmonary embolus. Also, with nuclear imaging studies there are increases in radiation doses to staff. This is of particular relevance in the ICU where staff are in close contact with patients for long periods of time.

The following paper highlights the potentially high doses to staff in the ICU if indwelling vascular catheters are used for injecting radiopharmaceuticals during bedside nuclear medicine investigations.


**Magnetic resonance imaging**

Magnetic resonance imaging (MRI) is an excellent technique for imaging the brain and spinal cord due to superb contrast resolution, lack of ionising radiation and multiplanar capability. It is superior to CT in the diagnosis of encephalitis, posterior fossa infarction, central pontine myelinolysis and in the assessment of spinal cord compression or tumour and discitis. Unfortunately although many radiology departments have MRI scanners, not all have MR compatible anaesthetic/critical care monitoring and invasive supportive equipment. MR compatible resuscitation and monitoring equipment is costly and requires regular maintenance.

**Anecdote** An MRI on a patient from an ICU takes at least one hour, even for a relatively straightforward MR scan of the brain. Remember the patient must be stable to be out of the ICU for this length of time. Considerable time is required to switch monitoring equipment, transfer the patient to an MRI compatible trolley and stabilise the patient. Close liaison with radiology is necessary to avoid delays. We recall an incident where total time for transfer of an intubated spinal trauma patient from the ICU to the MRI table took two and a half hours. The delays in this case were due to the difficult spinal lift of an intubated patient but also due to clinicians being unfamiliar with the MR compatible ventilator equipment. If transporting a critically ill patient to MRI, please familiarise yourself with the MR compatible critical care equipment there to help avoid delays which could compromise patient care.

Figure 1. Magnetic resonance cholangio-pancreatography

Good descriptions of radiological anatomy and CT and MR imaging can be found on the following website.

http://rad.usuhs.mil.rad/iong/homepage.html

[5]
Hazards associated with imaging

Radiation protection

Ionising radiation has the potential to cause permanent tissue damage and malignancy. Several measures of radiation exposure exist which allow us to determine the relative amounts of radiation involved with any particular investigation.

**Equivalent dose** – This is the absorbed dose of radiation multiplied by a radiation weighting factor which is the same for all diagnostic X-ray procedures. The unit of measurement of the equivalent dose is the Sievert (Sv).

**Effective dose** – This is the sum of the weighted equivalent doses for all the tissues which have been exposed. It is also expressed in Sieverts.

Everybody is exposed to background radiation and in the UK, for example, the annual individual background dose is 2.6 mSv. Procedures involving X-rays contribute 90% of the radiation dose from artificial sources. The doses from some commonly performed CT examinations are particularly high. CT now contributes almost half of the collective dose from all X-ray examinations. With the advent of multislice CT and its wide availability, this is likely to increase the overall contribution of CT to the collective population dose.

The following table gives some typical values of effective doses for a patient undergoing various radiological investigations.

<table>
<thead>
<tr>
<th>Diagnostic procedure</th>
<th>Effective dose</th>
<th>Equivalent period of natural background radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-ray</td>
<td>0.02 mSv</td>
<td>3 days</td>
</tr>
<tr>
<td>Intravenous urogram</td>
<td>2.5 mSv</td>
<td>14 months</td>
</tr>
<tr>
<td>Barium meal</td>
<td>3 mSv</td>
<td>16 months</td>
</tr>
<tr>
<td>Barium enema</td>
<td>7 mSv</td>
<td>3.2 years</td>
</tr>
<tr>
<td>Isotope bone scan</td>
<td>4 mSv</td>
<td>1.8 years</td>
</tr>
<tr>
<td>CT chest</td>
<td>8 mSv</td>
<td>3.6 years</td>
</tr>
<tr>
<td>CT brain</td>
<td>2.3 mSv</td>
<td>1 year</td>
</tr>
<tr>
<td>CT abdomen</td>
<td>10 mSv</td>
<td>4.5 years</td>
</tr>
<tr>
<td>Gallium imaging Ga$^{67}$</td>
<td>18 mSv</td>
<td>8 years</td>
</tr>
</tbody>
</table>
The ALARA principle

It is good practice to keep patients’ radiation exposures ‘As Low As Reasonably Achievable – ALARA’. Other measures can be employed to reduce the risks associated with radiation exposure to both patients and staff.

Q. What hospital/radiological measures are advised to reduce radiation dose to both patients and staff in the ICU?

A.
- Use investigations appropriately
- Restrict the radiation field – i.e. proper collimation
- Gonad shields should be used where appropriate
- Rooms with X-ray equipment should be under regulatory control
- A radiation protection supervisor should be appointed
- Priority should be given to tests that do not involve ionising radiation

Q. Where should ICU staff stand during portable radiography?

A. ICU staff should stand at a safe distance during portable radiography. Local guidelines will be available from the radiation safety officer. In our institution a distance of at least two metres is advised following a local study which found that there was no detectable radiation dose at this distance. Those standing inside two metres should wear protective clothing.


Intravenous contrast agents

Contrast agents are used in a variety of settings in the radiology department. For ICU patients this will normally take the form of intravenous, iodine based, contrast enhancement, often used for interventional procedures, contrast enhanced CT and MRI. Historically high osmolar agents were widely used and were associated with significant morbidity. The use of low and iso-osmolar contrast agents is now commonplace and these are estimated to be 5 to 10 times safer. The toxic effects of intravenous contrast media are a function of osmolarity, ionic charge, chemical structure and lipophilicity. Immediate adverse effects include flushing, urticaria, bronchospasm, non-cardiogenic pulmonary oedema, arrhythmias, hypotension and anaphylaxis. Toxic effects although rare may occur in the soft tissues at the injection site particularly in the setting of contrast extravasation. Nephrotoxicity, cardiovascular toxicity, neurotoxicity and haematological changes may all be seen and are more common with higher osmolarity and ionic agents. Most of these effects will be mild and self-limiting. The incidence of severe or very severe non-ionic contrast reaction is 0.044%.
Precautions should be taken for those patients with documented allergies or a history of contrast reaction where prophylactic steroids may be beneficial. Those patients with renal impairment or at risk of renal impairment may benefit from prehydration and other prophylactic measures such as N-acetylcysteine and bicarbonate.

The MR contrast agents most commonly used are gadolinium based and work by altering the magnetic resonance properties of protons in water and lipid which form the basis of the MRI image. These agents are generally safe and well tolerated and have a much lower incidence of adverse reaction than iodinated contrast agents. At higher doses gadolinium based contrast agents are potentially nephrotoxic. In patients with renal disease there is a small risk of developing nephrogenic systemic fibrosis following gadolinium contrast agents; the risk benefit of the MR examination should be carefully weighed in patients with a glomerular filtration rate (GFR) of less than 60 mL/min/1.73 m².

http://www.ajronline.org/content/188/6/1447.long

MRI safety

Extreme care is needed to prevent injury to patients and staff in the MRI department as it may be a relatively unfamiliar area to critical care personnel. There are potentially life-threatening hazards to consider and therefore the area around the MR magnet is carefully supervised. The fringe magnetic field, which extends for a few metres around the MR scanner, may convert scissors, scalpels, stethoscopes, oxygen bottles and other metallic objects into lethal projectiles and these items must NEVER be taken into the scanning room. Only MR compatible monitoring equipment should be used within the scan room. ALWAYS check with MRI staff which equipment is MR compatible.

Utmost care must be taken to ensure patients do not have metallic pacemakers, metallic heart valves or other metal prostheses which are not MRI compatible. A patient’s renal function should be checked prior to administering gadolinium contrast agents given the risk of nephrogenic systemic fibrosis.

Q. What are the patient contraindications to MRI?

A.
- Patients who have pacemaker devices and implantable defibrillators in situ
- Patients with certain heart valve prostheses
- Patients with retained metal fragments in their eyes (e.g. metal workers). If unsure, or if the patient is unconscious, obtain a plain radiograph of the orbits to rule out intraocular foreign bodies.

The following FDA website has good links to excellent and relevant sites dealing with MRI safety.
http://www.fda.gov/MedicalDevices/Safety/
Cost/benefit of imaging

The choice of appropriate radiological investigations should also reflect cost. Plain radiographs and ultrasound are relatively inexpensive examinations, whereas CT and MR scans are costly. Appropriate imaging leads to accurate diagnosis and timely therapeutic intervention and is thus cost-effective. For most patients the cost of imaging is a relatively small component of their overall ICU bill. An area of recent interest is the cost-effectiveness of the Picture Archiving Communication System (PACS). PACS offers the ability to view images on a monitor, with simultaneous access to previous studies and other modalities e.g. CT. Reports are displayed with the patient image and the capacity to manipulate the image avoids the need for repeat films at a different penetration. It permits simultaneous multisite viewing, and avoids film loss. PACS also avoids the need for film storage and manual transport of films, but is expensive due to the number of high resolution monitors needed, the memory requirements and cabling required. We believe that all intensive care units should move to PACS if funding can be obtained.

The following references discuss the controversial areas of cost-effectiveness of PACS and daily chest radiography. You can also find more information about cost-effectiveness in the PACT modules on Quality assurance and cost-effectiveness and Organisation and management.


2/ USING IMAGING – THE PATIENT WITH INTRATHORACIC DISEASE

Chest radiography – normal appearances

The vast majority of chest radiographs in the ICU setting will be performed using a portable anteroposterior (AP) technique which is less reproducible than posteroanterior (PA) technique employed in the radiology department. A brief overview and understanding of the standard PA chest radiograph will provide valuable insight and aid interpretation.

The standard PA chest radiograph is performed with the X-ray tube and cassette at a fixed distance of 180 cm (6 ft). The patient faces the cassette and the beam traverses the patient in posterior to anterior projection (PA), on full inspiration to minimise magnification of the heart. The PA chest X-ray is obtained by a standardised technique which facilitates comparison more easily with subsequent radiographs.

Inspiration

Ideally the chest X-ray should be taken at the peak of full inspiration. Incomplete inspiration can make evaluation problematic and diagnoses such as basilar atelectasis and lung oedema more difficult. Incomplete inspiration may also cause changes in the apparent size of the heart and mediastinum.

Adequate inspiration is seen if the diaphragm is intersected by the 5th to 7th anterior ribs in the mid-clavicular line.

Rotation

If the spinous processes of the thoracic vertebrae are equidistant from the medial ends of each clavicle, then there is no rotation. If the spinous process appears closer to the right clavicle then the patient is rotated to their own left side and vice versa. Patient rotation can lead to the spurious interpretation of mediastinal and hilar appearances, and asymmetry which can lead to one lung appearing blacker than the other.

Penetration

A well penetrated chest X-ray is one where the thoracic vertebrae are just visible behind the heart. Over or under-penetrated films are rarely a problem with modern digital systems, as images may be ‘windowed’ after acquisition to optimise the visibility of anatomical structures.

The heart and cardiothoracic ratio

In a normal adult the cardiothoracic ratio should be less than 50% on a PA chest radiograph on full inspiration.

An AP view can result in the magnification of anterior structures such as the clavicle, sternum, and heart. There can be up to a 15% difference between the width of the mediastinum in a standard PA and an AP view. This can lead to a misinterpretation of cardiac or mediastinal enlargement.
The heart borders should be well defined. If the cardiac contour is incompletely seen, this may be as a result of an increase in density in the adjacent lung and pathology should be suspected.

**Diaphragms**

The hemidiaphragms should be well defined, dome shaped and visible to the midline. The right hemidiaphragm will often be slightly higher than the left due to the liver. The costophrenic recesses form where the hemidiaphragm meets the chest wall. The costophrenic angles should form acute angles and be well defined.

**Hila**

The hila are predominantly composed of the pulmonary arteries and to a lesser extent the pulmonary veins. Normal lymph nodes and the bronchial walls offer only a minor contribution to the hila.

Whilst there can be a wide variation in appearances of the normal hila, many disease processes can affect the hila so core knowledge of their normal appearance on chest X-ray is important.

Both hila should be of similar size and density. The left hilum is normally higher than the right, and the right hilum should never be higher than the left. Any change in size or density of one of the hila should alert the physician that there is an abnormality.

**Bones**

Bones are often easily overlooked in interpreting a frontal chest X-ray. Bones are useful landmarks in assessing the quality of a chest X-ray, including patient rotation and adequacy of inspiration. Furthermore, fractures, bony tumours or more generalised bony pathology may be evident.

**Lung zones**

In interpreting chest X-rays, it is often useful to divide the lungs into corresponding upper, middle and lower zones. Each zone occupies approximately a third of the lung and the zones do not correspond to the lung lobes.

The lung zones should be assessed for any asymmetry and also individually, bearing in mind that disease processes can affect both lungs equally and each zone should be examined in turn.

**Widened mediastinum**

Widening of the mediastinum is most often due to technical factors such as patient positioning, AP projection or incomplete inspiration. A guideline measurement for the widened mediastinum on a properly centred, non-rotated PA radiograph is 8 cm at the level of the aortic arch; however there is considerable variability in the normal population.
Figure 2012:103. Normal PA chest radiograph. Good inspiration, properly centred with good penetration.

Figure 2012:104. Underinspired chest radiograph. Note the aberrancy of the 7th rib position – it is replaced by the 4th rib. There is increased density in both lung bases showing that underinspired films may give the impression of atelectasis in the lung bases.
**Barotrauma**

Mechanical ventilation is a risk factor for barotrauma. Although the advent of 'lung protection ventilation' has likely reduced the incidence of this complication, it is important to check for a pneumothorax or pneumomediastinum on every ICU chest radiograph.

**NOTE**

A pneumomediastinum can decompress to the pleural space causing a pneumothorax whereas a pneumothorax will never decompress into the mediastinum.

**Q. Pneumothoraces can be difficult to detect on supine portable chest radiographs. Other than the classic appearances of pneumothorax, what are the more subtle signs of pneumothorax on an ICU chest radiograph?**

**A.**

- ‘Deep sulcus sign’ – an abnormally deep and radiolucent lateral costophrenic sulcus
- Unusually sharp definition of the cardiac and mediastinal borders due to anterior collection of air which may appear as lucency
- ‘Bunch of grapes sign’ – the pericardial fat outlined by free air is unusually conspicuous
- ‘V sign’ – this occurs when air is seen trapped in the pleural space medial and inferior to an area of atelectasis or consolidated lung
- ‘Double diaphragm sign’ – air outlining anterior costophrenic angle and aerated lung outlining diaphragmatic dome
- Band of air in minor fissure bounded by two visceral pleural lines
- Visible lateral edge of right middle lobe due to medial retraction in the presence of anterior pneumothorax.
Remember when you see or feel subcutaneous emphysema to exclude a pneumothorax or pneumomediastinum as a cause.

We recall an incident that involved a patient transferred from the ICU for CT scan to rule out pulmonary embolism. The patient had been intubated for about one week and had a difficult and complicated ICU stay following a road traffic accident during which he had sustained multiple injuries. The patient’s respiratory status deteriorated in the CT room. The topogram (initial scan performed in a CT scan) was performed (see below). This revealed a tension pneumothorax that was treated immediately by the critical care resident using a 14 gauge cannula (see below). It is important to review all CT scans as they are being performed on critically ill patients as they may expedite emergency therapy.

A topogram (scannogram) acts as a planning scan and looks like a plain film.

Imaging of tubes/catheters/circulatory supports

The ICU chest X-ray

The vast majority of chest X-rays obtained in the ICU are portable anteroposterior (AP) radiographs, obtained with the patient in the semi-erect position. There are technical limitations to consider with portable bedside radiography. The limited maximum Kilovoltage (analogous to the penetrating power of the X-rays created) of portable units often requires larger and longer exposures. This increases the risk of motion artefact, which can degrade image quality. AP chest X-rays increase the apparent cardiac diameter by 15–20% compared to PA chest X-rays. Many films are taken in the supine position making it more difficult for the patient to deeply inspire; therefore these films show smaller lung volumes and are more difficult to interpret. Rotation is often seen on portable ICU chest X-rays and care must be taken to avoid the patient slipping on pillows during positioning; this can exaggerate the normal
thoracic lordosis and result in what is known as a lordotic view which would normally only be employed in a specific assessment of the lung.

Figure 9. Chest X-ray in semi-upright position
Figure 10. Chest X-ray in lordotic position

Detection of mild pulmonary venous hypertension and small or moderate pleural effusions is difficult.

Pleural fluid tends to lie posteriorly with the patient supine. The only clue to the presence of an effusion may be a subtle veil of increased opacity over the affected lung field, a small ‘apical cap’ of fluid over the lung apex, or obscuration of a hemidiaphragm. Effusions can be confirmed by obtaining upright or decubitus films or by using portable ultrasound.

Figure 11. High-density fluid in lungs

**Tracheal tube position**

The position of the tip of the tracheal tube of ventilated patients should be checked on every ICU radiograph with respect to the carina. In the adult, the tube tip should be seen at about 4 cm above the carina with the chin in the neutral position. This allows the normal +/− 2 cm range of tube movement to occur without complication.

THINK Remember the tracheal tube position will change with the chin position – as the chin is raised for the radiographic examination the tracheal tube will move in a cephalad direction, conversely the tube descends as the chin descends. See the PACT module on Airway management.

This tube position avoids traumatising the cords or tracheal carina. If the carina cannot be identified, its position can be estimated to be at the level of the arch of the aorta. Intubation of a bronchus (usually the right main stem bronchus) is not uncommon in the ICU. This will cause collapse of the contralateral lung, and occasionally the ipsilateral upper lobe. Collapse occurs relatively quickly and is easily identified on subsequent radiographs.

Although inadvertent oesophageal intubation would be a catastrophic complication if not normally and rapidly detected by clinical and capnographic signs, the following are the described radiographic signs.

- Projection of the endotracheal tube outside the tracheobronchial air column
- Marked gastric air distension
- Pneumomediastinum or pneumoperitoneum (secondary to oesophageal laceration)
- An enlarged tracheal balloon cuff – the diameter of the tracheal tube should be two-thirds of the tracheal cross-sectional diameter and the cuff should fill but not distend the tracheal lumen.

See the PACT module on Airway management for more information on intubation.

Figure 12. Endotracheal tube in good position
Central venous catheters

The ideal position of a central venous catheter inserted from above is the superior vena cava (SVC), central to the venous valves found in the internal jugular and subclavian veins. Although placement of the catheter tip in the right atrium might seem desirable, the risk of atrial arrhythmias and atrial perforation from catheter migration make this position sub-optimal. Incorrect positioning of central venous catheters occurs in up to 30% of patients. A post procedure chest X-ray is therefore necessary to confirm catheter position and to rule out any complications of catheter placement (such as pneumothorax and haemothorax). Commonly misplaced locations include the right atrium, right ventricle, contralateral subclavian vein, internal jugular vein and the internal mammary vein.

Q. What are the complications associated with central venous catheter misplacement?

A. The most commonly encountered immediate complications of central venous catheter misplacement include pneumothorax and haematoma formation. Pneumothorax occurs more frequently with a subclavian approach. The major longer term complications include catheter-related infection (CRI) and venous thromboembolism.

See the PACT module on Pyrexia for further information on catheter-related infection.

Pulmonary arterial catheters

The resting position of the catheter tip is ideally in a central right or left pulmonary artery. The balloon at the tip of the tube should not be inflated on the post insertion chest X-rays, it is inflated only briefly for PAOP measurement – see PACT module on Haemodynamic monitoring. The major complication rate for pulmonary arterial catheters (PACs) (or ‘Swan-Ganz’ catheters) ranges from 3–17%. If the tip is too distal in the pulmonary circulation (1–2 cm outside cardiac shadow), complications, such as pulmonary artery thrombosis and pulmonary infarction, can occur.

Enteral tube placement

On chest X-ray, the tip of a correctly placed enteral feeding tube projects over the stomach or duodenum, as appropriate. In many cases the duodenum is not visualised on chest X-ray. If the tube passes below the diaphragm, the standard judgment is that this position is adequate in most cases (unless jejunal tube placement is required). The authors do not routinely perform abdominal X-rays to confirm nasogastric tube position. The most commonly seen complications are related to malposition of feeding tubes. The tube may lie too proximal in the oesophagus, be coiled in the hypopharynx or it may be seen in the bronchi or lungs. A rarely seen complication is pneumothorax secondary to perforation of the pleura.
Figures 20 and 21. Nasogastric tube lying in the right lower lobe bronchus

**Chest drains**

Pleural tubes should be placed anterosuperiorly for air collections and posteroinferiorly for fluid collections. The most proximal side hole (seen as a break in the radio-opaque line along chest tube) should be seen to project inside the ribs. Tube malposition can be identified on chest radiograph, and lateral views can often be helpful. An intraparenchymal tube, which in modern practice should be avoided by the non-employment of trocars during the ‘mini-thoracotomy’ insertion technique, is usually not recognised on chest radiograph but is often first suspected by unusual ‘air-leak’ clinically or first noted on CT. Lung laceration or herniation into the tube may result from this uncommon condition.

Figure 22. Bilateral chest tubes

**Intra-aortic balloon pump**

This is a 26 cm long helium filled balloon which works by deflating during systole to decrease afterload and inflating during diastole to improve coronary artery (and cerebral) perfusion. The balloon is usually placed via the femoral artery and positioned in the proximal descending aorta. The ideal position for the tip of the balloon is just distal to the origin of the left subclavian artery and just above the left main bronchus on chest X-ray. This position allows for maximal perfusion of the coronary circulation while avoiding occlusion of the left subclavian and renal arteries. If the chest radiograph is obtained during diastole, a tubular lucency of ‘air’ can be identified over the descending aorta, which is caused by gas within the inflated balloon. Complications of placement include aortic dissection, renal and mesenteric ischaemia, emboli to the lower extremities, balloon rupture and femoral artery pseudoaneurysm.

**Extracorporeal Membrane Oxygenation**

Extracorporeal Membrane Oxygenation (ECMO), as a means of therapeutic support in patients with severe respiratory or cardiac failure, has increased substantially in the past few years. Imaging plays a central role in the management of these patients both before and during ECMO support. The percutaneous placement of wide bore ECMO cannulae is guided by vascular ultrasound, surface or transoesophageal echocardiography or fluoroscopy. Some ECMO cannulae have a radiolucent distal segment and the tip of these cannulae may lie more distally than appears on radiographic imaging. More recently, the availability of double lumen venous cannulae [see X-ray image (Figure 2012:106) below] has encouraged their wider use for venovenous ECMO. Arterial cannulation is achieved directly into the ascending aorta during sternotomy for central VA ECMO or percutaneously via the femoral artery for peripheral VA ECMO. Chest radiographs confirm the position of the ECMO cannulae and record any improvement in pulmonary infiltrates. Thoracic complications associated with ECMO include malpositioning of the cannulae, pneumothorax, pneumomediastinum, pleural effusion and pulmonary haemorrhage, all of which can be assessed radiographically. CT is used in the evaluation of bleeding complications in the brain, chest or abdomen during ECMO treatment but this normally requires transport of the patient to the radiology department with the risk of complications such as cannula dislodgement. Sonography may be extremely useful...
in the ICU setting allowing assessment of catheter position with minimal disturbance of the patient and supporting apparatus.


**Left ventricular assist device**

Left ventricular assist devices (LVAD) or biventricular assist devices have become a well-recognised option in the management of acute and chronic heart failure where they may be used as a bridge to transplant or recovery or as a destination therapy. These devices generate either pulsatile or continuous flow and a wide variety is in current clinical use.

Echocardiography is routinely employed during the intraoperative and postoperative periods for the evaluation of thrombus, mechanical or circulatory problems and ventricular filling and unloading. This imaging modality is very portable, offers dynamic assessment and is ideally suited to the ICU setting.

Chest radiography may be used to assess positioning of the pump and the inflow and outflow cannulae.
CT is useful as a problem solving tool in these patients. It allows visualisation of regions not well seen at ultrasound. CT will allow assessment of the ventricular assist device pocket, the cannulae, the anastomoses, the drive lines, the native vessels and may provide information about ventricular function.

**Note** MRI is contraindicated in patients with a ventricular assist device.

![AP chest radiograph of a heart failure patient with an LVAD in position. The aortic anastomosis is not well visualised due to the relative radiolucency of the outflow cannula. Note also the dual chamber implantable cardioverter-defibrillator (ICD).](image)

Figure 2012:107. AP chest radiograph of a heart failure patient with an LVAD in position. The aortic anastomosis is not well visualised due to the relative radiolucency of the outflow cannula. Note also the dual chamber implantable cardioverter-defibrillator (ICD).
Figures 2012:109 and 110. Contrast enhanced axial CT thorax showing the LVAD cannulae and the anastomoses. CT is used to assess for anastomotic complications such as thrombotic occlusion, stenosis, anastomotic breakdown or infection.

Carr CM, Jacob J, Park SJ, Karon BL, Williamson EE, Araoz PA. CT of left ventricular assist devices. Radiographics 2010; 30(2): 429–444. PMID 20228327 http://radiographics.rsna.org/content/30/2/429.long


[20]
**Cardiac pacemakers**

Pneumothorax may occur following placement or the pacemaker wire may be malpositioned in the coronary sinus or in the right ventricular outflow tract. Lead fracture has an overall incidence of 2–3% and in most cases occurs at the point of lead connection to the generator, within a loop, or at the point of venous entry. Other complications which should be excluded on the chest radiograph include perforation of the myocardium or lead dislodgement. In cases of myocardial perforation the perforated wire tip lies lateral to the heart on the AP view, or anterior to the heart within the epicardial fat pad on the lateral view. This is typically seen with an increase in heart size due to an associated haemorrhagic pericardial effusion.

**THINK** Remember aberrant venous anatomy when reviewing chest radiographs post pacemaker placement. A pacemaker placed from the left may enter a persistent left superior vena cava, present in 0.5% of the population.

Figure 23. AP ICU chest X-ray in a patient with a sternal infection post CABG

Over the next week analyse each ICU chest radiograph with regard to tube and intravascular catheter position. Make a record of which cases you think have misplaced tubes and catheters. Discuss the cases with a radiology colleague.

**Thoracic trauma**

**NOTE** Trauma is the leading cause of death in patients under 40 years of age.

Sixty per cent of patients with multiple traumatic injuries have associated thoracic trauma. In European practice, blunt trauma accounts for 90% of thoracic trauma. Seventy-five per cent of thoracic injuries are attributable to road traffic accidents, 18% result from a fall from height and 7% are due to injuries sustained at work. The numbers of stab and gunshot wounds are low in Europe and vary regionally depending on social factors and crime rates.

The imaging work up of patients with suspected thoracic injuries begins with a portable chest film taken on arrival at the emergency centre. This allows rapid diagnosis of injuries such as pneumothorax and haemothorax. Other conditions such as aortic trauma, lung laceration, thoracic spine injuries and tracheobronchial injury require further evaluation with CT.

Spiral CT scanning, with a single row of detectors, revolutionised the imaging of thoracic trauma but today, multidetector CT scanners can quickly and accurately diagnose a wide range of thoracic injuries.

**Thoracic skeletal injuries**

Upper rib fractures occur with severe chest trauma and may be associated with injuries of the aorta, great vessels and brachial plexus. Sternal fractures can be readily identified on lateral radiographs. Occasionally sternal fractures can be associated with mediastinal haematomas which are better evaluated with CT. About 70% of
thoracic spinal injuries are seen on plain X-rays but almost all will be identified on CT.

An often overlooked and potentially life-threatening injury is posterior dislocation of the clavicle at the sternoclavicular joint. The displaced clavicle may impinge on the trachea, great vessels or major nerves in the superior mediastinum.

Figure 24. Fracture of the medial 1/3 of the left clavicle

**Aortic and great vessel injuries**

Ninety per cent of patients with traumatic aortic rupture die before emergency treatment can be instituted. Almost all aortic injuries involve the junction of the posterior aortic arch and descending aorta, just distal to the origin of the left subclavian artery. A normal chest radiograph has a high negative predictive value (98%) but an abnormal chest radiograph has a low positive predictive value for aortic injury. The gold standard for the diagnosis of aortic injury has been aortography, however in most trauma centres aortography has been almost completely replaced with spiral or multidetector CT.

Figures 25 and 26. Traumatic aortic transection

Patients with no direct evidence of aortic injury at CT and no mediastinal haematoma (an indirect sign) do not require further imaging to rule out aortic trauma.

Q. How would you classify the CT signs of aortic injury on CT?

A. The CT findings include both direct and indirect signs of aortic injury.

Figures 27 – 31 Selected images demonstrating multiple injuries including aortic transection in a young male patient following a fall


**Pulmonary contusion and pulmonary laceration**

Pulmonary contusions appear as patchy areas of consolidation on plain X-rays which may be extensive in severe injuries. These areas of consolidation represent traumatic extravasation of blood and oedema to the interstitium and air spaces of the lung. Contusion is usually evident within six hours of injury and resolves rapidly (3–10 days). Pulmonary lacerations are tears of the lung parenchyma that may be initially obscured by surrounding lung contusion. Pulmonary lacerations are commonly
associated with rib fractures. They are better evaluated with CT and characteristically take weeks or months to heal, resulting in residual lung scarring in many cases.

**Tracheobronchial injury**

These are uncommon injuries and will only be diagnosed with a high index of suspicion. Eighty per cent of injuries occur within 2 cm of the carina. The most common findings are pneumomediastinum and subcutaneous emphysema on plain chest radiographs.

A pneumothorax that does not resolve with chest tube suction may be due to an air leakage from a tracheal or bronchial injury/rupture. Resolution of a pneumothorax after chest tube placement does not, however, exclude this diagnosis.

A rare sign of transection of a bronchus is the ‘fallen lung sign’. In these cases of bronchial laceration the lung comes to lie in a characteristic dependent position. These injuries are best detected by CT.

**Cardiac injuries**

These injuries can occur secondary to severe blows to the anterior chest, the most common mechanism of blunt injury to the heart being a steering wheel. They are uncommon conditions and are best assessed with echocardiography and CT. Injuries include cardiac rupture, cardiac contusion, haemopericardium, cardiac tamponade and cardiac valve injury. An electrocardiogram may reveal an infarct if a coronary artery is injured directly or thrombosed.

**Diaphragmatic injury**

Rupture of the diaphragm is seen in 5% of patients undergoing emergency thoraco-abdominal surgery for trauma. The chest radiograph may show a haemothorax, a pneumothorax, apparent diaphragmatic elevation or cephalad extension of a nasogastric (NG) tube into the hemithorax. CT with coronal and sagittal multiplanar reconstructions (MPRs) is helpful in confirming the diagnosis. MRI can also be useful as it has the ability to directly visualise the diaphragm in the coronal plane.

Missing a diaphragmatic rupture can have serious consequences when strangulation of herniated viscera occurs. Radiological signs are often non-specific. In some cases the chest radiograph can be completely normal.

THINK Remember visceral herniation may not be present when the patient is ventilated due to positive intrathoracic pressures. Transdiaphragmatic herniation with respiratory compromise or organ infarction of abdominal organs may only occur following extubation.

Figure 32. Extravasation of contrast into the mediastinum and right pleural space

Q. Which diaphragm is most commonly injured in cases of thoracic trauma?

A. Seventy-five per cent of diaphragmatic injuries are left sided. Bilateral rupture is seen in 4.5% of patients.

Q. What percentage of traumatic transdiaphragmatic organ herniations are left sided?

A. Ninety-five per cent
3/ USING IMAGING – THE PATIENT WITH CIRCULATORY DISEASE OR DYSFUNCTION

Pulmonary embolic disease

Acute pulmonary embolism is a common and often fatal illness. In contrast to many other pathological conditions, confirmation of the diagnosis is entirely dependent on imaging/radiologic findings. In routine practice, multidetector row CT has become the modality of choice for evaluating the pulmonary circulation in patients suspected of having a pulmonary embolus. CT pulmonary angiography (CTPA) uses a spiral acquisition technique with overlapping reconstruction intervals and the rapid administration of intravenous contrast during suspended respiration. It allows the excellent spatial resolution necessary to accurately diagnose emboli. CTPA allows actual clot visualisation. Reported sensitivities for this technique range from 60–100% and specificities ranging from 78–100%. Multidetector CT with reconstructed scans of 1.25 mm-thick sections has been shown to allow analysis of peripheral pulmonary arteries down to the fifth order on CT pulmonary angiograms. Incidental findings are commonly diagnosed during CTPA.

Ventilation-perfusion scanning was used for many years as the initial imaging method of choice in suspected pulmonary embolism. Ventilation-perfusion scanning is a highly sensitive (98%) investigation, but its specificity is very low (10%). The PIOPED 3 (Prospective Investigation of Pulmonary Embolism Diagnosis III) study recently reported on the diagnostic usefulness of gadolinium enhanced MR angiography in the diagnosis of pulmonary embolus. Investigators found assessment was technically inadequate in 25% of patients. Where studies were technically adequate the reported sensitivity of MR angiography is 78% and specificity is 99%. This test should only be considered in centres where it is performed routinely and where standard tests are contraindicated.

CTPA has replaced V/Q scanning for the investigation of ICU patients with suspected pulmonary embolism where multislice CT is available. This is because multislice CTPA is a highly sensitive investigation, even in patients with comorbid pulmonary disease. CTPA also allows an accurate diagnosis to be made quickly and allows assessment of coexistent pulmonary pathology.

In those patients where CTPA is contraindicated, bedside echocardiography may provide useful information to support the diagnosis of pulmonary embolism including evidence of right ventricular dilatation, hypokinesis and possibly visualisation of thrombus in the right heart if this is present. Bedside V/Q imaging has been performed in certain centres but has been found to have limited impact on patient management.

Deep venous thrombosis

ICU patients are at significant risk for deep vein thrombosis (DVT). Ultrasound (US) Doppler evaluation of the upper or lower limbs for deep venous thrombosis can be performed at the bedside in ICU patients and may be performed by appropriately skilled intensivists. In some centres, a lower limb CT venogram is performed post CTPA using delayed scanning. This technique has not yet been fully validated but
may represent a move towards a ‘one stop’ evaluation of the pulmonary circulation and the deep veins of the pelvis and lower limbs. This technique may be particularly useful in assessing seriously ill ICU patients. You can read more about CTPA in the following references.


Ginsberg MS, Oh J, Welber A, Panicek DM. Clinical usefulness of imaging performed after CT angiography that was negative for pulmonary embolus in a high-risk oncologic population. AJR Am J Roentgenol 2002; 179(5): 1205–1208. PMID 12388500 http://www.ajronline.org/content/179/5/1205.long


We recall a patient who had pulmonary embolism diagnosed on CT pulmonary angiography and then presented with unstable angina requiring coronary artery bypass surgery. Following anticoagulation for six weeks, a subsequent CT pulmonary angiogram showed that the embolus had resolved and the patient proceeded to surgery with a good result. Two-thirds of pulmonary emboli resolve within six weeks of commencement of anticoagulation.

**Indications for placement of inferior vena caval filters**

This straightforward procedure is performed by interventional radiologists or vascular physicians/surgeons under fluoroscopic guidance. The filter is placed below the level of the renal veins via a right femoral (or occasionally jugular) approach. These filters may be temporary or permanent. Temporary filters may be removed via a jugular approach.

The function of the filter is to prevent any clot propagating via the inferior vena cava to the pulmonary circulation.

**Indications:**
DVT and/or pulmonary embolism (PE) plus one of the following:

1. Contraindication to anticoagulation e.g. post neurosurgical procedure
2. Failure of anticoagulation
3. Significant bleeding while on anticoagulation.

**Aortic dissection**

Classification of aortic dissection is based on location as this determines treatment and prognosis.

Stanford Classification:
*Type A* – involves the ascending aorta; surgical treatment required.
*Type B* – limited to the descending aorta (distal to the origin of the left subclavian artery); medical treatment in most cases.

Q. Why are Type A aortic dissections (non-traumatic) treated surgically and generally associated with a worse prognosis?

A. Type A dissections require surgery because of involvement of the aortic root and have a number of early lethal consequences.

Q. What are the possible acute complications of Type A dissections?

A. Secondary complications of dissection of the ascending aorta include pericardial tamponade, aortic rupture, coronary artery dissection/occlusion and acute aortic insufficiency.

If a patient with aortic dissection becomes hypotensive think of pericardial tamponade as a potentially reversible cause.

**Goals of imaging studies:**
- Determine if ascending aorta is involved.
- Determine extent of dissection.
- Define branch vessel involvement.
- Determine patency of the true lumen.
- Determine whether there is aortic regurgitation present.

The chest radiograph is normal in 25% of patients with aortic dissection. Patients can be imaged for suspected aortic dissection with either CT, MRI, conventional contrast aortography or with transoesophageal echocardiography (TOE). In unstable patients, TOE is often used as the first triage exam as it will rapidly determine the status of the ascending aorta. In stable patients contrast enhanced CT scanning is usually the modality of choice but occasionally other studies will be needed for full evaluation.
CT features of aortic dissection:

- Presence of an intimal flap.
- Presence of a true and false lumen.
  - The false lumen usually demonstrates delayed opacification.
  - The true lumen is often compressed by the false lumen.
- CT is excellent at demonstrating thrombosed false channels and secondary solid organ ischaemia.

Figures 33–36. Stanford Type A aortic dissection

Q. What critical vascular structure is not accurately assessed by contrast enhanced CT scanning in patients with suspected aortic dissection?

A. The aortic valve is not well assessed by CT scanning. If the patient is unstable, transoesophageal echocardiography (TOE) should be performed to assess the aortic valve and ascending aorta.

Figures 37–39. CT scan of the aorta

http://radiology.rsna.org/content/228/2/430.long

Klompas M. Does this patient have an acute thoracic aortic dissection? JAMA 2002; 287(17): 2262–2272. PMID 11980527

Aortic aneurysms

Ninety per cent of abdominal aortic aneurysms are infrarenal. The abdominal aorta is defined as aneurysmal when its diameter is greater than 3 cm. The risk of aneurysm rupture increases dramatically when the diameter becomes greater than 5 cm.

Q. What are the advantages of CT over ultrasound (US) in assessment of suspected aortic aneurysm?

A. CT is more accurate than US in the assessment of aneurysm size and extent. CT is the best imaging study in suspected rupture and allows visualisation of other potential complications such as mesenteric ischaemia and renal infarction (which would not be easily assessed with US). US is however a good initial screening test in a stable patient with a suspected abdominal aortic aneurysm.

Figure 40. Aneurysm of the abdominal aorta
Figures 41–43. Abdominal aortic aneurysm not containing contrast
Figures 44–46. Axial images from an emergency CT scan of the abdomen

[28]
Endovascular treatment of abdominal aortic aneurysms

Endovascular placement of aortic stents is an alternative therapy to open surgery for the treatment of suitable abdominal aortic aneurysms. The procedure requires careful planning with preoperative CT. Not all aneurysms are suitable; a 1.5 cm neck is required below the level of the renal arteries and the iliac vessels must be of suitable size to allow placement of the stent graft. Patients who are unfit for open abdominal aortic aneurysm repair should be assessed for endovascular therapy.

Q. What are the advantages of endovascular repair of abdominal aortic aneurysms?

A. The advantages include lower volume of blood loss, shorter stay in hospital (and often no ICU stay) and quicker recovery.

Figure 47. Axial image from a CT scan of the abdomen
Figures 48–49. Contrast enhanced CT of abdomen

The following papers discuss the advantages, techniques and potential complications of endovascular repair of abdominal aortic aneurysms.


http://radiology.rsna.org/content/228/3/647.long

Imaging of pulmonary oedema

Pulmonary oedema can be broadly classified into two types, which can generally be distinguished radiographically.
**Cardiogenic** – elevated pulmonary venous pressure e.g. congestive cardiac failure, renal failure.

<table>
<thead>
<tr>
<th>Pulmonary capillary wedge pressure mmHg</th>
<th>Chest X-ray findings (in upright position)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12</td>
<td>Normal</td>
</tr>
<tr>
<td>12–17</td>
<td>Upper lobe redistribution</td>
</tr>
<tr>
<td>18–24</td>
<td>Interstitial oedema</td>
</tr>
<tr>
<td>&gt;24</td>
<td>Consolidation + interstitial oedema</td>
</tr>
</tbody>
</table>

**Non-cardiogenic** – increased capillary permeability e.g. ARDS of any aetiology such as near-drowning, severe acute pancreatitis, increased intracranial pressure.

<table>
<thead>
<tr>
<th>Effusion</th>
<th>Cardiogenic</th>
<th>Non-cardiogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary vessels</td>
<td>Redistribution</td>
<td>Normal</td>
</tr>
<tr>
<td>Kerley B lines</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Heart size</td>
<td>Enlarged</td>
<td>Normal</td>
</tr>
<tr>
<td>Fissures</td>
<td>Thickened</td>
<td>Normal</td>
</tr>
</tbody>
</table>

A combination of the two types can coexist, particularly when treatment has been instituted. Unilateral or asymmetric pulmonary oedema is commonly seen and is often secondary to the gravitational effect of patient positioning, and would favour cardiogenic pulmonary oedema.

**Figure 50. AP ICU chest X-ray in a patient with meningococcal septicaemia**

> Acute cardiogenic pulmonary oedema secondary to acute myocardial infarction or an arrhythmia can be associated with a normal heart size.

> Compare the chest X-ray findings to the echocardiogram findings in the next five patients you see with cardiogenic pulmonary oedema. Although not always reported, echocardiography can be used to estimate pulmonary artery pressure and act as an alternative to direct PA catheterisation.
There are many atypical patterns of pulmonary oedema. One described atypical pattern is that of interstitial oedema in the right upper lobe secondary to rupture of the posterior leaflet of the mitral valve.

The following paper outlines the spectrum of radiological findings seen in heart failure and ARDS. See also the PACT module on Acute respiratory failure.


**CT in ARDS**

The high resolution CT findings in ARDS have been well described by many authors (see references below).

Typical patterns can be seen in survivors of ARDS with a reticular pattern, and a striking anterior distribution, being a frequent finding of follow-up CT in ARDS survivors. This has been most strongly related to the duration of pressure-controlled, inverse-ratio ventilation.


4/ USING IMAGING – THE PATIENT WITH SPINAL DISEASE

**Spinal trauma**

Most spinal fractures occur in the upper (C1–C2) or lower (C5–C7) cervical spine and at the thoracolumbar region (T10–L2). Twenty per cent of spinal fractures are multiple. The causes of spinal fractures include motor vehicle accidents (50% of patients), falls (25%) and sports related injuries.

**Cervical spine assessment**

The cervical spine is injured in 3% of major trauma patients. Initial radiographic evaluation of the cervical spine typically includes AP, lateral and odontoid peg views. A basic systematic radiological assessment of the C-spine series should review the bony alignment, the vertebral body height, intervertebral disc height, the posterior elements and the soft tissues.

**Bony alignment**

The lateral view will allow evaluation of the three arcuate lines, these are the anterior vertebral body line, the posterior body line and the spinal laminar line. These lines should be followed from top to bottom of the C-spine to exclude malalignment – see Figure 2012:111 below.

**Vertebral body height**

The vertebral bodies below C2 have a fairly uniform square or rectangular shape and the anterior and posterior heights should be the same.

**Intervertebral disc height**

The intervertebral disc height should be uniform. Loss of disc height typically occurs with degenerative disc disease. Widening of an intervertebral disc space may occasionally follow severe C-spine injury.

**Prevertebral soft tissues**

The prevertebral soft tissues have a characteristic appearance anterior to the anterior vertebral body line. From C1 to C4 the prevertebral soft tissues should not measure more than 7 mm or 30% of the width of the corresponding vertebral body. From C5 to C7 there is an increase in the normal thickness of the prevertebral soft tissues which measure 22 mm or less corresponding to 100% of the corresponding vertebral body width.

**Posterior elements**

Finally the posterior elements should be examined for evidence of fracture.
Most suspected cervical spine fractures are followed with thin section CT for more accurate evaluation. CT detects 97–100% of fractures. Multislice CT allows multiplanar and three-dimensional reconstructions for accurate surgical planning.

Figure 51. CT scan of the upper cervical spine

**Q. Within the cervical spine, what are the clinical implications of a high vs a low cervical fracture?**

**A.** A fracture high in the cervical spine (i.e. above C3–C4) which causes neurological injury is likely to result in loss of diaphragmatic innervation and loss of power in both upper limbs. The patient may require long-term ventilation.

**CT scanning/screening**

Recent studies support the use of helical CT as a cost-effective method for screening the cervical spine in high-risk trauma patients. Screening cervical spine CT can be performed at the time of head CT to lower the cost of the test, and when all short- and long-term costs are considered, CT may actually save money when compared with traditional radiographic screening. In addition to having higher sensitivity and specificity for cervical spine injury, CT screening also allows more rapid radiological...
clearance of the cervical spine than radiography. Patients who are involved in high-energy trauma, who sustain head injury, or who have neurological deficits are candidates for CT screening. Screening with CT may enhance detection of other potentially important injuries of the cervical region such as facet dislocation.

The following references discuss the use of plain radiographs and CT scanning in the assessment of patients presenting with cervical spine trauma. The PACT module on Multiple trauma will give more information.


Since the introduction of multislice CT to our department for cases where C1–C2 or C6–C7 are poorly seen on plain radiograph the radiology trainee on call has been able to more confidently, accurately and quickly exclude bony pathology at these sites.

The following papers provide an excellent overview of the radiological findings and discuss the various classification systems employed in acute spinal trauma.


**Magnetic resonance imaging**

MRI is the investigation of choice to rule out spinal cord compression, cord injury and pathological fractures. MRI is highly sensitive in the detection of ligamentous injury. Patients presenting with neurological impairment following spinal injury should have an MRI examination. The ability to see clearly the spinal cord, nerve roots, ligaments, intervertebral discs and adjacent vascular structures allows a more accurate assessment of the extent of injury, and long-term prognosis.
Spinal MR has an increasingly important role in the assessment of major trauma.

MRI is, however, less sensitive than CT to fractures of the posterior elements of the spine, and to injuries of the craniocervical junction.

THINK What additional information will MRI add over CT in examination of the cervical spine?

Figures 52–55. Sagittal T2 weighted MRI of the cervical spine/Vertebral artery dissection
Figures 56 and 57. Sagittal T1 image of cervical spine and Sagittal T2 images of the cervical spine

For the next patient that is admitted to your ICU with spinal trauma ask your radiology colleagues if you could join them while they report the CT and MRI scans. Note the use of multiplanar reconstructions and the meticulous attention that must be given to vertebral alignment and integrity of the facet joints.

It is important for the radiology service on call to assess the spinal status of patients who suffer major trauma that are being admitted to the ICU. It is the role of the radiologist to assess the plain radiographs, CT scans and MRI examinations in such cases, and to declare the patient ‘cleared of vertebral fractures’ or not.

Spinal cord injury without radiographic abnormality

SCIWORA is defined as spinal cord injury without evidence of vertebral fracture or misalignment on plain radiographs and CT.

SCIWORA is commoner in younger children, possibly because their more elastic spinal ligaments allow excessive movement during trauma, causing spinal cord distraction or compression in the absence of spinal fracture or dislocation. A delayed onset of paralysis of up to 48 hours occurs in as many as 50% of cases but in these children there is often a history of transient neurological symptoms such as tingling or numbness in the extremities at the time of injury.

Full assessment is required to exclude osseous or ligamentous injury as, by definition, the initial cervical spine radiographs will be normal. Flexion and extension lateral cervical radiographs and CT cervical spine can be done, when the patient is awake and with the physician in attendance, to exclude subtle fractures and instability. MRI will exclude treatable causes of cord compression such as retropulsed disc or extradural haematoma. Various specific MRI sequences (such as T1, T2 and gradient...
echo sequences), will distinguish cord haemorrhage from oedema and will also show ligamentous injury. Cord oedema is seen as high signal on T2 weighted scans and subacute haemorrhage will demonstrate high signal on T1 and T2 weighted sequences. Gradient echo sequences are useful to demonstrate the presence of haemosiderin which is a permanent marker of previous haemorrhage. The appearances of the spinal cord on MRI have been shown to correlate with prognosis: cord transection or major haemorrhage is associated with poor recovery; minor haemorrhage or oedema only is associated with a moderate to good chance of recovery; and a cord which appears normal is associated with complete recovery.


**Spinal cord compression**

The most common cause of spinal cord compression is secondary to spinal trauma (discussed above). The second commonest cause of spinal cord compression is metastatic disease. It is imperative to distinguish between metastatic disease and other causes of spinal cord compression, as subsequent patient management is completely different.

**Q. What is the test of choice in suspected spinal cord compression?**

A. MRI is the imaging modality of choice.

**Q. Why?**

A. MRI will allow assessment of the severity of spinal cord compression and allows assessment of the marrow within the vertebral bodies to determine whether there is evidence of marrow pathology (e.g. metastatic disease, myeloma or lymphoma). The findings at MRI will ultimately determine appropriate therapy.

We recall a patient who presented following a fall with neurological abnormalities in both lower limbs. Plain radiographs revealed a burst fracture of L1. The patient then underwent MRI of the lumbar region. It was noted that there was signal abnormality within the cord at a higher level in the thoracic cord. Focused MRI of the thoracic region revealed an unsuspected burst fracture at the T4 level, with significant fracture fragment retropulsion.

Therefore we recommend that in cases where there is unexplained neurological impairment, a sagittal scan of the cord should extend from the brain stem to the conus. The entire cord should be examined in cases of multilevel or unexplained neurology.

Figures 58 and 59. MRI of the thoracic cord
**Spinal infection – discitis and epidural abscess**

The incidence of discitis and associated epidural abscess is rising worldwide, even in the non-immunocompromised host. The reason for this increasing incidence is unclear. These entities are usually diagnosed late as symptoms and signs may be non-specific. Spinal MRI +/- contrast enhancement is the only reliable method for diagnosis. Early diagnosis permits early therapy and improves prognosis. Tuberculosis and staphylococcus are the most commonly implicated microorganisms. The radiologist may assist in detection of the causative organism by CT or fluoroscopically guided needle aspiration of the infected disc space.

Q. What imaging features of a discitis would favour tuberculosis as a cause?

A. Subligamentous spread of infection and preservation of the disc space.

Q. Where in the spinal cord do epidural abscesses occur and why?

A. Epidural abscesses tend to occur anteriorly because they arise from pre-existing discitis.

*Figures 60–64. Large epidural abscess/Sagittal T1 image of lumbar spine/Sagittal T2 image of lumbar spine/Axial image of lumbar spine*

5/ USING IMAGING – THE PATIENT WITH ABDOMINAL DISEASE

Bowel obstruction, ileus and perforation

Q. What are the commonest causes of mechanical small bowel obstruction in an ICU patient?

A. 
- Adhesions
- Hernias (external or internal)
- Tumours
- Small bowel strictures – secondary to inflammation or ischaemia
- Gallstones – i.e. gallstone ileus.

Obstruction

Patients are initially evaluated for suspected bowel obstruction with a supine plain abdominal radiograph. CT is an extremely useful technique in assessing patients with suspected bowel obstruction. Oral contrast media is not routinely required in cases of suspected small bowel obstruction as distended fluid filled small bowel proximal to the obstruction can be distinguished from non-distended small bowel distal to the obstruction. The cause of obstruction e.g. adhesion vs mass vs hernia can usually be readily distinguished. Intravenous contrast in this setting is useful in assessing the abdominal vasculature and solid organ perfusion. Bowel obstruction may be associated with bowel wall ischaemia and absence of normal bowel wall enhancement on the post contrast study can demonstrate this complication.

http://radiographics.rsna.org/content/21/2/341.long

http://www.ajronline.org/content/165/5/1187.long


Q. What advantages does abdominal CT have in investigation of suspected small bowel obstruction?

A. CT will often demonstrate the transition point (see below) of an intestinal obstruction and will reveal the actual cause of obstruction in many cases. It is a sensitive and specific technique in the assessment of small bowel obstruction.
The transition point in intestinal obstruction is identified by an abrupt change in the bowel calibre. The bowel proximal to the transition point is distended while the bowel distal to this point is decompressed.

**Ileus**

Paralytic ileus can often be distinguished from acute mechanical small bowel obstruction on plain abdominal radiographs. In small bowel obstruction the small bowel loops appear dilated within the central abdomen and no air is visualised within the rectum. In paralytic ileus there is evidence of non-specific gaseous dilation of the small and large bowel loops.

Figures 65–67. Supine plain film of the abdomen/Contrast enhanced CT of abdomen
Figures 68–70. Caecal volvulus and small bowel obstruction/Caecal volvulus and small bowel obstruction

**Perforation**

Bowel perforation in the ICU patient is often difficult to diagnose clinically as most patients are sedated or unconscious. It is possible to demonstrate as little as 1 ml of free intra-abdominal air on erect chest or left lateral decubitus films. Not all cases of intra-abdominal viscus perforation will demonstrate free intra-abdominal air. Initially the patient should have either an erect chest X-ray or a left lateral decubitus film. As these are often difficult or impossible to perform in the ICU patient it is important to be aware of the signs of a pneumoperitoneum on a supine abdominal radiograph (only present in approximately 50% of patients with bowel perforation).

**Q. What are the signs of a pneumoperitoneum on a supine abdominal radiograph?**

A. Signs of pneumoperitoneum on a supine abdominal radiograph:
   - ‘Rigler’s sign’ – visualisation of the outer as well as the inner wall of a loop of bowel
   - Small triangular collections of gas between bowel loops
   - Air may be seen along the falciform ligament
   - Large amounts of air may accumulate beneath the diaphragm, or in the centre of the abdomen (‘football sign”).

Figure 71. Left lower lobe collapse
Figure 72. Ischaemic change within the right colon
Figure 73. Hepatic cysts and free fluid

CT scanning of the abdomen is excellent at diagnosing intestinal perforation. CT will often demonstrate the actual site of perforation, any complications that have arisen (e.g. ascites, abscess formation), and will allow accurate preoperative surgical planning.

**Intestinal ischaemia**

Many ICU patients are at risk of developing bowel ischaemia – a condition that is notoriously difficult to diagnose clinically. Acute intestinal ischaemia secondary to thrombosis or embolic disease is usually seen in elderly patients and typically, in the
non-ICU patient, presents with crampy abdominal pain, diarrhoea and bloody stools. Other causes of acute intestinal ischaemia include vascular compression secondary to volvulus, hernias or intussusception and non-occlusive causes such as hypotensive/low cardiac output states. Chronic ischaemia occurs when progressive occlusive disease (usually athlerosclerosis), affects the mesenteric arteries.

Radiological diagnosis of intestinal ischaemia can also be very difficult. Plain radiographs of the abdomen are typically normal or may demonstrate the classical findings of pneumatosis with portal venous gas seen in the right upper quadrant (very rarely seen in clinical practice). CT scanning may demonstrate indirect signs such as bowel wall thickening (earliest sign but is non-specific) and ascites. CT may also demonstrate direct signs of mesenteric ischaemia such as pneumatosis (Figs. 72 & 73 above), portal venous gas or thrombus within the mesenteric vessels and has become the everyday investigation for suspected bowel ischaemia. In patients where CT is contraindicated, MR mesenteric angiography is an alternative option and although it is regarded as the gold standard investigation for suspected intestinal ischaemia, it is usually reserved for cases where non-invasive modalities have been non-diagnostic or where intervention is required. This is mainly due to its invasive nature and the diagnostic challenge often presented by mesenteric ischaemia regardless of which procedure is used.

**Acalculous cholecystitis**

Many ICU patients are at risk of developing acalculous cholecystitis. Knowledge of the condition coupled with a high index of suspicion should help in ensuring that the diagnosis is not overlooked. The imaging technique of choice is biliary ultrasonography.

Ultrasound features of acalculous cholecystitis:
- Distended gall bladder without calculi
- Sludge and debris in the gall bladder
- Sonographic Murphy’s sign (presence of maximal tenderness, elicited by direct pressure of the transducer over a sonographically located gall bladder)
- Gall bladder wall thickening >2 mm
- Pericholecystic fluid.

None of the above features are diagnostic and the condition can occur without any of the signs listed.

Treatment is with endoscopic retrograde cholangioduodenal stent drainage or ultrasound guided insertion of a percutaneous cholecystostomy tube (a pigtail catheter). Often a ‘trial’ of cholecystostomy is warranted as this will lead to an improvement in clinical status in approximately 60% of patients. Cholecystectomy could be considered in patients fit to undergo operation.

**Note** Acalculous cholecystitis is seen in ICU patients with serious comorbid life-threatening conditions such as trauma, burns, diabetes, AIDS and in patients who are postoperative.
The following paper describes the use of percutaneous cholecystostomy in ICU patients who had no other definable source of sepsis.

http://www.ajronline.org/content/163/2/339.long

Over the next four weeks identify patients in your ICU who develop sepsis and who are at risk of acalculous cholecystitis. Has this condition been ruled out as a potential source of sepsis in these patients? Discuss the merits of investigating these patients further at the multidisciplinary ICU meeting. If no one thinks of this diagnosis it will never be made!

**Intra-abdominal collections, abscesses and pancreatitis**

Many critical care patients are at risk of developing intra-abdominal collections/abscesses. Postoperative patients are at particular risk. The investigation of an ICU patient with a suspected intra-abdominal collection may include an initial portable ultrasound but CT scanning of the abdomen remains the gold standard investigation.

Hepatic abscesses may arise *de novo* or often as a complication of biliary pathology, hepatic malignancy or inflammatory bowel disease. Imaging with US, CT and MRI will help in characterisation and in distinguishing hepatic abscesses from other liver lesions such as metastases, haemangiomas, adenomas, focal nodular hyperplasia, simple cysts, regenerative nodules or liver infarction. Contrast enhanced CT is the most useful test in diagnosing and assessing hepatic abscess. Typically abscesses are hypodense and may exhibit the ‘cluster sign’ where a number of smaller abscesses coalesce to form a larger abscess. They may contain air or an air fluid level. Following the administration of intravenous contrast, peripheral rim enhancement is typical. In cases of diagnostic uncertainty T1 weighted contrast enhanced MRI imaging will demonstrate a hypointense lesion with peripheral rim enhancement. An abscess will be hyperintense on T2 weighted imaging. Diffusion weighted MR imaging and ADC mapping is often particularly useful in distinguishing hepatic abscess from necrotic tumour when these entities may appear identical on other sequences. US or CT can be used to guide percutaneous drainage.

For more information on the MR physics of these sequences: http://www.mrinotes.com

For further information on ADC mapping and other sequences used in MR imaging see http://radiographics.rsna.org/content/26/6/e24.full

*T1 and T2 weighting refer to time parameters used in the acquisition of the MR image. Different weightings can be used to highlight different tissue types depending on the physical characteristics of the particular tissue.*

*ADC mapping refers to the Apparent Diffusion Coefficient map. This is derived from a diffusion weighted data set used to evaluate the movement of water.*
Pancreatitis may result in critical illness and is often complicated by abscess formation, pancreatic necrosis (often infected) and multiorgan failure. These patients frequently require prolonged ICU admission. Traditionally severe acute pancreatitis was managed surgically but modern multislice CT imaging and widespread use of CT guided percutaneous drainage (or alternative non-invasive surgery) and critical care has meant that many patients now avoid surgery, or necrosectomy can be usefully delayed for a number of weeks. Pancreatitis has very typical imaging characteristics on CT.

Link to PACT module on Pancreatitis

Figures 74 and 75. Inflammatory stranding in fat/Air fluid level within collection
Figures 76 and 77. Axial contrast enhanced CT scan of the abdomen

**Figure 2012:112.**
Hepatic abscess on contrast enhanced CT in a patient with a tumour at the head of pancreas. Note the ill-defined area of low attenuation in the right lobe of liver. There is no contrast enhancement seen in this case and the appearances could be in keeping with either a metastasis or a hepatic abscess.
Figures 2012:113, 114, 115, 116. The same lesion as seen in image 2012:112 is further characterised with contrast enhanced MRI and diffusion weighted imaging. Image 2012:113 is a T1 weighted image (see definition p. 41) showing a focal area of low signal intensity in the right lobe of liver. Figure 2012:114 shows the same area on T2 weighted imaging has abnormally high signal when compared to background liver. Figure 2012:115 shows the same area has abnormally restricted diffusion on diffusion weighted imaging. Figure 2012:116 shows a thin rim of enhancement at the periphery of this lesion on T1 post contrast imaging. These MR imaging characteristics are in keeping with an abscess as opposed to a tumour and thus MR allows us to definitively identify this liver lesion.

Figures 2012:117 and 118. Image 2012:117 shows an enlarged pancreas. Note the heterogenous enhancement to the pancreas with focal non-enhancing areas representing pancreatic necrosis. There are multiple fluid collections, obliteration of the normal fat planes and ascites. This image was acquired immediately prior to the placement of a pigtail drain in the necrotic pancreatic tail. Note the skin markers on the patients left side. 2012:118 shows the pigtail drain post insertion.
Common indications for percutaneous drainage include:

- Appendiceal abscess
- Diverticular abscess
- Postoperative collection/abscess
- Biloma/biliary ascites
- Hepatic abscess
- Pancreatitis/pancreatic pseudocyst/infected pancreatic necrosis.

Early discussion of each individual case with the interventional radiologist is important to successful patient management. Patient preparation for percutaneous drainage includes:

- Informed consent from patient, if possible. Benefits and potential risks should be explained (this is best done by the radiologist performing the procedure).
- Checking coagulation status. Coagulopathy is a relative contraindication to percutaneous drainage and in this setting its appropriateness will depend on the prospective patient benefit, the alternatives and local practices. Generally speaking, the INR should be <1.2 for all abdominal interventional techniques (exceptions may be necessary in emergency situations). An APTT and platelet count should also be checked.
- Prophylactic antibiotics in certain cases e.g., in those not already on appropriate antibiotic therapy for related systemic sepsis.

Two techniques of abscess drainage are widely used – Trochar technique and Seldinger technique.

**Trochar technique**

This technique is used for larger abscesses and those with uncomplicated access. The technique can be performed under ultrasound or CT guidance. The catheter is placed on a trochar, which is placed into the abscess using a ‘single stick’ technique.
**Seldinger technique**

Using this technique, the pigtail catheter is placed over a guide wire following initial localisation of the collection with a Seldinger needle. This technique is useful for small, complex collections with more difficult access. Generally this technique is performed under CT guidance, but fluoroscopy may also be useful for catheter exchange. It is difficult to see the guide wire using ultrasound guidance.

The Seldinger technique is used commonly for vascular and airway access. For more information on the Seldinger technique for airway access during cricothyroid and tracheostomy tube placement, see the PACT module on Airway management.

**Note** When the catheter is placed into the abscess it should be aspirated until dry and irrigated with normal saline. Interval imaging after drainage is helpful to detect any undrained locules.

**THINK** All abscess drainage catheters require proper management. Placement of the catheter is just the initial part of the treatment. Regular irrigation and aspiration are required for effective treatment.

The following papers discuss the techniques used for catheter placement and also describe proper catheter management.


**AneCdotE** In our practice, we discuss any ICU cases requiring possible percutaneous drainage before the patient is brought to the radiology department. This ensures senior review of the ICU scans as they are performed and immediate radiologic intervention e.g. abscess drainage if required.
Drains for aspiration of pancreatic collections and for drainage of infected pancreatic necrosis need to be large bore. It is essential that the correct size of drain is inserted as a narrow bore drain in these cases would be ineffective.

For further information on pancreatic necrosis, see the PACT module on Pancreatitis.

Figure 78. Acute haemorrhage on CT appearing as high-density fluid
Figures 79 and 80. Haemoperitoneum

Upper urinary tract

Ultrasound allows rapid, accurate imaging of upper urinary tract. One of the advantages of ultrasound is that it can be performed at the bedside in the ICU. Ultrasound allows assessment of patterns of renal parenchymal injury, and allows exclusion of obstructive uropathy with hydronephrosis as a potentially reversible cause of sepsis or renal failure. For an overview of the investigation of oliguria including obstructive uropathy, see the PACT module on Oliguria and anuria (Acute Kidney Injury Part I).

Figures 81 and 82. Focal hyperechogenicity and oedema

Percutaneous nephrostomy

Percutaneous nephrostomy is the introduction of a drainage catheter into the collecting system of the kidney. The procedure is performed under ultrasound and fluoroscopic guidance in the interventional radiology suite. Patients are given prophylactic antibiotics prior to the procedure if not already on appropriate antibiotic therapy for urosepsis. The complication rate for percutaneous nephrostomy is 2–4%. Major complications are haemorrhage and sepsis.

Q. What are the indications for percutaneous nephrostomy?

A. Indications for nephrostomy:
   - Obstructive uropathy
   - Obstructive uropathy especially when accompanied by (non-resolving) urosepsis.

Q. What are the contraindications to percutaneous nephrostomy?

A. The only absolute contraindication to percutaneous nephrostomy is the presence of an uncontrolled bleeding diathesis.

Investigation of nephrolithiasis

Traditionally patients were investigated for suspected renal calculi with intravenous urography (IVU) examinations. More recently, there has been increased use of non-contrast helical CT for the detection of renal calculi and the assessment of their potential complications. IVU examinations are rarely, if ever, carried out on ICU patients.
Q. What are the advantages of non-contrast CT over IVU examinations for the investigation of renal colic?

A. CT is quicker and more accurate in the detection of renal calculi. CT can detect smaller calculi and can assess the secondary complications of an obstructing calculus, e.g. hydronephrosis, inflammatory stranding in the perinephric fat. With CT there is no need for delayed imaging and also there is usually no need for intravenous contrast administration.

Figures 83–85. Non-contrast CT scan of the abdomen and pelvis

The following papers discuss the merits of non-contrast helical CT scanning for the investigation of acute renal colic.


It is now generally accepted in the radiological literature that non-contrast helical CT scanning – ‘CT IVU’, can replace the standard IVU for the investigation of acute renal colic.
CONCLUSION

As demonstrated, clinical imaging plays an integral role in intensive care medicine and it is essential that good communication exists between the critical care physician and the clinical radiologist.

Radiation safety is of paramount importance. Good working knowledge of radiation safety issues and procedures is important to ICU staff for the safe and effective practice of portable radiography.

Ultrasound is a cheap, portable and radiation free means of assessing patients at the bedside in the ICU. It is most useful in the hands of experienced operators and can be used to address a wide variety of clinical problems in the critical care patient.

Given the widespread and everyday use of plain radiography in the ICU and the limitations of the physical examination in sedated intubated patients, competent interpretive skills in the more common images, particularly the chest X-ray but also the C-spine X-ray, are crucial to the critical care practitioner.

Cross-sectional imaging technologies such as CT and MRI as well as image guided procedures can be very useful in the diagnosis and management of complex issues often seen in ICU patients and require active radiology involvement.

The authors advocate scheduled meetings between the critical care and radiology medical staff – a forum for discussing specific patient related problems regarding diagnosis and therapy. This will facilitate appropriate patient management and is an excellent opportunity for multidisciplinary continuing education.

See the PACT module on Teaching and learning.
SELF-ASSESSMENT

EDIC-style Type K

1. Magnetic resonance imaging of an ICU patient has the following advantages compared with CT scans:
   A. Is superior to CT in a number of CNS diseases
   B. Requires less time in the radiology department
   C. Is the preferred radiological investigation in severe ARDS
   D. No radiation exposure to patient

2. The correct position of a central venous catheter tip (distal part) is:
   A. In the right atrium if inserted from the right internal jugular or subclavian vein
   B. In the superior vena cava
   C. In the brachiocephalic vein if inserted from the left side
   D. In the inferior vena cava if inserted from the femoral vein

3. Diagnostic pointers to a thoracic aortic rupture on a plain film chest X-ray include:
   A. Mediastinal haematoma
   B. A right pleural effusion
   C. A left pleural effusion
   D. A mediastinal: chest diameter larger than 1:2 in the standard P-A chest X-ray

4. Definitive diagnostic tests of a thoracic aortic rupture include:
   A. Plain film chest X-ray
   B. Aortography
   C. Spiral CT of the chest
   D. Sonography of the chest
5. MRI is increasingly used in the diagnosis of spinal cord trauma. Compared to CT scan of the cervical spine, MRI:

A. Will give a better view of the bony fractures
B. Gives a better view of the content of the spinal cord
C. Gives a better view of the cervical spine ligaments
D. Has a better sensitivity to detect injuries in the craniocervical junction

6. Regarding image diagnostics of acalculous cholecystitis

A. CT with intravenous contrast is the image of choice
B. Typical image is a distended gall bladder with a stone in the common bile duct
C. Ultrasound often reveals a distended gall bladder and ‘sludge’
D. Thickening (>2 mm) of the gall bladder wall is a diagnostic sign

7. In a patient with suspected bowel ischaemia, you consider carrying out a radiology investigation to confirm your diagnosis. Regarding this option which answers are true/false?

A. Plain radiographs of the abdomen generally exhibit bowel wall thickening or other abnormality compatible with bowel wall ischaemia
B. Bowel wall thickening is an indirect sign of bowel ischaemia on the abdominal CT
C. Bowel wall pneumatosis on abdominal CT is a direct sign of bowel ischaemia
D. The reference ‘gold standard’ investigation for bowel ischaemia is mesenteric angiography

8. In reviewing a baseline diagnostic chest X-ray, the following are signs of an image which has been taken in the standardised manner:

A. Vertebral bodies are just visible behind the heart
B. The medial ends of the clavicles are equidistant from the spinous processes of the thoracic vertebrae
C. The 6th rib posteriorly intersects the ipsilateral hemidiaphragm in the mid-clavicular line
D. The 5th to 7th rib anteriorly intersect the ipsilateral hemidiaphragm in the mid-clavicular line
9. In the critical evaluation of a supine abdominal X-ray for signs of pneumoperitoneum, the following are recognised signs:
   A. Rigler’s sign of visualisation of outer as well as inner wall of a loop of bowel
   B. Air along Falciform ligament
   C. Interloop small triangular gas collections
   D. Air accumulation in the anterior of the abdomen – ‘football sign’

EDIC-style Type A

10. If you were to arrange the following radiological procedures in order from the one with the highest effective radiation dose to the lowest, please indicate the option with the correct sequence.
   1. Barium meal
   2. Urography
   3. Abdominal CT
   4. Chest CT
   5. Chest X-ray
   A. 4-2-3-1-5
   B. 3-4-2-1-5
   C. 5-4-1-5-2
   D. 4-3-1-2-5
   E. 1-5-4-3-2

11. The incidence of severe to very severe non-ionic contrast reaction is:
   A. Less than 0.05%
   B. 0.05 to 0.1%
   C. 0.1 to 0.5%
   D. 0.5 to 1%
   E. 1 to 1.5%
12. Differences between the chest X-ray in the ICU and those obtained in the radiology department include all EXCEPT:
   A. In the ICU a Posterior-Anterior radiograph must be used
   B. The exposure is usually larger and longer
   C. Motion artefacts are more frequent
   D. The apparent cardiac diameter is increased in the ICU radiograph
   E. Pleural effusions are more often overlooked

13. The attached X-ray taken in an ICU patient in the supine position shows:
   A. Massive pleural effusion on the left side
   B. Right bronchial intubation
   C. Left-sided pneumothorax with compression of the right lung
   D. Extreme left-sided patient rotation with a large mediastinum overshadowing the left lung
   E. Massive pulmonary embolism in the left branch of the pulmonary artery
14. The following radiological signs suggest cardiogenic (rather than non-cardiogenic) pulmonary oedema EXCEPT:

A. Cardiomegaly
B. Kerley B lines
C. Redistribution of pulmonary vessels
D. Diffuse interstitial infiltrates
E. Pleural effusions – usually with right greater than left

15. If the absence of obvious signs (of pneumothorax) on a chest X-ray, critical evaluation may reveal the following signs of a pneumothorax EXCEPT:

A. Deep sulcus sign
B. Unusually sharp definition of cardiac and mediastinal borders
C. ‘Bunch of grapes’ (pericardial fat) sign
D. Murray’s Oesophageal Air sign
E. V sign in the presence of atelectatic/consolidated lung

16. Diagnostic features in the systematic evaluation of the cervical spine X-ray should include the following EXCEPT:

A. AP, lateral and odontoid peg views
B. Bony alignment which includes the anterior vertebral body, posterior vertebral body and spinal laminar arcuate lines
C. Vertebral body evaluation (below C2) should show them to be fairly uniformly square or rectangular in shape and the anterior and posterior heights should be the same
D. A uniform intervertebral disc height
E. Recognition that the soft tissue evaluation is not of diagnostic significance to the cervical spine evaluation
Self-assessment Answers

1. TFFFT
2. FTFFT
3. TFTTT
4. FTFTF
5. FTFTF
6. FFTTT
7. FTTTT
8. TTFFT
9. TTTTT
10. Correct: B
11. Correct: A
12. Correct: A
13. Correct: B
14. Correct: D
15. Correct: D
16. Correct: E
Patient Challenges

Patient 1

A 24-year-old man is involved in a high-speed motorcycle accident. He receives blunt chest trauma in addition to multiple lower limb fractures. On admission to accident and emergency he is hypotensive, tachycardic and confused. Resuscitation is promptly initiated and subsequently a chest X-ray is performed (Fig. 86).

Interpretation of the chest X-ray in thoracic trauma

Q. The evidence of pulmonary contusion is noted. What are the pressing findings on this chest X-ray?

A. There is a widened mediastinum, a left apical cap and depression of the left main bronchus and some evidence of a left-sided pleural effusion.

http://radiology.rsna.org/content/213/1/195.long

Q. What is the preliminary diagnosis in this case?

A. There is evidence of severe chest trauma, left pleural haemorrhage and a widened mediastinum.

Q. Which injury/pathology needs to be urgently excluded?

A. An acute traumatic aortic transection.
CT features of aortic transection

Q. What further radiological investigation should be performed to confirm this diagnosis?

A. Either a CT scan of the thorax with intravenous contrast or an arch aortogram should be performed to rule out aortic transection.

The diagnosis is confirmed on CT scanning of the chest (Figs. 87, 88 & 89). Multiplanar reconstructions aid in the diagnosis of aortic transection.

Fig. 87 is an axial image from a contrast-enhanced CT scan of the thorax in a 24-year-old male post motorcycle accident. Note the bibasal pleural effusions. Note the intimal flap within the descending aorta (lower arrow). The findings are consistent with acute traumatic aortic transection. Note the mediastinal haematoma seen anterior to the great vessels (upper arrow).

Figs. 88 & 89 – Oblique sagittal multiplanar reconstructions from the same CT scan of the thorax demonstrate the calibre change in the lumen of the descending aorta at the level of the ligamentum arteriosum (arrows). The findings are consistent with acute aortic transection.
The patient is assessed by the cardiothoracic team and is transferred to the operating theatre where an aortic repair using an interposition graft is performed. The procedure is successful and the patient is admitted to the ICU for further management. He is intubated and ventilated and has an uneventful 72 hours postoperative period and is extubated after a further 24 hours. Five days following extubation the patient develops respiratory distress and central chest pain. PO$_2$ is 7.2 kPa (54 mmHg) on 60% oxygen. You are called to evaluate the patient and you suspect an acute pulmonary embolus or fat embolism as the cause of the patient’s symptoms but there are no clinical signs of the fat embolism syndrome.

You discuss with your Radiology colleagues the types of radiological tests you could order to establish the diagnosis of acute pulmonary embolus.

**Learning issues**

Imaging the patient with suspected acute pulmonary embolus

**Q. Which radiological test would you consider? Give reasons for your answer.**

A. The options are ventilation/perfusion (V/Q) lung scanning, CT pulmonary angiography or conventional pulmonary angiography.

**Q. Give reasons for differentiating between these three options?**

A. V/Q scan is unlikely to allow definite decision making in this postoperative situation. In the ICU setting, spiral CT pulmonary angiography has considerable advantages. It is a rapid and accurate test which has the added advantage of excluding other concomitant conditions, as ancillary findings are commonly found at CT pulmonary angiography.


Spiral CT pulmonary angiography using a multislice CT scanner is performed and reveals central pulmonary artery filling defects bilaterally consistent with massive pulmonary emboli (Figs. 90 & 91).
New developments in CT scanning


Duplex ultrasonography reveals a right common femoral DVT (Figs. 92 & 93) with occlusion of the left femoral vein.
The patient is reintubated and requires inotropic support. The CVP is normal and an echocardiogram shows no sign of right heart failure.

Q. What are the treatment options in this case, considering that the patient has had recent thoracic surgery?

A. In this case anticoagulation would be hazardous given the history of recent surgery. Likewise thrombolysis would almost certainly be associated with haemorrhage from the recent surgical intervention and is not indicated on haemodynamic or echocardiographic grounds. The next step in the management of this case would justifiably be the placement of an inferior vena caval filter to prevent further pulmonary embolus. Caval filters are normally placed via the right common femoral vein.

**Learning Issues**

Indications for placement of caval filters
Vena caval filter procedures are performed under fluoroscopy and are well tolerated in seriously ill patients. The procedure involves a femoral or jugular venous puncture using local anaesthesia.

As the right common femoral vein is occluded in this patient and left-sided placement should be avoided, the vena caval filter is placed via a transjugular route, below the level of the renal veins. The procedure is performed without complication and the patient is returned to the ICU. Over the following days the patient improves and is extubated on day five of his ICU admission. On day six the patient develops a temperature of 39 °C and vague epigastric tenderness. A clinical work up finds right upper quadrant tenderness and a full septic screen is performed. You discuss the case with a radiology colleague who agrees to perform a portable abdominal ultrasound in order to rule out cholecystitis or other intra-abdominal source of sepsis.

The ultrasound reveals a grossly distended, thick walled gall bladder without evidence of gallstones (Fig. 94). There is no evidence of intrahepatic duct dilatation and the remainder of the examination is within normal limits.

Q. In the face of a negative septic screen in this seriously ill patient other than the grossly distended gall bladder, what treatment option should be considered?

A. In a febrile patient with a distended gall bladder, in the absence of another cause of sepsis, consideration must be given to the diagnosis of acute acalculous cholecystitis and performance of percutaneous cholecystostomy.

Fig. 94 is a portable abdominal ultrasound of the upper abdomen which demonstrates a distended, thick walled gall bladder (arrows), without evidence of gallstones.
Interventional radiological techniques

**Note** Unexplained fever in an ICU patient

PACT module on Pyrexia

PACT module on Severe infection

PACT module on Sepsis and MODS

Portable ultrasound in the ICU

Acute acalculous cholecystitis

**Q. How is percutaneous drainage performed?**

**A.** Percutaneous cholecystostomy is performed under ultrasound guidance. A pigtail catheter is inserted into the distended gall bladder and locked in position. Samples of bile are sent for culture and sensitivity, and microscopy. The procedure can be performed in the ICU at the bedside.

Following placement of a percutaneous cholecystostomy tube frank pus was drained from the gall bladder (Fig. 95).

Within 24 hours of the procedure the patient’s temperature settled and thereafter he continued to make an uneventful recovery without jaundice. Following injection of the catheter to ensure cystic duct patency the cholecystostomy tube was removed after ten days and the patient was discharged from the ICU. Successful interval laparoscopic cholecystectomy was performed two weeks post discharge from the ICU when the patient was clinically stable and ready for home.
Patient 2

A 64-year-old man is admitted to the Coronary Care Unit with severe refractory heart failure secondary to dilated cardiomyopathy. His ejection fraction is 10% and echocardiography reveals dilated left and right heart chambers. A coronary angiogram reveals normal coronary arteries. A chest X-ray is performed (Fig. 96). The patient is evaluated and subsequently listed for heart transplant.

Q. What abnormalities are demonstrated on this chest X-ray and what conclusions do you draw?

A. This chest X-ray demonstrates gross cardiomegaly, upper lobe venous diversion, septal lines and bibasal pleural effusions. These are features of severe cardiac failure with resultant pulmonary oedema.

Learning Issues

Interpretation of the ICU chest X-ray

Chest X-ray findings in cardiac failure

A suitable donor becomes available and cardiac transplantation is performed following which the patient is admitted to the ICU. A postoperative chest X-ray is performed (Fig. 97).
Q. What intravascular catheters and tubes are shown on this plain film and where are they positioned?

A. This chest X-ray demonstrates a tracheal tube, a left chest drain, a mediastinal drain, a central venous catheter at the junction of SVC and right atrium, a pulmonary arterial catheter (coiled in right atrium) with tip in proximal left main pulmonary artery, and an intra-aortic balloon pump with its tip in the proximal descending aorta. There are also external ECG leads and a left effusion with atelectasis in the left lower lobe.

Learning issues

Imaging of tubes and intravascular catheters

During the immediate postoperative period he makes excellent progress, being extubated and off vasoactive support by the second postoperative day. On the third postoperative day he develops acute abdominal pain. Clinical examination reveals mild epigastric tenderness and decreased bowel sounds. A supine plain abdominal X-ray is performed which reveals faecal loading in the right side of the colon. The patient’s condition worsens and a CT scan of the abdomen is performed (Fig. 98).
Indications for abdominal CT

Q. What does this CT scan of the abdomen demonstrate and what are the likely causes of this abnormality?

A. This CT scan demonstrates the presence of free intra-abdominal air consistent with bowel perforation. The likely cause in this case would be bowel perforation secondary to peptic ulcer disease, diverticular disease or bowel ischaemia.

Bowel perforation

Q. In retrospect, what radiological investigation could have been performed to confirm the presence of free intra-abdominal air?

A. An erect or left lateral decubitus plain film of the abdomen could have been performed to confirm the presence of intra-abdominal air. This is a useful and frequently overlooked investigation.

The use of plain film radiographs in the ICU

The patient is resuscitated, has blood cultures taken and is started on antimicrobial therapy for abdominal sepsis. He is transferred to the operating theatre and a laparotomy is performed. A perforated duodenal ulcer is discovered which is successfully repaired. Mild peritoneal soiling is managed with abdominal wash out. Intravenous broad-spectrum antibiotics are maintained and the patient is readmitted to the ICU.

[65]
Five days later the patient develops diarrhoea, abdominal distension and a pyrexia of 39.5 °C. Clinical examination reveals tenderness in the right flank, there is loss of tolerance of enteral feed and a new leukocytosis supervenes. After renewed blood cultures, an antifungal is added to his (peritonitis targeted) antibiotics but the temperature fails to settle, the tenderness in the right flank persists and his serum creatinine is elevated.

A portable abdominal ultrasound is performed (Figs. 99 & 100) which demonstrates an abnormal appearance of the wall of the large bowel.

Imaging the patient with abdominal/GI dysfunction

Puylaert JB. Ultrasound of acute GI tract conditions. Eur Radiol 2001; 11(10): 1867–1877. PMID 11702119
Q. Describe the abnormality seen in the bowel wall. What is the most likely cause?

A. The bowel wall appears markedly thickened consistent with extensive oedema. These findings are suggestive of acute colitis.

Q. What is the most likely cause of the colitis?

A. The most likely cause of colitis in this patient who is receiving antibiotics and who is immunocompromised is *Clostridium difficile* colitis (pseudomembranous colitis).

Metronidazole was added (enterally), the diagnosis was confirmed by exotoxin from a stool sample and the symptoms and signs resolved. The patient made a good recovery and was discharged from the ICU on day 12 post cardiac transplant.

**Patient 3**

A 68-year-old lady is transferred to your ICU from a district hospital with a background history of atrial fibrillation. She had undergone a laparoscopic cholecystectomy five days earlier which was complicated by postoperative sepsis. A laparotomy was performed two days after the initial surgery, and a collection of infected bile was drained from her gall bladder fossa. Her clinical condition has deteriorated over the 72 hours preceding her transfer to your hospital, she required ventilatory and inotropic support and she was transferred to your ICU for further critical care and multidisciplinary management due to lack of appropriate facilities at the referring institution. That evening she develops a pyrexia of 40 °C and a full septic screen is performed.

Further to this, a CT scan of the abdomen is requested to exclude any residual fluid collection which might account for her ongoing pyrexia (Fig. 101).
Q. What does this CT scan of the abdomen show? What are your conclusions?

A. There is stranding of the intra-abdominal fat seen in the gall bladder fossa consistent with recent surgical intervention. Note the surgical drain in the gall bladder fossa (arrow – Fig 101). No discrete fluid collection is seen.

CT scanning of the abdomen

Despite a change in her broad-spectrum antibiotic therapy, her condition deteriorates. Forty-eight hours later a repeat CT is performed, as her temperature has not settled (Fig. 102).

Q. What does this CT scan of the abdomen demonstrate? What is your opinion of the splenic image?

A. There is persistent stranding seen in the region of the gall bladder fossa but again, no discrete fluid collection or abscess is identified. There is no enhancement in the spleen consistent with complete splenic infarction (arrows – Fig 102).

Q. How do these findings explain the patient's continued pyrexia?

A. Splenic infarction can cause persistent pyrexia. Due to the large volume of tissue infarcted there is a massive inflammatory response which may take days to settle.

Q. What are the implications for the patient's immediate management?

A. Consider stopping her systemic antimicrobials which were started for a presumed infective aetiology.
Q. What other implications are there for the patient’s future management?

A. The patient no longer has any functioning spleen and should be managed in the same way as a patient who has a splenectomy with regards to prophylactic antibiotics (from now) and vaccinations (before leaving hospital).

**On reflection**, the clinical course of these patients was complicated and involved many radiological investigations. When deciding on the most appropriate radiological investigation, a simple discussion with your radiology colleague can be rewarding and time-saving. Ideally, a radiologist should attend each multidisciplinary meeting to provide advice on ordering radiological investigations, to plan interventional procedures and to provide image interpretation particularly of the chest and other radiographs. There are many occasions when the simplest and least expensive test may yield the most diagnostic information but likewise the diagnostic capabilities of the more sophisticated tests are continuously expanding. Many radiological interventional techniques can be performed at the bedside in the ICU using portable ultrasound and with the emergence of multislice CT, the time spent by the patient outside the ICU can be greatly reduced.
