DATA INTERPRETATION FOR MEDICAL STUDENTS

Second Edition

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Contents

Preface to second edition vi
Acknowledgements v
Normal values vi
1. Haematology 1
2. Biochemistry 55
3. Endocrinology 139
4. Toxicology 167
5. Pleural and peritoneal fluid analysis 189
6. Microbiology 213
7. Neurology 221
8. Immunology 239
9. Imaging 245
10. Cardiology 341
11. Pathology 395
12. Genetics 401
13. Respiratory medicine 419
14. Interpreting bedside chart data 451
15. Miscellaneous 493
16. Complete clinical cases 509
Index 597
IMAGING

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The interpretation of imaging investigations is a comprehensive topic that forms a specialty in its own right. Its influence and remit in contemporary medicine are vast forming huge amounts of ‘digital data’ for interpretation. It is essential that medical students and trainee doctors have a sound basic understanding of plain radiographs (X-rays), in particular chest and abdominal radiographs. Likewise an appreciation and insight into the more advanced imaging investigations at their disposal is increasingly important, in particular the ever popular and influential computed tomography (CT). A good professional relationship with the radiology department, including thoughtful and selective referral, can hugely aid patient care.

This chapter does not aim to be a concise undergraduate textbook on radiology. Nor will it be an exhaustive description of characteristic radiological findings in common diseases or a gallery of images. It is a guide to approaching the interpretation of common X-rays and the basics of CT of the head. In the clinical cases featured the emphasis will be on inpatient films – these are X-rays that one might be expected to interpret during work on general medical and surgical wards or the accident and emergency department. Films are presented in a symptom-based manner to best reflect everyday practice and to provide instruction on how interpretation may immediately assist your diagnostic pathway and therefore your management decisions. No film will be viewed in isolation without clinical information. As with all the data interpretation considered in this book, investigations should be assessed in the light of the clinical scenario and laboratory results. This should also be the gold standard to aspire to in clinical practice.

Imaging studies may feature in both written and clinical examinations, offering the chance to assess a broad knowledge base.

**DON’T FORGET**
Always interpret X-ray findings in a clinical context.
Compare the images with old films if available.
Interpreting the chest X-ray

The chest X-ray (CXR) is the single most requested imaging investigation and is also the most likely film to feature in daily practice or an undergraduate exam. It is the perfect prompt for questioning other aspects of a patient’s condition and to explore management strategies. To be able to comment confidently on the film’s findings, and have an understanding of how to approach interpretation, an appreciation of normality is required. Don’t forget that a CXR is a two-dimensional representation of a three-dimensional structure.

One may think of a CXR as a picture that contains five ‘shades’ on a black-and-white scale. These shades represent four different natural ‘tissues’ and one for artefacts.

These are:

1. Bone is WHITE
2. Gas is BLACK.
3. Soft tissue is GREY
4. Fat is DARKER GREY.
5. Most man-made things on the film are BRIGHT WHITE.
Film specifics and technical factors

Before proceeding to interpret a CXR, always comment on film specifics and technical factors as shown in the boxes below.

**FILM SPECIFICS (DETAILS)**

- Name of patient
- Age and date of birth
- Location of patient
- Date taken
- Film number (if applicable)

**FILM TECHNICAL FACTORS**

- Type of projection (see box below)
- Markings regarding any special techniques used (e.g., taken in expiration)
  - Rotation
  - Inspiration
  - Penetration

**TYPES OF PROJECTION**

- **Posteroanterior (PA):** the X-ray tube is behind the patient and film against the chest. The GOLD standard projection
- **Anteroposterior (AP):** the X-ray tube is in front of the patient and film against the back
- **Supine:** the patient is lying on his or her back
- **Erect:** the patient is upright
- **Semi-erect:** the patient is partially upright
- **Mobile:** the X-ray has been taken with a mobile X-ray unit. VERY SICK patients ONLY (on the ITU/HDU/CCU usually)

These descriptions may be combined. For example, an acutely unwell patient who has a CXR taken on an intensive therapy unit (ITU) may have a mobile, semi-erect AP film.

You might think of this part of the interpretation, like the safety announcement on an airplane, as one you have heard many times: necessary to acknowledge, but tedious and of little consequence. However, this could not be further from the truth. Changes in these parameters can give the impression of
abnormalities in the structures visualised. For example, a widened mediastinum, on an AP chest X-ray may provoke the impression of a thoracic dissection or a pneumothorax may be overlooked if one does not appreciate that the chest X-ray is supine rather than erect.

**Assess the film in detail**

A structured systematic approach is needed for thorough interpretation, just as one would approach a clinical system examination in a methodical manner.

It is good practice to mention a clear-cut abnormality at the outset. A reasonable way to say this would be, ‘The technical quality of the film is satisfactory. The most striking abnormality on initial assessment is …’.

The examiner will then expect the candidate to demonstrate an organised approach to looking at the rest of the film. Do not stop when one abnormality has been noted (termed ‘the satisfaction of search’) – there may be more to see.

**DON’T FORGET**

Keep looking – multiple findings may give the definitive diagnosis.

The structures below need to be assessed in the interpretation of the CXR. It is fair to assume that, if one major abnormality is clearly ‘spotted’ at the beginning, this structure or system should be commented on first.

**Structures to assess on CXR**

- Heart and major vessels
- Lungs and pleura
- Mediastinum (including hila)
- Bones and soft tissues.

Be particularly careful not to miss the following REVIEW areas. They should be specifically checked as abnormalities in these areas may be easily overlooked.

**Review areas**

- Costophrenic angles (1)
- Apices (2)
- Behind the heart (3)
- Below the diaphragms (4)
- Breast shadows (in females) (5).
Heart and major vessels

Assess:

- Size of the heart
- Size of individual chambers of the heart
- Size of pulmonary vessels
- Evidence of stents, clips, wires, valves, pacemakers
- Outline of aorta, inferior (IVC) and superior (SVC) vena cava.

DON’T FORGET

Do not comment on heart size on an AP chest X-ray because it is magnified.
Lungs
Assess:
- Size
- Intrapulmonary pathology
- Bronchovascular lung markings.

Pleura
Assess:
- Thickness or calcification
- Fluid or air in the pleural space.

Mediastinum (including hila)
Assess:
- Width of the mediastinum
- Contour of the mediastinum
- Size and density of the hila
- Level and symmetry of the hila.

Bones and soft tissues
Assess:
- Diffuse or focal bony abnormalities
- Surgical emphysema
- Breast presence/absence and symmetry.
Interpreting the abdominal X-ray

Abdominal X-ray
The abdominal X-ray (AXR) has more limited value in diagnosis than a CXR. Its chief value is in the diagnosis of bowel obstruction and renal tract calculi, although other pathology may be identified. Even in these cases, the abdominal X-ray is often just a ‘stepping stone’ to further imaging with ultrasonography or CT. Indiscriminate requesting of the abdominal X-ray is discouraged.

The radiation exposure of an AXR compared with a CXR is also considerably higher. One AXR is equivalent to 35 CXRs.

As with a CXR, an appreciation of normality is vital in order to make a correct interpretation.

Film specifics and technical factors
The initial assessment of an AXR is similar to for a CXR.

<table>
<thead>
<tr>
<th>FILM SPECIFICS</th>
<th>FILM TECHNICAL FACTORS</th>
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<tbody>
<tr>
<td>Name of patient</td>
<td>Type of projection (supine is standard)</td>
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<tr>
<td>Age of patient</td>
<td>Markings of any special techniques used</td>
</tr>
<tr>
<td>Location of patient</td>
<td>Adequate anatomical coverage</td>
</tr>
<tr>
<td>Date taken</td>
<td></td>
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<tr>
<td>Film number (if applicable)</td>
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Assess the film in detail
A simple guide to interpretation is shown below. Working through these headings, one covers ‘black bits’, ‘white bits’, ‘grey bits’ and ‘bright white bits’ in turn. Alternatively one may take an anatomical approach to interpretation.

‘Black bits’
Intraluminal gas
Intraluminal gas can be normal. Extraluminal gas is abnormal. However, intraluminal gas can be abnormal if it is in the wrong place or if too much is seen.

The maximum normal diameter of the large bowel is 5.5 cm. Small bowel should be no more than 3.5 cm in diameter. The natural presence of gas within the bowel allows assessment of calibre, although the amount varies between individuals. The caecum is not considered to be dilated unless wider than 8.0 cm in diameter.

Large and small bowel may be distinguished by looking at bowel wall markings.

DON’T FORGET
The hastra of the large bowel extend only a third of the way across the diameter of the large bowel from each side. The valvulae conniventes of the small bowel traverse the whole diameter.

It is usual to see small volumes of gas throughout the gastrointestinal (GI) tract and the absence in one region may in itself represent pathology. For example, if gas is seen to the level of the splenic flexure and nothing is apparent distal to this, a site of the obstruction at this site – a ‘cut-off’ point – is assumed.

Extraluminal gas
When a bowel or any other gas-containing structure perforates, its contained gas becomes extraluminal. Extraluminal gas is never normal, but it may be seen following intra-abdominal surgery or laparoscopy.

CAUSES OF EXTRALUMINAL GAS

<table>
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<tr>
<th>Post-abdominal surgery/laparoscopy</th>
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<tr>
<td>Perforation of viscus (eg bowel, stomach)</td>
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<tr>
<td>Abscess/Collection</td>
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DON’T FORGET
An erect CXR (not AXR) is the best projection to diagnose a pneumoperitoneum (gas in the peritoneal cavity).
‘White bits’
Calcification
Calcified structures are often seen on an AXR. The main question is: ‘Does their presence have any important implications?’ Calcification can be broadly divided into three types:

1. Calcification that is an abnormal structure, eg gallstones, renal calculi, calcified splenic artery aneurysm.
2. Calcification that is within a normal structure, but represents pathology, eg pancreatic ductal calcification.
3. Calcification that is within a normal structure, but is not clinically significant, eg lymph node calcification or a calcified pelvic phlebolith.

Bones are normal ‘white’ structures. On the AXR they comprise mainly those of the thoracolumbar spine and pelvis. Findings are often incidental.

‘Grey bits’
Soft tissues
Soft tissues represent most of the contents of the abdomen and feature prominently in the AXR. However, these tissues are poorly visualised and delineated when compared with other imaging techniques such as ultrasonography, CT or MRI.

The outlines of the kidneys, spleen, liver and bladder (if filled) can be seen in addition to psoas muscle shadows. An abdominal X-ray, however, should not be requested to specifically look at these structures.

‘Bright white bits’
Foreign bodies
Foreign bodies represent an interesting final observation. These may have been purposely placed in or on the body, for example, an aortic stent, an inferior vena cava filter or abdominal drains. Sterilisation clips and an intrauterine device are common findings in women. Other objects that may be seen include ingested and rectal foreign bodies, as well as items in the path of the X-ray beam, such as belt buckles, dress buttons and umbilical jewellery.

Other imaging modalities
There is a range of other imaging modalities in regular use – the majority of which do not feature significantly in undergraduate exams. Knowledge of their importance in diagnosis should be sufficient, in particular which investigation should be requested for different common clinical scenarios.
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### IONISING RADIATION TECHNIQUES

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<tr>
<th>Technique</th>
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<tr>
<td>Contrast/fluoroscopic studies</td>
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<tr>
<td>Positron emission tomography (PET)</td>
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<tr>
<td>Computed tomography (CT)</td>
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<tr>
<td>Nuclear (radionuclide) imaging</td>
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### NON-IONISING RADIATION TECHNIQUES

<table>
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<tr>
<th>Technique</th>
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<tbody>
<tr>
<td>Ultrasonography</td>
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<tr>
<td>Magnetic resonance imaging (MRI)</td>
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Computed tomography (CT) and MRI play a diverse and pivotal role in contemporary clinical care. These cross-sectional imaging modalities have a hugely influential position in the diagnostic process.

**Fig 9.6:** CT Pulmonary angiography: saddle pulmonary embolus.

**Fig 9.7:** MRCP: CBD stones
**CT of the head**

In the last decade the use of computed tomography (CT) has exploded, with clinicians increasingly becoming familiar with its value and undertaking self-review of images within their specialty areas. This is particularly true for CT of the head. With this there is a growing expectation of familiarity and knowledge of key pathologies.

The most commonly requested CT scan, all hours of the day and night, is a head CT. Quick and inexpensive to acquire, and fast to report, an ever-growing number of clinicians view CT of the head independently. For this reason an introduction to CT of the head is included and key pathologies are featured in the clinical cases.

Specific NICE (National Institute for Health and Clinical Excellence) guidelines have been written with respect to the indications for head CT after trauma. These include:

- Glasgow Coma Scale (GCS) <13 when first assessed or GCS <15 2 hours after injury
- Suspected open or depressed skull fracture
- Signs of base of skull fracture
- Post-traumatic seizure
- Focal neurological deficit
- More than one episode of vomiting (SIGN [Scottish Intercollegiate Guidelines Network] guidance suggests two distinct episodes of vomiting)
- Coagulopathy + any amnesia or loss of consciousness since injury
- More than 30 minutes of amnesia of events before impact.

**DON’T FORGET**

If there is concern over intracranial haemorrhage, the scan must be performed unenhanced. Acute blood and contrast look the same!
**Approach to assessment of a head CT**

A brief outline of how to approach reviewing a head CT study is outlined below, starting with an understanding of the major anatomical structures.

The normal appearances of key structures in the supra- and infratentorial brain are shown in Figs 9.8–9.12.

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**Fig 9.8**

**Fig 9.9**
Fig 9.10

Fig 9.11

Fig 9.12
Head CT: key basic facts
CT demonstrates a wide-ranging grey scale, referred to as attenuation. In the brain this is often stated to be hypo-, iso- or hyperdense in relation to the brain normal parenchyma:

- CSF in the brain will appear black
- The bone of the skull will appear white
- Grey and white matter within the brain have different attenuations; the densely packed nerve cell bodies of the grey matter have a higher attenuation than the nerve axons of the white matter, meaning that surprisingly white matter is darker than grey matter on CT
- Blood contains protein, making it dense, and areas of acute haemorrhage appear high attenuation (white) on a CT scan
- Areas of dead or damaged brain tissue (encephalomalacia or ischaemic brain) will become less dense, meaning that they will appear darker than the surrounding brain (low attenuation)
- Intravenous contrast on CT highlights blood vessels or vascular areas of the brain. It is also useful for identifying areas of high cell turnover, such as tumours and infection. Aneurysms, tumours and abscesses all become brighter after contrast administration.

Assessment of the CT head

- Is the ventricular system the appropriate size?
- Is there any acute blood present? If so, is it intraparenchymal, subarachnoid or an extra-axial collection?
- Is there any evidence of ischaemia? If so is it focal or territorial in nature?
- Is there normal differentiation between the grey and white matter of the brain?
- Is there space around the cord at the level of the foramen magnum?
- Are the sulci effaced or the ventricles displaced suggesting mass effect?
- Check the bony skull (on bone window settings) to look for a fracture or other bony abnormality.

Check the review areas to finish:

- Anything in the ventricular system, eg blood in the occipital horns?
- Are the visualised orbits normal?
- Is there any abnormality in the mastoid air cells or paranasal sinuses?
Scenarios presenting with shortness of breath

Case 9.1

This 23-year-old university student presents to A&E acutely short of breath.

1. Describe your findings on the chest X-ray.
2. List five conditions that predispose to this condition.
1. The left hemithorax is translucent with absent pulmonary markings. The collapsed left lung is apparent centrally. No evidence of mediastinal shift. The appearances are consistent with a large left-sided pneumothorax.

2. Numerous chronic pulmonary diseases predispose to pneumothoraces. These include: chronic obstructive pulmonary disease (COPD), asthma, pulmonary fibrosis and cystic fibrosis. Other important causes of pneumothorax include: trauma, congenital pulmonary blebs and iatrogenic reasons (eg central venous line insertion, mechanical ventilation).