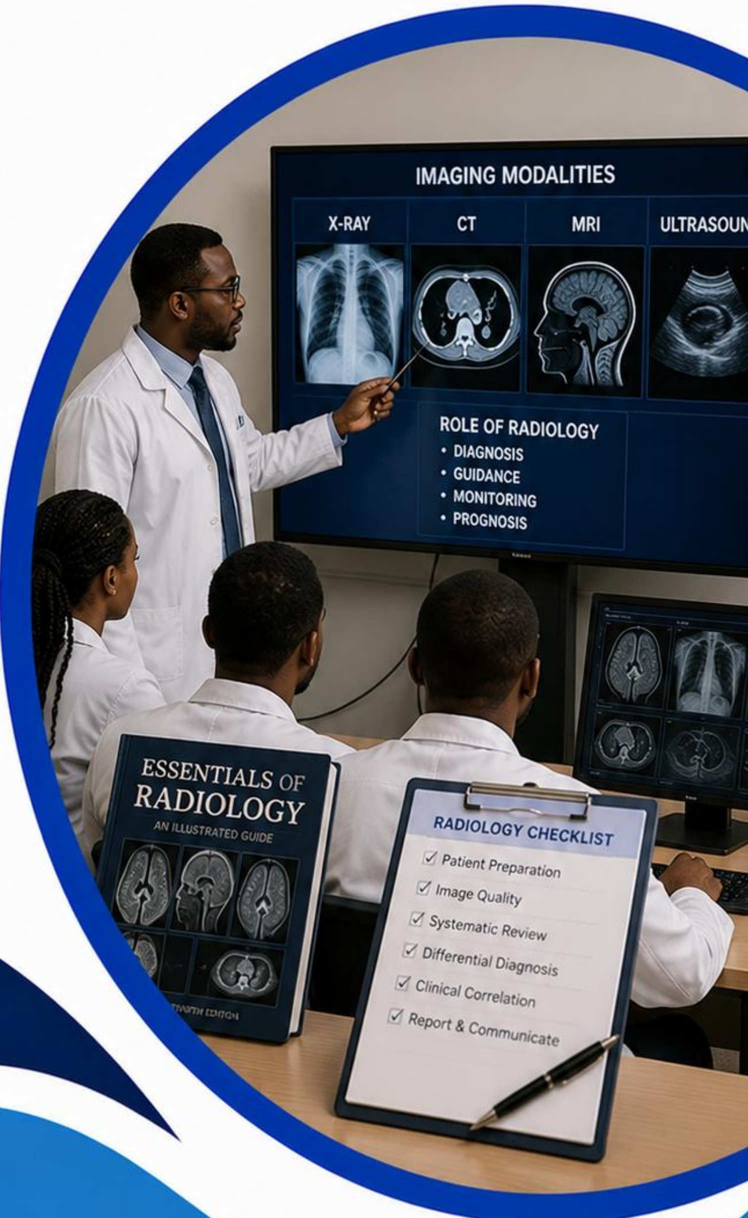
La-Net

RAD 601

LECTURES IN RADIOLOGY



Course code: RAD 601

Course title: Lectures in Radiology

Course credit load: 3 Units

Series 1: X-Ray, Fluoroscopy, and Contrast Principles

- **Part 1.1: Introduction to Radiological Sciences**
  - Sub Part 1.1.1: Definition and classification of radiology
  - Sub Part 1.1.2: Overview of imaging equipment used in radiologic practice
  - Sub Part 1.1.3: Descriptive terminology in radiologic practice
- **Part 1.2: The X-Ray Unit and X-Ray Generation**
  - Sub Part 1.2.1: Components of an X-ray unit
  - Sub Part 1.2.2: The process of X-ray generation
  - Sub Part 1.2.3: Factors affecting X-ray image quality
- **Part 1.3: Principles of Fluoroscopy**
  - Sub Part 1.3.1: Basic principles of fluoroscopy
  - Sub Part 1.3.2: Fluoroscopy equipment and image intensification
  - Sub Part 1.3.3: Clinical applications of fluoroscopy
- **Part 1.4: Principles of Contrast in Imaging**
  - Sub Part 1.4.1: The concept of contrast in radiological imaging
  - Sub Part 1.4.2: Types of contrast media
  - Sub Part 1.4.3: The principle of contrast across different imaging modalities
- **Part 1.5: Contrast Media Reactions and the Radiology Request Form**
  - Sub Part 1.5.1: Adverse reactions to contrast media
  - Sub Part 1.5.2: Management of contrast media reactions
  - Sub Part 1.5.3: Completing the radiology request form correctly

Introduction

Radiology rests on a small number of fundamental physical principles, how X-rays are generated, how fluoroscopy produces real-time imaging, and how **contrast** is created and manipulated across different imaging modalities, each essential to understanding every subsequent clinical application examined throughout this course. Equally essential are the practical skills of recognising and managing contrast media reactions and correctly completing a radiology request form, skills every referring clinician must possess.

The aim of this Series is to equip you with a thorough understanding of the definition and classification of radiology, the imaging equipment used in radiologic practice, the components of an X-ray unit and the process of X-ray generation, the principles of fluoroscopy, the principle of contrast in different imaging modalities, adverse reactions to contrast media and their management, and correct completion of the radiology request form.

This Series begins with an **introduction to radiological sciences**, before examining the **X-ray unit and X-ray generation**. We then turn to the **principles of fluoroscopy**, followed by the **principles of contrast in imaging**, concluding with **contrast media reactions and the radiology request form**.

Series Learning Outcomes

At the end of this Series, you should be able to:

- **SLO 1.1:** define radiology and classify it into diagnostic and interventional radiology
- **SLO 1.2:** describe the imaging equipment used in radiologic practice and the descriptive terminology relevant to it
- **SLO 1.3:** list the components of an X-ray unit
- **SLO 1.4:** explain the process of X-ray generation and the factors affecting X-ray image quality
- **SLO 1.5:** describe the principles of fluoroscopy
- **SLO 1.6:** describe fluoroscopy equipment and its clinical applications
- **SLO 1.7:** explain the concept of contrast in radiological imaging
- **SLO 1.8:** explain the principle of contrast in the different imaging modalities
- **SLO 1.9:** describe adverse reactions to contrast media and their management, and
- **SLO 1.10:** correctly complete a radiology request form.

1.1 Introduction to Radiological Sciences

1.1.1 definition and classification of radiology

A discipline spanning image production, interpretation, and therapeutic intervention

Radiology is the medical discipline concerned with the production and interpretation of images of the human body using various forms of energy, principally ionising radiation, magnetic fields, and sound waves, to support clinical **diagnosis** and, increasingly, image-guided therapeutic intervention.

Radiology is broadly classified into **diagnostic radiology**, encompassing the production and interpretation of images to identify and characterise disease, and **interventional radiology**, using image guidance to perform minimally invasive therapeutic procedures, discussed further in relation to specific uro-genital procedures in a later Series of this course.

Fill in the blank: Radiology is broadly classified into diagnostic radiology and ________ radiology.

1.1.2 overview of imaging equipment used in radiologic practice

Radiologic practice employs a range of specific imaging equipment, including conventional **X-ray machines** and **fluoroscopy machines**, discussed further later in this Series, together with **computed tomography** and **magnetic resonance imaging** scanners, discussed in the next Series of this course, each producing images through fundamentally different physical mechanisms.

Further important imaging equipment includes **ultrasound scan machines**, discussed in the next Series of this course, **mammography machines**, specifically optimised for breast imaging, and nuclear medicine equipment, including **positron emission tomography** and **single photon emission computed tomography**, each producing images based on the distribution of administered radioactive tracers.

Fill in the blank: Nuclear medicine equipment, including positron emission tomography and single photon emission computed tomography, produces images based on the distribution of administered radioactive ________.

1.1.3 descriptive terminology in radiologic practice

Radiologic practice employs specific descriptive terminology relevant to each modality, including, on **ultrasound**, the term **hypoechogenicity**, describing a structure that returns fewer reflected sound waves than surrounding tissue and therefore appears relatively dark, or hypoechoic, on the resulting image.

On **plain radiography** and **fluoroscopy**, structures are generally described according to their relative **radiodensity**, ranging from radiolucent, appearing dark, to radiopaque, appearing white, while **radionuclide imaging**, discussed earlier in this Part, describes areas of relatively increased or decreased tracer uptake, with corresponding implications for the underlying tissue's physiological **activity**.

Fill in the blank: On ultrasound, the term hypoechogenicity describes a structure that returns fewer reflected sound waves than surrounding tissue and therefore appears relatively dark, or ________, on the resulting image.

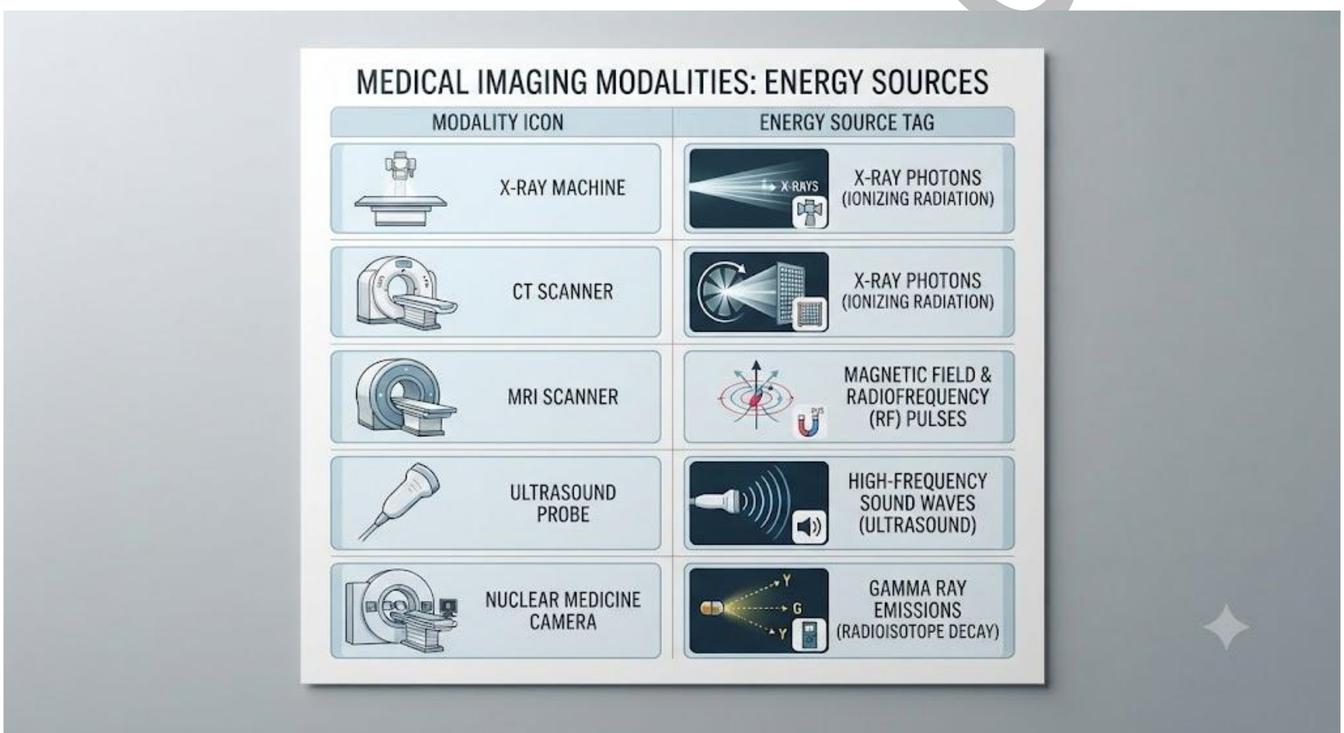


Figure 1.1: A schematic overview diagram showing the main radiological imaging modalities and their primary energy source.

Pilot questions 1.1

1. Define radiology. (Linked to SLO 1.1)
2. Distinguish diagnostic radiology from interventional radiology. (Linked to SLO 1.1)
3. List four types of imaging equipment used in radiologic practice. (Linked to SLO 1.2)
4. Define hypoechogenicity as used in ultrasound terminology. (Linked to SLO 1.2)
5. Describe the terminology used to characterise structures on plain radiography. (Linked to SLO 1.2)

1.2 The X-Ray Unit and X-Ray Generation

1.2.1 components of an x-ray unit

An integrated system of tube, generator, and detector

An **X-ray unit** comprises several essential components, including the **X-ray tube**, housing the cathode and anode responsible for X-ray production, discussed further in the next sub-Part, and the **generator**, supplying and regulating the high voltage and current delivered to the tube.

Further essential components include the **collimator**, restricting the X-ray beam to the specific area of clinical interest and reducing unnecessary patient radiation exposure, and the **image receptor**, historically photographic film but now generally a digital detector, capturing the transmitted X-ray beam to form the final **image**.

Fill in the blank: The X-ray tube houses the cathode and anode responsible for X-ray production, while the collimator restricts the X-ray beam to reduce unnecessary patient radiation ________.

1.2.2 the process of x-ray generation

X-ray generation begins with **thermionic emission** of electrons from a heated filament at the **cathode**, with these electrons then accelerated across the tube by a high voltage potential toward the **anode**, generally constructed of tungsten given its high atomic number and melting point.

On striking the anode, the rapidly decelerating electrons produce X-rays through two mechanisms, **bremsstrahlung** radiation, resulting from electron deceleration within the anode's electric field, and **characteristic** radiation, resulting from electron transitions within anode atoms, with the vast majority of the electrons' kinetic energy converted to **heat** rather than useful X-ray output.

Fill in the blank: X-ray generation begins with thermionic emission of electrons from a heated filament at the ________.

1.2.3 factors affecting x-ray image quality

X-ray image quality is influenced by several exposure factors, including **kilovoltage**, or **kVp**, controlling the energy and penetrating power of the produced X-ray beam, and **milliamperage-seconds**, or **mAs**, controlling the quantity of X-rays produced and, correspondingly, overall image **density**.

Further important quality factors include **patient positioning**, ensuring the anatomical structure of interest is appropriately demonstrated without distortion, and **focal spot size**, with a smaller focal spot generally producing sharper spatial resolution at the expense of reduced heat-loading **capacity** of the X-ray tube.

Fill in the blank: Kilovoltage, or kVp, controls the energy and penetrating power of the produced X-ray beam, while milliamperage-seconds, or mAs, controls the quantity of X-rays produced and overall image ________.

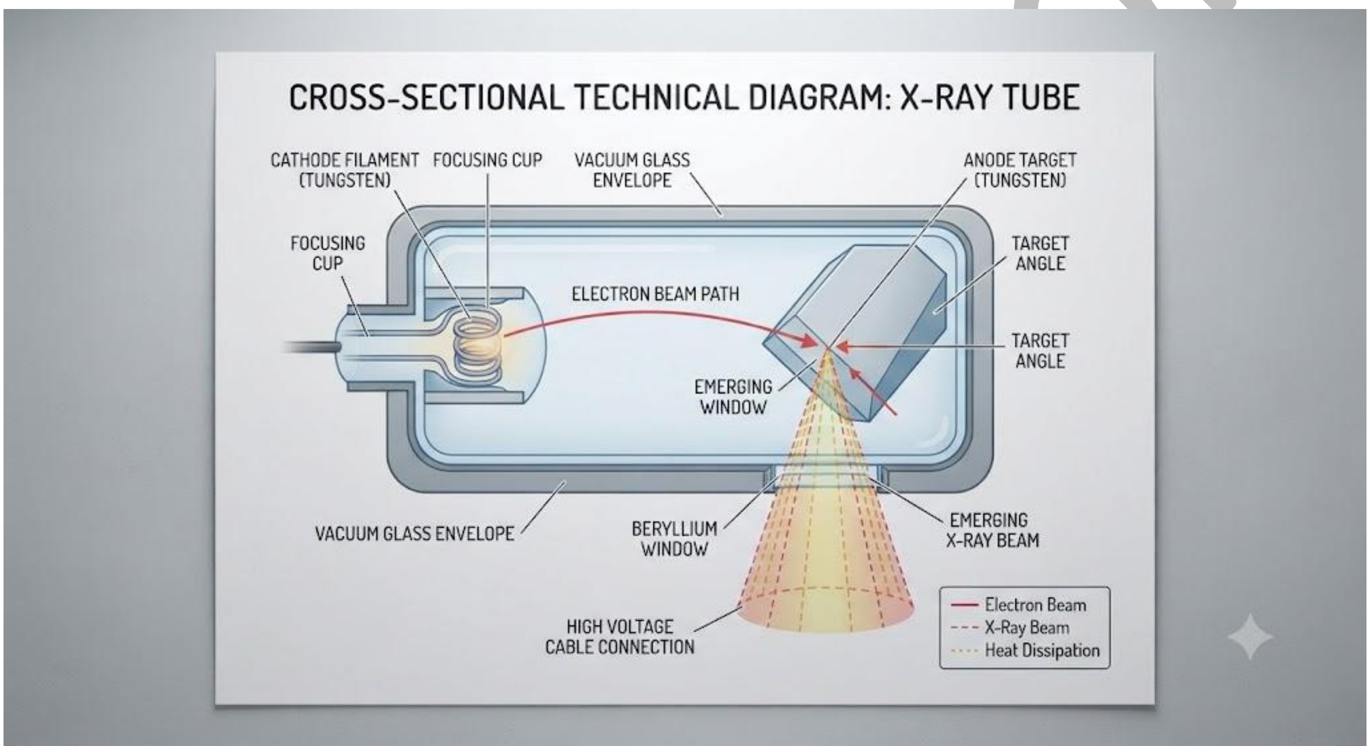


Figure 1.2: Cross-sectional diagram of an X-ray tube showing the cathode filament, anode, and electron beam path.

Pilot questions 1.2

1. List the essential components of an X-ray unit. (Linked to SLO 1.3)
2. Describe the process by which electrons are produced and accelerated within the X-ray tube. (Linked to SLO 1.4)
3. Distinguish bremsstrahlung radiation from characteristic radiation. (Linked to SLO 1.4)
4. Explain the effect of kilovoltage (kVp) on the produced X-ray beam. (Linked to SLO 1.4)
5. Explain the effect of milliamperage-seconds (mAs) on the produced X-ray beam. (Linked to SLO 1.4)

1.3 Principles of Fluoroscopy

1.3.1 basic principles of fluoroscopy

Continuous, real-time X-ray imaging of dynamic processes

Fluoroscopy produces continuous, real-time X-ray images, allowing direct visualisation of dynamic physiological processes, such as swallowing, discussed in relation to barium studies in an earlier related course, or the passage of injected contrast media, discussed further later in this Series, through the gastrointestinal, urinary, or vascular systems.

Unlike a single static radiographic exposure, discussed in the previous Part of this Series, fluoroscopy involves continuous or **pulsed** low-dose X-ray exposure over the duration of the examination, meaning cumulative patient and operator radiation exposure requires particular attention during fluoroscopic **procedures**.

Fill in the blank: Unlike a single static radiographic exposure, fluoroscopy involves continuous or pulsed low-dose X-ray exposure over the duration of the ________.

1.3.2 fluoroscopy equipment and image intensification

Modern fluoroscopy equipment generally employs an **image intensifier** or, increasingly, a **flat panel detector**, converting the transmitted X-ray beam into a visible, amplified image displayed in real time on a monitor, allowing the operator to observe the examination as it proceeds.

The image intensifier specifically works by converting incident X-rays to light via an input **phosphor**, then converting this light to electrons, accelerating and focusing these electrons, and finally reconverting them to a substantially brighter visible light image at an output **phosphor**, achieving the overall image brightness gain essential to real-time viewing.

Fill in the blank: The image intensifier works by converting incident X-rays to light via an input phosphor, then converting this light to electrons before reconverting them to a brighter image at an output ________.

1.3.3 clinical applications of fluoroscopy

Fluoroscopy finds direct clinical application in **contrast studies** of the gastrointestinal tract, discussed in an earlier related course, and genitourinary tract, discussed further in relation to specific urogenital examinations in a later Series of this course, including intravenous urography and micturating cysto-urethrography.

Further important applications include guidance for **interventional procedures**, discussed earlier in this Series, such as vascular catheterisation and orthopaedic fracture reduction, and, in the cardiac catheterisation laboratory, real-time guidance during coronary angiography and **percutaneous** cardiac intervention.

Fill in the blank: Fluoroscopy finds application in guiding interventional procedures such as vascular catheterisation and orthopaedic fracture ________.

Table 1.3: Comparing plain radiography and fluoroscopy.

Feature	Plain radiography	Fluoroscopy
Image acquisition	Single static exposure	Continuous or pulsed, real-time
Radiation exposure per examination	Generally low, single exposure	Cumulative, dependent on screening time
Typical use	Static anatomical assessment	Dynamic process or procedural guidance

Pilot questions 1.3

1. Define fluoroscopy and distinguish it from a single static radiographic exposure. (Linked to SLO 1.5)
2. Describe how an image intensifier converts X-rays into a visible image. (Linked to SLO 1.6)
3. Name the modern alternative to the image intensifier used in fluoroscopy equipment. (Linked to SLO 1.6)
4. List two clinical applications of fluoroscopy involving contrast studies. (Linked to SLO 1.6)
5. Describe the role of fluoroscopy in guiding interventional procedures. (Linked to SLO 1.6)

1.4 Principles of Contrast in Imaging

1.4.1 the concept of contrast in radiological imaging

Distinguishing structures through differential signal or attenuation

Contrast in radiological imaging refers to the ability to distinguish one anatomical structure or tissue from another based on a measurable difference in signal, attenuation, or reflected energy, with greater contrast generally permitting clearer visualisation of anatomical boundaries and pathological **abnormality**.

Contrast may arise from inherent tissue properties alone, termed **intrinsic contrast**, such as the naturally differing radiodensity of bone, soft tissue, and air, or may be deliberately enhanced through administration of an external **contrast agent**, discussed further in the next sub-Part, to improve visualisation of a specific structure or process.

Fill in the blank: Contrast that arises from inherent tissue properties alone, without an administered agent, is termed ________ contrast.

1.4.2 types of contrast media

Iodinated contrast media, used in X-ray, fluoroscopy, and CT imaging, discussed throughout this course, increase radiodensity in proportion to their local concentration, generally administered intravenously, orally, or directly into a body cavity or lumen depending on the specific examination being performed.

Barium-based contrast media, used specifically for gastrointestinal fluoroscopic studies, discussed in the previous Part of this Series, provide excellent luminal opacification, while **gadolinium-based contrast agents**, used in MRI, discussed in the next Series of this course, alter local magnetic relaxation properties rather than radiodensity, reflecting the fundamentally different physical basis of MRI contrast **enhancement**.

Fill in the blank: Gadolinium-based contrast agents, used in MRI, alter local magnetic relaxation properties rather than radiodensity, reflecting the fundamentally different physical basis of MRI contrast ________.

1.4.3 the principle of contrast across different imaging modalities

On **X-ray, fluoroscopy, and CT**, contrast fundamentally reflects differential **attenuation** of the X-ray beam by tissues of differing density and atomic number, discussed in relation to Hounsfield units in the next Series of this course, with denser structures such as bone or iodinated contrast appearing relatively bright.

On **MRI**, contrast reflects differences in tissue proton density and magnetic relaxation properties, discussed further in the next Series of this course, while on **ultrasound**, contrast reflects the differential reflection, or **echogenicity**, of transmitted sound waves at tissue interfaces, discussed earlier in this Series, illustrating the genuinely distinct physical basis of contrast generation across these different imaging modalities.

Fill in the blank: On ultrasound, contrast reflects the differential reflection, or ________, of transmitted sound waves at tissue interfaces.

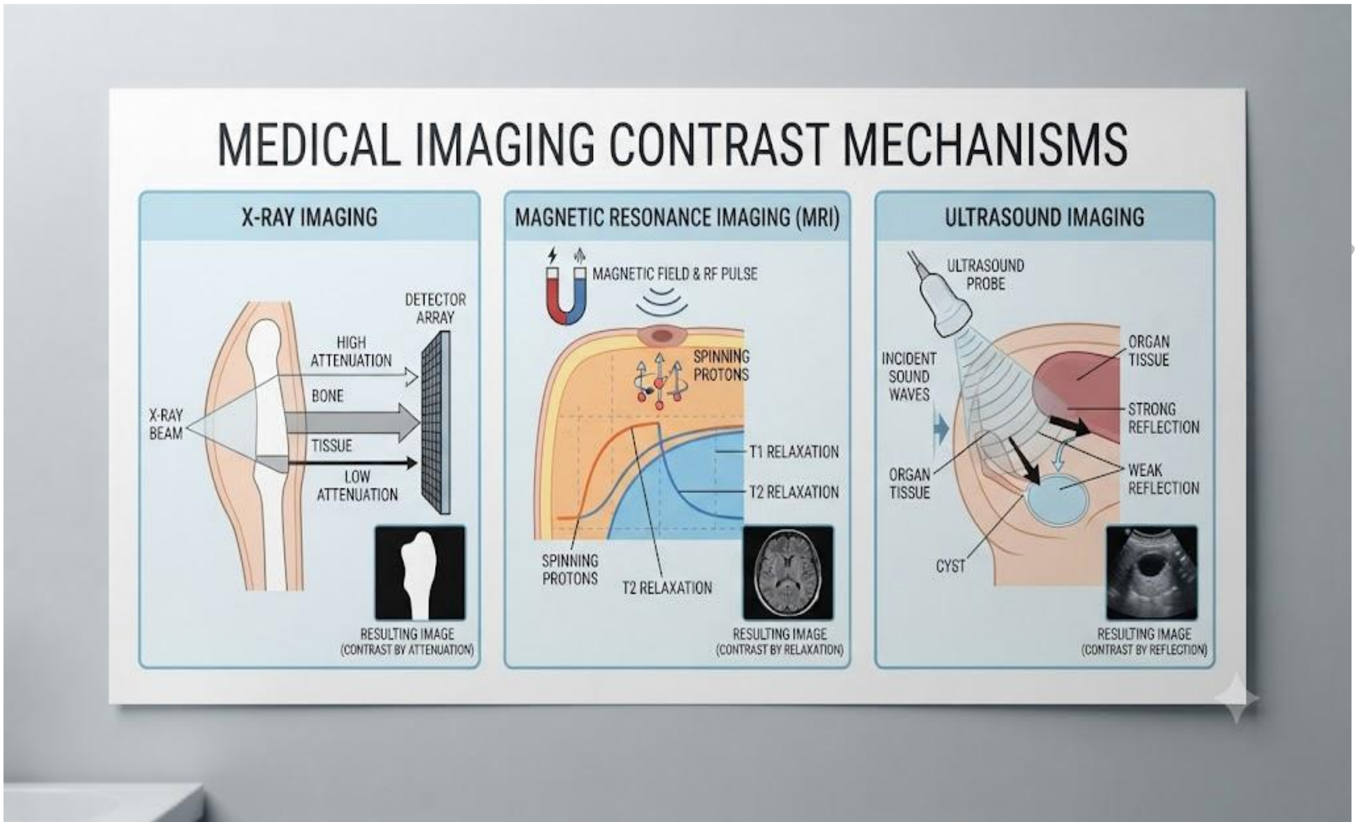


Figure 1.4: A comparative diagram showing how contrast arises differently on X-ray/CT (attenuation), MRI (relaxation properties), and ultrasound (echogenicity).

Pilot questions 1.4

1. Define contrast as it applies to radiological imaging. (Linked to SLO 1.7)
2. Distinguish intrinsic contrast from contrast produced by an administered contrast agent. (Linked to SLO 1.7)
3. Name the three types of contrast media discussed and their typical modality of use. (Linked to SLO 1.8)
4. Explain the physical basis of contrast on X-ray, fluoroscopy, and CT. (Linked to SLO 1.8)
5. Explain the physical basis of contrast on MRI and on ultrasound. (Linked to SLO 1.8)

1.5 Contrast Media Reactions and the Radiology Request Form

1.5.1 adverse reactions to contrast media

A spectrum from mild discomfort to genuine anaphylaxis

Adverse reactions to iodinated contrast media, discussed earlier in this Series, are classified as **mild**, including transient nausea, warmth, or urticaria, **moderate**, including more pronounced urticaria, bronchospasm, or vomiting, and **severe**, including hypotension, laryngeal oedema, or cardiopulmonary **arrest**, reflecting a genuine spectrum of clinical severity.

Adverse reactions may be classified mechanistically as **anaphylactoid**, non-dose-dependent reactions resembling true allergy, or **chemotoxic**, dose-dependent reactions related to the physicochemical properties of the specific contrast agent used, with **contrast-induced nephropathy** representing a further important delayed adverse effect, discussed further in relation to renal failure in a later Series of this course.

Fill in the blank: Adverse reactions to iodinated contrast media are classified as mild, moderate, or severe, reflecting a genuine spectrum of clinical ________.

1.5.2 management of contrast media reactions

Management of a mild contrast reaction generally requires only reassurance and close **observation**, while moderate reactions may require specific treatment such as antihistamines for urticaria or bronchodilators for bronchospasm, together with continued close monitoring for potential progression to more severe reaction.

Management of a severe reaction, particularly anaphylaxis, requires immediate **intramuscular adrenaline**, discussed in relation to emergency management principles in an earlier related course, together with airway support, intravenous fluids, and activation of emergency response resources, meaning every radiology department performing contrast administration must maintain appropriate emergency **equipment** and staff training.

Fill in the blank: Management of a severe contrast reaction, particularly anaphylaxis, requires immediate intramuscular ________.

1.5.3 completing the radiology request form correctly

A correctly completed **radiology request form** should include accurate patient identification details, the specific clinical question or reason for the requested examination, and relevant clinical history, including any known contrast **allergy** or renal impairment, discussed earlier in this Part, directly relevant to safe contrast administration where indicated.

The request should additionally specify the precise examination requested and, where relevant, the specific anatomical region or side of interest, avoiding ambiguity that could result in the **wrong** examination being performed, together with appropriate clinical urgency indication guiding prioritisation of the requested **investigation**.

Fill in the blank: A correctly completed radiology request form should specify the precise examination requested and the specific anatomical region or side of interest, avoiding ambiguity that could result in the ________ examination being performed.

Table 1.5: Classification of contrast media reactions by severity.

Severity	Typical features	General management approach
Mild	Transient nausea, warmth, or urticaria	Reassurance and observation
Moderate	Pronounced urticaria, bronchospasm, or vomiting	Specific treatment and close monitoring
Severe	Hypotension, laryngeal oedema, or cardiopulmonary arrest	Immediate intramuscular adrenaline and emergency support

Pilot questions 1.5

- Classify adverse reactions to contrast media by severity, giving an example of each. (Linked to SLO 1.9)
- Distinguish anaphylactoid from chemotoxic contrast reactions. (Linked to SLO 1.9)
- Describe the management of a mild contrast reaction. (Linked to SLO 1.9)
- Describe the immediate management of a severe contrast reaction. (Linked to SLO 1.9)
- List the essential information that should be included on a correctly completed radiology request form. (Linked to SLO 1.10)

Series Summary

This opening Series established the physical and practical foundation of radiological science, beginning with an **introduction to radiological sciences**, the definition and classification of radiology, an overview of imaging equipment, and descriptive terminology, before examining the **X-ray unit and X-ray generation**, its essential components, the process of X-ray production, and factors affecting image quality.

We then examined the **principles of fluoroscopy**, its basic principles, equipment, and clinical applications, followed by the **principles of contrast in imaging**, the concept of contrast, types of contrast media, and the distinct physical basis of contrast across different modalities, concluding with **contrast media reactions and the radiology request form**, adverse reaction classification and management, and correct request form completion. Having worked through this Series, you should now possess the essential physical foundation needed to understand CT, MRI, ultrasound, and imaging informatics examined in the next Series of this course.

Glossary of Terms

- **Diagnostic radiology:** the branch of radiology concerned with image production and interpretation for diagnosis.
- **Interventional radiology:** the branch of radiology using image guidance for minimally invasive therapeutic procedures.
- **Hypoechogenicity:** an ultrasound descriptive term for a structure returning fewer reflected sound waves than surrounding tissue.
- **X-ray tube:** the component of an X-ray unit housing the cathode and anode responsible for X-ray production.
- **Bremsstrahlung radiation:** X-rays produced by the deceleration of electrons within the anode's electric field.
- **Kilovoltage (kVp):** the exposure factor controlling the energy and penetrating power of the X-ray beam.
- **Fluoroscopy:** continuous, real-time X-ray imaging of dynamic physiological processes.
- **Image intensifier:** fluoroscopy equipment converting X-rays into a brighter, visible real-time image.
- **Intrinsic contrast:** image contrast arising from inherent tissue properties without an administered agent.
- **Iodinated contrast media:** contrast agents used in X-ray, fluoroscopy, and CT that increase radiodensity.
- **Contrast-induced nephropathy:** a delayed adverse effect of iodinated contrast media affecting renal function.
- **Radiology request form:** the document communicating the clinical reason and details for a requested imaging examination.

Concept Check Questions [Series 1]

Objective questions

1. Radiology is broadly classified into diagnostic radiology and ________ radiology.
2. X-ray generation begins with thermionic emission of electrons from a heated filament at the ________.
3. Unlike a single static radiographic exposure, fluoroscopy involves continuous or pulsed low-dose X-ray exposure over the duration of the ________.
4. Contrast that arises from inherent tissue properties alone, without an administered agent, is termed ________ contrast.
5. Management of a severe contrast reaction, particularly anaphylaxis, requires immediate intramuscular ________.

Short-answer questions

6. List four types of imaging equipment used in radiologic practice.
7. Distinguish bremsstrahlung radiation from characteristic radiation.
8. Describe how an image intensifier converts X-rays into a visible image.
9. Name the three types of contrast media discussed and their typical modality of use.
10. Classify adverse reactions to contrast media by severity, giving an example of each.

Long-answer questions

11. Discuss the definition and classification of radiology, imaging equipment, and descriptive terminology used in radiologic practice. (Linked to SLO 1.1, SLO 1.2)
12. Discuss the components of an X-ray unit, the process of X-ray generation, and factors affecting image quality. (Linked to SLO 1.3, SLO 1.4)
13. Discuss the principles of fluoroscopy, its equipment, and its clinical applications. (Linked to SLO 1.5, SLO 1.6)
14. Discuss the concept of contrast in imaging, types of contrast media, and the principle of contrast across different modalities. (Linked to SLO 1.7, SLO 1.8)
15. Discuss adverse reactions to contrast media, their management, and correct completion of the radiology request form. (Linked to SLO 1.9, SLO 1.10)

Answers to Concept Check Questions [Series 1]

Objective questions

1. Interventional.
2. Cathode.
3. Examination.
4. Intrinsic.
5. Adrenaline.

Short-answer questions

6. X-ray machines, fluoroscopy machines, CT scanners, and MRI scanners, among others such as ultrasound and nuclear medicine equipment.
7. Bremsstrahlung radiation results from electron deceleration in the anode's electric field; characteristic radiation results from electron transitions within anode atoms.
8. It converts X-rays to light at an input phosphor, converts this light to electrons, accelerates and focuses them, then reconverts them to a brighter visible image at an output phosphor.
9. Iodinated contrast (X-ray, fluoroscopy, CT), barium-based contrast (gastrointestinal fluoroscopy), and gadolinium-based contrast (MRI).
10. Mild (e.g. transient nausea or urticaria), moderate (e.g. bronchospasm or vomiting), and severe (e.g. hypotension or cardiopulmonary arrest).

Long-answer questions

11. **Basic response:** Radiology is defined as the production and interpretation of body images, classified into diagnostic and interventional radiology, using equipment ranging from X-ray machines to nuclear medicine cameras.

Value-added response: Descriptive terminology, such as hypoechogenicity on ultrasound and radiodensity on plain radiography, provides the shared language supporting accurate image interpretation.

12. **Basic response:** The X-ray unit comprises the tube, generator, collimator, and image receptor, with X-rays generated through thermionic emission, electron acceleration, and bremsstrahlung and characteristic radiation at the anode.

Value-added response: Image quality is influenced by kVp, mAs, patient positioning, and focal spot size, each affecting beam energy, quantity, or spatial resolution.

13. **Basic response:** Fluoroscopy provides continuous, real-time imaging using an image intensifier or flat panel detector, distinct from the single static exposure of plain radiography.

Value-added response: Clinical applications include gastrointestinal and genitourinary contrast studies and guidance for interventional and cardiac catheterisation procedures.

14. **Basic response:** Contrast reflects the ability to distinguish structures, arising intrinsically or through administered agents such as iodinated, barium, or gadolinium contrast media.

Value-added response: The physical basis of contrast differs fundamentally across modalities, reflecting attenuation on X-ray/CT, magnetic relaxation on MRI, and echogenicity on ultrasound.

15. **Basic response:** Contrast media reactions range from mild to severe, classified as anaphylactoid or chemotoxic, managed from simple observation to immediate intramuscular adrenaline for anaphylaxis.

Value-added response: A correctly completed radiology request form includes patient details, clinical question, relevant history including allergy or renal impairment, and precise examination details to avoid error.

Answers to Pilot Questions [Series 1]

Part 1.1

1. The medical discipline concerned with producing and interpreting body images to support diagnosis and intervention.
2. Diagnostic radiology focuses on image production and interpretation; interventional radiology uses image guidance for therapeutic procedures.
3. X-ray machines, fluoroscopy machines, CT scanners, MRI scanners, ultrasound machines, and nuclear medicine equipment, among others.
4. A structure returning fewer reflected sound waves than surrounding tissue, appearing relatively dark on ultrasound.
5. Structures are described according to relative radiodensity, from radiolucent (dark) to radiopaque (white).

Part 1.2

1. The X-ray tube, generator, collimator, and image receptor.
2. Thermionic emission from a heated cathode filament, with electrons accelerated across the tube by a high voltage toward the anode.
3. Bremsstrahlung radiation results from electron deceleration in the anode's field; characteristic radiation results from electron transitions within anode atoms.
4. kVp controls the energy and penetrating power of the produced X-ray beam.
5. mAs controls the quantity of X-rays produced and, correspondingly, overall image density.

Part 1.3

1. Continuous, real-time X-ray imaging, distinct from a single static exposure.
2. It converts X-rays to light, then to electrons, accelerates and focuses them, and reconverts them to a brighter visible image.
3. The flat panel detector.
4. Gastrointestinal contrast studies and genitourinary contrast studies, such as intravenous urography.
5. It guides interventional procedures such as vascular catheterisation and orthopaedic fracture reduction.

Part 1.4

1. The ability to distinguish anatomical structures based on differences in signal, attenuation, or reflected energy.
2. Intrinsic contrast arises from inherent tissue properties; contrast from an administered agent is deliberately introduced to enhance visualisation.
3. Iodinated (X-ray, fluoroscopy, CT), barium-based (gastrointestinal fluoroscopy), and gadolinium-based (MRI).
4. Contrast on X-ray, fluoroscopy, and CT reflects differential attenuation of the X-ray beam by tissues of differing density.
5. MRI contrast reflects proton density and magnetic relaxation differences; ultrasound contrast reflects differential echogenicity at tissue interfaces.

Part 1.5

- Mild (e.g. transient nausea), moderate (e.g. bronchospasm), and severe (e.g. hypotension or cardiopulmonary arrest).
- Anaphylactoid reactions are non-dose-dependent and resemble true allergy; chemotoxic reactions are dose-dependent, related to the agent's physicochemical properties.
- Reassurance and close observation.
- Immediate intramuscular adrenaline, airway support, intravenous fluids, and activation of emergency response resources.
- Patient identification, the clinical question, relevant history including allergy or renal impairment, precise examination details, and urgency indication.

References and Attributions [Series 1]

- Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2020). The Essential Physics of Medical Imaging (4th ed.). Wolters Kluwer.
- Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.
- American College of Radiology (2023). ACR Manual on Contrast Media.
- Dendy, P. P., & Heaton, B. (2011). Physics for Diagnostic Radiology (3rd ed.). CRC Press.

Figures, Plates, Tables, and Boxes

- Figure 1.1: A schematic overview diagram showing the main radiological imaging modalities and their primary energy source. AI-generated using the prompt: "A single clean, accurate schematic diagram organised as a simple labelled chart listing five imaging modality icons, X-ray machine, CT scanner, MRI scanner, ultrasound probe, and nuclear medicine camera, each with a short labelled energy source tag, textbook educational diagram style, neutral background, no photographic realism, no other panels."
- Figure 1.2: Cross-sectional diagram of an X-ray tube showing the cathode filament, anode, and electron beam path. AI-generated using the prompt: "A single clean, accurate cross-sectional technical diagram of an X-ray tube showing labelled cathode filament, electron beam path with directional arrow, angled anode target, and emerging X-ray beam through a window, textbook physics diagram style, neutral background, no photographic realism, no other panels."
- Table 1.3: Comparing plain radiography and fluoroscopy. AI-generated using the prompt: "Create a clean technical reference table titled Comparing Plain Radiography and Fluoroscopy, listing feature, plain radiography, and fluoroscopy. Radiology reference table style with outside border, no photographic elements."
- Figure 1.4: A comparative diagram showing how contrast arises differently on X-ray/CT (attenuation), MRI (relaxation properties), and ultrasound (echogenicity). AI-generated using the prompt: "A single clean, accurate three-panel schematic educational diagram, each panel labelled with a different imaging modality name and a simple icon representing its contrast mechanism (beam attenuation, magnetic relaxation, sound wave reflection), textbook physics diagram style, neutral background, no photographic realism."
- Table 1.5: Classification of contrast media reactions by severity. AI-generated using the prompt: "Create a clean clinical reference table titled Classification of Contrast Media Reactions by Severity, listing severity, typical features, and general management

approach. Radiology reference table style with outside border, no photographic elements."

Course code: RAD 601

Course title: Lectures in Radiology

Course credit load: 3 Units

Series 2: CT, MRI, Ultrasound, and Imaging Informatics

- **Part 2.1: Physical Basis of CT Image Formation**
  - Sub Part 2.1.1: CT scanner components and generations
  - Sub Part 2.1.2: The principle of CT image formation
  - Sub Part 2.1.3: Image reconstruction in CT
- **Part 2.2: Hounsfield Units, Windowing, and CT Anatomy**
  - Sub Part 2.2.1: The Hounsfield unit scale
  - Sub Part 2.2.2: Window centre and window width
  - Sub Part 2.2.3: Normal anatomy of the organs on CT
- **Part 2.3: Principles of MRI**
  - Sub Part 2.3.1: Basic principles of MRI image formation
  - Sub Part 2.3.2: T1 and T2 weighting and common pulse sequences
  - Sub Part 2.3.3: Normal anatomical appearance on MRI
- **Part 2.4: MRI Safety**
  - Sub Part 2.4.1: The MRI environment and magnetic field hazards
  - Sub Part 2.4.2: Patient safety issues in MRI
  - Sub Part 2.4.3: Staff safety and MRI screening procedures
- **Part 2.5: Ultrasound, Doppler, and Imaging Informatics**
  - Sub Part 2.5.1: Basic principles of ultrasound image formation
  - Sub Part 2.5.2: Tissue properties determining ultrasound appearance
  - Sub Part 2.5.3: The Doppler effect and imaging informatics

Introduction

In the last Series, we established X-ray, fluoroscopy, and contrast principles. We now turn to three further cross-sectional and functional imaging modalities, **computed tomography**, **magnetic resonance imaging**, and **ultrasonography**, together with the **Doppler effect** and the essential **imaging informatics** infrastructure, picture archiving and communication systems and radiological information systems, that underpins their storage, distribution, and reporting in modern radiologic practice.

The aim of this Series is to equip you with a thorough understanding of the physical basis of CT image formation, the Hounsfield unit scale and windowing, normal CT anatomy, the basic principles of MRI image formation and MRI safety, the basic principles of ultrasonography and the Doppler effect, and the basic infrastructure of imaging informatics.

This Series begins with the **physical basis of CT image formation**, before examining **Hounsfield units, windowing, and CT anatomy**. We then turn to the **principles of MRI**, followed by **MRI safety**, concluding with **ultrasound, Doppler, and imaging informatics**.

Series Learning Outcomes

At the end of this Series, you should be able to:

- **SLO 2.1:** describe CT scanner components and the physical basis of CT image formation
- **SLO 2.2:** describe image reconstruction in CT
- **SLO 2.3:** discuss the scale of Hounsfield units and the principle of window centre and width
- **SLO 2.4:** describe the normal anatomy of the various organs on CT
- **SLO 2.5:** list the basic principles of image formation with MRI, including T1 and T2 weighting
- **SLO 2.6:** describe the normal anatomical appearance on MRI
- **SLO 2.7:** explain the safety issues in the MRI environment with regard to patients and staff
- **SLO 2.8:** describe MRI screening procedures for patients and staff
- **SLO 2.9:** describe the basic principles of image formation with ultrasonography and list the tissue properties that determine it, and
- **SLO 2.10:** list the principles of the Doppler effect and discuss the basic infrastructure of imaging informatics, including PACS and RIS.

2.1 Physical Basis of CT Image Formation

2.1.1 ct scanner components and generations

A rotating X-ray tube and detector array acquiring cross-sectional data

A **computed tomography** scanner comprises an X-ray tube and an opposing **detector array**, discussed in relation to the X-ray tube in the previous Series of this course, mounted on a rotating **gantry** that continuously acquires X-ray attenuation measurements as it rotates around the patient, who moves through the gantry on a motorised table.

Modern **multidetector** or **multislice CT** scanners employ multiple parallel rows of detectors, allowing simultaneous acquisition of several image slices per gantry rotation, substantially reducing overall scan time compared with earlier single-slice scanner **generations**, while improving spatial resolution along the longitudinal, or z, axis.

Fill in the blank: Multidetector, or multislice, CT scanners employ multiple parallel rows of detectors, allowing simultaneous acquisition of several image slices per gantry ________.

2.1.2 the principle of ct image formation

CT image formation relies on measuring X-ray **attenuation** along many thousands of individual projection paths through the patient as the tube and detector array rotate through a full circle, discussed earlier in this Part, with each detector reading representing the cumulative attenuation along one specific ray path.

These raw attenuation measurements, termed **projection data**, are mathematically processed to reconstruct a cross-sectional image representing the attenuation coefficient at each individual **voxel**, or three-dimensional pixel, within the scanned slice, discussed further in the next sub-Part, forming the basis of the final CT image.

Fill in the blank: CT image formation relies on measuring X-ray attenuation along many thousands of individual projection paths, with raw attenuation measurements termed projection ________.

2.1.3 image reconstruction in ct

Raw projection data is converted into a viewable cross-sectional image through a mathematical process termed **reconstruction**, historically performed using **filtered back projection**, and, in modern scanners, increasingly using **iterative reconstruction** algorithms, which generally permit reduced radiation dose while maintaining acceptable image quality.

The reconstructed image is displayed as a matrix of pixels, each representing the calculated attenuation value at the corresponding tissue voxel, discussed earlier in this Part, expressed on the standardised **Hounsfield unit** scale, discussed further in the next Part of this Series, allowing consistent, quantitative tissue characterisation across different scanners and institutions.

Fill in the blank: Modern CT scanners increasingly use iterative reconstruction algorithms, which generally permit reduced radiation ________ while maintaining acceptable image quality.

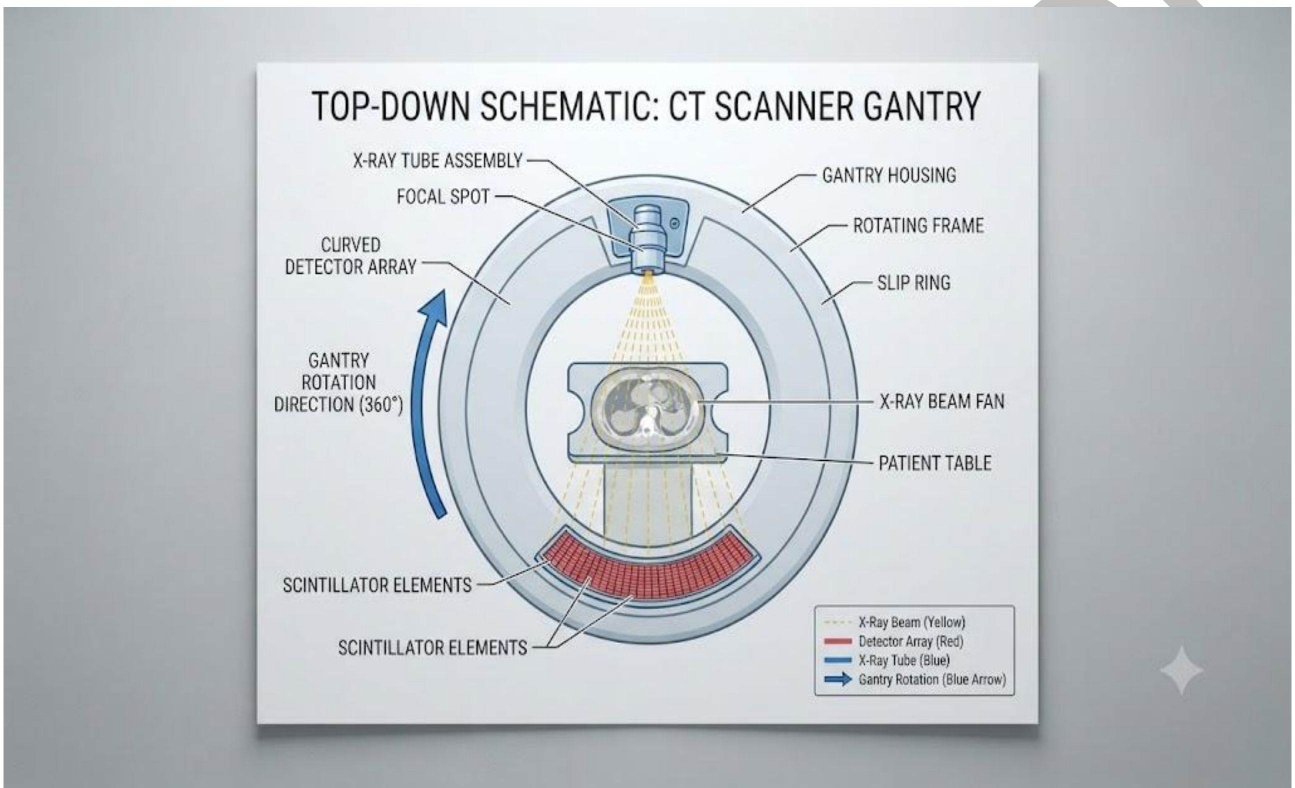


Figure 2.1: Diagram illustrating the rotating gantry of a CT scanner with the X-ray tube and detector array acquiring projection data around the patient.

Pilot questions 2.1

- Describe the essential components of a CT scanner. (Linked to SLO 2.1)
- Explain the advantage of multidetector CT over earlier single-slice scanner generations. (Linked to SLO 2.1)
- Describe the principle by which CT images are formed. (Linked to SLO 2.1)
- Define a voxel. (Linked to SLO 2.1)
- Distinguish filtered back projection from iterative reconstruction. (Linked to SLO 2.2)

2.2 Hounsfield Units, Windowing, and CT Anatomy

2.2.1 the hounsfield unit scale

A standardised scale anchored to water and air

The **Hounsfield unit**, or **HU**, scale is a standardised, quantitative measure of tissue attenuation on CT, anchored with **water** defined as **0 HU** and **air** defined as **-1000 HU**, with all other tissues assigned a value relative to these fixed reference points.

Typical Hounsfield unit values include fat at approximately **-100 HU**, reflecting its relatively low attenuation, soft tissue and muscle in the range of **40 to 80 HU**, and cortical bone exceeding **+1000 HU**, reflecting its markedly higher attenuation, with these consistent values allowing reliable tissue characterisation across different CT **examinations**.

Fill in the blank: On the Hounsfield unit scale, water is defined as 0 HU and air is defined as ________ HU.

2.2.2 window centre and window width

Since the human eye cannot distinguish the full range of Hounsfield unit values present within a typical CT image simultaneously, **windowing** selects a specific range of HU values to display across the full greyscale, defined by the **window centre**, the HU value at the midpoint of the displayed range, and the **window width**, the total range of HU values displayed.

Different **window settings** are selected to optimally display different tissue types, with a narrow window width providing high contrast suited to soft tissue evaluation, and a wide window width, such as **bone windowing** or **lung windowing**, providing lower contrast but a broader displayed range suited to structures spanning a much wider range of attenuation values.

Fill in the blank: A narrow window width provides high contrast suited to soft tissue evaluation, while a wide window width, such as bone or lung windowing, provides lower contrast but a broader displayed ________.

2.2.3 normal anatomy of the organs on ct

Normal abdominal organ appearance on CT includes the **liver**, generally appearing as a homogeneous, moderately attenuating structure slightly denser than the spleen on unenhanced imaging, and the **kidneys**, demonstrating a characteristic corticomedullary attenuation difference on early contrast-enhanced imaging that gradually equalises during later contrast phases.

Normal thoracic organ appearance includes the **lungs**, appearing markedly hypoattenuating given their predominantly air content, discussed in relation to lung windowing earlier in this Part, and the mediastinal great vessels, appearing as rounded or tubular structures of soft tissue attenuation that enhance briskly following intravenous contrast **administration**, discussed in the previous Series of this course.

Fill in the blank: The kidneys demonstrate a characteristic corticomedullary attenuation difference on early contrast-enhanced imaging that gradually ________ during later contrast phases.

Table 2.2: Typical Hounsfield unit values for common tissues.

Tissue	Typical Hounsfield unit value	Relative appearance
Air	-1000 HU	Very dark (black)
Fat	Approximately -100 HU	Dark grey
Soft tissue/muscle	40 to 80 HU	Mid grey
Cortical bone	Greater than +1000 HU	Very bright (white)

Pilot questions 2.2

1. Define the Hounsfield unit scale and state the values assigned to water and air. (Linked to SLO 2.3)
2. State the typical Hounsfield unit range for soft tissue and for cortical bone. (Linked to SLO 2.3)
3. Define window centre and window width. (Linked to SLO 2.3)
4. Explain why different window settings are used for soft tissue versus lung or bone evaluation. (Linked to SLO 2.3)
5. Describe the normal CT appearance of the liver and kidneys. (Linked to SLO 2.4)

2.3 Principles of MRI

2.3.1 basic principles of mri image formation

Exploiting the magnetic behaviour of hydrogen protons

Magnetic resonance imaging exploits the magnetic properties of **hydrogen protons**, abundant within water and fat throughout the body, which align with a powerful external **magnetic field**, generally measured in **tesla**, generated by the MRI scanner's main magnet.

A **radiofrequency pulse** is then applied, temporarily displacing the aligned protons from their equilibrium position, and the resulting **signal** emitted as these protons subsequently return to equilibrium, or **relax**, is detected and spatially localised using additional magnetic field **gradients**, ultimately forming the reconstructed MRI image.

Fill in the blank: MRI exploits the magnetic properties of hydrogen protons, which align with a powerful external magnetic field generated by the MRI scanner's main ________.

2.3.2 t1 and t2 weighting and common pulse sequences

T1 relaxation describes the time taken for excited protons to realign with the main magnetic field, with **T1-weighted** images generally demonstrating fat as bright and fluid as relatively dark, making this sequence particularly useful for demonstrating normal anatomical **detail**.

T2 relaxation describes the time taken for excited protons to lose phase coherence with one another, with **T2-weighted** images generally demonstrating fluid as bright, making this sequence particularly sensitive to oedema and many pathological processes, discussed further in relation to specific organ systems throughout this course, while **STIR** and other fat-suppression sequences further enhance conspicuity of fluid and pathology by specifically suppressing the normally bright fat **signal**.

Fill in the blank: T2-weighted images generally demonstrate fluid as bright, making this sequence particularly sensitive to oedema and many pathological ________.

2.3.3 normal anatomical appearance on mri

Normal soft tissue appearance on MRI reflects the specific relaxation properties of each tissue type, discussed earlier in this Part, with normal **brain grey matter** and **white matter** demonstrating distinct, characteristic signal intensities on both T1 and T2-weighted sequences, supporting confident differentiation of normal neuroanatomical structures.

Normal musculoskeletal appearance on MRI includes **cortical bone**, appearing uniformly dark on all standard sequences given its low proton density, and **articular cartilage**, demonstrating intermediate signal intensity, with the superior soft tissue contrast resolution of MRI, discussed in the previous Series of this course, allowing detailed evaluation of ligaments, tendons, and other soft tissue structures not well demonstrated on CT.

Fill in the blank: Cortical bone appears uniformly dark on all standard MRI sequences given its low proton ________.

Table 2.3: Comparing T1-weighted and T2-weighted MRI appearance of common tissues.

Tissue	T1-weighted appearance	T2-weighted appearance
Fat	Bright	Intermediate to bright
Fluid (e.g. CSF, oedema)	Dark	Bright
Cortical bone	Dark	Dark

Pilot questions 2.3

1. Describe the basic principle underlying MRI image formation. (Linked to SLO 2.5)
2. Distinguish T1 relaxation from T2 relaxation. (Linked to SLO 2.5)
3. Describe the typical appearance of fat and fluid on T1-weighted and T2-weighted images. (Linked to SLO 2.5)
4. Describe the purpose of a fat-suppression sequence such as STIR. (Linked to SLO 2.5)
5. Describe the normal MRI appearance of cortical bone and articular cartilage. (Linked to SLO 2.6)

2.4 MRI Safety

2.4.1 the mri environment and magnetic field hazards

A powerful, permanently active magnetic field demanding constant vigilance

The MRI scanner's main magnetic field remains permanently active, generally measuring **1.5 to 3 tesla** in typical clinical scanners, meaning the **projectile effect**, ferromagnetic objects being forcefully attracted toward the magnet, represents a genuine, ever-present hazard within the MRI environment, regardless of whether active scanning is underway.

Further recognised hazards include **radiofrequency heating** of certain implanted devices or metallic objects during active scanning, discussed further in the next sub-Part, and acoustic noise generated by rapidly switching magnetic field **gradients**, discussed in relation to spatial localisation earlier in this Series, requiring appropriate hearing protection during examination.

Fill in the blank: The projectile effect, ferromagnetic objects being forcefully attracted toward the magnet, represents a genuine, ever-present hazard within the MRI environment, regardless of whether active ________ is underway.

2.4.2 patient safety issues in mri

Patient safety screening before MRI requires careful enquiry regarding **implanted devices**, including cardiac pacemakers, certain aneurysm clips, and cochlear implants, discussed in an earlier related course, since many such devices are either absolutely contraindicated or require specific MRI-conditional confirmation before safe scanning can proceed.

Further important patient safety considerations include screening for retained **metallic foreign bodies**, particularly relevant in patients with a history of metalworking or ocular trauma, and appropriate management of **claustrophobia** or anxiety, which can limit patient tolerance of the enclosed scanner bore, occasionally requiring sedation or alternative open-configuration scanning **arrangements**.

Fill in the blank: Patient safety screening before MRI requires careful enquiry regarding implanted devices, since many such devices are either absolutely contraindicated or require specific MRI-conditional ________ before safe scanning can proceed.

2.4.3 staff safety and mri screening procedures

Staff safety within the MRI environment requires strict adherence to designated **zone** restrictions, generally structured as four progressively more controlled zones, with only appropriately screened, MRI-safe personnel and equipment permitted access to the innermost zone directly surrounding the scanner **magnet**.

All staff and patients must complete a structured **MRI safety screening questionnaire** before entry into the controlled zones, discussed earlier in this sub-Part, with any uncertainty regarding a specific implanted device or metallic object requiring confirmation of its MRI compatibility, or **exclusion** from the MRI environment, before proceeding.

Fill in the blank: All staff and patients must complete a structured MRI safety screening questionnaire before entry into the controlled ________.

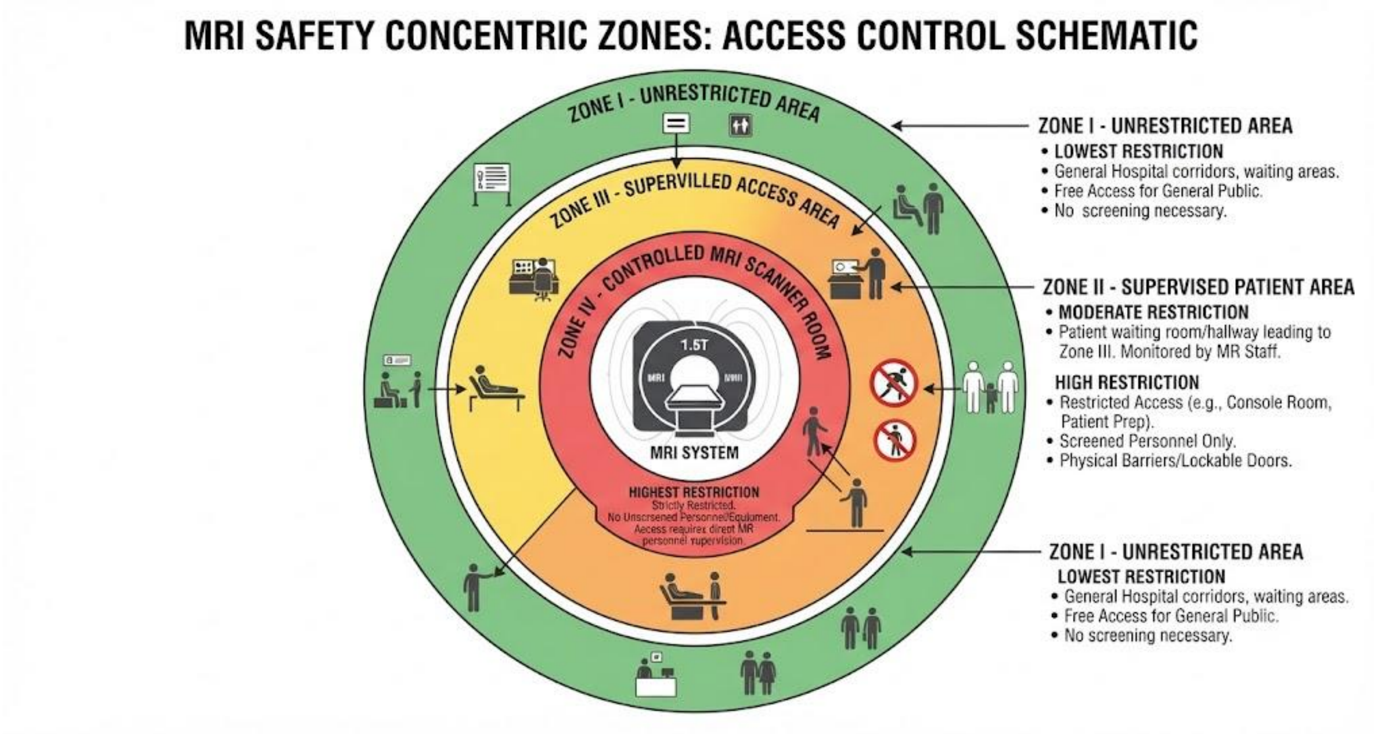


Figure 2.4: Diagram illustrating the four progressively restricted safety zones surrounding an MRI scanner.

Pilot questions 2.4

1. Explain why the projectile effect represents a hazard even when active scanning is not underway. (Linked to SLO 2.7)
2. Describe two further recognised hazards within the MRI environment beyond the projectile effect. (Linked to SLO 2.7)
3. List two categories of implanted device relevant to MRI patient safety screening. (Linked to SLO 2.7)
4. Describe the structure of the four MRI safety zones. (Linked to SLO 2.8)
5. Describe the purpose of the MRI safety screening questionnaire. (Linked to SLO 2.8)

2.5 Ultrasound, Doppler, and Imaging Informatics

2.5.1 basic principles of ultrasound image formation

Pulse-echo imaging using high-frequency sound waves

Ultrasonography generates images using high-frequency sound waves, generally in the range of 2 to 15 **megahertz**, emitted by a piezoelectric transducer, which also detects the returning **echoes** reflected from tissue interfaces within the body, forming the basis of the pulse-echo imaging principle.

The time delay between sound wave transmission and echo reception is used to calculate the **depth** of each reflecting interface, while echo **amplitude** determines the corresponding image brightness, together allowing reconstruction of a real-time, two-dimensional cross-sectional image without the ionising radiation associated with X-ray-based imaging.

Fill in the blank: The time delay between sound wave transmission and echo reception is used to calculate the depth of each reflecting ________.

2.5.2 tissue properties determining ultrasound appearance

Acoustic impedance, determined principally by tissue **density** and the speed of sound transmission through that tissue, governs the degree of sound wave reflection at any given tissue interface, with larger acoustic impedance differences between adjacent tissues producing stronger reflected echoes and correspondingly brighter image appearance.

Further important tissue properties include **attenuation**, the progressive weakening of the sound beam with increasing depth of tissue penetration, and tissue **homogeneity**, with uniform tissues, such as simple fluid, transmitting sound with minimal internal reflection, producing an **anechoic**, or echo-free, appearance, in contrast to the more heterogeneous echo pattern of solid organs.

Fill in the blank: Larger acoustic impedance differences between adjacent tissues produce stronger reflected echoes and correspondingly brighter image ________.

2.5.3 the doppler effect and imaging informatics

The **Doppler effect** describes the change in observed sound wave frequency resulting from relative motion between the sound source and the reflecting target, with **flowing blood** producing a characteristic frequency shift proportional to flow velocity, allowing ultrasound to assess both the presence and direction of blood flow within vessels.

Imaging informatics infrastructure, essential to modern radiologic practice, includes the **picture archiving and communication system**, or **PACS**, storing and distributing digital images across a healthcare institution, and the **radiological information system**, or **RIS**, managing patient scheduling, reporting workflow, and examination tracking throughout the imaging **department**.

Fill in the blank: The picture archiving and communication system, or PACS, stores and distributes digital images, while the radiological information system, or RIS, manages patient scheduling, reporting workflow, and examination ________.

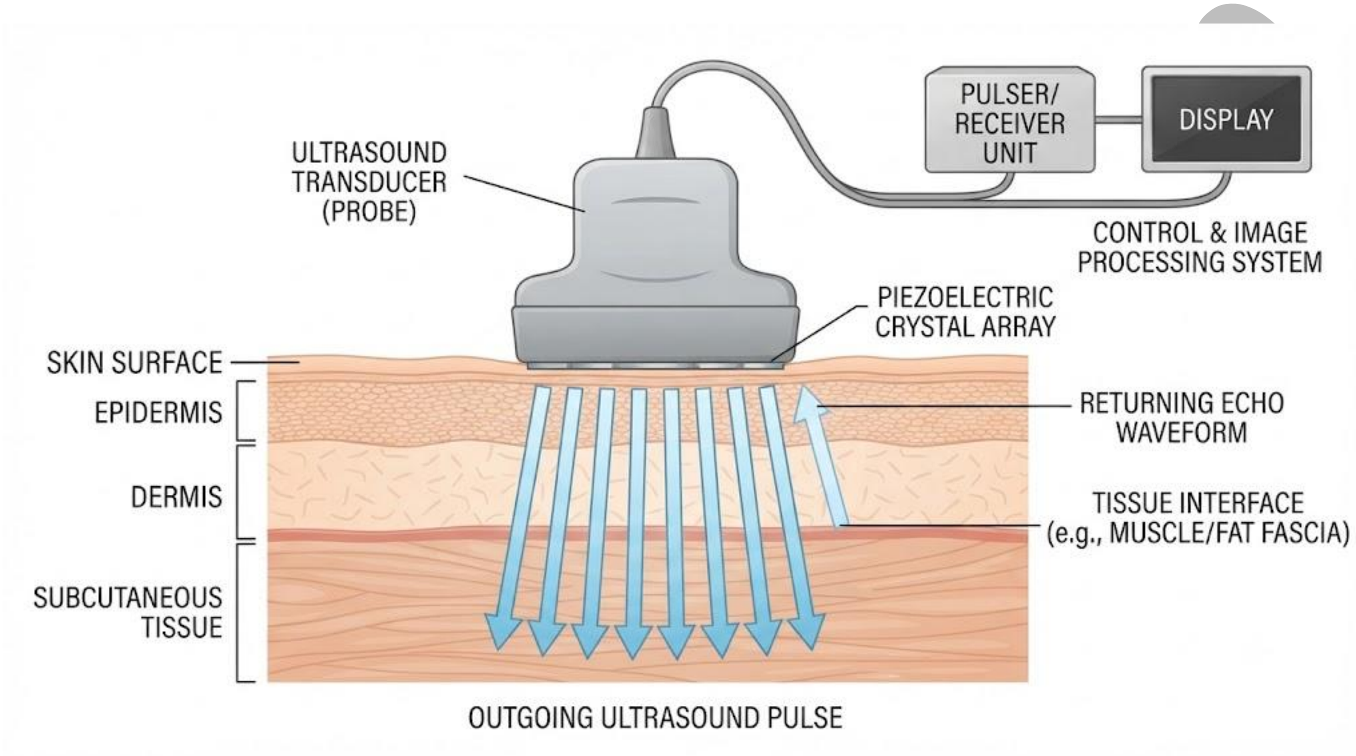


Figure 2.5: Diagram illustrating the pulse-echo principle of ultrasound, showing a transducer emitting sound waves and detecting reflected echoes from a tissue interface.

Pilot questions 2.5

1. Describe the basic principle of pulse-echo ultrasound image formation. (Linked to SLO 2.9)
2. Define acoustic impedance and explain its relevance to ultrasound appearance. (Linked to SLO 2.9)
3. Define an anechoic structure and give an example. (Linked to SLO 2.9)
4. Describe the Doppler effect and its application to assessing blood flow. (Linked to SLO 2.10)
5. Distinguish PACS from RIS in terms of their respective functions. (Linked to SLO 2.10)

Series Summary

This Series examined **CT, MRI, ultrasound, and imaging informatics**, beginning with the **physical basis of CT image formation**, scanner components, the attenuation-based image formation principle, and image reconstruction, before turning to **Hounsfield units, windowing, and CT anatomy**, the HU scale, window centre and width, and normal organ appearance on CT.

We then examined the **principles of MRI**, image formation, T1 and T2 weighting, and normal anatomical appearance, followed by **MRI safety**, magnetic field hazards, patient and staff safety considerations, and screening procedures, concluding with **ultrasound, Doppler, and imaging informatics**, pulse-echo image formation, tissue properties, the Doppler effect, and PACS and RIS infrastructure. Having worked through this Series, you should now be equipped to understand chest radiology examined in the next Series of this course.

Glossary of Terms

6. **Multidetector CT:** a CT scanner design using multiple parallel detector rows to acquire several slices per rotation.
7. **Voxel:** a three-dimensional pixel representing a discrete unit of tissue volume in a CT or MRI image.
8. **Iterative reconstruction:** a modern CT image reconstruction method permitting reduced radiation dose.
9. **Hounsfield unit (HU):** a standardised quantitative measure of tissue attenuation on CT, anchored to water and air.
10. **Window centre:** the Hounsfield unit value at the midpoint of the displayed greyscale range on a CT image.
11. **Window width:** the total range of Hounsfield unit values displayed across the greyscale on a CT image.
12. **T1-weighted image:** an MRI sequence in which fat appears bright and fluid appears relatively dark.
13. **T2-weighted image:** an MRI sequence in which fluid appears bright, sensitive to oedema and pathology.
14. **Projectile effect:** the forceful attraction of ferromagnetic objects toward an MRI scanner's magnetic field.
15. **MRI safety zones:** four progressively restricted access areas surrounding an MRI scanner.
16. **Acoustic impedance:** a tissue property determined by density and sound speed, governing ultrasound reflection.

17. **Picture archiving and communication system (PACS):** the infrastructure storing and distributing digital medical images.

Concept Check Questions [Series 2]

Objective questions

- Multidetector CT scanners employ multiple parallel rows of detectors, allowing simultaneous acquisition of several image slices per gantry ________.
- On the Hounsfield unit scale, water is defined as 0 HU and air is defined as ________ HU.
- MRI exploits the magnetic properties of hydrogen protons, which align with a powerful external magnetic field generated by the scanner's main ________.
- The projectile effect represents a genuine, ever-present hazard within the MRI environment, regardless of whether active ________ is underway.
- The time delay between ultrasound transmission and echo reception is used to calculate the depth of each reflecting ________.

Short-answer questions

1. Distinguish filtered back projection from iterative reconstruction.
2. Define window centre and window width.
3. Distinguish T1 relaxation from T2 relaxation.
4. List two categories of implanted device relevant to MRI patient safety screening.
5. Define acoustic impedance and explain its relevance to ultrasound appearance.

Long-answer questions

6. Discuss CT scanner components, the physical basis of CT image formation, and image reconstruction. (Linked to SLO 2.1, SLO 2.2)
7. Discuss the Hounsfield unit scale, window centre and width, and normal organ anatomy on CT. (Linked to SLO 2.3, SLO 2.4)
8. Discuss the basic principles of MRI image formation, T1 and T2 weighting, and normal anatomical appearance. (Linked to SLO 2.5, SLO 2.6)
9. Discuss the safety issues in the MRI environment with regard to patients and staff, and MRI screening procedures. (Linked to SLO 2.7, SLO 2.8)
10. Discuss the basic principles of ultrasound image formation, tissue properties, the Doppler effect, and imaging informatics. (Linked to SLO 2.9, SLO 2.10)

Answers to Concept Check Questions [Series 2]

Objective questions

11. Rotation.
12. -1000.
13. Magnet.
14. Scanning.
15. Interface.

Short-answer questions

16. Filtered back projection is the traditional reconstruction method; iterative reconstruction is a modern method permitting reduced radiation dose.
17. Window centre is the HU value at the midpoint of the displayed range; window width is the total range of HU values displayed.
18. T1 relaxation is the time for protons to realign with the main field; T2 relaxation is the time for protons to lose phase coherence.
19. Cardiac pacemakers and certain aneurysm clips or cochlear implants.
20. Acoustic impedance is determined by tissue density and sound speed; larger impedance differences between tissues produce stronger echoes and brighter appearance.

Long-answer questions

21. **Basic response:** CT scanners use a rotating X-ray tube and detector array to measure attenuation along many projection paths, forming projection data.

Value-added response: This data is mathematically reconstructed, using filtered back projection or iterative reconstruction, into a cross-sectional image of voxel attenuation values.

22. **Basic response:** The Hounsfield unit scale quantifies attenuation relative to water and air, with windowing selecting a specific HU range for optimal display of different tissue types.

Value-added response: Normal organ anatomy on CT, such as the liver, kidneys, and lungs, reflects characteristic attenuation and enhancement patterns relevant to accurate interpretation.

23. **Basic response:** MRI exploits hydrogen proton alignment in a magnetic field and radiofrequency-induced signal, with T1 and T2 weighting reflecting different relaxation properties.

Value-added response: Normal anatomical appearance, such as grey and white matter differentiation or musculoskeletal soft tissue contrast, reflects these characteristic tissue relaxation properties.

24. **Basic response:** The MRI environment carries hazards including the projectile effect, radiofrequency heating, and acoustic noise, requiring careful patient screening for implanted devices and foreign bodies.

Value-added response: Staff safety relies on structured zone restrictions and screening questionnaires, ensuring only appropriately verified personnel and equipment enter controlled areas.

25. **Basic response:** Ultrasound forms images through pulse-echo principles, with tissue properties including acoustic impedance and attenuation determining image appearance, and Doppler assessing blood flow.

Value-added response: Imaging informatics, through PACS and RIS, provides the essential infrastructure for image storage, distribution, and workflow management across the modern radiology department.

Answers to Pilot Questions [Series 2]

Part 2.1

1. An X-ray tube and opposing detector array mounted on a rotating gantry, with a motorised patient table.
2. It allows simultaneous acquisition of several slices per rotation, reducing scan time and improving longitudinal resolution.
3. Measurement of X-ray attenuation along many projection paths as the tube and detector rotate around the patient.
4. A three-dimensional pixel representing tissue volume within a scanned slice.
5. Filtered back projection is the traditional method; iterative reconstruction is a modern method allowing reduced radiation dose.

Part 2.2

6. A standardised scale of tissue attenuation; water is 0 HU and air is -1000 HU.
7. Soft tissue is approximately 40 to 80 HU; cortical bone exceeds +1000 HU.

8. Window centre is the HU value at the midpoint of the displayed range; window width is the total range of HU values displayed.
9. Because different tissue types require different display ranges to be optimally visualised, given their differing attenuation values.
10. The liver appears homogeneous and moderately attenuating; the kidneys show corticomedullary differentiation on early contrast phases.

Part 2.3

11. Hydrogen protons align with a magnetic field, are displaced by a radiofrequency pulse, and emit a signal as they relax back to equilibrium.
12. T1 relaxation is the time for protons to realign with the main field; T2 relaxation is the time for protons to lose phase coherence.
13. On T1, fat is bright and fluid is dark; on T2, fluid is bright.
14. It suppresses the normally bright fat signal to enhance conspicuity of fluid and pathology.
15. Cortical bone appears uniformly dark; articular cartilage shows intermediate signal intensity.

Part 2.4

1. Because the main magnetic field remains permanently active even when scanning is not in progress.
2. Radiofrequency heating of implanted devices during scanning, and acoustic noise from gradient switching.
3. Cardiac pacemakers and certain aneurysm clips or cochlear implants.
4. Four progressively more controlled zones, with only screened personnel and equipment permitted into the innermost zone.
5. It identifies any implanted device or metallic object requiring confirmation of MRI compatibility before scanning.

Part 2.5

1. A transducer emits sound pulses and detects reflected echoes, with time delay and amplitude used to reconstruct the image.
2. A tissue property determined by density and sound speed; larger differences between adjacent tissues produce stronger echoes and brighter appearance.
3. A structure with an echo-free, dark appearance from uniform sound transmission; simple fluid is an example.
4. A change in observed sound frequency from relative motion, used to assess blood flow presence, direction, and velocity.

5. PACS stores and distributes digital images; RIS manages scheduling, reporting workflow, and examination tracking.

References and Attributions [Series 2]

6. Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2020). The Essential Physics of Medical Imaging (4th ed.). Wolters Kluwer.
7. Westbrook, C., & Talbot, J. (2018). MRI in Practice (5th ed.). Wiley-Blackwell.
8. American College of Radiology (2020). ACR Manual on MR Safety.
9. Hoskins, P. R., Martin, K., & Thrush, A. (Eds.). (2019). Diagnostic Ultrasound: Physics and Equipment (3rd ed.). Cambridge University Press.

Figures, Plates, Tables, and Boxes

1. Figure 2.1: Diagram illustrating the rotating gantry of a CT scanner with the X-ray tube and detector array acquiring projection data around the patient. AI-generated using the prompt: "A single clean, accurate technical diagram of a CT scanner gantry viewed from above, showing an X-ray tube and opposing curved detector array positioned around a patient outline on the table, with a curved arrow indicating gantry rotation, textbook physics diagram style, neutral background, no photographic realism, no other panels."
2. Table 2.2: Typical Hounsfield unit values for common tissues. AI-generated using the prompt: "Create a clean technical reference table titled Typical Hounsfield Unit Values for Common Tissues, listing tissue, typical Hounsfield unit value, and relative appearance. Radiology reference table style with outside border, no photographic elements."
3. Table 2.3: Comparing T1-weighted and T2-weighted MRI appearance of common tissues. AI-generated using the prompt: "Create a clean technical reference table titled Comparing T1-Weighted and T2-Weighted MRI Appearance, listing tissue, T1-weighted appearance, and T2-weighted appearance. Radiology reference table style with outside border, no photographic elements."
4. Figure 2.4: Diagram illustrating the four progressively restricted safety zones surrounding an MRI scanner. AI-generated using the prompt: "A single clean, accurate schematic diagram of four concentric labelled zones surrounding a central MRI scanner icon, each zone ring labelled with its restriction level from least to most controlled, textbook safety diagram style, neutral background, no photographic realism, no other panels."

5. Figure 2.5: Diagram illustrating the pulse-echo principle of ultrasound, showing a transducer emitting sound waves and detecting reflected echoes from a tissue interface. AI-generated using the prompt: "A single clean, accurate schematic diagram of an ultrasound transducer positioned on a skin surface with labelled outgoing sound wave arrows travelling into tissue and a labelled returning echo arrow from a tissue interface below, textbook physics diagram style, neutral background, no photographic realism, no other panels."

Course code: RAD 601

Course title: Lectures in Radiology

Course credit load: 3 Units

Series 3: Chest Radiology

- **Part 3.1: Overview of Chest Imaging and Imaging Patterns**
  - Sub Part 3.1.1: Relative values and indications for radiography and CT in chest imaging
  - Sub Part 3.1.2: When to refer for radiography, CT, or MRI of the chest
  - Sub Part 3.1.3: Basic imaging patterns: consolidation, nodules, hyperlucency, and hyperinflation
- **Part 3.2: Pulmonary Infections**
  - Sub Part 3.2.1: Imaging appearance of pneumonia
  - Sub Part 3.2.2: Imaging appearance of pulmonary tuberculosis
  - Sub Part 3.2.3: Imaging appearance of HIV/AIDS-related opportunistic infections
- **Part 3.3: Pleural Disease and Lung Collapse**
  - Sub Part 3.3.1: Pleural effusion: appearances and causes
  - Sub Part 3.3.2: Pneumothorax and tension pneumothorax
  - Sub Part 3.3.3: Lung abscess and lung collapse
- **Part 3.4: Chest Neoplasms and Pulmonary Embolism**
  - Sub Part 3.4.1: Imaging appearance of bronchogenic carcinoma
  - Sub Part 3.4.2: Imaging appearance of pulmonary metastases
  - Sub Part 3.4.3: Imaging signs of pulmonary embolism
- **Part 3.5: Chest Trauma Imaging**
  - Sub Part 3.5.1: Imaging features of rib and sternal fractures
  - Sub Part 3.5.2: Imaging features of pneumothorax and haemothorax in trauma
  - Sub Part 3.5.3: Imaging features of pulmonary contusion and traumatic aortic injury

Introduction

In the last Series, we established CT, MRI, ultrasound, and imaging informatics. We now apply these principles directly to **chest radiology**, one of the most frequently requested and clinically consequential areas of everyday radiologic practice, spanning basic imaging patterns, pulmonary infection, pleural disease, thoracic neoplasm, pulmonary embolism, and chest trauma, conditions of particular importance given the substantial burden of tuberculosis and HIV/AIDS-related lung disease within the Nigerian environment.

The aim of this Series is to equip you with a thorough understanding of the relative values and indications for imaging in chest disease, basic imaging patterns, the imaging appearance of pulmonary infections, pleural disease and lung collapse, chest neoplasms, pulmonary embolism, and chest trauma.

This Series begins with an **overview of chest imaging and imaging patterns**, before examining **pulmonary infections**. We then turn to **pleural disease and lung collapse**, followed by **chest neoplasms and pulmonary embolism**, concluding with **chest trauma imaging**.

Series Learning Outcomes

At the end of this Series, you should be able to:

- **SLO 3.1:** enumerate the relative values of and indications for radiography and CT in chest imaging
- **SLO 3.2:** explain when to refer a patient to radiography, CT, or MRI of the chest, and describe basic imaging patterns
- **SLO 3.3:** describe the imaging appearance of pneumonia and pulmonary tuberculosis
- **SLO 3.4:** describe the imaging appearance of HIV/AIDS-related opportunistic pulmonary infections
- **SLO 3.5:** enumerate the typical chest radiography appearances and common causes of pleural effusion
- **SLO 3.6:** enumerate the typical appearances and causes of pneumothorax, tension pneumothorax, lung abscess, and lung collapse
- **SLO 3.7:** explain the typical imaging appearances of bronchogenic carcinoma and pulmonary metastases
- **SLO 3.8:** list the imaging signs of pulmonary embolism
- **SLO 3.9:** describe the imaging features of rib and sternal fractures, and of pneumothorax and haemothorax in trauma, and

- **SLO 3.10:** describe the imaging features of pulmonary contusion and traumatic aortic injury.

3.1 Overview of Chest Imaging and Imaging Patterns

3.1.1 relative values and indications for radiography and ct in chest imaging

Complementary roles reflecting cost, availability, and diagnostic detail

Chest radiography remains the first-line imaging investigation for most respiratory presentations, discussed throughout this Series, given its wide availability, low cost, and relatively low radiation dose, discussed in relation to X-ray generation in an earlier Series of this course, providing sufficient diagnostic information for many common conditions.

Computed tomography of the chest, discussed in the previous Series of this course, provides considerably greater anatomical detail and sensitivity, reserved for cases where radiography proves equivocal or insufficient, discussed further in the next sub-Part, including detailed staging of suspected malignancy, evaluation of suspected pulmonary embolism, and characterisation of complex pleural or parenchymal **abnormality**.

Fill in the blank: Chest radiography remains the first-line imaging investigation for most respiratory presentations given its wide availability, low cost, and relatively low radiation ________.

3.1.2 when to refer for radiography, ct, or mri of the chest

Referral for chest radiography is generally appropriate as the initial investigation for suspected pneumonia, discussed further later in this Series, pleural effusion, or pneumothorax, discussed further later in this Series, while referral for chest **CT** is generally indicated when radiography is normal or equivocal despite persistent clinical suspicion, or when detailed characterisation of an identified abnormality is required.

Chest **MRI**, discussed in the previous Series of this course, plays a considerably more limited role in routine chest imaging given the lower spatial resolution achievable within moving, air-containing lung tissue, but retains specific value in selected indications, including assessment of chest wall or mediastinal tumour invasion where its superior soft tissue contrast provides genuine additional **benefit**.

Fill in the blank: Chest MRI plays a considerably more limited role in routine chest imaging given the lower spatial resolution achievable within moving, air-containing lung ________.

3.1.3 basic imaging patterns: consolidation, nodules, hyperlucency, and hyperinflation

Consolidation refers to replacement of normal air-containing lung with fluid, pus, blood, or cells, producing a homogeneous area of increased opacity, often containing visible **air bronchograms**, air-filled bronchi outlined against the surrounding opacified lung, a pattern discussed further in relation to pneumonia later in this Series.

A **pulmonary nodule** refers to a discrete, rounded opacity, generally less than 3 centimetres in diameter, discussed further in relation to malignancy later in this Series, while **hyperlucency** describes an area of abnormally increased radiolucency, or blackness, reflecting reduced tissue density or increased air content, and **hyperinflation** describes generalised lung overexpansion, both patterns of particular relevance to obstructive airway **disease**.

Fill in the blank: Consolidation often contains visible air bronchograms, air-filled bronchi outlined against the surrounding ________ lung.

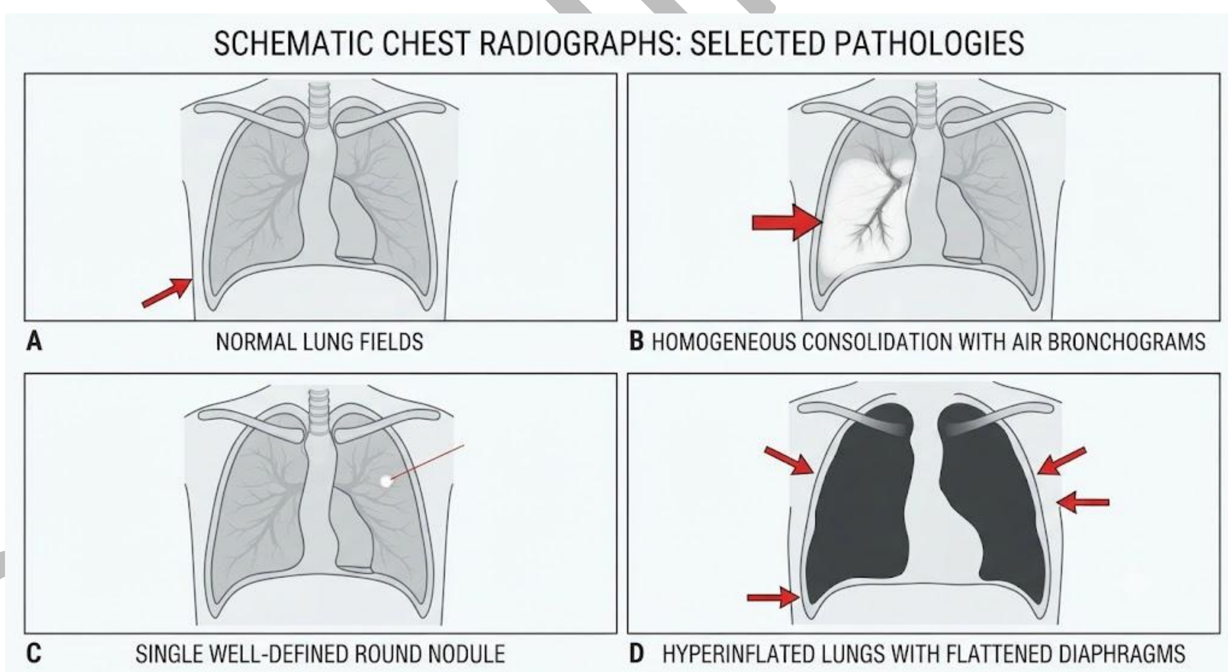


Figure 3.1: Diagram comparing normal lung radiographic appearance with focal consolidation, a discrete pulmonary nodule, and generalised hyperinflation.

Pilot questions 3.1

- State the relative advantages of chest radiography over CT as a first-line investigation. (Linked to SLO 3.1)
- List two indications for proceeding to chest CT after an equivocal chest radiograph. (Linked to SLO 3.1)
- Explain why chest MRI plays a limited role in routine chest imaging. (Linked to SLO 3.2)
- Define consolidation and describe the significance of an air bronchogram. (Linked to SLO 3.2)
- Distinguish hyperlucency from hyperinflation. (Linked to SLO 3.2)

3.2 Pulmonary Infections

3.2.1 imaging appearance of pneumonia

A pattern-based approach to infective consolidation

Lobar pneumonia typically produces homogeneous consolidation confined to a single anatomical lobe, discussed in relation to consolidation earlier in this Series, often with visible air bronchograms, while **bronchopneumonia** produces a more patchy, multifocal pattern of consolidation reflecting infection spreading through the airways rather than a single contiguous lobar process.

Atypical pneumonia, caused by organisms such as Mycoplasma, characteristically produces a more **interstitial** pattern, with fine reticular or ground-glass opacity rather than dense consolidation, meaning careful attention to the specific radiographic pattern can assist in narrowing the differential diagnosis of the likely causative **organism**.

Fill in the blank: Bronchopneumonia produces a more patchy, multifocal pattern of consolidation reflecting infection spreading through the ________ rather than a single contiguous lobar process.

3.2.2 imaging appearance of pulmonary tuberculosis

Primary pulmonary tuberculosis typically presents with consolidation in any lobe, discussed earlier in this Part, accompanied by ipsilateral hilar or mediastinal **lymphadenopathy**, together occasionally forming the classical, though not universally present, **Ghon complex** when a calcified peripheral focus and calcified lymph node are both identified.

Post-primary, or reactivation, tuberculosis characteristically involves the **upper lobes** and superior segments of the lower lobes, producing patchy consolidation, **cavitation**, and, with healing, fibrosis and volume loss, with miliary tuberculosis producing innumerable tiny, randomly-distributed nodules reflecting **haematogenous** dissemination.

Fill in the blank: Post-primary tuberculosis characteristically involves the upper lobes, producing patchy consolidation, cavitation, and, with healing, fibrosis and volume ________.

3.2.3 imaging appearance of hiv/aids-related opportunistic infections

Pneumocystis jirovecii pneumonia, an important opportunistic infection in advanced HIV/AIDS, discussed in an earlier related course, characteristically produces bilateral, symmetrical, **perihilar** ground-glass opacity, occasionally progressing to more extensive consolidation, typically without significant pleural effusion or lymphadenopathy.

Patients with HIV/AIDS additionally show an increased incidence of **atypical** tuberculosis presentation, discussed earlier in this Part, particularly at lower CD4 counts, where the characteristic upper lobe cavitary pattern may be replaced by more diffuse, lower lobe, or lymphadenopathy-predominant disease, together with increased susceptibility to bacterial pneumonia and fungal pulmonary **infection**.

Fill in the blank: Pneumocystis jirovecii pneumonia characteristically produces bilateral, symmetrical, perihilar ________ opacity.

Table 3.2: Comparing primary and post-primary pulmonary tuberculosis.

Feature	Primary tuberculosis	Post-primary tuberculosis
Typical location	Any lobe, with hilar lymphadenopathy	Upper lobes and superior segments of lower lobes
Cavitation	Uncommon	Common
Classical finding	Ghon complex (calcified focus and node)	Fibrosis and volume loss with healing

Pilot questions 3.2

1. Distinguish lobar pneumonia from bronchopneumonia in terms of radiographic pattern. (Linked to SLO 3.3)
2. Describe the typical radiographic appearance of atypical pneumonia. (Linked to SLO 3.3)

3. Describe the classical Ghon complex of primary pulmonary tuberculosis. (Linked to SLO 3.3)
4. Describe the typical radiographic distribution of post-primary tuberculosis. (Linked to SLO 3.3)
5. Describe the characteristic imaging appearance of Pneumocystis jirovecii pneumonia. (Linked to SLO 3.4)

3.3 Pleural Disease and Lung Collapse

3.3.1 pleural effusion: appearances and causes

Fluid within the pleural space producing a characteristic meniscus

Pleural effusion on an erect chest radiograph characteristically produces a homogeneous opacity with a curved, concave upper border, termed a **meniscus sign**, reflecting the physical behaviour of fluid within the pleural space, with larger effusions producing more extensive opacification and associated mediastinal shift away from the affected side.

Common causes of pleural effusion include **parapneumonic** effusion, discussed in relation to pneumonia earlier in this Series, tuberculosis, discussed earlier in this Series, malignancy, discussed further later in this Series, and cardiac failure, generally producing bilateral effusions together with other radiographic signs of cardiac decompensation, with the specific clinical context guiding the most likely underlying **cause**.

Fill in the blank: Pleural effusion on an erect chest radiograph characteristically produces a homogeneous opacity with a curved, concave upper border, termed a ________ sign.

3.3.2 pneumothorax and tension pneumothorax

Pneumothorax appears radiographically as a thin, visible **visceral pleural line**, with absent lung markings peripheral to this line, reflecting air within the pleural space rather than expanded lung tissue, most easily identified toward the lung apex on an erect chest radiograph.

Tension pneumothorax, a genuine radiological and clinical emergency, additionally demonstrates **mediastinal shift** away from the affected side, and, in more severe cases, **diaphragmatic flattening or inversion** on the affected side, reflecting the progressively rising intrapleural pressure characteristic of this life-threatening **condition**.

Fill in the blank: Tension pneumothorax additionally demonstrates mediastinal shift away from the affected side, reflecting the progressively rising intrapleural ________ characteristic of this life-threatening condition.

3.3.3 lung abscess and lung collapse

A **lung abscess** typically appears as a cavitating lesion with a thick, irregular wall, often containing a visible **air-fluid level**, discussed in relation to fluid behaviour earlier in this Part, distinguishing it from a simple thin-walled cavity and reflecting the necrotic, suppurative nature of the underlying infective process.

Lung collapse, or atelectasis, reflects loss of lung volume, generally producing increased opacity of the affected segment or lobe together with volume loss signs, including displacement of fissures, mediastinal shift toward the affected side, and elevation of the ipsilateral hemidiaphragm, each reflecting the characteristic **volume loss** distinguishing collapse from consolidation.

Fill in the blank: Lung collapse produces volume loss signs including displacement of fissures, mediastinal shift toward the affected side, and elevation of the ipsilateral ________.

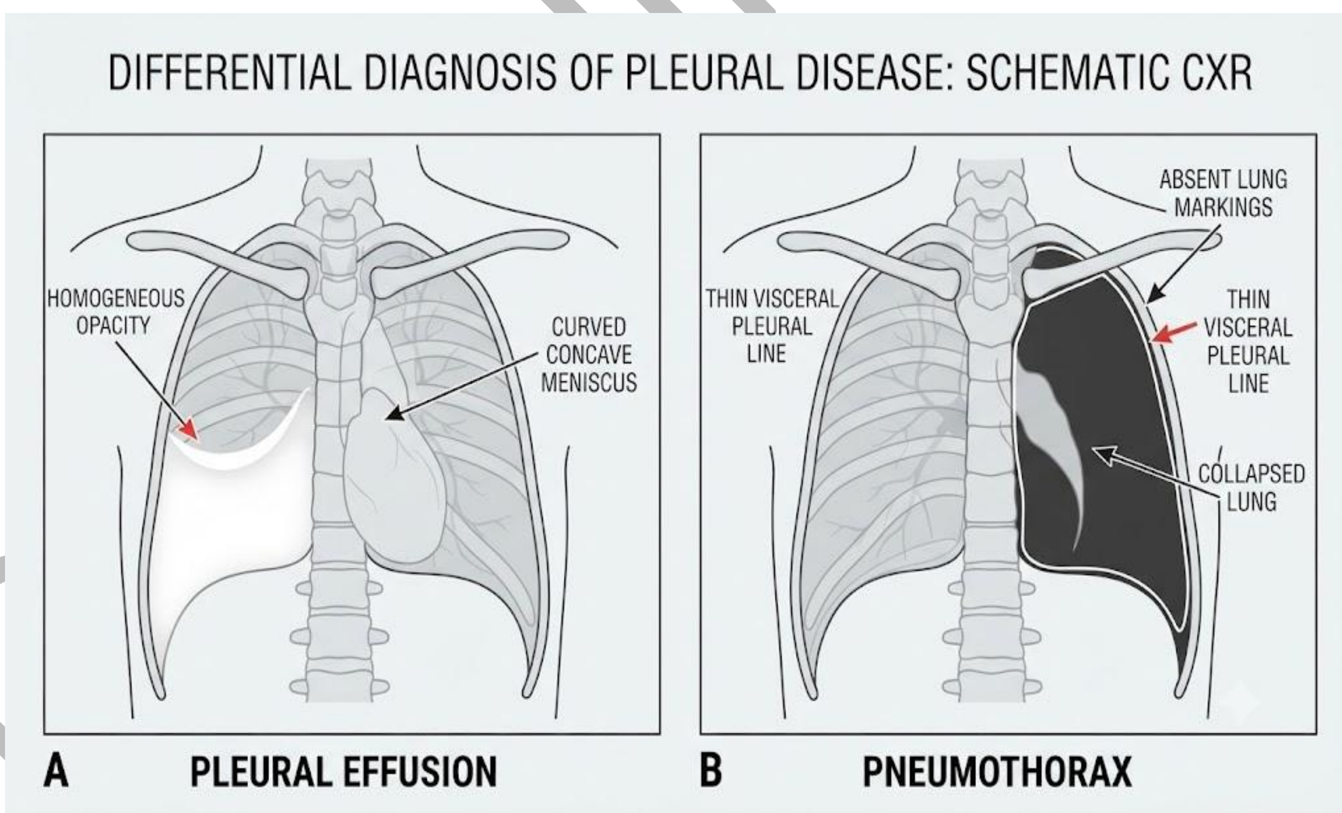


Figure 3.3: Diagram comparing the radiographic appearance of pleural effusion with its meniscus sign against pneumothorax with a visible visceral pleural line.

Pilot questions 3.3

1. Describe the meniscus sign of pleural effusion. (Linked to SLO 3.5)
2. List three common causes of pleural effusion. (Linked to SLO 3.5)
3. Describe the radiographic appearance of a pneumothorax. (Linked to SLO 3.6)
4. Describe the additional radiographic findings distinguishing tension pneumothorax from simple pneumothorax. (Linked to SLO 3.6)
5. Describe the radiographic signs of lung collapse. (Linked to SLO 3.6)

3.4 Chest Neoplasms and Pulmonary Embolism

3.4.1 imaging appearance of bronchogenic carcinoma

A spectrum of appearances from central mass to peripheral nodule

Bronchogenic carcinoma may present radiographically as a central hilar mass, discussed in relation to bronchial anatomy in an earlier related course, or as a peripheral pulmonary nodule or mass, discussed in relation to nodules earlier in this Series, with features suggesting malignancy including a **spiculated** or irregular margin, and interval growth on serial imaging.

Further recognised radiographic and CT findings suggestive of bronchogenic carcinoma include associated **lymphadenopathy**, discussed in relation to tuberculosis earlier in this Series, distal obstructive collapse or consolidation resulting from airway obstruction by the tumour mass, and, in advanced disease, direct chest wall or mediastinal **invasion**, with CT providing considerably superior local and nodal staging information compared with radiography alone.

Fill in the blank: Features suggesting malignancy in a pulmonary nodule or mass include a spiculated or irregular margin, and interval ________ on serial imaging.

3.4.2 imaging appearance of pulmonary metastases

Pulmonary metastases typically present as multiple, well defined, rounded nodules of varying size, generally distributed throughout both lungs and more numerous in the lower lobes given their greater relative blood flow, discussed in relation to haematogenous spread in an earlier related course, in contrast to the single dominant lesion more characteristic of primary lung cancer.

Certain primary tumours produce characteristic metastatic patterns, including **cannonball metastases**, large, well defined, rounded nodules classically associated with renal cell carcinoma, and **lymphangitic carcinomatosis**, producing a diffuse, reticular or reticulonodular interstitial pattern reflecting tumour infiltration along pulmonary lymphatic **channels**.

Fill in the blank: Cannonball metastases are large, well defined, rounded nodules classically associated with ________ cell carcinoma.

3.4.3 imaging signs of pulmonary embolism

Chest radiography in **pulmonary embolism** is frequently normal or non-specifically abnormal, though recognised though relatively insensitive signs include **Westermark's sign**, a focal area of oligaemia, or reduced vascularity, distal to an occluded vessel, and **Hampton's hump**, a wedge-shaped, pleural-based opacity representing pulmonary infarction.

CT pulmonary angiography represents the primary diagnostic investigation for suspected pulmonary embolism, discussed in relation to CT contrast principles in an earlier Series of this course, directly demonstrating a **filling defect** within the pulmonary arterial tree, providing considerably greater diagnostic sensitivity and specificity than chest radiography **alone**.

Fill in the blank: CT pulmonary angiography directly demonstrates a filling defect within the pulmonary arterial tree, providing considerably greater diagnostic sensitivity and specificity than chest radiography ________.

Table 3.4: Comparing radiographic signs relevant to pulmonary embolism.

Sign	Description	Relative sensitivity
Westermark's sign	Focal oligaemia distal to an occluded vessel	Relatively insensitive
Hampton's hump	Wedge-shaped pleural-based opacity of infarction	Relatively insensitive
CT filling defect	Direct visualisation of the arterial clot on CT angiography	High sensitivity and specificity

Pilot questions 3.4

1. Describe the radiographic features suggesting malignancy in a pulmonary nodule. (Linked to SLO 3.7)
2. Describe the typical distribution pattern of pulmonary metastases. (Linked to SLO 3.7)
3. Define cannonball metastases and name their classic primary tumour association. (Linked to SLO 3.7)

4. Describe Westermark's sign and Hampton's hump. (Linked to SLO 3.8)
5. Describe the role of CT pulmonary angiography in diagnosing pulmonary embolism. (Linked to SLO 3.8)

3.5 Chest Trauma Imaging

3.5.1 imaging features of rib and sternal fractures

Frequently subtle fractures with important associated complications

Rib fractures, discussed in relation to chest trauma throughout this Part, may be subtle on standard chest radiography, particularly for non-displaced fractures, meaning careful, systematic review of the entire rib cage, together with clinical correlation, remains essential, with **CT** offering considerably greater sensitivity for fracture detection where clinically indicated.

Sternal fractures, generally resulting from direct anterior chest impact, such as in deceleration injury, are best evaluated on a lateral chest radiograph or CT given their frequent poor visualisation on the standard frontal projection, with associated **cardiac contusion** warranting specific clinical consideration given the mechanism of injury involved.

Fill in the blank: Rib fractures may be subtle on standard chest radiography, particularly for non-displaced fractures, with CT offering considerably greater ________ for fracture detection where clinically indicated.

3.5.2 imaging features of pneumothorax and haemothorax in trauma

Traumatic pneumothorax, discussed in relation to its radiographic appearance earlier in this Series, may additionally demonstrate specific findings relevant to the trauma setting, including **subcutaneous emphysema**, air tracking within the soft tissues of the chest wall, and, on supine trauma radiographs, more subtle signs such as the **deep sulcus sign**, an abnormally deep, lucent costophrenic angle.

Haemothorax, blood within the pleural space, produces a radiographic appearance generally indistinguishable from other pleural effusions, discussed earlier in this Series, on plain radiography alone, though the specific trauma context and, where performed, CT attenuation measurement can help confirm the haemorrhagic nature of the effusion.

Fill in the blank: On supine trauma radiographs, traumatic pneumothorax may show subtle signs such as the deep sulcus sign, an abnormally deep, lucent costophrenic ________.

3.5.3 imaging features of pulmonary contusion and traumatic aortic injury

Pulmonary contusion typically presents as non-segmental, patchy consolidation or ground-glass opacity, discussed in relation to consolidation patterns earlier in this Series, appearing within hours of significant chest trauma and generally overlying the site of direct impact, distinguishing it from the more delayed onset typical of aspiration or infective consolidation.

Traumatic aortic injury, a genuine life-threatening emergency generally resulting from rapid deceleration injury, may be suggested on chest radiography by **mediastinal widening**, discussed in relation to mediastinal structures in an earlier Series of this course, with **CT angiography** representing the definitive investigation directly demonstrating the aortic injury and guiding urgent surgical or endovascular **management**.

Fill in the blank: Traumatic aortic injury may be suggested on chest radiography by mediastinal widening, with CT angiography representing the definitive investigation directly demonstrating the aortic ________.

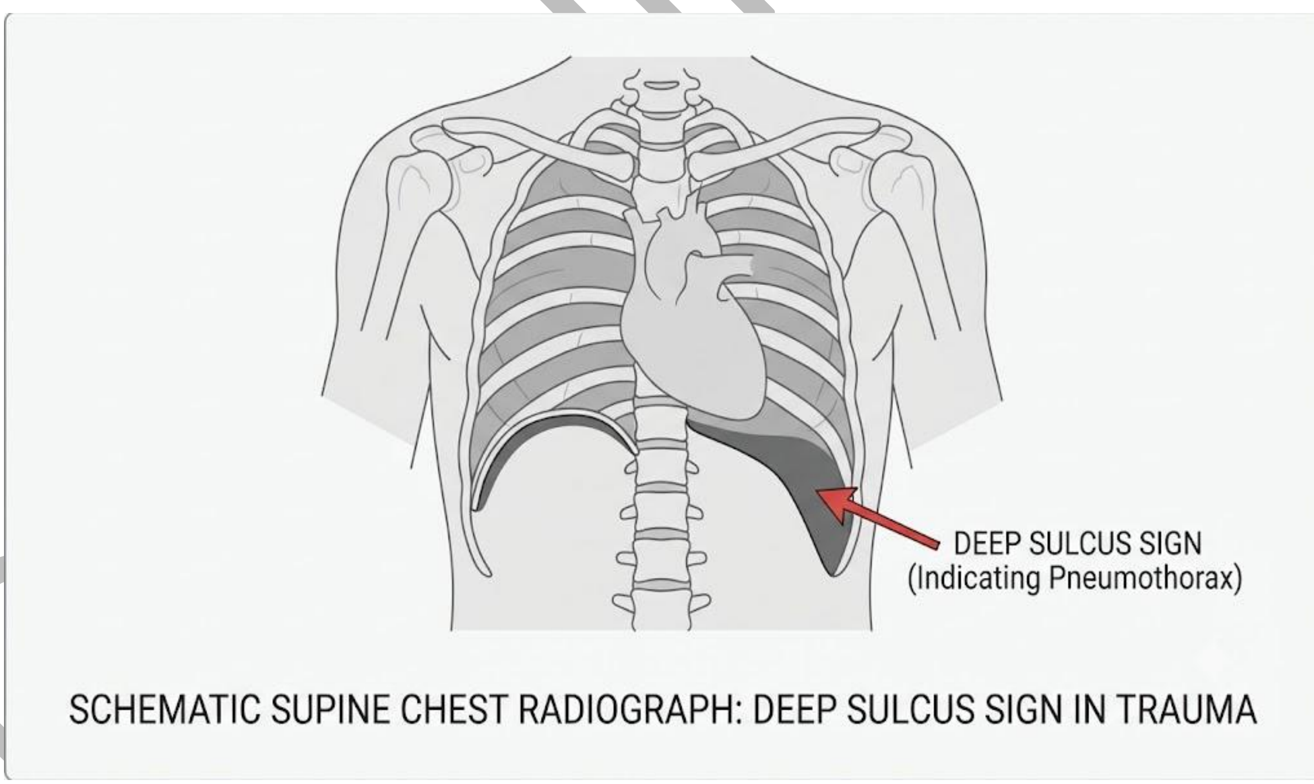


Figure 3.5: Diagram illustrating the deep sulcus sign of an occult pneumothorax on a supine trauma chest radiograph.

Pilot questions 3.5

1. Explain why CT offers greater sensitivity than plain radiography for rib fracture detection. (Linked to SLO 3.9)
2. Describe the best radiographic projection for evaluating a suspected sternal fracture. (Linked to SLO 3.9)
3. Define the deep sulcus sign and explain its clinical significance. (Linked to SLO 3.9)
4. Describe the typical radiographic appearance and timing of pulmonary contusion. (Linked to SLO 3.10)
5. Describe the radiographic and CT findings suggestive of traumatic aortic injury. (Linked to SLO 3.10)

Series Summary

This Series examined **chest radiology**, beginning with an **overview of chest imaging and imaging patterns**, the relative roles of radiography, CT, and MRI, and basic patterns including consolidation, nodules, hyperlucency, and hyperinflation, before turning to **pulmonary infections**, pneumonia, tuberculosis, and HIV/AIDS-related opportunistic infection.

We then examined **pleural disease and lung collapse**, pleural effusion, pneumothorax, lung abscess, and atelectasis, followed by **chest neoplasms and pulmonary embolism**, bronchogenic carcinoma, pulmonary metastases, and the imaging signs of embolism, concluding with **chest trauma imaging**, rib and sternal fractures, traumatic pneumothorax and haemothorax, pulmonary contusion, and traumatic aortic injury. Having worked through this Series, you should now be equipped to understand uro-genital radiology examined in the next Series of this course.

Glossary of Terms

6. **Consolidation:** replacement of normal air-containing lung with fluid, pus, blood, or cells, producing increased opacity.
7. **Air bronchogram:** air-filled bronchi visible against surrounding consolidated lung.
8. **Ghon complex:** a calcified peripheral pulmonary focus with a calcified regional lymph node in primary tuberculosis.

9. **Meniscus sign:** the curved, concave upper border of fluid within the pleural space on an erect chest radiograph.
10. **Tension pneumothorax:** a pneumothorax with rising intrapleural pressure causing mediastinal shift, a genuine emergency.
11. **Air-fluid level:** a horizontal interface visible within a cavity, indicating both air and fluid content.
12. **Cannonball metastases:** large, well defined, rounded pulmonary metastases classically from renal cell carcinoma.
13. **Westermark's sign:** focal pulmonary oligaemia distal to an occluded vessel in pulmonary embolism.
14. **Hampton's hump:** a wedge-shaped, pleural-based opacity representing pulmonary infarction.
15. **Deep sulcus sign:** an abnormally deep, lucent costophrenic angle indicating occult pneumothorax on a supine radiograph.
16. **Pulmonary contusion:** non-segmental, patchy consolidation from direct lung trauma, appearing within hours of injury.
17. **Mediastinal widening:** an abnormally widened mediastinal silhouette on chest radiography, raising suspicion of aortic injury.

Concept Check Questions [Series 3]

Objective questions

- Consolidation often contains visible air bronchograms, air-filled bronchi outlined against the surrounding ________ lung.
- Post-primary tuberculosis characteristically involves the upper lobes, producing patchy consolidation, cavitation, and, with healing, fibrosis and volume ________.
- Pleural effusion on an erect chest radiograph characteristically produces a homogeneous opacity with a curved, concave upper border, termed a ________ sign.
- Cannonball metastases are large, well defined, rounded nodules classically associated with ________ cell carcinoma.
- Traumatic aortic injury may be suggested on chest radiography by mediastinal widening, with CT angiography demonstrating the aortic ________.

Short-answer questions

1. Distinguish lobar pneumonia from bronchopneumonia in terms of radiographic pattern.
2. Describe the classical Ghon complex of primary pulmonary tuberculosis.

3. Describe the additional radiographic findings distinguishing tension pneumothorax from simple pneumothorax.
4. Describe Westermark's sign and Hampton's hump.
5. Define the deep sulcus sign and explain its clinical significance.

Long-answer questions

6. Discuss the relative values of and indications for radiography, CT, and MRI in chest imaging, and basic imaging patterns. (Linked to SLO 3.1, SLO 3.2)
7. Discuss the imaging appearance of pneumonia, pulmonary tuberculosis, and HIV/AIDS-related opportunistic infections. (Linked to SLO 3.3, SLO 3.4)
8. Discuss pleural effusion, pneumothorax, tension pneumothorax, lung abscess, and lung collapse. (Linked to SLO 3.5, SLO 3.6)
9. Discuss the imaging appearances of bronchogenic carcinoma, pulmonary metastases, and pulmonary embolism. (Linked to SLO 3.7, SLO 3.8)
10. Discuss the imaging features of chest trauma, including rib and sternal fractures, pneumothorax and haemothorax, pulmonary contusion, and traumatic aortic injury. (Linked to SLO 3.9, SLO 3.10)

Answers to Concept Check Questions [Series 3]

Objective questions

11. Consolidated.
12. Loss.
13. Meniscus.
14. Renal.
15. Injury.

Short-answer questions

16. Lobar pneumonia produces homogeneous consolidation confined to a single lobe; bronchopneumonia produces a patchy, multifocal pattern.
17. A calcified peripheral pulmonary focus together with a calcified regional lymph node, seen in primary tuberculosis.
18. Mediastinal shift away from the affected side, and diaphragmatic flattening or inversion on the affected side.

19. Westermark's sign is focal oligaemia distal to an occluded vessel; Hampton's hump is a wedge-shaped, pleural-based opacity of infarction.
20. An abnormally deep, lucent costophrenic angle on a supine trauma radiograph, indicating an occult pneumothorax that may be missed on a standard supine view.

Long-answer questions

21. **Basic response:** Chest radiography remains the first-line investigation given its availability and low dose, with CT reserved for equivocal findings or detailed characterisation, and MRI playing a limited but specific role.

Value-added response: Basic imaging patterns, including consolidation, nodules, hyperlucency, and hyperinflation, provide the foundational vocabulary for interpreting chest pathology throughout this Series.

22. **Basic response:** Pneumonia patterns vary between lobar, bronchopneumonic, and atypical presentations, while tuberculosis differs radiographically between primary and post-primary disease.

Value-added response: HIV/AIDS-related opportunistic infection, including Pneumocystis pneumonia and atypical tuberculosis presentation, reflects the impact of immunosuppression on typical disease patterns.

23. **Basic response:** Pleural effusion produces a characteristic meniscus sign with varied causes, while pneumothorax shows a visible pleural line, with tension pneumothorax additionally showing mediastinal shift.

Value-added response: Lung abscess produces a cavitating lesion with an air-fluid level, and lung collapse produces characteristic volume loss signs distinguishing it from consolidation.

24. **Basic response:** Bronchogenic carcinoma may present as a central mass or peripheral nodule with malignant features, while pulmonary metastases typically show multiple bilateral nodules or specific patterns such as cannonball metastases.

Value-added response: Pulmonary embolism shows relatively insensitive radiographic signs, with CT pulmonary angiography providing definitive diagnosis through direct filling defect visualisation.

25. **Basic response:** Chest trauma imaging includes often subtle rib and sternal fractures, traumatic pneumothorax and haemothorax with specific signs such as the deep sulcus sign, and pulmonary contusion appearing within hours of injury.

Value-added response: Traumatic aortic injury, suggested by mediastinal widening on radiography, requires urgent CT angiography for definitive diagnosis given its life-threatening nature.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Wide availability, low cost, and relatively low radiation dose.
2. Equivocal radiographic findings despite persistent clinical suspicion, and staging of suspected malignancy.
3. Because lower spatial resolution is achievable within moving, air-containing lung tissue.
4. Replacement of normal air-containing lung with fluid, pus, blood, or cells; air bronchograms are air-filled bronchi visible against consolidated lung.
5. Hyperlucency describes increased radiolucency from reduced density or increased air; hyperinflation describes generalised lung overexpansion.

Part 3.2

6. Lobar pneumonia produces homogeneous single-lobe consolidation; bronchopneumonia produces a patchy, multifocal pattern.
7. A more interstitial pattern with fine reticular or ground-glass opacity rather than dense consolidation.
8. A calcified peripheral focus together with a calcified hilar or mediastinal lymph node.
9. Upper lobes and superior segments of the lower lobes.
10. Bilateral, symmetrical, perihilar ground-glass opacity, typically without significant effusion or lymphadenopathy.

Part 3.3

11. A homogeneous opacity with a curved, concave upper border reflecting fluid behaviour within the pleural space.
12. Parapneumonic effusion, tuberculosis, and malignancy, among others such as cardiac failure.
13. A thin visceral pleural line with absent lung markings peripheral to it.
14. Mediastinal shift away from the affected side, and diaphragmatic flattening or inversion.
15. Increased opacity of the affected segment or lobe with displaced fissures, mediastinal shift toward the affected side, and elevated hemidiaphragm.

Part 3.4

1. A spiculated or irregular margin, and interval growth on serial imaging.
2. Multiple, well defined, rounded nodules distributed throughout both lungs, more numerous in the lower lobes.
3. Large, well defined, rounded nodules; classically associated with renal cell carcinoma.
4. Westermark's sign is focal oligaemia distal to an occluded vessel; Hampton's hump is a wedge-shaped pleural-based opacity of infarction.
5. It directly demonstrates a filling defect in the pulmonary arterial tree, offering greater sensitivity and specificity than radiography alone.

Part 3.5

1. Because rib fractures may be subtle on plain radiography, particularly non-displaced fractures, while CT offers superior detection.
2. The lateral chest radiograph or CT, given poor visualisation on the standard frontal projection.
3. An abnormally deep, lucent costophrenic angle on a supine trauma radiograph, indicating an occult pneumothorax.
4. Non-segmental, patchy consolidation or ground-glass opacity appearing within hours of injury, overlying the site of impact.
5. Mediastinal widening on radiography, with CT angiography directly demonstrating the aortic injury.

References and Attributions [Series 3]

6. Hansell, D. M., Lynch, D. A., McAdams, H. P., & Bankier, A. A. (2019). Imaging of Diseases of the Chest (6th ed.). Elsevier.
7. Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.
8. World Health Organization (2016). Chest Radiography in Tuberculosis Detection: Summary of Current WHO Recommendations.
9. Marx, J. A., et al. (2018). Rosen's Emergency Medicine: Concepts and Clinical Practice (9th ed.), chest trauma imaging chapter. Elsevier.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: Diagram comparing normal lung radiographic appearance with focal consolidation, a discrete pulmonary nodule, and generalised hyperinflation. AI-generated using the prompt: "A single clean, accurate four-panel schematic chest radiograph diagram, each panel labelled, showing normal lung fields, an area of homogeneous consolidation with visible branching air bronchogram lines, a single well defined round nodule, and hyperinflated lungs with flattened diaphragm contours, radiology teaching diagram style, neutral background, no photographic realism."
2. Table 3.2: Comparing primary and post-primary pulmonary tuberculosis. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Primary and Post-Primary Pulmonary Tuberculosis, listing feature, primary tuberculosis, and post-primary tuberculosis. Radiology reference table style with outside border, no photographic elements."
3. Figure 3.3: Diagram comparing the radiographic appearance of pleural effusion with its meniscus sign against pneumothorax with a visible visceral pleural line. AI-generated using the prompt: "A single clean, accurate two-panel schematic chest radiograph diagram, one panel labelled pleural effusion showing a homogeneous opacity with a curved concave upper meniscus border, the other panel labelled pneumothorax showing a thin visceral pleural line with absent lung markings beyond it toward the apex, radiology teaching diagram style, neutral background, no photographic realism."
4. Table 3.4: Comparing radiographic signs relevant to pulmonary embolism. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Radiographic Signs Relevant to Pulmonary Embolism, listing sign, description, and relative sensitivity. Radiology reference table style with outside border, no photographic elements."
5. Figure 3.5: Diagram illustrating the deep sulcus sign of an occult pneumothorax on a supine trauma chest radiograph. AI-generated using the prompt: "A single clean, accurate schematic chest radiograph diagram in the supine trauma projection, with a labelled arrow pointing to an abnormally deep, dark costophrenic angle at the lower lateral chest compared with the normal contralateral side, radiology teaching diagram style, neutral background, no photographic realism, no other panels."

Course code: RAD 601

Course title: Lectures in Radiology

Course credit load: 3 Units

Series 4: Uro-Genital Radiology

- **Part 4.1: Imaging Modalities in Uro-Genital Radiology**
  - Sub Part 4.1.1: Plain radiography (KUB), ultrasonography, and intravenous urography
  - Sub Part 4.1.2: MCUG, RUG, CT urography, and specialised genital studies
  - Sub Part 4.1.3: Relative values, indications, and contrast medium management in renal failure
- **Part 4.2: Congenital and Cystic Renal Disease**
  - Sub Part 4.2.1: Posterior urethral valves and congenital hydronephrosis
  - Sub Part 4.2.2: Renal agenesis, ectopic kidneys, and ureterocoeles
  - Sub Part 4.2.3: Renal cystic disorders
- **Part 4.3: Renal and Urinary Tract Infections and Malignancy**
  - Sub Part 4.3.1: Pyelonephritis and renal abscess
  - Sub Part 4.3.2: Schistosomiasis and uro-genital tuberculosis
  - Sub Part 4.3.3: Renal and bladder tumours
- **Part 4.4: Uro-Genital Trauma and Pathology of the Prostate, Urethra, and Testes**
  - Sub Part 4.4.1: Trauma to the kidneys and urinary bladder
  - Sub Part 4.4.2: Pathology of the prostate and urinary bladder
  - Sub Part 4.4.3: Pathology of the urethra, seminal vesicles, and testes
- **Part 4.5: Interventional Procedures in Uro-Genital Radiology**
  - Sub Part 4.5.1: Percutaneous nephrostomy and ureteral stenting
  - Sub Part 4.5.2: Lithotripsy and balloon dilatation of ureteral stricture
  - Sub Part 4.5.3: Ultrasound-guided drainage and CT/MRI-guided biopsy

Introduction

In the last Series, we examined chest radiology. We now turn to **uro-genital radiology**, encompassing the specific imaging modalities used to evaluate the kidneys, urinary tract, and genital structures, congenital and cystic renal disease, infection and malignancy affecting the genitourinary system, uro-genital trauma, and the essential **interventional radiological procedures** used in the management of urological disease, an area of particular relevance given the substantial burden of schistosomiasis and urinary tuberculosis within the Nigerian environment.

The aim of this Series is to equip you with a thorough understanding of the imaging modalities used in uro-genital radiology, congenital and cystic renal disease, urinary tract infection and malignancy, uro-genital trauma and prostate, urethral, and testicular pathology, and interventional procedures in uro-genital radiology.

This Series begins with **imaging modalities in uro-genital radiology**, before examining **congenital and cystic renal disease**. We then turn to **renal and urinary tract infections and malignancy**, followed by **uro-genital trauma and pathology of the prostate, urethra, and testes**, concluding with **interventional procedures in uro-genital radiology**.

Series Learning Outcomes

At the end of this Series, you should be able to:

- **SLO 4.1:** list the imaging modalities used in the evaluation of uro-genital disorders
- **SLO 4.2:** discuss the relative values of and indications for radiography, ultrasonography, CT, and MRI in urogenital radiology, and describe contrast medium management in renal failure
- **SLO 4.3:** describe the imaging features of common congenital urological anomalies
- **SLO 4.4:** describe the classification and imaging features of renal cystic disorders
- **SLO 4.5:** describe the imaging features of pyelonephritis, renal abscess, schistosomiasis, and uro-genital tuberculosis
- **SLO 4.6:** describe the imaging features of renal and bladder tumours
- **SLO 4.7:** describe the imaging features of trauma to the kidneys and urinary bladder
- **SLO 4.8:** describe the imaging features of common pathologies of the prostate, urinary bladder, urethra, seminal vesicles, and testes
- **SLO 4.9:** describe percutaneous nephrostomy, ureteral stenting, and lithotripsy, and

- **SLO 4.10:** describe ultrasound-guided drainage and CT/MRI-guided biopsy in uro-genital radiology.

4.1 Imaging Modalities in Uro-Genital Radiology

4.1.1 plain radiography (kub), ultrasonography, and intravenous urography

Foundational modalities visualising the urinary tract

Plain radiography of the kidneys, ureters, and bladder, or **KUB**, provides a baseline assessment for suspected urinary tract calculi, discussed further later in this Series, given the radiopacity of most calcium-containing stones, though its sensitivity remains limited compared with cross-sectional imaging.

Ultrasonography provides a widely available, radiation-free means of assessing renal size, cortical thickness, and the presence of hydronephrosis or focal renal lesions, discussed in the previous Series of this course, while **intravenous urography**, or **IVU**, uses sequential radiographs following intravenous iodinated contrast administration to demonstrate the entire collecting system's **anatomy** and function, though largely superseded by CT urography for detailed evaluation.

Fill in the blank: Intravenous urography uses sequential radiographs following intravenous iodinated contrast administration to demonstrate the entire collecting system's anatomy and ________.

4.1.2 mcug, rug, ct urography, and specialised genital studies

Micturating cysto-urethrography, or **MCUG**, involves instilling contrast into the bladder via a catheter and imaging during voiding, particularly valuable for demonstrating vesicoureteric reflux and posterior urethral valves in children, discussed further later in this Series, while **retrograde urethrography**, or **RUG**, directly opacifies the urethra to assess suspected urethral **stricture** or trauma.

CT urography combines cross-sectional anatomical detail with contrast-enhanced excretory phase imaging of the urinary tract, representing the current preferred investigation for detailed evaluation of the collecting system, while specialised genital studies include **hysterosalpingography**, assessing uterine cavity and tubal patency, **vasography**, assessing the vas deferens, and **flush genito-graphy**, assessing the urethra and genital tract in specific clinical contexts.

Fill in the blank: Retrograde urethrography directly opacifies the urethra to assess suspected urethral stricture or ________.

4.1.3 relative values, indications, and contrast medium management in renal failure

Selection of the appropriate imaging modality generally favours **ultrasonography** as the initial investigation given its safety and wide availability, with **CT** reserved for detailed characterisation of suspected calculi, malignancy, or trauma, discussed further later in this Series, and **MRI** offering particular value in soft tissue characterisation and in patients where iodinated contrast is relatively contraindicated.

Contrast medium management in renal failure requires careful attention to the risk of **contrast-induced nephropathy**, discussed in an earlier Series of this course, generally favouring use of the lowest diagnostically adequate contrast volume, adequate patient hydration where clinically appropriate, and, in severe renal impairment, consideration of alternative, non-iodinated contrast imaging strategies where diagnostically **sufficient**.

Fill in the blank: Contrast medium management in renal failure generally favours use of the lowest diagnostically adequate contrast volume and adequate patient ________ where clinically appropriate.

Table 4.1: Comparing key uro-genital imaging modalities.

Modality	Primary strength	Typical indication
Ultrasonography	Safe, widely available, no radiation	Initial assessment of renal size, hydronephrosis, lesions
CT urography	Detailed anatomical and functional detail	Detailed collecting system evaluation, calculi, malignancy
MCUG	Dynamic assessment during voiding	Vesicoureteric reflux and posterior urethral valves

Pilot questions 4.1

- Describe the role of plain radiography (KUB) in uro-genital imaging. (Linked to SLO 4.1)
- Distinguish MCUG from RUG in terms of technique and typical indication. (Linked to SLO 4.1)
- Describe the role of CT urography in uro-genital imaging. (Linked to SLO 4.1)

- List three specialised genital imaging studies discussed. (Linked to SLO 4.1)
- Describe the approach to contrast medium management in a patient with renal failure. (Linked to SLO 4.2)

4.2 Congenital and Cystic Renal Disease

4.2.1 posterior urethral valves and congenital hydronephrosis

Obstructive congenital anomalies with characteristic imaging patterns

Posterior urethral valves, an obstructive congenital anomaly occurring exclusively in males, produce a characteristic **dilated posterior urethra** with a normal-calibre anterior urethra on MCUG, discussed earlier in this Series, together with a thickened, trabeculated bladder wall reflecting chronic outflow obstruction.

Congenital hydronephrosis, most commonly resulting from pelviureteric junction obstruction, presents on ultrasound as dilatation of the renal pelvis and calyces, discussed in relation to ultrasound principles in an earlier Series of this course, with severity graded according to the degree of collecting system **dilatation** and associated cortical thinning.

Fill in the blank: Posterior urethral valves produce a characteristic dilated posterior urethra with a normal-calibre anterior urethra, together with a thickened, trabeculated bladder ________.

4.2.2 renal agenesis, ectopic kidneys, and ureterocoeles

Renal agenesis refers to complete absence of one or, rarely, both kidneys, generally identified on ultrasound by the absence of a kidney within its expected renal fossa, occasionally accompanied by compensatory **hypertrophy** of the contralateral kidney.

Ectopic kidneys may be found in a variety of abnormal locations, most commonly **pelvic**, reflecting incomplete embryological ascent, while a **ureterocoele** appears as a cystic dilatation of the distal ureter protruding into the bladder lumen, classically producing a characteristic **cobra head** appearance on contrast studies of the urinary tract.

Fill in the blank: A ureterocoele appears as a cystic dilatation of the distal ureter protruding into the bladder lumen, classically producing a characteristic cobra ________ appearance on contrast studies.

4.2.3 renal cystic disorders

Simple renal cysts appear on ultrasound as well defined, anechoic, thin-walled structures with posterior acoustic enhancement, discussed in relation to ultrasound tissue properties in an earlier Series of this course, representing an extremely common, generally clinically insignificant finding with advancing age.

Polycystic kidney disease, whether the autosomal dominant adult-onset form or the less common autosomal recessive infantile form, produces bilaterally enlarged kidneys replaced by numerous cysts of varying size, with renal cystic disorders more broadly classified according to systems such as the **Bosniak classification**, stratifying cystic renal lesions by their malignant potential based on specific imaging characteristics.

Fill in the blank: Renal cystic disorders are classified according to systems such as the Bosniak classification, stratifying cystic renal lesions by their malignant ________ based on specific imaging characteristics.

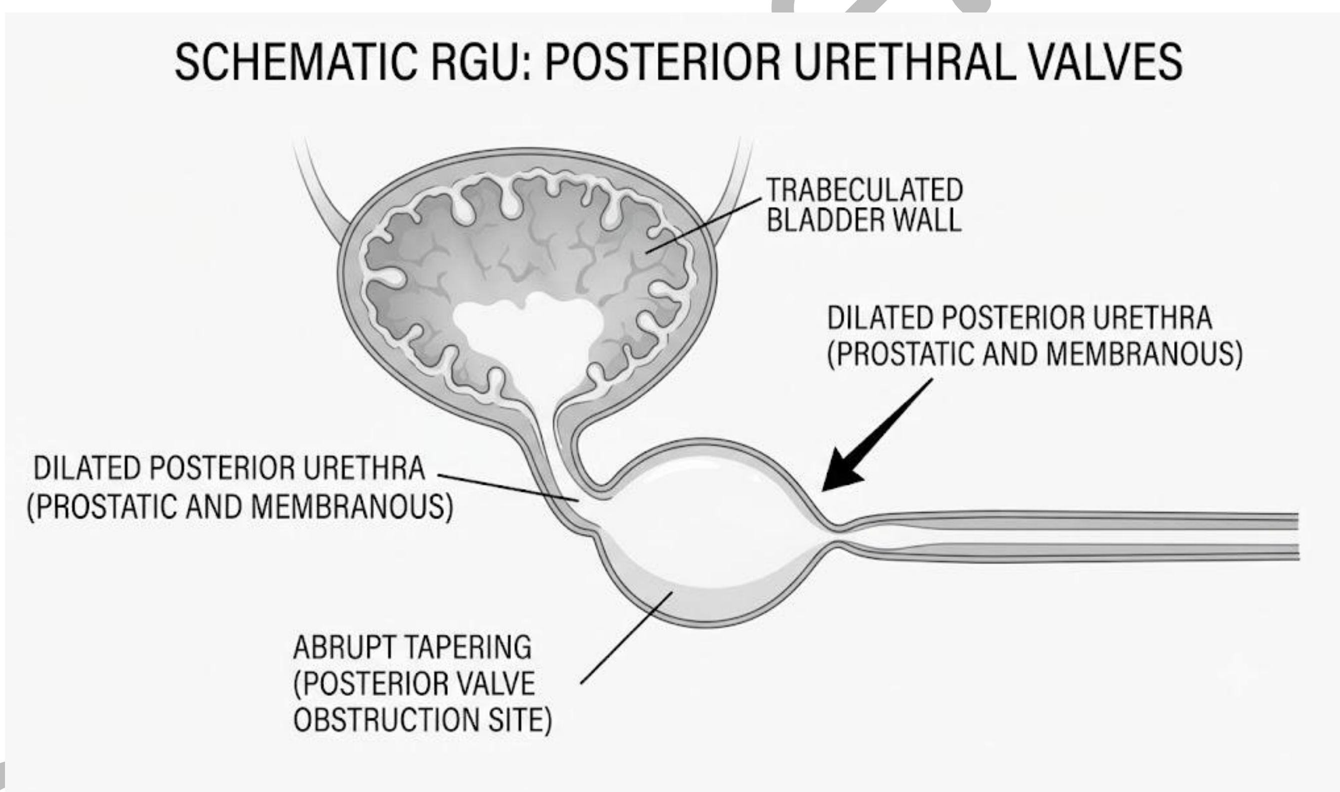


Figure 4.2: Diagram illustrating the dilated posterior urethra and trabeculated bladder characteristic of posterior urethral valves on micturating cysto-urethrography.

Pilot questions 4.2

1. Describe the characteristic MCUG findings of posterior urethral valves. (Linked to SLO 4.3)
2. Describe the ultrasound appearance of congenital hydronephrosis. (Linked to SLO 4.3)
3. Define renal agenesis and describe its typical ultrasound finding. (Linked to SLO 4.3)
4. Describe the cobra head appearance of a ureterocoele. (Linked to SLO 4.3)
5. Describe the ultrasound appearance of a simple renal cyst and the purpose of the Bosniak classification. (Linked to SLO 4.4)

4.3 Renal and Urinary Tract Infections and Malignancy

4.3.1 pyelonephritis and renal abscess

Infective processes ranging from diffuse inflammation to focal collection

Acute pyelonephritis on contrast-enhanced CT typically demonstrates one or more wedge-shaped or striated areas of reduced renal parenchymal enhancement, reflecting focal areas of inflammation and impaired perfusion, generally without a discrete, well defined mass **lesion**.

A **renal abscess**, representing a more localised, suppurative complication of pyelonephritis, discussed earlier in this Part, appears as a discrete, thick-walled, fluid-containing lesion, typically showing rim **enhancement** on contrast-enhanced imaging with a non-enhancing central necrotic component, generally requiring drainage where large or clinically unresponsive to antibiotic therapy alone.

Fill in the blank: A renal abscess appears as a discrete, thick-walled, fluid-containing lesion, typically showing rim enhancement with a non-enhancing central necrotic ________.

4.3.2 schistosomiasis and uro-genital tuberculosis

Uro-genital schistosomiasis, of substantial endemic importance within Nigeria, characteristically produces **bladder wall calcification**, often described as a fine, linear, or curvilinear pattern outlining the bladder contour, together with ureteric wall thickening and calcification in more extensive **disease**.

Uro-genital tuberculosis produces a wide range of imaging findings, including irregular calyceal destruction, ureteric strictures producing a characteristic **beaded** appearance, and, in advanced disease, a small, contracted, fibrotic bladder, discussed in relation to pulmonary tuberculosis patterns in the previous Series of this course, reflecting the chronic, destructive nature of untreated disease.

Fill in the blank: Uro-genital tuberculosis produces ureteric strictures with a characteristic ________ appearance.

4.3.3 renal and bladder tumours

Renal cell carcinoma, the most common primary renal malignancy, typically appears as a heterogeneously enhancing solid renal mass, often demonstrating **washout** of contrast on delayed imaging, distinguishing it from the simple cysts discussed earlier in this Series, with CT providing essential local and vascular staging information.

Bladder carcinoma, most commonly transitional cell carcinoma, typically presents as a focal **polypoid** or sessile mass projecting into the bladder lumen, best demonstrated on CT urography or cystoscopy-correlated imaging, discussed earlier in this Series, with imaging additionally assessing for local invasion and regional lymph node **involvement**.

Fill in the blank: Renal cell carcinoma typically demonstrates washout of contrast on delayed imaging, distinguishing it from a simple ________.

Table 4.3: Comparing key infective and neoplastic uro-genital imaging findings.

Condition	Characteristic imaging finding	Preferred modality
Acute pyelonephritis	Wedge-shaped areas of reduced enhancement	Contrast-enhanced CT
Uro-genital schistosomiasis	Bladder wall calcification	Plain radiography or CT
Renal cell carcinoma	Heterogeneously enhancing mass with contrast washout	Contrast-enhanced CT

Pilot questions 4.3

1. Describe the CT appearance of acute pyelonephritis. (Linked to SLO 4.5)
2. Describe the imaging appearance of a renal abscess. (Linked to SLO 4.5)
3. Describe the characteristic imaging finding of uro-genital schistosomiasis. (Linked to SLO 4.5)
4. Describe the ureteric imaging findings of uro-genital tuberculosis. (Linked to SLO 4.5)

5. Describe the typical CT appearance of renal cell carcinoma and bladder carcinoma. (Linked to SLO 4.6)

4.4 Uro-Genital Trauma and Pathology of the Prostate, Urethra, and Testes

4.4.1 trauma to the kidneys and urinary bladder

Graded injury requiring careful contrast-enhanced assessment

Renal trauma is generally graded according to injury severity, from simple contusion or subcapsular haematoma at the mild end, through parenchymal laceration, to shattered kidney or **renal pedicle injury** at the severe end, with contrast-enhanced CT, including a delayed excretory phase, essential for accurate grading and identification of active contrast **extravasation**.

Bladder trauma, most commonly following pelvic fracture or direct blunt trauma, is classified as **extraperitoneal** rupture, with contrast extravasation confined around the bladder, or **intraperitoneal** rupture, with contrast extravasation outlining loops of bowel within the peritoneal cavity, a distinction of direct relevance to subsequent surgical **management**.

Fill in the blank: Bladder trauma is classified as extraperitoneal rupture or intraperitoneal rupture, a distinction of direct relevance to subsequent surgical ________.

4.4.2 pathology of the prostate and urinary bladder

Benign prostatic hyperplasia, discussed in relation to prostate pathology throughout this sub-Part, produces generalised or nodular prostatic enlargement, best assessed on ultrasound or MRI, while **prostate carcinoma** typically appears as a focal area of reduced signal on T2-weighted MRI, discussed in the previous Series of this course, within the peripheral zone of the gland.

Bladder pathology beyond the tumours discussed earlier in this Series includes **cystitis**, generally producing non-specific bladder wall thickening, and bladder **calculi**, appearing as mobile, radiopaque or echogenic structures within the bladder lumen, occasionally associated with chronic outflow obstruction, discussed earlier in this Series, as a predisposing **factor**.

Fill in the blank: Prostate carcinoma typically appears as a focal area of reduced signal on T2-weighted MRI within the peripheral ________ of the gland.

4.4.3 pathology of the urethra, seminal vesicles, and testes

Urethral strictures, discussed in relation to retrograde urethrography earlier in this Series, appear as a focal area of luminal narrowing, generally resulting from prior infection, instrumentation, or trauma, with the length and location of the stricture directly informing subsequent surgical or endoscopic management **planning**.

Testicular pathology ranges from infective epididymo-orchitis, producing enlargement and increased vascularity on Doppler ultrasound, discussed in the previous Series of this course, to **testicular torsion**, a genuine surgical emergency demonstrating markedly reduced or absent intratesticular blood flow, and testicular tumours, generally presenting as a focal, hypoechoic intratesticular **mass**.

Fill in the blank: Testicular torsion is a genuine surgical emergency demonstrating markedly reduced or absent intratesticular blood ________ on Doppler ultrasound.

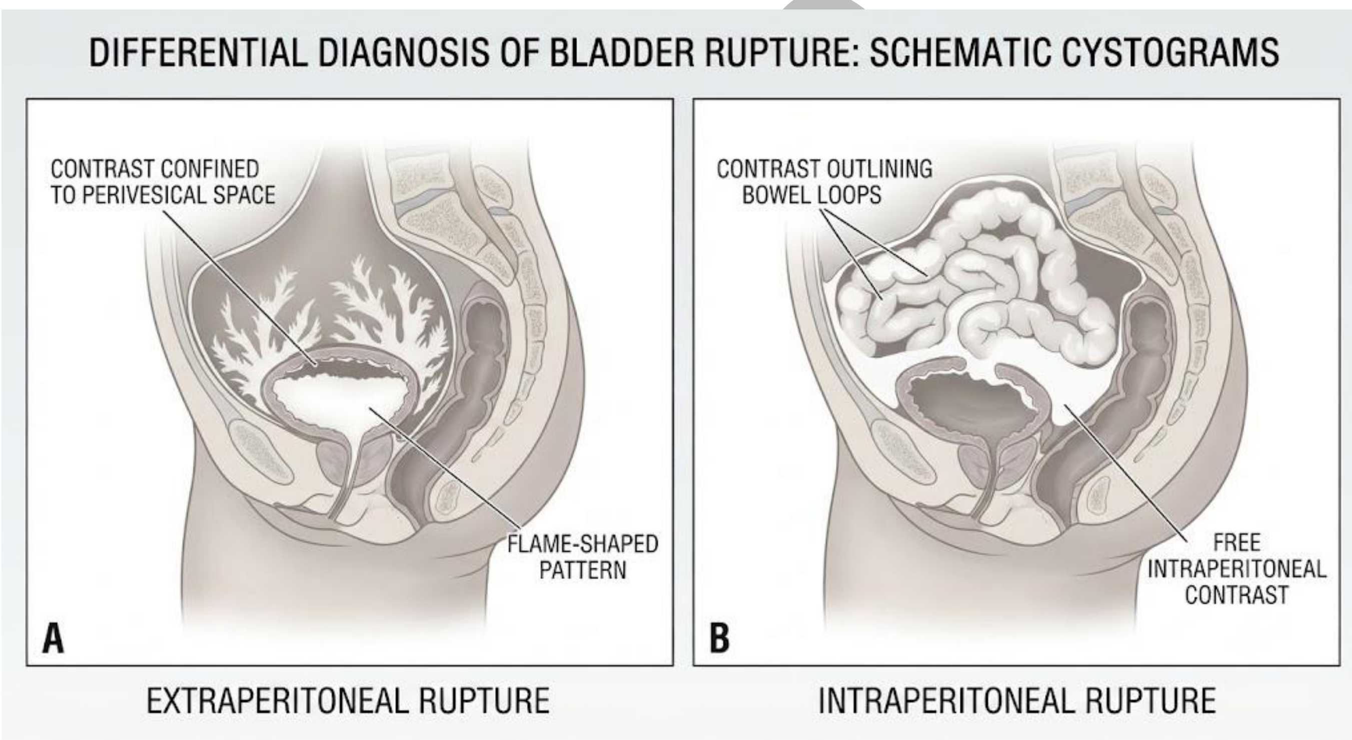


Figure 4.4: Diagram comparing extraperitoneal and intraperitoneal bladder rupture patterns of contrast extravasation on CT cystography.

Pilot questions 4.4

1. Describe the grading approach used for renal trauma. (Linked to SLO 4.7)
2. Distinguish extraperitoneal from intraperitoneal bladder rupture. (Linked to SLO 4.7)

3. Describe the imaging appearance of prostate carcinoma on MRI. (Linked to SLO 4.8)
4. Describe the imaging appearance of a urethral stricture. (Linked to SLO 4.8)
5. Describe the Doppler ultrasound finding of testicular torsion and explain its clinical significance. (Linked to SLO 4.8)

4.5 Interventional Procedures in Uro-Genital Radiology

4.5.1 percutaneous nephrostomy and ureteral stenting

Image-guided decompression of an obstructed collecting system

Percutaneous nephrostomy involves image-guided, generally ultrasound- or fluoroscopy-assisted, placement of a drainage catheter directly into the renal collecting system, discussed in relation to hydronephrosis earlier in this Series, providing urgent decompression of an obstructed kidney, particularly valuable where retrograde ureteric access is not feasible.

Ureteral stenting, placing an internal drainage tube, or stent, spanning the ureter, offers an alternative or complementary means of relieving ureteric obstruction, discussed earlier in this Part, with **percutaneous nephrolithotomy** additionally providing image-guided access for direct endoscopic removal of large renal **calculi**.

Fill in the blank: Percutaneous nephrostomy provides urgent decompression of an obstructed kidney, particularly valuable where retrograde ureteric access is not ________.

4.5.2 lithotripsy and balloon dilatation of ureteral stricture

Extracorporeal shock wave lithotripsy, or **ECWL**, uses externally generated, focused shock waves to fragment urinary tract calculi, discussed in relation to plain radiography earlier in this Series, into smaller fragments capable of spontaneous passage, representing a non-invasive alternative to surgical stone **removal** for appropriately selected patients.

Balloon dilatation of ureteral stricture involves image-guided passage of a balloon catheter across a ureteric narrowing, discussed in relation to uro-genital tuberculosis earlier in this Series, with subsequent balloon inflation mechanically dilating the stricture, offering a minimally invasive alternative to open surgical **repair** in appropriately selected cases.

Fill in the blank: Extracorporeal shock wave lithotripsy uses externally generated, focused shock waves to fragment urinary tract calculi into smaller fragments capable of spontaneous ________.

4.5.3 ultrasound-guided drainage and ct/mri-guided biopsy

Ultrasound-guided drainage provides real-time image guidance for percutaneous drainage of symptomatic or infected renal cystic lesions, including renal abscesses, discussed earlier in this Series, allowing precise needle or catheter placement while continuously monitoring the relationship of the needle to surrounding structures.

CT-guided and, less commonly, **MRI-guided biopsy** provide precise, image-directed sampling of suspected renal, prostatic, or other uro-genital masses, discussed earlier in this Series, allowing definitive **histological** diagnosis while minimising the risk of injury to adjacent critical structures during the procedure.

Fill in the blank: CT-guided and MRI-guided biopsy provide precise, image-directed sampling allowing definitive ________ diagnosis while minimising injury to adjacent structures.

Table 4.5: Comparing key interventional uro-genital radiology procedures.

Procedure	Primary purpose	Typical indication
Percutaneous nephrostomy	Decompress an obstructed kidney	Ureteric obstruction, especially when retrograde access fails
Extracorporeal shock wave lithotripsy	Fragment urinary calculi non-invasively	Appropriately sized renal or ureteric stones
CT/MRI-guided biopsy	Obtain tissue for histological diagnosis	Suspicious renal, prostatic, or other uro-genital mass

Pilot questions 4.5

1. Describe the purpose and technique of percutaneous nephrostomy. (Linked to SLO 4.9)
2. Describe ureteral stenting and percutaneous nephrolithotomy. (Linked to SLO 4.9)
3. Describe the principle of extracorporeal shock wave lithotripsy. (Linked to SLO 4.9)
4. Describe balloon dilatation of a ureteral stricture. (Linked to SLO 4.9)
5. Describe the role of ultrasound-guided drainage and CT/MRI-guided biopsy in uro-genital radiology. (Linked to SLO 4.10)

Series Summary

This Series examined **uro-genital radiology**, beginning with **imaging modalities in uro-genital radiology**, plain radiography, ultrasonography, IVU, MCUG, RUG, CT urography, and specialised genital studies, together with contrast medium management in renal failure, before turning to **congenital and cystic renal disease**, posterior urethral valves, hydronephrosis, renal agenesis, ectopic kidneys, ureterocoeles, and renal cystic disorders.

We then examined **renal and urinary tract infections and malignancy**, pyelonephritis, renal abscess, schistosomiasis, uro-genital tuberculosis, and renal and bladder tumours, followed by **uro-genital trauma and pathology of the prostate, urethra, and testes**, renal and bladder trauma, and prostate, urethral, and testicular pathology, concluding with **interventional procedures in uro-genital radiology**, percutaneous nephrostomy, ureteral stenting, lithotripsy, and image-guided drainage and biopsy. Having worked through this Series, you should now be equipped to understand the radiology subspecialties overview examined in the final Series of this course.

Glossary of Terms

6. **Intravenous urography (IVU):** sequential radiographs following intravenous contrast demonstrating the urinary collecting system.
7. **Micturating cysto-urethrography (MCUG):** contrast imaging of the bladder and urethra performed during voiding.
8. **Posterior urethral valves:** an obstructive congenital urethral anomaly occurring exclusively in males.
9. **Ureterocoele:** cystic dilatation of the distal ureter protruding into the bladder, producing a cobra head appearance.
10. **Bosniak classification:** a system stratifying cystic renal lesions by malignant potential based on imaging features.
11. **Acute pyelonephritis:** renal infection producing wedge-shaped areas of reduced parenchymal enhancement on CT.
12. **Uro-genital schistosomiasis:** parasitic infection producing characteristic bladder wall calcification.
13. **Renal cell carcinoma:** the most common primary renal malignancy, typically showing contrast washout on delayed imaging.
14. **Extraperitoneal bladder rupture:** bladder trauma with contrast extravasation confined around the bladder.
15. **Testicular torsion:** twisting of the testis causing reduced or absent blood flow, a surgical emergency.

16. **Percutaneous nephrostomy:** image-guided placement of a drainage catheter into the renal collecting system.
17. **Extracorporeal shock wave lithotripsy (ECWL):** non-invasive fragmentation of urinary calculi using focused shock waves.

Concept Check Questions [Series 4]

Objective questions

- Intravenous urography demonstrates the entire collecting system's anatomy and ________.
- A ureterocoele classically produces a characteristic cobra ________ appearance on contrast studies.
- A renal abscess typically shows rim enhancement with a non-enhancing central necrotic ________.
- Bladder trauma is classified as extraperitoneal or intraperitoneal rupture, a distinction relevant to surgical ________.
- Extracorporeal shock wave lithotripsy fragments urinary calculi into smaller fragments capable of spontaneous ________.

Short-answer questions

1. Distinguish MCUG from RUG in terms of technique and typical indication.
2. Describe the ultrasound appearance of a simple renal cyst.
3. Describe the characteristic imaging finding of uro-genital schistosomiasis.
4. Distinguish extraperitoneal from intraperitoneal bladder rupture.
5. Describe the Doppler ultrasound finding of testicular torsion and explain its clinical significance.

Long-answer questions

6. Discuss the imaging modalities used in uro-genital radiology and contrast medium management in renal failure. (Linked to SLO 4.1, SLO 4.2)
7. Discuss congenital urological anomalies and renal cystic disorders. (Linked to SLO 4.3, SLO 4.4)
8. Discuss pyelonephritis, renal abscess, schistosomiasis, uro-genital tuberculosis, and renal and bladder tumours. (Linked to SLO 4.5, SLO 4.6)
9. Discuss trauma to the kidneys and urinary bladder and pathology of the prostate, urethra, and testes. (Linked to SLO 4.7, SLO 4.8)

10. Discuss interventional procedures in uro-genital radiology. (Linked to SLO 4.9, SLO 4.10)

Answers to Concept Check Questions [Series 4]

Objective questions

11. Function.
12. Head.
13. Component.
14. Management.
15. Passage.

Short-answer questions

16. MCUG images during voiding to assess reflux and posterior urethral valves; RUG directly opacifies the urethra to assess stricture or trauma.
17. A well defined, anechoic, thin-walled structure with posterior acoustic enhancement.
18. Bladder wall calcification, often fine, linear, or curvilinear.
19. Extraperitoneal rupture confines contrast around the bladder; intraperitoneal rupture allows contrast to outline bowel loops in the peritoneal cavity.
20. Markedly reduced or absent intratesticular blood flow; it represents a surgical emergency requiring urgent intervention to preserve the testis.

Long-answer questions

21. **Basic response:** Uro-genital imaging modalities range from plain radiography and ultrasound to IVU, MCUG, RUG, CT urography, and specialised genital studies, each suited to specific clinical questions.

Value-added response: Contrast medium management in renal failure requires minimising contrast volume and ensuring adequate hydration, given the risk of contrast-induced nephropathy.

22. **Basic response:** Congenital urological anomalies include posterior urethral valves, hydronephrosis, renal agenesis, ectopic kidneys, and ureterocoeles, each with characteristic imaging findings.

Value-added response: Renal cystic disorders range from simple cysts to polycystic kidney disease, classified by systems such as Bosniak to stratify malignant potential.

23. **Basic response:** Pyelonephritis and renal abscess reflect a spectrum of infective severity, while schistosomiasis and uro-genital tuberculosis produce characteristic calcification and stricture patterns respectively.

Value-added response: Renal and bladder tumours show characteristic enhancement and morphological features on CT, essential for diagnosis and staging.

24. **Basic response:** Renal and bladder trauma are graded and classified based on injury pattern, directly informing management, while prostate, urethral, and testicular pathology span infection to malignancy.

Value-added response: Imaging plays an essential role in characterising each of these conditions and guiding appropriate clinical management.

25. **Basic response:** Interventional uro-genital procedures include percutaneous nephrostomy and ureteral stenting for obstruction, and lithotripsy and balloon dilatation for calculi and stricture.

Value-added response: Ultrasound-guided drainage and CT/MRI-guided biopsy provide further essential image-directed diagnostic and therapeutic capability within modern uro-genital radiology.

Answers to Pilot Questions [Series 4]

Part 4.1

1. It provides baseline assessment for suspected urinary tract calculi given their radiopacity, though with limited sensitivity compared with cross-sectional imaging.
2. MCUG images the bladder and urethra during voiding for reflux/posterior urethral valves; RUG directly opacifies the urethra for stricture or trauma.
3. It provides detailed anatomical and functional evaluation of the collecting system, the current preferred detailed investigation.
4. Hysterosalpingography, vasography, and flush genito-graphy.
5. Using the lowest diagnostically adequate contrast volume, ensuring adequate hydration, and considering alternative non-iodinated strategies where sufficient.

Part 4.2

6. A dilated posterior urethra tapering to a normal-calibre anterior urethra, with a thickened, trabeculated bladder wall.
7. Dilatation of the renal pelvis and calyces, graded according to severity.
8. Complete absence of a kidney; identified by absence of a kidney in its expected renal fossa on ultrasound.
9. A cystic dilatation of the distal ureter protruding into the bladder, seen as a rounded lucency on contrast studies.
10. A well defined, anechoic, thin-walled structure with posterior acoustic enhancement; the Bosniak classification stratifies malignant potential of cystic lesions.

Part 4.3

11. Wedge-shaped or striated areas of reduced renal parenchymal enhancement without a discrete mass.
12. A discrete, thick-walled, fluid-containing lesion with rim enhancement and a non-enhancing necrotic centre.
13. Bladder wall calcification, often fine, linear, or curvilinear.
14. Ureteric strictures producing a characteristic beaded appearance, alongside calyceal destruction and a contracted bladder in advanced disease.
15. Renal cell carcinoma shows a heterogeneously enhancing mass with contrast washout; bladder carcinoma shows a polypoid or sessile intraluminal mass.

Part 4.4

1. Graded from contusion or subcapsular haematoma through parenchymal laceration to shattered kidney or pedicle injury.
2. Extraperitoneal rupture confines contrast around the bladder; intraperitoneal rupture allows contrast to outline bowel loops.
3. A focal area of reduced signal on T2-weighted MRI within the peripheral zone.
4. A focal area of luminal narrowing, generally from prior infection, instrumentation, or trauma.
5. Markedly reduced or absent blood flow; it indicates a surgical emergency requiring urgent intervention.

Part 4.5

1. Image-guided placement of a drainage catheter directly into the renal collecting system to decompress an obstructed kidney.
2. Ureteral stenting places an internal drainage tube spanning the ureter; nephrolithotomy provides percutaneous access for stone removal.

3. It uses externally generated, focused shock waves to fragment urinary calculi for spontaneous passage.
4. Image-guided passage and inflation of a balloon catheter across a ureteric narrowing to mechanically dilate the stricture.
5. They provide precise, real-time or image-guided access for draining fluid collections and obtaining tissue samples for diagnosis.

References and Attributions [Series 4]

6. Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.
7. Dyer, R. B. (Ed.). (2018). Genitourinary Imaging: The Requisites (3rd ed.). Elsevier.
8. World Health Organization (2022). Schistosomiasis: Key Facts and Diagnostic Overview.
9. Wein, A. J., et al. (Eds.). (2020). Campbell-Walsh-Wein Urology (12th ed.), imaging chapters. Elsevier.

Figures, Plates, Tables, and Boxes

1. Table 4.1: Comparing key uro-genital imaging modalities. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Uro-Genital Imaging Modalities, listing modality, primary strength, and typical indication. Radiology reference table style with outside border, no photographic elements."
2. Figure 4.2: Diagram illustrating the dilated posterior urethra and trabeculated bladder characteristic of posterior urethral valves on micturating cysto-urethrography. AI-generated using the prompt: "A single clean, accurate schematic diagram of a contrast-filled bladder and urethra outline showing an abnormally dilated posterior urethral segment tapering sharply to a normal narrower anterior urethra, with an irregular, trabeculated bladder wall outline, radiology teaching diagram style, neutral background, no photographic realism, no other panels."
3. Table 4.3: Comparing key infective and neoplastic uro-genital imaging findings. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Infective and Neoplastic Uro-Genital Imaging Findings, listing condition, characteristic imaging finding, and preferred modality. Radiology reference table style with outside border, no photographic elements."
4. Figure 4.4: Diagram comparing extraperitoneal and intraperitoneal bladder rupture patterns of contrast extravasation on CT cystography. AI-generated using the prompt: "A single clean, accurate two-panel schematic pelvic cross-sectional diagram, one panel labelled extraperitoneal rupture showing contrast confined in a flame-shaped pattern

around the bladder, the other labelled intraperitoneal rupture showing contrast outlining bowel loops within the abdominal cavity, radiology teaching diagram style, neutral background, no photographic realism."

5. Table 4.5: Comparing key interventional uro-genital radiology procedures. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Interventional Uro-Genital Radiology Procedures, listing procedure, primary purpose, and typical indication. Radiology reference table style with outside border, no photographic elements."

Course code: RAD 601

Course title: Lectures in Radiology

Course credit load: 3 Units

Series 5: Radiology Subspecialties Overview

- **Part 5.1: Paediatric Radiology and Radiology in Obstetrics**
  - Sub Part 5.1.1: Scope and principles of paediatric radiology
  - Sub Part 5.1.2: Scope and principles of radiology in obstetrics
  - Sub Part 5.1.3: Imaging modality selection in paediatric and obstetric practice
- **Part 5.2: Gynaecology and Women's Imaging, and Cardiovascular Radiology**
  - Sub Part 5.2.1: Scope of gynaecology and women's imaging
  - Sub Part 5.2.2: Scope of cardiovascular radiology
  - Sub Part 5.2.3: Imaging modality selection in women's and cardiovascular imaging
- **Part 5.3: Abdominal Radiology and Interventional Radiology**
  - Sub Part 5.3.1: Scope of abdominal radiology
  - Sub Part 5.3.2: Scope of interventional radiology
  - Sub Part 5.3.3: The role of interventional radiology within abdominal practice
- **Part 5.4: Musculoskeletal Radiology**
  - Sub Part 5.4.1: Scope and principles of musculoskeletal radiology
  - Sub Part 5.4.2: Imaging modality selection in musculoskeletal practice
  - Sub Part 5.4.3: The multidisciplinary role of musculoskeletal radiology
- **Part 5.5: Neuro-Radiology and ENT Radiology**
  - Sub Part 5.5.1: Scope and principles of neuro-radiology
  - Sub Part 5.5.2: Scope and principles of ENT radiology
  - Sub Part 5.5.3: Imaging modality selection in neuro-radiology and ENT radiology

Introduction

In the last Series, we examined uro-genital radiology. We now conclude this course with a broad **overview of the remaining major radiology subspecialties**, paediatric radiology, obstetric radiology, gynaecology and women's imaging, cardiovascular radiology, abdominal radiology, interventional radiology, musculoskeletal radiology, and neuro-radiology and ENT radiology, each building upon the physical principles and modality-specific knowledge established throughout this course and applying them to a distinct area of clinical practice.

The aim of this Series is to equip you with a broad, foundational understanding of the scope, principles, and typical imaging modality selection relevant to paediatric radiology, radiology in obstetrics, gynaecology and women's imaging, cardiovascular radiology, abdominal radiology, interventional radiology, musculoskeletal radiology, and neuro-radiology and ENT radiology.

This Series begins with **paediatric radiology and radiology in obstetrics**, before turning to **gynaecology and women's imaging, and cardiovascular radiology**. We then examine **abdominal radiology and interventional radiology**, followed by **musculoskeletal radiology**, concluding with **neuro-radiology and ENT radiology**.

Series Learning Outcomes

At the end of this Series, you should be able to:

- **SLO 5.1:** describe the scope and principles of paediatric radiology
- **SLO 5.2:** describe the scope and principles of radiology in obstetrics, and imaging modality selection in both fields
- **SLO 5.3:** describe the scope of gynaecology and women's imaging
- **SLO 5.4:** describe the scope of cardiovascular radiology and imaging modality selection in both fields
- **SLO 5.5:** describe the scope of abdominal radiology
- **SLO 5.6:** describe the scope of interventional radiology and its role within abdominal practice
- **SLO 5.7:** describe the scope and principles of musculoskeletal radiology
- **SLO 5.8:** describe imaging modality selection and the multidisciplinary role of musculoskeletal radiology
- **SLO 5.9:** describe the scope and principles of neuro-radiology, and
- **SLO 5.10:** describe the scope and principles of ENT radiology and imaging modality selection in both fields.

5.1 Paediatric Radiology and Radiology in Obstetrics

5.1.1 scope and principles of paediatric radiology

Imaging a growing body with particular attention to radiation exposure

Paediatric radiology encompasses the imaging of infants, children, and adolescents, a population presenting genuinely distinct challenges compared with adult imaging, including a developing skeleton and organ systems, discussed in relation to normal anatomy in an earlier Series of this course, and a particular imperative to minimise cumulative radiation **exposure** given children's greater radiosensitivity and longer remaining lifespan.

The principle of **ALARA**, or as low as reasonably achievable, discussed in relation to X-ray generation and dose factors in an earlier Series of this course, applies with particular force in paediatric practice, favouring non-ionising modalities such as ultrasound, discussed in an earlier Series of this course, wherever diagnostically **adequate**.

Fill in the blank: The principle of ALARA, or as low as reasonably achievable, applies with particular force in paediatric practice, favouring non-ionising modalities such as ultrasound wherever diagnostically ________.

5.1.2 scope and principles of radiology in obstetrics

Radiology in obstetrics centres principally on **ultrasonography**, discussed in an earlier Series of this course, given its safety in pregnancy and established value in confirming pregnancy viability, assessing fetal growth and anatomy, and monitoring for recognised pregnancy **complications** throughout gestation.

Ionising imaging modalities are generally avoided in pregnancy wherever a suitable alternative exists, reflecting the particular radiosensitivity of the developing **fetus**, discussed in relation to paediatric radiation principles earlier in this Part, with MRI, discussed in an earlier Series of this course, offering a valuable non-ionising alternative where more detailed cross-sectional assessment is genuinely required.

Fill in the blank: Ionising imaging modalities are generally avoided in pregnancy wherever a suitable alternative exists, reflecting the particular radiosensitivity of the developing ________.

5.1.3 imaging modality selection in paediatric and obstetric practice

In both paediatric and obstetric practice, **ultrasonography** generally represents the preferred initial imaging modality given its combination of safety, real-time capability, and diagnostic versatility, discussed throughout this course, with radiography reserved for specific indications, such as suspected skeletal injury or foreign body.

Where cross-sectional imaging beyond ultrasound is genuinely required, **MRI** is generally favoured over CT in both populations given its avoidance of ionising radiation, discussed earlier in this Part, with CT reserved for situations of genuine clinical urgency where its speed and detail outweigh the radiation **consideration**.

Fill in the blank: Where cross-sectional imaging beyond ultrasound is genuinely required, MRI is generally favoured over CT in both paediatric and obstetric populations given its avoidance of ionising ________.

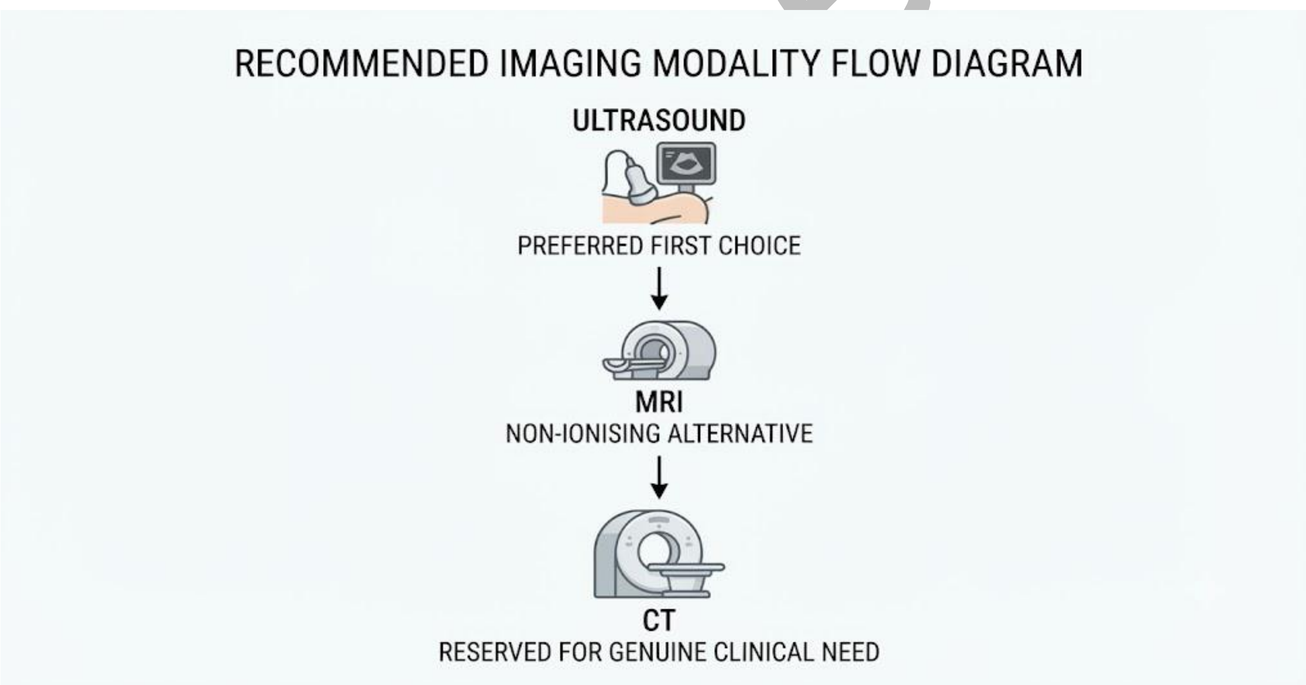


Figure 5.1: A schematic diagram illustrating the ALARA principle, showing ultrasound preferred over CT for paediatric and obstetric imaging where diagnostically adequate.

Pilot questions 5.1

- Explain why radiation exposure minimisation carries particular importance in paediatric radiology. (Linked to SLO 5.1)

- State the ALARA principle. (Linked to SLO 5.1)
- Explain why ultrasonography represents the principal imaging modality in obstetrics. (Linked to SLO 5.2)
- Explain why ionising imaging modalities are generally avoided in pregnancy where an alternative exists. (Linked to SLO 5.2)
- Describe the general hierarchy of imaging modality selection in paediatric and obstetric practice. (Linked to SLO 5.2)

5.2 Gynaecology and Women's Imaging, and Cardiovascular Radiology

5.2.1 scope of gynaecology and women's imaging

Imaging the female reproductive organs and breast

Gynaecology and women's imaging encompasses evaluation of the uterus, ovaries, and adnexal structures, generally using **ultrasonography**, discussed earlier in this Series, as the primary initial modality, together with dedicated **breast imaging**, using mammography and ultrasound, discussed in relation to mammography equipment in an earlier Series of this course.

This subspecialty additionally encompasses evaluation of infertility, including **hysterosalpingography**, discussed in the previous Series of this course, assessing tubal patency, and staging of gynaecological **malignancy**, generally combining ultrasound, CT, and MRI depending on the specific clinical question and tumour type involved.

Fill in the blank: Gynaecology and women's imaging additionally encompasses evaluation of infertility, including hysterosalpingography, assessing tubal ________.

5.2.2 scope of cardiovascular radiology

Cardiovascular radiology encompasses imaging of the heart and blood vessels, employing chest radiography, discussed in an earlier Series of this course, as an initial screening tool, together with more advanced techniques including **CT angiography**, discussed in relation to pulmonary embolism and aortic injury in an earlier Series of this course, and cardiac **MRI**, providing detailed functional and structural cardiac assessment.

This subspecialty additionally overlaps substantially with **interventional radiology**, discussed further later in this Series, given the frequent role of image-guided catheter-based techniques in both diagnosing and treating vascular disease, reflecting the close practical relationship between diagnostic and therapeutic cardiovascular **imaging**.

Fill in the blank: Cardiovascular radiology overlaps substantially with interventional radiology, given the frequent role of image-guided catheter-based techniques in both diagnosing and treating vascular ________.

5.2.3 imaging modality selection in women's and cardiovascular imaging

In women's imaging, **ultrasound** generally serves as the primary investigation for pelvic and breast symptoms, discussed earlier in this Part, with **mammography** specifically indicated for breast cancer screening and characterisation of suspicious breast findings, and MRI reserved for specific problem-solving indications requiring superior soft tissue **characterisation**.

In cardiovascular imaging, modality selection depends substantially on the specific clinical question, with **echocardiography**, a specialised ultrasound application, generally the first-line investigation for suspected structural heart disease, and **CT angiography** or **cardiac MRI** reserved for more detailed structural or functional assessment where echocardiography proves insufficient or **equivocal**.

Fill in the blank: In cardiovascular imaging, echocardiography, a specialised ultrasound application, is generally the first-line investigation for suspected structural heart ________.

Table 5.2: Comparing primary imaging modality by clinical question in women's and cardiovascular imaging.

Clinical question	Primary imaging modality	Reserved for detailed assessment
Pelvic or breast symptoms	Ultrasonography	MRI for problem-solving
Breast cancer screening	Mammography	MRI or biopsy for characterisation
Suspected structural heart disease	Echocardiography	CT angiography or cardiac MRI

Pilot questions 5.2

1. Describe the scope of gynaecology and women's imaging. (Linked to SLO 5.3)
2. Describe the role of hysterosalpingography within women's imaging. (Linked to SLO 5.3)
3. Describe the scope of cardiovascular radiology. (Linked to SLO 5.4)
4. Explain the relationship between cardiovascular radiology and interventional radiology. (Linked to SLO 5.4)

5. Describe the primary imaging modality generally used for suspected structural heart disease. (Linked to SLO 5.4)

5.3 Abdominal Radiology and Interventional Radiology

5.3.1 scope of abdominal radiology

Imaging the solid organs and gastrointestinal tract

Abdominal radiology encompasses imaging of the gastrointestinal tract and solid abdominal organs, including the liver, pancreas, and spleen, generally employing ultrasound as an initial modality, discussed earlier in this Series, with **CT** providing more detailed evaluation of suspected acute abdominal pathology or **malignancy**.

This subspecialty overlaps directly with uro-genital radiology, discussed in the previous Series of this course, given their shared anatomical region, and additionally encompasses evaluation of the **gastrointestinal tract** through both cross-sectional imaging and, where relevant, fluoroscopic contrast studies, discussed in relation to fluoroscopy in an earlier Series of this course.

Fill in the blank: Abdominal radiology overlaps directly with uro-genital radiology given their shared anatomical ________.

5.3.2 scope of interventional radiology

Interventional radiology, discussed in relation to its general classification in an earlier Series of this course, uses image guidance, whether ultrasound, fluoroscopy, or CT, to perform minimally invasive diagnostic and therapeutic procedures, encompassing the specific uro-genital interventional techniques discussed in the previous Series of this course, together with vascular and abdominal applications.

Interventional radiology procedures generally offer a genuine alternative to more invasive surgical management for appropriately selected patients, with reduced procedural morbidity and, frequently, shorter recovery time, reflecting the field's substantial and growing contribution to modern **therapeutic** medicine beyond its purely diagnostic origins.

Fill in the blank: Interventional radiology procedures generally offer a genuine alternative to more invasive surgical management, with reduced procedural morbidity and, frequently, shorter recovery ________.

5.3.3 the role of interventional radiology within abdominal practice

Within abdominal practice specifically, interventional radiology provides **image-guided biopsy** of suspicious abdominal masses, discussed in relation to CT/MRI-guided biopsy in the previous Series of this course, and **percutaneous drainage** of intra-abdominal abscesses or fluid collections, offering a minimally invasive alternative to open surgical drainage.

Further important applications include **transarterial embolisation**, used to control gastrointestinal or other abdominal haemorrhage, and biliary interventions, such as percutaneous transhepatic cholangiography and drainage, providing essential therapeutic options for patients with obstructive biliary **disease** unsuitable for immediate surgical management.

Fill in the blank: Transarterial embolisation is used to control gastrointestinal or other abdominal ________.

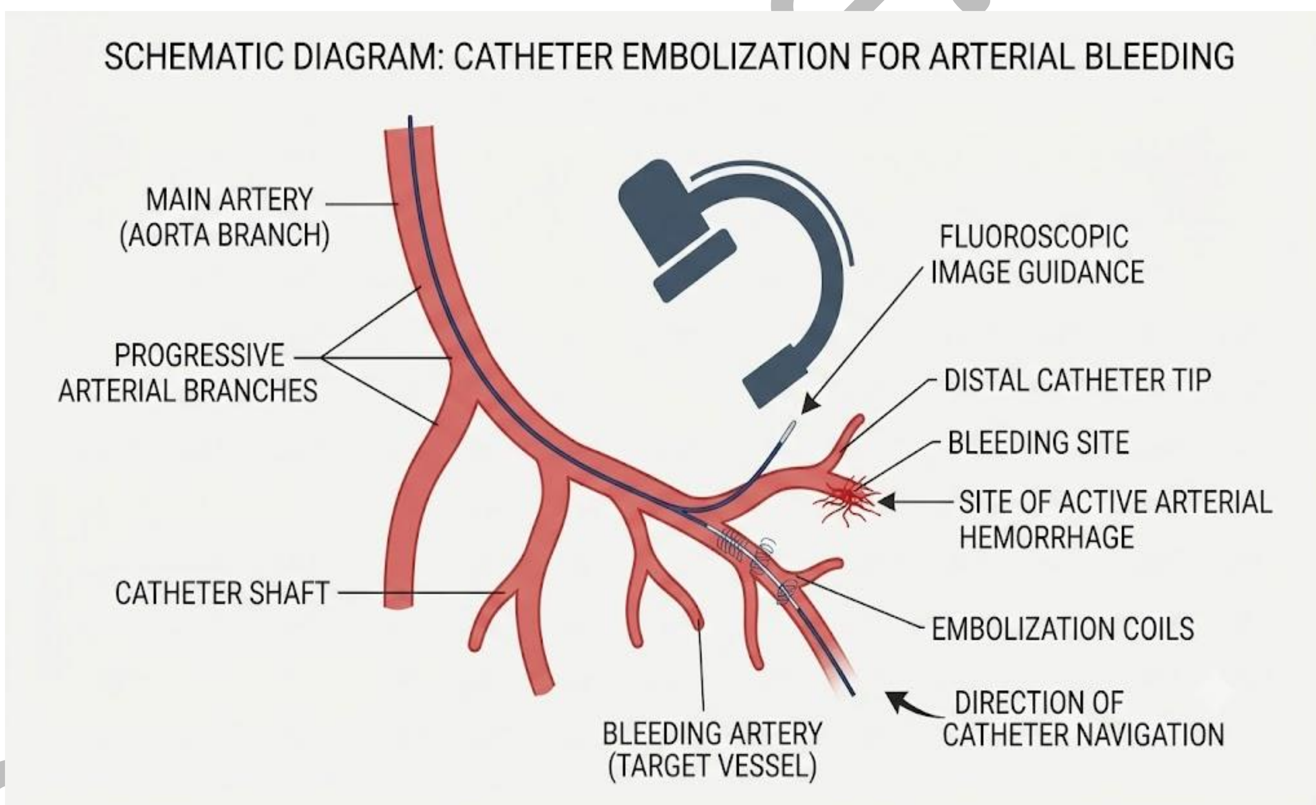


Figure 5.3: A schematic diagram illustrating a catheter-directed transarterial embolisation procedure controlling active abdominal bleeding under fluoroscopic guidance.

Pilot questions 5.3

1. Describe the scope of abdominal radiology. (Linked to SLO 5.5)

2. Explain the general principle underlying interventional radiology procedures. (Linked to SLO 5.6)
3. Describe the advantages interventional radiology procedures generally offer over open surgery. (Linked to SLO 5.6)
4. Describe the role of image-guided biopsy and percutaneous drainage within abdominal interventional practice. (Linked to SLO 5.6)
5. Describe the role of transarterial embolisation. (Linked to SLO 5.6)

5.4 Musculoskeletal Radiology

5.4.1 scope and principles of musculoskeletal radiology

Imaging bones, joints, and soft tissues of the locomotor system

Musculoskeletal radiology encompasses imaging of the bones, joints, and associated soft tissue structures, generally beginning with **plain radiography**, discussed in an earlier Series of this course, given its excellent depiction of bony detail, wide availability, and low cost, remaining the first-line investigation for most suspected fracture or joint **pathology**.

This subspecialty spans a genuinely broad range of clinical scenarios, from acute trauma, discussed in relation to chest trauma imaging principles in an earlier Series of this course, to chronic degenerative joint disease, and both primary and metastatic bone **tumours**, each requiring careful correlation between imaging findings and the specific clinical presentation.

Fill in the blank: Musculoskeletal radiology generally begins with plain radiography given its excellent depiction of bony detail, remaining the first-line investigation for most suspected fracture or joint ________.

5.4.2 imaging modality selection in musculoskeletal practice

Where plain radiography proves insufficient, **CT**, discussed in an earlier Series of this course, provides detailed evaluation of complex fracture patterns given its superior bony detail, while **MRI**, discussed in an earlier Series of this course, offers superior soft tissue contrast particularly valuable for evaluating ligaments, tendons, cartilage, and suspected soft tissue or bone marrow **pathology**.

Ultrasound, discussed earlier in this Series, additionally plays a valuable, increasingly utilised role in musculoskeletal practice, particularly for dynamic assessment of tendons and superficial soft tissue structures, and for guiding image-directed joint or soft tissue **injection** procedures.

Fill in the blank: Ultrasound plays a valuable role in musculoskeletal practice, particularly for dynamic assessment of tendons and guiding image-directed joint or soft tissue ________ procedures.

5.4.3 the multidisciplinary role of musculoskeletal radiology

Musculoskeletal radiology functions within a genuinely **multidisciplinary** clinical context, supporting orthopaedic surgery, rheumatology, and sports medicine practice, discussed throughout this course, with close communication between the radiologist and referring clinician essential to accurate interpretation of often subtle or clinically context-dependent imaging **findings**.

This multidisciplinary role additionally extends to image-guided musculoskeletal interventional procedures, discussed in relation to interventional radiology earlier in this Series, including joint aspiration and injection, and image-guided biopsy of suspected bone or soft tissue tumours, further integrating musculoskeletal radiology directly into ongoing patient **management**.

Fill in the blank: The multidisciplinary role of musculoskeletal radiology extends to image-guided interventional procedures, including joint aspiration and injection, and image-guided biopsy of suspected bone or soft tissue ________.

Table 5.4: Comparing musculoskeletal imaging modalities by primary strength.

Modality	Primary strength	Typical use
Plain radiography	Excellent bony detail, low cost	First-line fracture and joint assessment
CT	Superior detail for complex fractures	Complex or occult fracture characterisation
MRI	Superior soft tissue contrast	Ligament, tendon, cartilage, and marrow pathology

Pilot questions 5.4

1. Describe the scope of musculoskeletal radiology and its first-line imaging modality. (Linked to SLO 5.7)
2. Explain the respective advantages of CT and MRI in musculoskeletal imaging. (Linked to SLO 5.8)

3. Describe the role of ultrasound in musculoskeletal practice. (Linked to SLO 5.8)
4. Explain why musculoskeletal radiology is described as multidisciplinary. (Linked to SLO 5.8)
5. Describe two image-guided musculoskeletal interventional procedures. (Linked to SLO 5.8)

5.5 Neuro-Radiology and ENT Radiology

5.5.1 scope and principles of neuro-radiology

Imaging the brain, spine, and central nervous system

Neuro-radiology encompasses imaging of the brain, spinal cord, and associated structures, generally employing **CT** as the initial investigation in acute presentations, discussed in an earlier Series of this course, given its rapid acquisition and wide availability, particularly valuable in suspected acute stroke or head trauma.

MRI, discussed in an earlier Series of this course, provides superior soft tissue contrast for detailed evaluation of the brain and spinal cord parenchyma, discussed in relation to soft tissue contrast principles in an earlier Series of this course, representing the preferred modality for non-urgent or more detailed neurological imaging **assessment**.

Fill in the blank: MRI provides superior soft tissue contrast for detailed evaluation of the brain and spinal cord parenchyma, representing the preferred modality for non-urgent or more detailed neurological imaging ________.

5.5.2 scope and principles of ent radiology

ENT radiology, imaging the ear, nose, throat, and related head and neck structures, generally employs **CT** for detailed assessment of bony anatomy, particularly relevant to temporal bone and paranasal sinus evaluation, discussed in relation to bony detail earlier in this Series.

MRI plays a complementary role in ENT radiology, offering superior soft tissue characterisation particularly valuable for evaluating head and neck **malignancy**, discussed in relation to soft tissue tumour assessment in an earlier Series of this course, and for detailed assessment of the internal auditory canal and cerebellopontine angle.

Fill in the blank: MRI offers superior soft tissue characterisation particularly valuable for evaluating head and neck ________ in ENT radiology.

5.5.3 imaging modality selection in neuro-radiology and ent radiology

In both neuro-radiology and ENT radiology, modality selection reflects the same underlying principle established throughout this course, **CT** favoured where bony detail or acquisition speed is paramount, discussed throughout this Series, and **MRI** favoured where superior soft tissue characterisation is the primary diagnostic **requirement**.

This shared principle, balancing acquisition speed, bony versus soft tissue detail, and radiation considerations, discussed throughout this course, ultimately unifies imaging modality selection across every radiology subspecialty examined in this Series, reflecting the genuinely coherent physical and clinical foundation established from the very first Series of this **course**.

Fill in the blank: Imaging modality selection reflects a shared underlying principle across radiology subspecialties, balancing acquisition speed, bony versus soft tissue detail, and radiation ________.

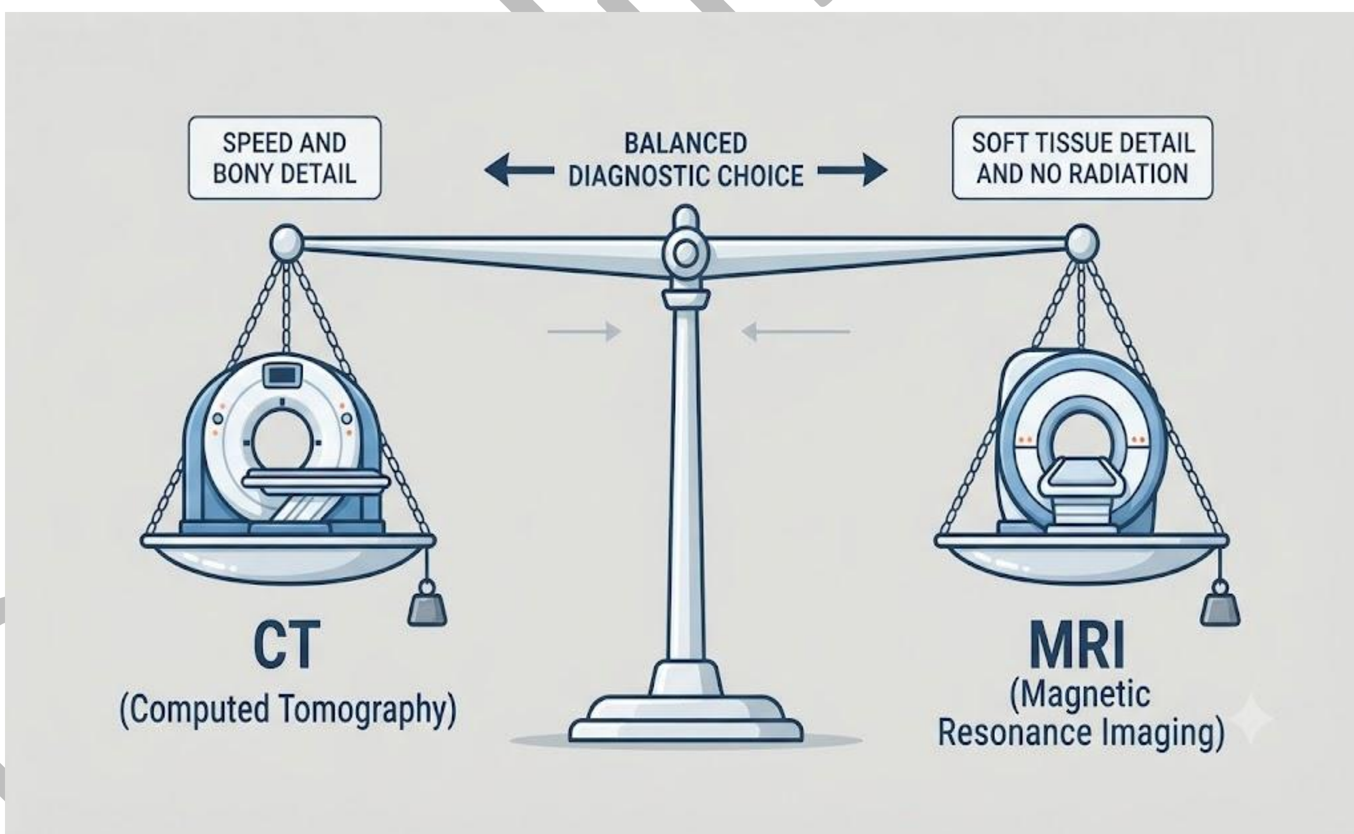


Figure 5.5: A schematic diagram summarising the shared modality selection principle across radiology subspecialties, balancing speed, bony versus soft tissue detail, and radiation dose.

Pilot questions 5.5

1. Describe the scope of neuro-radiology and its preferred modality for acute presentations. (Linked to SLO 5.9)
2. Explain why MRI is generally preferred for non-urgent, detailed neurological imaging assessment. (Linked to SLO 5.9)
3. Describe the scope of ENT radiology and the role of CT within it. (Linked to SLO 5.10)
4. Describe the role of MRI in ENT radiology. (Linked to SLO 5.10)
5. Summarise the shared underlying principle guiding imaging modality selection across radiology subspecialties. (Linked to SLO 5.10)

Series Summary

This final Series examined a broad **overview of the radiology subspecialties**, beginning with **paediatric radiology and radiology in obstetrics**, their shared emphasis on minimising radiation exposure and preference for ultrasonography, before turning to **gynaecology and women's imaging, and cardiovascular radiology**, and their respective imaging approaches.

We then examined **abdominal radiology and interventional radiology**, including the substantial therapeutic role of image-guided intervention, followed by **musculoskeletal radiology**, its scope, modality selection, and multidisciplinary role, concluding with **neuro-radiology and ENT radiology**, and the shared principle of modality selection unifying every radiology subspecialty examined throughout this course. Having worked through this Series, and indeed this entire course, you should now possess a comprehensive foundation in radiological science, from the physical principles underlying X-ray, fluoroscopy, contrast, CT, MRI, and ultrasound, through chest and uro-genital radiology, to a broad appreciation of every major radiology subspecialty addressed throughout RAD 601.

Glossary of Terms

6. **ALARA principle:** as low as reasonably achievable; the guiding principle minimising radiation exposure.
7. **Paediatric radiology:** the imaging of infants, children, and adolescents with particular attention to radiation exposure.

8. **Radiology in obstetrics:** imaging during pregnancy, centred principally on ultrasonography for safety.
9. **Women's imaging:** imaging of the female reproductive organs and breast, including mammography.
10. **Cardiovascular radiology:** imaging of the heart and blood vessels, encompassing diagnostic and interventional techniques.
11. **Abdominal radiology:** imaging of the gastrointestinal tract and solid abdominal organs.
12. **Interventional radiology:** the use of image guidance to perform minimally invasive diagnostic and therapeutic procedures.
13. **Transarterial embolisation:** an interventional technique controlling haemorrhage by occluding a bleeding vessel via catheter.
14. **Musculoskeletal radiology:** imaging of the bones, joints, and associated soft tissue structures.
15. **Neuro-radiology:** imaging of the brain, spinal cord, and associated central nervous system structures.
16. **ENT radiology:** imaging of the ear, nose, throat, and related head and neck structures.
17. **Echocardiography:** a specialised ultrasound application used for first-line structural heart disease assessment.

Concept Check Questions [Series 5]

Objective questions

- The principle of ALARA favours non-ionising modalities such as ultrasound wherever diagnostically ________.
- Ionising imaging modalities are generally avoided in pregnancy given the particular radiosensitivity of the developing ________.
- Interventional radiology procedures generally offer reduced procedural morbidity and, frequently, shorter recovery ________ compared with open surgery.
- Plain radiography remains the first-line investigation for most suspected fracture or joint ________.
- Imaging modality selection reflects a shared underlying principle across radiology subspecialties, balancing speed, bony versus soft tissue detail, and radiation ________.

Short-answer questions

1. Explain why ultrasonography represents the principal imaging modality in obstetrics.
2. Describe the role of hysterosalpingography within women's imaging.

3. Describe the advantages interventional radiology procedures generally offer over open surgery.
4. Explain the respective advantages of CT and MRI in musculoskeletal imaging.
5. Explain why MRI is generally preferred for non-urgent, detailed neurological imaging assessment.

Long-answer questions

6. Discuss the scope and principles of paediatric radiology and radiology in obstetrics, and imaging modality selection in both fields. (Linked to SLO 5.1, SLO 5.2)
7. Discuss the scope of gynaecology and women's imaging and cardiovascular radiology. (Linked to SLO 5.3, SLO 5.4)
8. Discuss the scope of abdominal radiology and interventional radiology, and the role of interventional radiology within abdominal practice. (Linked to SLO 5.5, SLO 5.6)
9. Discuss the scope, principles, modality selection, and multidisciplinary role of musculoskeletal radiology. (Linked to SLO 5.7, SLO 5.8)
10. Discuss the scope and principles of neuro-radiology and ENT radiology and imaging modality selection in both fields. (Linked to SLO 5.9, SLO 5.10)

Answers to Concept Check Questions [Series 5]

Objective questions

11. Adequate.
12. Fetus.
13. Time.
14. Pathology.
15. Dose.

Short-answer questions

16. Because it is safe in pregnancy and provides established value in assessing viability, growth, and anatomy.
17. It assesses tubal patency as part of infertility evaluation.
18. Reduced procedural morbidity and, frequently, shorter recovery time.
19. CT offers superior detail for complex fracture characterisation; MRI offers superior soft tissue contrast for ligaments, tendons, cartilage, and marrow.
20. Because it offers superior soft tissue contrast without ionising radiation, suited to detailed, non-urgent assessment.

Long-answer questions

21. **Basic response:** Paediatric and obstetric radiology share a particular emphasis on minimising radiation exposure, generally favouring ultrasonography as the initial modality given its safety and versatility.

Value-added response: Where cross-sectional imaging is required, MRI is generally favoured over CT in both populations, reserving CT for genuine clinical urgency.

22. **Basic response:** Gynaecology and women's imaging encompasses pelvic and breast imaging, using ultrasound, mammography, and MRI depending on the clinical question.

Value-added response: Cardiovascular radiology encompasses cardiac and vascular imaging, closely overlapping with interventional radiology given the frequent role of catheter-based techniques.

23. **Basic response:** Abdominal radiology encompasses the gastrointestinal tract and solid organs, employing ultrasound and CT as primary modalities.

Value-added response: Interventional radiology provides a substantial therapeutic role within abdominal practice, including biopsy, drainage, and embolisation, offering minimally invasive alternatives to surgery.

24. **Basic response:** Musculoskeletal radiology begins with plain radiography, with CT and MRI reserved for complex fracture or soft tissue characterisation respectively.

Value-added response: Its multidisciplinary role extends to supporting orthopaedic and rheumatology practice and enabling image-guided interventional procedures.

25. **Basic response:** Neuro-radiology favours CT for acute presentations and MRI for detailed, non-urgent assessment, while ENT radiology similarly uses CT for bony detail and MRI for soft tissue characterisation.

Value-added response: This shared principle of balancing speed, bony versus soft tissue detail, and radiation dose unifies imaging modality selection across every radiology subspecialty.

Answers to Pilot Questions [Series 5]

Part 5.1

1. Because children have greater radiosensitivity and a longer remaining lifespan over which harm could manifest.
2. As low as reasonably achievable, minimising radiation exposure wherever possible.
3. Because it is safe in pregnancy and provides established value in assessing viability, growth, and anatomy.
4. Because of the particular radiosensitivity of the developing fetus.
5. Ultrasound is generally preferred first, with MRI favoured over CT for further cross-sectional imaging where genuinely needed.

Part 5.2

6. Evaluation of the uterus, ovaries, adnexal structures, and breast, using ultrasound, mammography, and other modalities.
7. It assesses tubal patency as part of infertility evaluation.
8. Imaging of the heart and blood vessels, using radiography, CT angiography, and cardiac MRI.
9. They overlap substantially, given the frequent role of catheter-based image-guided techniques in both diagnosing and treating vascular disease.
10. Echocardiography, a specialised ultrasound application.

Part 5.3

11. Imaging of the gastrointestinal tract and solid abdominal organs, including the liver, pancreas, and spleen.
12. Using image guidance, whether ultrasound, fluoroscopy, or CT, to perform minimally invasive diagnostic and therapeutic procedures.
13. Reduced procedural morbidity and, frequently, shorter recovery time compared with open surgery.
14. They provide minimally invasive alternatives to open surgical biopsy or drainage of abdominal masses or fluid collections.
15. It controls gastrointestinal or other abdominal haemorrhage by occluding the bleeding vessel via catheter.

Part 5.4

1. Imaging of bones, joints, and soft tissues; plain radiography is the first-line modality.
2. CT provides superior detail for complex fractures; MRI provides superior soft tissue contrast for ligaments, tendons, cartilage, and marrow.

3. It provides dynamic assessment of tendons and superficial structures and guides image-directed injection procedures.
4. Because it closely supports orthopaedic surgery, rheumatology, and sports medicine practice through close clinical communication.
5. Joint aspiration and injection, and image-guided biopsy of suspected bone or soft tissue tumours.

Part 5.5

1. Imaging of the brain, spinal cord, and associated structures; CT is preferred for acute presentations such as stroke or trauma.
2. Because it offers superior soft tissue contrast without ionising radiation, suited to detailed, non-urgent assessment.
3. Imaging of the ear, nose, throat, and head and neck structures; CT is used for detailed bony anatomy assessment.
4. It offers superior soft tissue characterisation for head and neck malignancy and internal auditory canal assessment.
5. CT is favoured where bony detail or acquisition speed is paramount, while MRI is favoured where soft tissue characterisation is the primary requirement.

References and Attributions [Series 5]

6. Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.
7. Donnelly, L. F. (2017). Fundamentals of Pediatric Radiology (2nd ed.). Elsevier.
8. Kirkpatrick, I. D. C., & Rajiah, P. (Eds.). (2021). Diagnostic Imaging: Cardiovascular (3rd ed.). Elsevier.
9. Manaster, B. J., et al. (2013). Musculoskeletal Imaging: The Requisites (4th ed.). Elsevier.

Figures, Plates, Tables, and Boxes

1. Figure 5.1: A schematic diagram illustrating the ALARA principle, showing ultrasound preferred over CT for paediatric and obstetric imaging where diagnostically adequate. AI-generated using the prompt: "A single clean, accurate schematic flow diagram with an

ultrasound icon at the top labelled preferred first choice, an MRI icon in the middle labelled non-ionising alternative, and a CT icon at the bottom labelled reserved for genuine clinical need, connected by simple downward arrows, textbook educational diagram style, neutral background, no photographic realism, no other panels."

2. Table 5.2: Comparing primary imaging modality by clinical question in women's and cardiovascular imaging. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Primary Imaging Modality by Clinical Question, listing clinical question, primary imaging modality, and reserved for detailed assessment. Radiology reference table style with outside border, no photographic elements."
3. Figure 5.3: A schematic diagram illustrating a catheter-directed transarterial embolisation procedure controlling active abdominal bleeding under fluoroscopic guidance. AI-generated using the prompt: "A single clean, accurate schematic diagram showing a thin catheter threaded through a simplified arterial tree diagram toward a labelled bleeding site, with a small fluoroscopy unit icon indicating image guidance, textbook interventional radiology diagram style, neutral background, no photographic realism, no other panels."
4. Table 5.4: Comparing musculoskeletal imaging modalities by primary strength. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Musculoskeletal Imaging Modalities by Primary Strength, listing modality, primary strength, and typical use. Radiology reference table style with outside border, no photographic elements."
5. Figure 5.5: A schematic diagram summarising the shared modality selection principle across radiology subspecialties, balancing speed, bony versus soft tissue detail, and radiation dose. AI-generated using the prompt: "A single clean, accurate schematic balance-scale style diagram with a CT icon on one side labelled speed and bony detail, and an MRI icon on the other side labelled soft tissue detail and no radiation, textbook educational diagram style, neutral background, no photographic realism, no other panels."