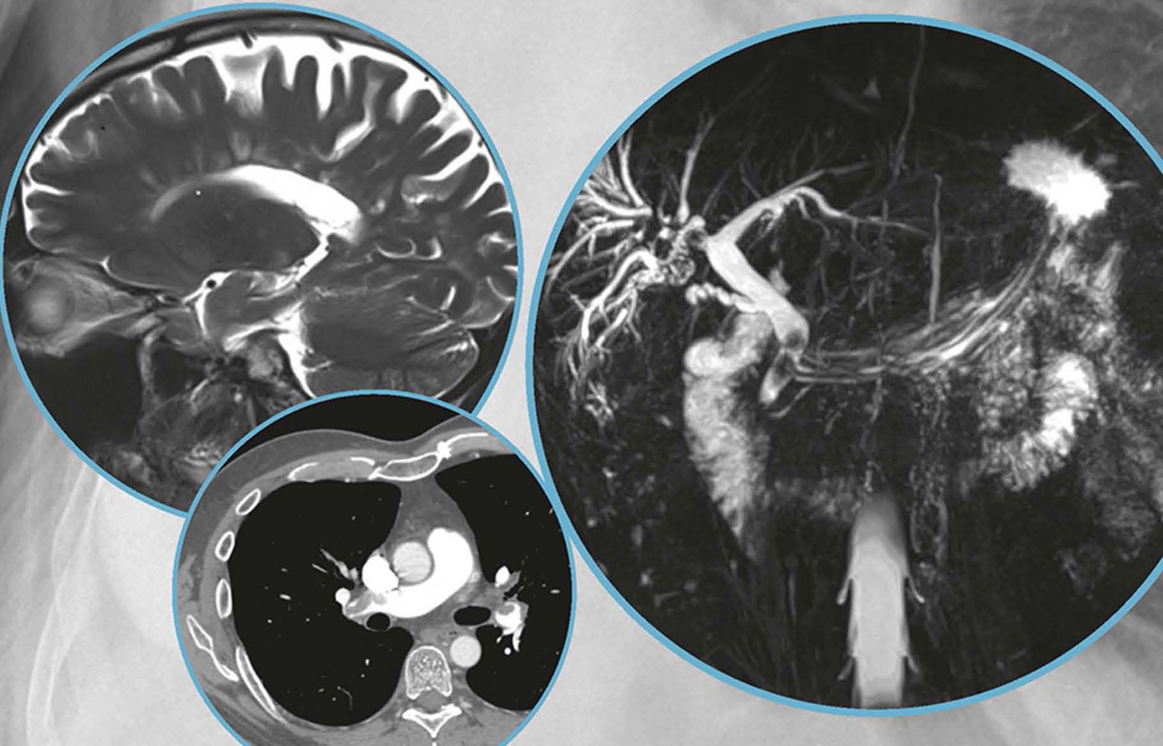
Radiology for Medical Finals

A case-based guide



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CRC Press
Taylor & Francis Group

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-8216-6 (Paperback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

For Louise and Lottie,
for their constant love, support and belief (ES)

To my dear wife Lara and all the children, Thomas, Ella, Robert and Miles,
also to my parents, Ken and Margaret, and remembering fondly
Joanna and Christopher (DCH)

Contents

Foreword by Professor Malcolm Reed

From the initial discovery of X-rays and their application to medical imaging by Wilhelm Röntgen, imaging has been an increasingly vital part of medical practice. The modern doctor needs a strong understanding of the different modalities and their application in the diagnosis and management of a wide range of medical conditions. While in many situations images are reported by expert radiologists, the ability to understand and interpret radiological images is essential and the vast majority of medical schools will require students to demonstrate fundamental skills in this area.

More importantly, diagnostic and therapeutic imaging opens a window to the internal structure and function of the human body and links the fundamental sciences of anatomy, physiology, and pathology to the patient as a whole presenting with symptoms and signs of disease. The clues gleaned from a careful history and thorough examination lead us to select the most appropriate investigations to expedite a diagnosis, allowing us to inform the patient about their condition and commence appropriate treatment. It is the distinction between normal and abnormal structure and function, which is at the core of radiological diagnosis, that provides an illustrative basis for learning and a truly patient-orientated understanding of medical disorders. As such, the use of radiology in teaching and learning facilitates and enhances the understanding of medicine and is of enormous benefit in preparing for examinations such as medical school Finals. This textbook edited by Edward Sellon and David Howlett provides an invaluable learning resource not just for students preparing for medical school Finals but any doctor preparing for subsequent professional assessments. In addition to the well-illustrated cases and a useful introduction to OSCE-style exams, the real value in this text is in the clearly structured cases based on high-quality radiological imaging, which span the whole spectrum of medicine. The book takes a regional anatomy approach with additional chapters on the normal chest and abdominal X-rays and paediatric cases.

The contributors and editors are to be commended for producing a high-quality, comprehensive compilation of cases with clear and concise questions, answers, and explanatory notes. I would commend this text book to its target audience of final year medical students but also to doctors in training in a wide range of clinical disciplines as well as those in established practice.

Professor Malcolm Reed BMedSci, MBChB, FRCS
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Foreword by Dr Giles Maskell

Radiology is an unusual medical discipline in being able to trace its origin precisely to a specific event – the discovery of X-rays by Wilhelm Röntgen in 1895. The practice of medicine was transformed almost overnight by the use of X-rays in diagnosis. The development of further imaging techniques such as ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) followed in the second half of the twentieth century and has led to medical imaging occupying a central place in the management of patients with a very wide range of conditions.

Whatever branch of medicine you pursue as a career, at some stage you will find that an understanding of medical images – X-rays and scans – will be essential to your work. You will need to understand not only the principles of interpretation of tests such as the chest X-ray but also their strengths and limitations and how to make the best use of these tests to benefit your patients.

Although imaging findings can occasionally be so characteristic that they could almost be called "pathognomonic", one of the most important lessons that you will learn is that the interpretation of an imaging test depends critically on the clinical context. The classic diagnostic sequence – history, examination, tests – is as valid today as it ever has been, despite the increasing sophistication of the imaging tests. The doctor who makes a diagnosis based only on imaging findings without due regard to the clinical context is more than likely to be tripped up.

Radiology is not a discipline that can be learned in isolation from clinical medicine. In this book, David Howlett, Edward Sellon, and their colleagues, renowned educators in this field, have therefore embedded the teaching of radiology in a series of clinical cases, which illustrate not only the specific imaging findings in certain conditions but, importantly, the principles that underpin the effective use of imaging tests in clinical practice.

Although there are encouraging signs with the establishment of undergraduate radiology societies in many medical schools, the teaching of radiology to undergraduates has not always kept up with the progress in medical imaging. I believe that this book will prove invaluable, not only in preparing students for medical Finals, but also in giving them a better understanding of the central role of imaging in modern clinical management, which will serve them well in the early years of their careers as doctors. Maybe some will even be inspired to consider a future career in this most exciting and rapidly developing discipline.

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Preface

This book has been a long time in the making and is the product of many years of both teaching and examining undergraduate medical students. Over this time there has been an exponential increase in the use of all forms of imaging in both acute and elective patient care and this has been reflected in undergraduate medical school curricula and also examinations. Radiology images feature prominently in both Finals written papers and Objective Structured Clinical Examination (OSCE), and whole OSCE stations may be based upon a chest X-ray for example. Various imaging modalities tend to feature, in particular X-rays of the chest, abdomen, and common fractures, but increasingly CT and MR images. The incorporation of radiology/imaging into Finals reflects the increasing exposure of both medical students and junior doctors to all forms of radiology and the requirement for trainees to be able to provide provisional interpretation of many forms of imaging.

This book is not intended to be an all-encompassing textbook of radiology, and the bibliography provides supplementary reading for those who wish to dig deeper. A case-based approach has been adopted and radiology images in questions have been selected in two broad categories – those that students could expect to encounter in Finals or, alternatively, to cover key learning points/educational aspects of radiology. This structure should allow students and also foundation doctors to approach both Finals and the foundation years with more confidence.

Inevitably within the book there is a strong emphasis on plain film interpretation, as these investigations are the most common form of imaging that students and junior doctors will encounter and they will also often be expected to provide a provisional interpretation. Extensive additional examples are used in case answer sections to explain and reinforce learning points throughout the book. There is widespread use also of common/important CT/MR images, again because these modalities are increasingly frontline; for example, CT head interpretation in stroke care. There is less emphasis on ultrasound and nuclear medicine, as these modalities occur less frequently in Finals, although an understanding of their use is necessary. Ultrasound does feature in some cases reflecting more widespread use of this modality on the wards and in the emergency department.

We hope you will enjoy this book and that it will stimulate and enhance your knowledge and understanding of radiology, and improve your confidence in image interpretation.

Edward Sellon
David C Howlett

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ACKNOWLEDGEMENTS

Two people in particular have been fundamental to the successful production of this book. Nick Taylor, medical photographer, has worked tirelessly and with great skill preparing the images, which are such a vital component of any book on imaging. Also Susi Arjomand who has, with her customary patience and attention to detail, typed up the numerous editing iterations of the manuscript. Thank you both.

The editors would also like to thank Jo Koster, commissioning editor at Taylor Francis, for her support and guidance throughout the publishing process. Dr Gillian Watson and Dr Justin Harris kindly provided some of the radiological images used in the text and Kirstie Leach also helped with manuscript preparation.

Finally, we would like to gratefully acknowledge all the book's contributors for their hard work and enthusiasm, and for finding the time to prepare their cases amidst busy schedules.

Abbreviations

AA	aortic arch
AAA	abdominal aortic aneurysm
AAFB	acid-and-alcohol fast bacilli
AAST	American Association for the Surgery of Trauma
ABCDE	airway, breathing, circulation, diaphragm, everything else
ABG	arterial blood gas
ACE	angiotensin-converting enzyme
AIDS	acquired immune deficiency syndrome
ALP	alkaline phosphatase
ALT	alanine transaminase
ALARA	as low as reasonably achievable
ANA	antinuclear antibodies
AP	anteroposterior (view)
ARB	angiotensin receptor blocker
AST	aspartate transaminase
AVN	avascular necrosis
AVPU	alert, voice, pain, unresponsive
AXR	abdominal X-ray
BCG	bacille Calmette-Guérin
BMI	body mass index
BNP	brain natriuretic peptide
BP	blood pressure
BPD	bronchopulmonary dysplasia
bpm	beats per minute/breaths per minute
CABG	coronary artery bypass graft
CBD	common bile duct
CC	craniocaudal (view)
CDH	congenital diaphragmatic hernia
CF	cystic fibrosis
CFTR	cystic fibrosis transmembrane conductance regulator (gene)
CLD	chronic lung disease of prematurity
CLL	chronic lymphoid leukemia
CMC	carpometacarpal
CNS	central nervous system
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
CPPD	calcium pyrophosphate deposition disease
CRP	C-reactive protein
CSF	cerebrospinal fluid
CT	computed tomography
CT IVU	computed tomography intravenous urogram
CT KUB	computed tomography kidneys ureters and bladder
CTR	cardiothoracic ratio
CTPA	computed tomography pulmonary angiogram
CXR	chest X-ray
2D	two-dimensional
3D	three-dimensional
DCIS	ductal carcinoma in situ
DEXA	dual energy X-ray absorptiometry
DHS	dynamic hip screw
DJ	duodenojejunal
DIP	distal interphalangeal
DLCO	diffusion capacity of the lung for carbon monoxide (test)
DMARD	disease modifying antirheumatic drug
DRUJ	distal radioulnar joint
DSA	digital subtraction angiography
DVT	deep vein thrombosis
DWI	diffusion-weighted imaging
ECG	electrocardiogram
ECMO	extracorporeal membrane oxygenation
ED	emergency department
eGFR	estimated glomerular filtration rate
ENT	ear, nose, and throat
ERCP	endoscopic retrograde cholangiopancreatography

ESR	erythrocyte sedimentation rate
ESWL	extracorporeal shock wave lithotripsy
ET	endotracheal
ETT	endotracheal tube
EVAR	endovascular aneurysm repair
FAST	focused assessment with sonography for trauma
FBC	full blood count
FDG	fluorodeoxyglucose
FEV	forced expiratory volume
FFDM	full field digital mammography
FLAIR	fluid-attenuated inversion recovery
FOOSH	fall on an outstretched hand
GCS	Glasgow coma scale
GFR	glomerular filtration rate
GGT	gamma-glutamyl transferase
GH	glenohumeral
GI	gastrointestinal
GORD	gastro-oesophageal reflux disease
GP	general practitioner
GTN	glyceryl trinitrate
Hb	haemoglobin
HCG	human chorionic gonadotropin
HER2	human epidermal growth factor 2
HIV	human immunodeficiency virus
HLA	human leukocyte antigen
HR	heart rate
HRCT	high-resolution computed tomography
HU	Hounsfield units
ICD	implantable cardiac defibrillator
ICE	ideas, concerns, and expectations
ICP	intracranial pressure
ICU	intensive care unit
Ig	immunoglobulin
INR	international normalised ratio
IP	interphalangeal
ITU	intensive therapy unit
IUCD	intrauterine contraceptive device
IV	intravenous
IVC	inferior vena cava
kg	kilogram
LA	left atrium
LBO	large bowel obstruction
LCIS	lobular carcinoma in situ
LDH	lactate dehydrogenase
LFTs	liver function tests
LHB	left heart border
LMP	last menstrual period
LMWH	low molecular weight heparin
LUQ	left upper quadrant
LV	left ventricle
LVA	left ventricular aneurysm
MAC	*Mycobacterium avium* complex
MAS	meconium aspiration syndrome
MCA	middle cerebral artery
MCP	metacarpophalangeal
MCV	mean cell volume
MDT	multidisciplinary team
MI	myocardial infarction
MIBG	metaiodobenzylguanidine
micromol/L	micromoles per litre
MIP	maximum intensity projection
MLO	medial lateral oblique (view)
mmol/L	millimoles per litre
MR	magnetic resonance
MRCP	magnetic resonance cholangiopancreatography
MRI	magnetic resonance imaging
mmHg	millimetres of mercury
MS	multiple sclerosis
MSU	mid-stream urine
mSv	millisieverts
MTP	metatarsophalangeal
NAI	nonaccidental injury
NEC	necrotising enterocolitis
NG	nasogastric
NHL	non-Hodgkin lymphoma
NICU	neonatal intensive care unit
NPSA	National Patient Safety Agency
NSAID	nonsteroidal anti-inflammatory drug
NYHA	New York Heart Association
OA	osteoarthritis
OGD	oesophago-gastro-duodenoscopy
ORIF	open reduction and internal fixation
OSCE	Objective Structured Clinical Examination
PA	posteroanterior (view)

PAOD	peripheral artery occlusive disease
PCR	polymerase chain reaction
PE	pulmonary embolism
PEFR	peak expiratory flow rate
PET	positron emission tomography
PIC	peripherally inserted catheter
PIP	proximal interphalangeal
PKD	polycystic kidney disease
PPHN	persistent pulmonary hypertension of the newborn
PPP	projection, personal demographics, previous CXR comparison
PR	per rectum
PTH	parathyroid hormone
RA	right atrium
RCC	renal cell carcinoma
RDS	respiratory distress syndrome
RhA	rheumatoid arthritis
RHB	right heart border
RhF	rheumatoid factor
RIF	right iliac fossa
RIP	rotation/inspiration/penetration
RLQ	right lower quadrant
RR	respiration rate
RTA	road traffic accident
rTPA	recombinant tissue plasminogen activator
RUQ	right upper quadrant
SBO	small bowel obstruction
SCFE	slipped capital femoral epiphysis
SH	Salter–Harris
SIADH	syndrome of inappropriate antidiuretic hormone (secretion)
SOBOE	short of breath on exertion
SPO_2	saturation pressure of oxygen
STIR	short tau inversion recovery
SUFE	slipped upper femoral epiphysis
TB	tuberculosis
TFCC	triangular fibrocartilage complex
TFTs	thyroid function tests
THA	total hip arthroplasty
THR	total hip replacement
TIA	transient ischaemic attack
TNF	tumour necrosis factor
TNM	tumour, nodes, metastases
UAC	umbilical arterial catheter
U&Es	urea and electrolytes
UGI	upper gastrointestinal
US	ultrasound
UVC	umbilical venous catheter
VBG	venous blood gas
VCF	vertebral compression fracture
VUJ	vesicoureteric junction
V/Q	ventilation/perfusion scan
WBC	white blood cell
WCC	white cell count
WHO	World Health Organisation
XR	X-ray
ZN	Ziehl–Neelsen

1 Overview of imaging modalities

THOMAS KURKA AND DAVID C HOWLETT

It is helpful for finals to have an understanding of the core imaging modalities you are likely to encounter and to have an idea of the relative strengths/weaknesses and indications/contraindications for each.

PLAIN FILMS: CHEST X-RAY, ABDOMINAL X-RAY, AND ORTHOPAEDIC BONE/JOINT X-RAYS

Conventional X-ray remains an important diagnostic tool in medicine and remains the most commonly used imaging modality. Plain films are commonly the chest X-ray (CXR), abdominal X-ray (AXR), and orthopaedic bone/joint X-rays (XRs). An XR is relatively inexpensive, time effective, and does not require any special preparation of the patient. There is a degree of ionising radiation associated with X-ray exposure and this radiation dose varies with body part; a lumbar spine XR entails a far higher radiation dose than a wrist XR for example owing to radiation of pelvic organs. However, generally X-ray doses are far lower than those associated with computed tomography (CT). Dose information is included in Chapters 3 and 4. As always 'justify' the exposure: does the benefit to the patient outweigh the potential risk of irradiation?

When a radiograph is taken, the X-ray beam passes through the body part onto an X-ray sensitive screen. Bones, owing to their high calcium content, absorb most of the X-rays whereas soft tissues absorb a smaller amount, depending on composition and density. As a result, X-rays from the bones do not reach the screen and appear white on the radiograph, with the soft tissue appearing darker. X-rays pass through the air without being absorbed at all, which is then detected by the screen and appears black on the radiograph.

ADVANTAGES

- Inexpensive.
- Usually quick to perform.

- Painless, noninvasive.
- Good diagnostic tool for many pathologies.

DISADVANTAGES

- Soft tissue, lung, bone resolution much reduced compared with CT/magnetic resonance imaging (MRI).
- Provides a two-dimensional (2D), single image only.
- Radiation exposure.

INDICATIONS – ARE BROAD

CXR

- Respiratory – infection, septic screen, pneumothorax, chest trauma, inhaled foreign body, pleural effusion, suspected malignancy.
- Cardiac – clinical heart failure, clinical cardiomegaly, heart murmurs.

AXR

- Abdomen – bowel obstruction, perforated viscus (erect CXR more sensitive), ingested foreign body, abdominal pain in the emergency setting.
- Pelvic – pelvic fracture, neck of femur fracture.

Soft tissue XR neck

- Inhaled foreign body.
- Retropharyngeal abscess.

Bone XR

- Limbs – trauma, fractures, skeletal survey, acutely swollen joint, osteomyelitis, septic arthritis, bone pain, tumour/metastasis.
- Skulls – skeletal survey, myeloma, dental imaging.
- Spine – trauma, scoliosis.

ULTRASOUND

Ultrasound (US) uses sound waves of high frequencies, which are emitted towards the studied tissues and are reflected/echoed back to the probe depending on the tissue density and composition. This signal is then translated into an US image. US is a 'live' imaging modality and requires interpretation while the investigation is being carried out. US colour Doppler techniques are used to assess moving blood and are used in vascular assessment, e.g. carotid stenosis.

ADVANTAGES

- No radiation, noninvasive (some US is performed using endocavity probes, e.g. transrectal, transvaginal, transoesophageal).
- Real-time assessment and interpretation of results.
- Relatively inexpensive.

- Useful for imaging of soft tissue and muscles, extremities, testes, breast, and eye, plus abdomen, pelvis, chest, and vascular colour Doppler applications.

DISADVANTAGES

- Requires a skilled practitioner with US interpretation skills, operator dependent.
- No use for bone imaging as sound is attenuated/absorbed by bone.
- Images are degraded by gas and fat, and this restricts US use in the abdomen/pelvis in some patients.

INDICATIONS

- Abdomen – trauma, malignancy, abdominal aortic aneurysm (AAA) surveillance, gallstones, suspected hydronephrosis.
- Chest – assessment of pleural spaces.
- Musculoskeletal – assessment of muscles, ligaments, and tendons.
- Scrotal – assessment of testicles, epididymis, and scrotum.
- Obstetrics – growth scans, placental sighting, anomaly scans.
- Gynaecology – transabdominal and transvaginal imaging of ovaries, uterus, and Fallopian tubes.
- Baby hips.
- Breast, eye assessment.
- Vascular applications – suspected upper/lower limb deep vein thrombosis (DVT), carotid/peripheral vascular assessment.

COMPUTED TOMOGRAPHY

CT uses X-rays, which are emitted from a rotating X-ray source around the patient with multiple detectors to produce a series of 2D axial images of the studied body part. This can then be computer-reconstructed to obtain axial, coronal, sagittal 2D, and three-dimensional (3D) images of the studied body parts. There are other imaging modalities that make use of CT imaging such as positron emission tomography (PET scan).

ADVANTAGES

- Provides 2D cross-sectional images of the body, which are rapidly acquired with the potential to reformat in multiple planes; 3D reformatting is also possible.
- Provides a detailed image of the studied body part and the surrounding tissue.
- High sensitivity and specificity in particular for assessment of the lungs, mediastinum, bones, abdomen/pelvis structures, the brain – especially acute blood.

DISADVANTAGES

- CT scanners are expensive.
- Moderate to high dose of radiation, depending on areas scanned.
- May require intravenous (IV) iodinated contrast use – risk of contrast reaction (allergy, anaphylaxis) and nephrotoxicity in those at risk.

INDICATIONS

- Head – trauma, brain imaging (ischaemic/haemorrhagic strokes, calcifications, haemorrhage, malignancy).
- Chest – detailed imaging of the lungs to detect abnormalities not seen on CXR, used in diagnosis and surveillance of malignancy, pulmonary embolism (CT pulmonary angiogram: CTPA), emphysema, fibrosis. Cardiac – CT to image coronary arteries.
- Abdomen and pelvis – diagnosis, staging, and surveillance of malignancies, bowel obstruction, AAA, pancreatitis, renal calculi (CT kidneys ureters and bladder [CT KUB] and CT IV urogram [CT IVU]).
- CT angiography and venography – for example, suspected limb or mesenteric vascular occlusion, sagittal sinus thrombosis.
- Orthopaedic – complex fractures.
- CT-guided biopsy, surgery, and radiosurgery.

MAGNETIC RESONANCE IMAGING

MRI does not use any X-rays, thus does not expose the patient to ionising radiation. It is superior to CT in obtaining detailed images of the soft tissues and also the brain. MRI uses strong magnetic fields, radio waves, and field gradients to generate the image.

In structural MRI, the images are obtained by proton alignment by an external magnet and a subsequent radiofrequency pulse disrupts the equilibrium, which gives an MRI signal. Details of MRI protocols and sequences are not needed for finals – T1- and T2-weighted are common sequences (in the brain cerebrospinal fluid [CSF] appears bright/white on T2), and IV contrast can also be used (gadolinium).

ADVANTAGES

- No ionising radiation exposure.
- Provides 2D and 3D cross-sectional images of the body.
- Superior to other imaging modalities in obtaining high-resolution images of the brain and musculoskeletal system.
- Ideal for soft tissue structures, cartilage, and ligament imaging.
- Vascular and cardiac applications.

DISADVANTAGES

- Expensive equipment – the most expensive imaging modality.
- Time consuming, requiring patient cooperation, ability to lie still, often for 30–60 minutes.
- Contraindicated in patients with ferrous metal implants – pacemakers, cochlear implants, metallic foreign bodies in the eyes.
- MRI is undertaken in a relatively enclosed space – unsuitable for patients with claustrophobia and young children (may need general anaesthesia).
- Relatively contraindicated in pregnancy, particularly first trimester.