La-Net

RAD 603

RADIOLOGY PROCEDURES AND RESULTS INTERPRETATION

Course code: RAD 603

Course title: Radiology Procedures and Results Interpretation

Course credit load: 2 Units

Series 1: Contrast Studies: Technique and Indications

- **Part 1.1: Barium Swallow, Meal, and Follow-Through**
  - Sub Part 1.1.1: Technique of barium swallow
  - Sub Part 1.1.2: Technique of barium meal and follow-through
  - Sub Part 1.1.3: Indications for barium swallow, meal, and follow-through
- **Part 1.2: Barium Enema**
  - Sub Part 1.2.1: Technique of barium enema
  - Sub Part 1.2.2: Single-contrast versus double-contrast barium enema
  - Sub Part 1.2.3: Indications for barium enema
- **Part 1.3: Intravenous Urography and Hysterosalpingography**
  - Sub Part 1.3.1: Technique of intravenous urography (IVU)
  - Sub Part 1.3.2: Technique of hysterosalpingography (HSG)
  - Sub Part 1.3.3: Indications for IVU and HSG
- **Part 1.4: Micturating Cysto-Urethrography and Retrograde Urethrography**
  - Sub Part 1.4.1: Technique of micturating cysto-urethrography (MCUG)
  - Sub Part 1.4.2: Technique of retrograde urethrography (RUG)
  - Sub Part 1.4.3: Indications for MCUG and RUG

Introduction

Fluoroscopic contrast studies remain a genuinely essential practical skill in everyday radiologic practice, providing dynamic, functional information about the gastrointestinal, urinary, and genital tracts that cross-sectional imaging alone cannot always fully replicate. This opening Series establishes the practical technique and clinical indications for the core barium and contrast studies performed in radiologic practice, from barium swallow through to retrograde urethrography.

The aim of this Series is to equip you with a thorough, practical understanding of the technique and indications for barium swallow, meal and follow-through, barium enema, intravenous urography, hysterosalpingography, micturating cysto-urethrography, and retrograde urethrography.

This Series begins with **barium swallow, meal, and follow-through**, before turning to **barium enema**. We then examine **intravenous urography and hysterosalpingography**, concluding with **micturating cysto-urethrography and retrograde urethrography**.

Series Learning Outcomes

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

- **SLO 1.1:** demonstrate the technique of barium swallow, and barium meal and follow-through
- **SLO 1.2:** list the indications for barium swallow, meal, and follow-through
- **SLO 1.3:** demonstrate the technique of barium enema and distinguish single-contrast from double-contrast technique
- **SLO 1.4:** list the indications for barium enema
- **SLO 1.5:** demonstrate the technique of intravenous urography (IVU)
- **SLO 1.6:** demonstrate the technique of hysterosalpingography (HSG) and list the indications for IVU and HSG
- **SLO 1.7:** demonstrate the technique of micturating cysto-urethrography (MCUG) and retrograde urethrography (RUG), and
- **SLO 1.8:** list the indications for MCUG and RUG.

1.1 Barium Swallow, Meal, and Follow-Through

1.1.1 technique of barium swallow

A dynamic fluoroscopic assessment of swallowing and the oesophagus

A **barium swallow** requires the patient to swallow barium sulphate suspension while under continuous **fluoroscopic** observation, discussed in relation to fluoroscopy principles in an earlier related course, with spot radiographic images obtained in multiple projections to assess the pharynx and oesophagus during active swallowing.

The examination typically assesses the **oral** and **pharyngeal phases** of swallowing, particularly relevant to suspected aspiration risk, and the **oesophageal phase**, evaluating peristaltic motility and luminal calibre throughout the length of the oesophagus, with the patient generally imaged in both erect and prone or recumbent **positions**.

Fill in the blank: A barium swallow requires the patient to swallow barium sulphate suspension while under continuous fluoroscopic ________.

1.1.2 technique of barium meal and follow-through

A **barium meal** extends the barium swallow examination to include detailed assessment of the **stomach** and **duodenum**, discussed further in relation to peptic ulcer disease in the next Series of this course, generally using a combination of barium suspension and, in the double-contrast technique, an effervescent agent producing gaseous distension to improve mucosal detail.

A **barium follow-through** extends the examination further, obtaining sequential radiographs at timed intervals as barium progresses through the **small bowel**, assessing small bowel calibre, mucosal pattern, and transit time, with the patient generally repositioned and compression applied to separate overlapping bowel loops for optimal **visualisation**.

Fill in the blank: A barium follow-through obtains sequential radiographs at timed intervals as barium progresses through the ________.

1.1.3 indications for barium swallow, meal, and follow-through

Barium swallow is generally indicated for suspected dysphagia, discussed in relation to swallowing dysfunction in an earlier related course, or suspected oesophageal structural abnormality, such as stricture or motility disorder, providing valuable dynamic functional information complementary to endoscopic assessment.

Barium meal and follow-through is generally indicated for suspected peptic ulcer disease, discussed further in the next Series of this course, gastric outlet obstruction, or small bowel pathology, including suspected small bowel obstruction or inflammatory bowel disease, particularly where cross-sectional imaging is unavailable or insufficiently **conclusive**.

Fill in the blank: Barium meal and follow-through is generally indicated for suspected peptic ulcer disease, gastric outlet obstruction, or ________ bowel pathology.

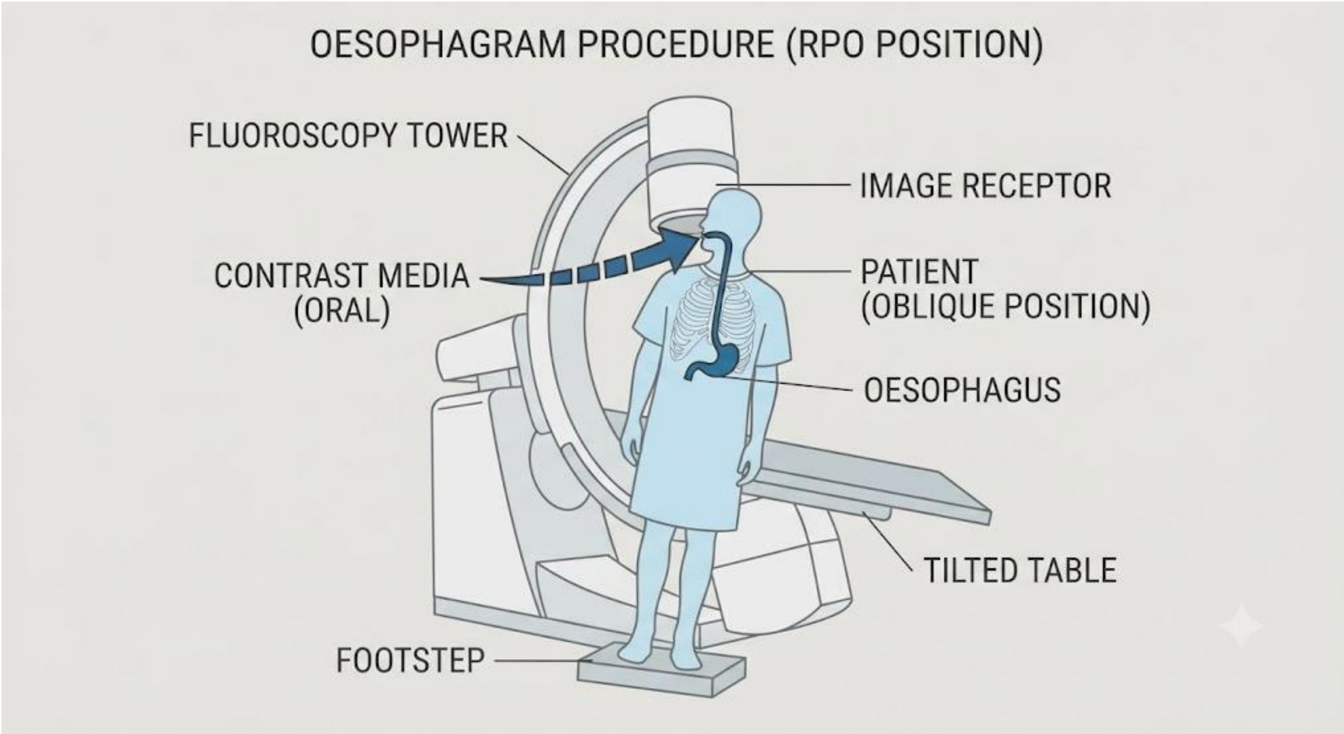

Figure 1.1: Diagram illustrating fluoroscopic barium swallow technique showing the patient swallowing contrast while imaged in the erect oblique position.

Pilot questions 1.1

1. Describe the basic technique of a barium swallow examination. (Linked to SLO 1.1)
2. Describe the additional structures assessed in a barium meal compared with a barium swallow. (Linked to SLO 1.1)
3. Describe the technique of a barium follow-through examination. (Linked to SLO 1.1)
4. List two indications for barium swallow. (Linked to SLO 1.2)
5. List two indications for barium meal and follow-through. (Linked to SLO 1.2)

1.2 Barium Enema

1.2.1 technique of barium enema

Retrograde contrast instillation to assess the colon

A **barium enema** involves retrograde instillation of barium suspension through a rectal catheter, discussed in relation to fluoroscopic technique earlier in this Series, under continuous fluoroscopic monitoring, with the patient repositioned through multiple oblique and lateral projections to demonstrate the entire colon free of overlapping bowel loops.

Adequate bowel **preparation**, generally involving dietary restriction and laxative administration in the days preceding the examination, is essential to remove residual faecal material that could otherwise obscure or mimic pathology, meaning careful patient instruction beforehand directly influences the diagnostic quality of the resulting **examination**.

Fill in the blank: A barium enema involves retrograde instillation of barium suspension through a rectal catheter under continuous fluoroscopic ________.

1.2.2 single-contrast versus double-contrast barium enema

Single-contrast barium enema uses barium suspension alone to opacify the colonic lumen, providing a relatively straightforward technique well suited to assessing gross structural abnormality, such as obstruction, but offering more limited mucosal **detail**.

Double-contrast barium enema additionally introduces air or carbon dioxide following barium instillation, coating the colonic mucosa with a thin barium layer against a background of gaseous distension, considerably improving detection of subtle mucosal lesions such as **polyps**, discussed further in relation to colonic tumours in a later Series of this course.

Fill in the blank: Double-contrast barium enema additionally introduces air or carbon dioxide following barium instillation, considerably improving detection of subtle mucosal lesions such as ________.

1.2.3 indications for barium enema

Barium enema is generally indicated for suspected colonic structural abnormality, including **diverticular disease**, colonic stricture, or suspected colorectal tumour, discussed further in a later Series of this course, particularly where colonoscopy is unavailable, incomplete, or clinically contraindicated.

Further indications include evaluation of suspected inflammatory bowel disease affecting the colon, and, in **paediatric** practice, assessment of suspected intussusception, where a therapeutic reduction may additionally be attempted under the same fluoroscopic contrast **procedure**.

Fill in the blank: In paediatric practice, barium enema may be used for assessment of suspected intussusception, where a therapeutic reduction may additionally be attempted under the same fluoroscopic contrast ________.

Table 1.2: Comparing single-contrast and double-contrast barium enema.

Feature	Single-contrast barium enema	Double-contrast barium enema
Contrast used	Barium suspension alone	Barium plus air or carbon dioxide
Mucosal detail	Limited	Considerably improved
Best suited for	Gross structural abnormality	Subtle mucosal lesions such as polyps

Pilot questions 1.2

1. Describe the basic technique of a barium enema examination. (Linked to SLO 1.3)
2. Explain why adequate bowel preparation is essential before barium enema. (Linked to SLO 1.3)
3. Distinguish single-contrast from double-contrast barium enema technique. (Linked to SLO 1.3)
4. Explain why double-contrast technique is preferred for detecting subtle mucosal lesions. (Linked to SLO 1.3)
5. List two indications for barium enema. (Linked to SLO 1.4)

1.3 Intravenous Urography and Hysterosalpingography

1.3.1 technique of intravenous urography (ivu)

Sequential radiographs following intravenous contrast excretion

Intravenous urography, discussed in relation to urinary tract imaging in an earlier related course, involves intravenous administration of iodinated contrast medium, discussed in relation to contrast principles in an earlier related course, followed by a series of timed radiographs as the contrast is excreted by the kidneys and progressively opacifies the collecting system, ureters, and bladder.

A preliminary **control radiograph** is generally obtained before contrast administration to identify any radiopaque calculi or other abnormality that could be obscured once contrast is present, with subsequent films obtained at defined time intervals, generally including an immediate **nephrogram** phase and later, delayed films demonstrating the ureters and bladder.

Fill in the blank: A preliminary control radiograph is generally obtained before contrast administration to identify any radiopaque calculi or other abnormality that could be obscured once contrast is ________.

1.3.2 technique of hysterosalpingography (hsg)

Hysterosalpingography, discussed in relation to women's imaging in an earlier related course, involves instillation of iodinated contrast medium through the cervix into the uterine cavity via a specifically designed **cannula**, discussed further in relation to interventional instruments in a later Series of this course, under continuous fluoroscopic observation.

Contrast is observed filling the **uterine cavity** and then passing through the fallopian tubes, with free spillage into the peritoneal cavity confirming **tubal patency**, the primary functional information this examination is specifically designed to provide, generally performed at a specific point in the menstrual cycle to avoid inadvertent imaging during **pregnancy**.

Fill in the blank: Hysterosalpingography confirms tubal patency by demonstrating free spillage of contrast into the ________ cavity.

1.3.3 indications for ivu and hsg

IVU is generally indicated for suspected urinary tract calculi, discussed in an earlier related course, congenital urinary tract anomaly, or evaluation of suspected obstruction, though it has been substantially superseded by CT urography, discussed in an earlier related course, for detailed evaluation in many contemporary practice settings.

HSG is generally indicated as part of infertility investigation, specifically to assess tubal patency and uterine cavity contour, discussed earlier in this Part, and to evaluate suspected uterine structural abnormality, such as a septate uterus, providing essential functional information relevant to fertility **management**.

Fill in the blank: HSG is generally indicated as part of infertility investigation, specifically to assess tubal patency and uterine cavity ________.

Table 1.3: Comparing IVU and HSG.

Feature	Intravenous urography (IVU)	Hysterosalpingography (HSG)
Contrast route	Intravenous administration	Instillation via cervical cannula
Primary structures assessed	Kidneys, ureters, and bladder	Uterine cavity and fallopian tubes

Key functional information	Renal excretion and collecting system anatomy	Tubal patency

Pilot questions 1.3

1. Describe the basic technique of intravenous urography. (Linked to SLO 1.5)
2. Explain the purpose of the preliminary control radiograph in IVU. (Linked to SLO 1.5)
3. Describe the basic technique of hysterosalpingography. (Linked to SLO 1.6)
4. Explain how tubal patency is confirmed on HSG. (Linked to SLO 1.6)
5. List the indications for IVU and for HSG. (Linked to SLO 1.6)

1.4 Micturating Cysto-Urethrography and Retrograde Urethrography

1.4.1 technique of micturating cysto-urethrography (mcug)

Dynamic imaging of the bladder and urethra during voiding

Micturating cysto-urethrography, discussed in relation to posterior urethral valves in an earlier related course, involves instilling iodinated contrast into the bladder via a urethral catheter, with fluoroscopic imaging obtained both while the bladder is filling and, critically, during active **voiding**, once the catheter has been removed.

Imaging during the voiding phase specifically allows assessment of the **urethra** and detection of **vesicoureteric reflux**, contrast passing retrogradely from the bladder up one or both ureters, information that cannot be reliably obtained from the filling phase alone, meaning the voiding phase represents the diagnostically essential component of this **examination**.

Fill in the blank: Micturating cysto-urethrography allows assessment of vesicoureteric reflux, contrast passing retrogradely from the bladder up one or both ________.

1.4.2 technique of retrograde urethrography (rug)

Retrograde urethrography, discussed in relation to urethral stricture in an earlier related course, involves gentle instillation of contrast directly into the distal urethra via a small catheter or specialised urethral clamp, with the contrast column observed under fluoroscopy as it passes retrogradely along the length of the urethra.

This technique specifically allows detailed assessment of urethral **calibre** and identification of any stricture, its precise length and location, discussed in relation to urethral pathology in an earlier related course, without requiring the patient to void, in contrast to the specifically voiding-dependent technique of MCUG discussed in the previous sub-Part.

Fill in the blank: Retrograde urethrography allows detailed assessment of urethral calibre without requiring the patient to void, in contrast to the specifically voiding-dependent technique of ________.

1.4.3 indications for mcug and rug

MCUG is generally indicated in children with recurrent urinary tract infection to assess for vesicoureteric reflux, discussed earlier in this Part, and in suspected posterior urethral valves, discussed in an earlier related course, where dynamic voiding-phase imaging is specifically required for diagnosis.

RUG is generally indicated for suspected male urethral stricture, discussed earlier in this Part, particularly following prior instrumentation, infection, or trauma, and, in the acute trauma setting, to assess urethral **integrity** before attempting urethral catheterisation, given the risk of worsening injury if a urethral disruption is present but unrecognised.

Fill in the blank: RUG is used in the acute trauma setting to assess urethral integrity before attempting urethral ________, given the risk of worsening an unrecognised disruption.

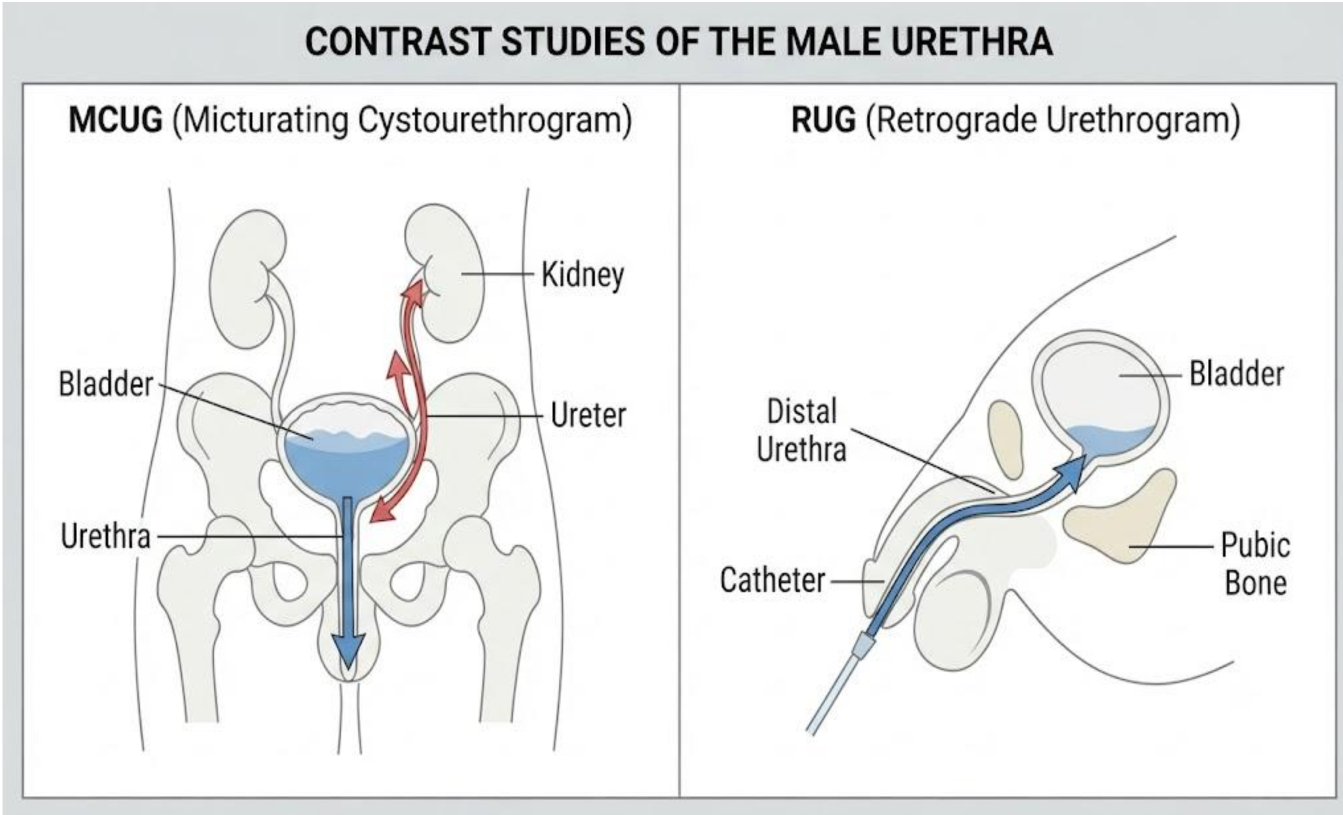

Figure 1.4: Diagram comparing micturating cysto-urethrography during the voiding phase with retrograde urethrography technique.

Pilot questions 1.4

1. Describe the basic technique of micturating cysto-urethrography. (Linked to SLO 1.7)
2. Explain why the voiding phase is the diagnostically essential component of MCUG. (Linked to SLO 1.7)
3. Describe the basic technique of retrograde urethrography. (Linked to SLO 1.7)
4. List two indications for MCUG. (Linked to SLO 1.8)
5. Explain why RUG may be performed before attempting urethral catheterisation in trauma. (Linked to SLO 1.8)

Series Summary

This opening Series established the practical technique and indications of the core fluoroscopic contrast studies used in radiologic practice, beginning with **barium swallow, meal, and follow-**

through, before turning to **barium enema**, including the distinction between single-contrast and double-contrast technique.

We then examined **intravenous urography and hysterosalpingography**, concluding with **micturating cysto-urethrography and retrograde urethrography**. Having worked through this Series, you should now possess the essential practical foundation needed to understand peptic ulcer disease and gastric pathology on contrast studies examined in the next Series of this course.

Glossary of Terms

- **Barium swallow:** a fluoroscopic contrast examination of swallowing and the oesophagus.
- **Barium follow-through:** sequential radiographs tracking barium contrast through the small bowel.
- **Double-contrast barium enema:** a barium enema technique adding gas distension for improved mucosal detail.
- **Bowel preparation:** dietary and laxative measures clearing the colon before a barium enema.
- **Intravenous urography (IVU):** sequential radiographs following intravenous contrast excretion by the kidneys.
- **Nephrogram phase:** the early IVU film phase showing contrast within the renal parenchyma.
- **Hysterosalpingography (HSG):** contrast imaging of the uterine cavity and fallopian tubes to assess patency.
- **Tubal patency:** the state of the fallopian tubes being open and unobstructed, assessed by HSG.
- **Micturating cysto-urethrography (MCUG):** contrast imaging of the bladder and urethra performed during voiding.
- **Vesicoureteric reflux:** retrograde passage of urine or contrast from the bladder up the ureter.
- **Retrograde urethrography (RUG):** direct contrast imaging of the urethra without requiring voiding.
- **Urethral stricture:** a focal narrowing of the urethra, assessable by retrograde urethrography.

Concept Check Questions [Series 1]

Objective questions

1. A barium swallow requires the patient to swallow barium sulphate suspension while under continuous fluoroscopic ________.
2. Double-contrast barium enema considerably improves detection of subtle mucosal lesions such as ________.
3. A preliminary control radiograph is obtained before IVU contrast administration to identify calculi that could be obscured once contrast is ________.
4. Micturating cysto-urethrography allows assessment of vesicoureteric reflux, contrast passing retrogradely from the bladder up one or both ________.
5. Retrograde urethrography allows assessment of urethral calibre without requiring the patient to ________.

Short-answer questions

6. Describe the technique of a barium follow-through examination.
7. Distinguish single-contrast from double-contrast barium enema technique.
8. Explain how tubal patency is confirmed on HSG.
9. Explain why the voiding phase is the diagnostically essential component of MCUG.
10. Explain why RUG may be performed before attempting urethral catheterisation in trauma.

Long-answer questions

11. Discuss the technique and indications of barium swallow, and barium meal and follow-through. (Linked to SLO 1.1, SLO 1.2)
12. Discuss the technique, single-contrast versus double-contrast technique, and indications of barium enema. (Linked to SLO 1.3, SLO 1.4)
13. Discuss the technique and indications of intravenous urography and hysterosalpingography. (Linked to SLO 1.5, SLO 1.6)
14. Discuss the technique of micturating cysto-urethrography and retrograde urethrography. (Linked to SLO 1.7)
15. Discuss the indications for MCUG and RUG. (Linked to SLO 1.8)

Answers to Concept Check Questions [Series 1]

Objective questions

1. Observation.
2. Polyps.
3. Present.
4. Ureters.
5. Void.

Short-answer questions

6. Sequential radiographs at timed intervals as barium progresses through the small bowel, with repositioning and compression to separate bowel loops.
7. Single-contrast uses barium alone, suited to gross abnormality; double-contrast adds gas distension, improving mucosal detail for subtle lesions.
8. By demonstrating free spillage of contrast into the peritoneal cavity through the fallopian tubes.
9. Because urethral assessment and reflux detection can only be reliably obtained while the patient is actively voiding.
10. Because attempting catheterisation with an unrecognised urethral disruption risks worsening the injury.

Long-answer questions

11. **Basic response:** Barium swallow assesses swallowing and the oesophagus under fluoroscopy, while barium meal and follow-through extend assessment to the stomach, duodenum, and small bowel.

Value-added response: Indications include suspected dysphagia or oesophageal disorder for swallow, and peptic ulcer disease, gastric outlet obstruction, or small bowel pathology for meal and follow-through.

12. **Basic response:** Barium enema involves retrograde contrast instillation with careful bowel preparation, available as single-contrast or double-contrast technique depending on diagnostic need.

Value-added response: Indications include suspected colonic structural abnormality, diverticular disease, colorectal tumour, and, in children, intussusception with potential therapeutic reduction.

13. **Basic response:** IVU uses intravenous contrast with timed radiographs to assess the urinary collecting system, while HSG uses cervical instillation to assess the uterine cavity and tubal patency.

Value-added response: IVU is indicated for calculi, congenital anomaly, or obstruction, while HSG is indicated for infertility investigation and suspected uterine structural abnormality.

14. **Basic response:** MCUG involves bladder filling followed by voiding-phase imaging to assess the urethra and detect reflux, while RUG involves direct urethral contrast instillation without requiring voiding.

Value-added response: These complementary techniques together provide comprehensive assessment of the lower urinary tract depending on the specific clinical question.

15. **Basic response:** MCUG is indicated for recurrent urinary tract infection and suspected posterior urethral valves in children, requiring the voiding phase for diagnosis.

Value-added response: RUG is indicated for suspected urethral stricture and, in trauma, to confirm urethral integrity before catheterisation is attempted.

Answers to Pilot Questions [Series 1]

Part 1.1

1. The patient swallows barium suspension under continuous fluoroscopic observation, with spot images obtained in multiple projections.
2. A barium meal additionally assesses the stomach and duodenum, beyond the pharynx and oesophagus.
3. Sequential radiographs at timed intervals track barium through the small bowel, with repositioning and compression to separate loops.
4. Suspected dysphagia and suspected oesophageal structural abnormality or motility disorder.
5. Suspected peptic ulcer disease and suspected small bowel obstruction or inflammatory bowel disease.

Part 1.2

1. Retrograde instillation of barium via a rectal catheter under continuous fluoroscopic monitoring with multiple projections.
2. Because residual faecal material could obscure or mimic pathology, reducing diagnostic quality.
3. Single-contrast uses barium alone; double-contrast adds air or carbon dioxide for improved mucosal detail.
4. Because the thin barium coating against gas distension considerably improves visualisation of subtle mucosal abnormality.
5. Suspected diverticular disease and suspected colorectal tumour.

Part 1.3

1. Intravenous contrast is administered, followed by timed radiographs as it is excreted and opacifies the collecting system, ureters, and bladder.
2. It identifies radiopaque calculi or other abnormality that could be obscured once contrast is present.
3. Contrast is instilled through the cervix into the uterine cavity via a cannula under fluoroscopic observation.
4. By demonstrating free spillage of contrast into the peritoneal cavity through the fallopian tubes.
5. IVU is indicated for suspected calculi, congenital anomaly, or obstruction; HSG is indicated for infertility investigation and uterine abnormality.

Part 1.4

1. Contrast is instilled via a urethral catheter, with imaging during filling and, critically, during active voiding once the catheter is removed.
2. Because urethral assessment and reflux detection can only be reliably demonstrated while the patient is actively voiding.
3. Contrast is gently instilled directly into the distal urethra via a small catheter or clamp and observed under fluoroscopy as it passes retrogradely.
4. Recurrent urinary tract infection and suspected posterior urethral valves in children.
5. Because attempting catheterisation with an unrecognised urethral disruption risks worsening the injury.

References and Attributions [Series 1]

- Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.

- Chapman, S., & Nakielny, R. (2014). Aids to Radiological Differential Diagnosis (6th ed.). Elsevier.
- Dyer, R. B. (Ed.). (2018). Genitourinary Imaging: The Requisites (3rd ed.). Elsevier.
- Whitehouse, R. W., & Adams, J. E. (Eds.). (2016). Clinical Radiology: A Guide for Practitioners (5th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

- Figure 1.1: Diagram illustrating fluoroscopic barium swallow technique showing the patient swallowing contrast while imaged in the erect oblique position. AI-generated using the prompt: "A single clean, accurate technical diagram showing a patient standing in an oblique position in front of a fluoroscopy table, with a labelled arrow showing contrast passing down the oesophagus, textbook radiographic procedure diagram style, neutral background, no photographic realism, no other panels."
- Table 1.2: Comparing single-contrast and double-contrast barium enema. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Single-Contrast and Double-Contrast Barium Enema, listing feature, single-contrast barium enema, and double-contrast barium enema. Radiology reference table style with outside border, no photographic elements."
- Table 1.3: Comparing IVU and HSG. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing IVU and HSG, listing feature, intravenous urography (IVU), and hysterosalpingography (HSG). Radiology reference table style with outside border, no photographic elements."
- Figure 1.4: Diagram comparing micturating cysto-urethrography during the voiding phase with retrograde urethrography technique. AI-generated using the prompt: "A single clean, accurate two-panel schematic pelvic diagram, one panel labelled MCUG showing contrast flowing down the urethra during voiding with a labelled arrow showing reflux up one ureter, the other panel labelled RUG showing contrast instilled directly into the distal urethra via a small catheter, radiology teaching diagram style, neutral background, no photographic realism."

Course code: RAD 603

Course title: Radiology Procedures and Results Interpretation

Course credit load: 2 Units

Series 2: Peptic Ulcer Disease and Gastric Pathology on Contrast Studies

- **Part 2.1: Duodenal Ulcer**
  - Sub Part 2.1.1: Pathophysiology and clinical features of duodenal ulcer
  - Sub Part 2.1.2: Barium meal features of duodenal ulcer
  - Sub Part 2.1.3: Complications of duodenal ulcer and their imaging features
- **Part 2.2: Gastric Ulcer**
  - Sub Part 2.2.1: Pathophysiology and clinical features of gastric ulcer
  - Sub Part 2.2.2: Barium meal features of gastric ulcer
  - Sub Part 2.2.3: Distinguishing benign from malignant gastric ulcer on contrast studies
- **Part 2.3: Gastric Tumours**
  - Sub Part 2.3.1: Gastric carcinoma: clinical features
  - Sub Part 2.3.2: Barium meal features of gastric carcinoma
  - Sub Part 2.3.3: Gastric lymphoma and gastrointestinal stromal tumour
- **Part 2.4: Comparative Features and Differential Diagnosis**
  - Sub Part 2.4.1: Comparing duodenal ulcer, gastric ulcer, and gastric carcinoma on imaging
  - Sub Part 2.4.2: The role of endoscopy relative to barium studies in diagnosis
  - Sub Part 2.4.3: Complications common to peptic ulcer disease and gastric tumours

Introduction

In the last Series, we established the technique of the core fluoroscopic contrast studies used in radiologic practice. We now apply the barium meal technique directly to one of the most frequently encountered clinical scenarios in everyday radiologic reporting, **peptic ulcer disease** affecting the duodenum and stomach, and **gastric tumours**, together with the essential imaging features distinguishing benign ulceration from malignancy.

The aim of this Series is to equip you with a thorough understanding of the common features of peptic ulcers affecting the duodenum, gastric ulcers, and gastric tumours, as demonstrated on barium meal and related contrast studies.

This Series begins with **duodenal ulcer**, before turning to **gastric ulcer**. We then examine **gastric tumours**, concluding with **comparative features and differential diagnosis**.

Series Learning Outcomes

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

- **SLO 2.1:** describe the pathophysiology, clinical features, and barium meal features of duodenal ulcer
- **SLO 2.2:** describe the complications of duodenal ulcer and their imaging features
- **SLO 2.3:** describe the pathophysiology, clinical features, and barium meal features of gastric ulcer
- **SLO 2.4:** distinguish benign from malignant gastric ulcer on contrast studies
- **SLO 2.5:** describe the clinical and barium meal features of gastric carcinoma
- **SLO 2.6:** describe gastric lymphoma and gastrointestinal stromal tumour
- **SLO 2.7:** compare the imaging features of duodenal ulcer, gastric ulcer, and gastric carcinoma, and
- **SLO 2.8:** describe the complementary role of endoscopy and barium studies, and complications common to peptic ulcer disease and gastric tumours.

2.1 Duodenal Ulcer

2.1.1 pathophysiology and clinical features of duodenal ulcer

A mucosal defect strongly associated with Helicobacter pylori

Duodenal ulcer most commonly develops within the **duodenal cap**, or bulb, the first portion of the duodenum, resulting from an imbalance between mucosal protective factors and acid-peptic damage, strongly associated with **Helicobacter pylori** infection and, to a lesser extent, non-steroidal anti-inflammatory drug use.

Clinically, duodenal ulcer classically presents with epigastric pain characteristically relieved by eating, discussed in relation to gastric ulcer pain patterns in the next Part of this Series, and occurring more frequently at night, reflecting the specific pattern of acid secretion and mucosal exposure characteristic of this ulcer **location**.

Fill in the blank: Duodenal ulcer classically presents with epigastric pain characteristically relieved by eating, occurring more frequently at ________.

2.1.2 barium meal features of duodenal ulcer

On barium meal, a duodenal ulcer typically appears as a discrete, well defined **niche**, or pocket, of barium projecting beyond the expected duodenal contour, often accompanied by surrounding **mucosal oedema** producing radiating folds converging toward the ulcer crater.

Chronic or recurrent duodenal ulceration may additionally produce **deformity** of the duodenal cap, described as a **trefoil** or cloverleaf configuration resulting from scarring and fibrosis, with such deformity itself considered a reliable indirect sign of underlying or previous ulcer **disease**.

Fill in the blank: Chronic or recurrent duodenal ulceration may produce deformity of the duodenal cap, described as a trefoil or ________ configuration resulting from scarring and fibrosis.

2.1.3 complications of duodenal ulcer and their imaging features

Perforation of a duodenal ulcer represents a genuine surgical emergency, generally identified on erect chest or abdominal radiography by the presence of free intraperitoneal **air** beneath the diaphragm, discussed in relation to plain radiography earlier in this course, rather than on barium studies, which are generally contraindicated in this acute setting.

Gastric outlet obstruction, resulting from chronic scarring and stenosis at or near the pyloroduodenal junction, discussed earlier in this Part, produces a markedly dilated, fluid-filled stomach on barium meal, with delayed gastric emptying and, at times, a characteristic **string sign** as barium passes through the narrowed **channel**.

Fill in the blank: Perforation of a duodenal ulcer is generally identified on erect chest or abdominal radiography by the presence of free intraperitoneal air beneath the ________.

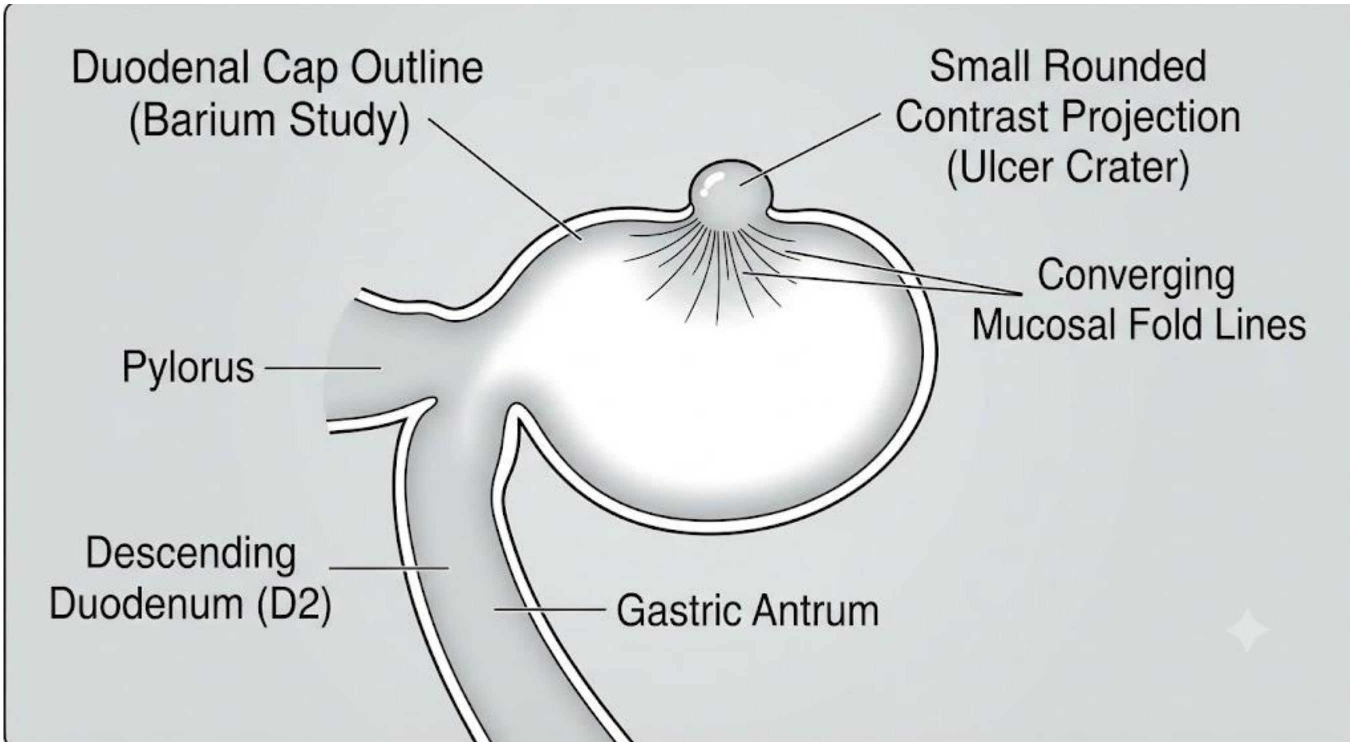

Figure 2.1: Diagram illustrating a duodenal ulcer niche with radiating mucosal folds on barium meal.

Pilot questions 2.1

- Describe the pathophysiology of duodenal ulcer. (Linked to SLO 2.1)
- Describe the classic clinical pain pattern of duodenal ulcer. (Linked to SLO 2.1)
- Describe the barium meal appearance of a duodenal ulcer niche. (Linked to SLO 2.1)
- Describe the trefoil deformity of the duodenal cap. (Linked to SLO 2.1)
- Describe the imaging findings of duodenal ulcer perforation and gastric outlet obstruction. (Linked to SLO 2.2)

2.2 Gastric Ulcer

2.2.1 pathophysiology and clinical features of gastric ulcer

A mucosal defect most commonly involving the lesser curvature

Gastric ulcer most commonly occurs along the **lesser curvature** of the stomach, discussed in relation to gastric anatomy in an earlier related course, similarly associated with Helicobacter pylori infection and non-steroidal anti-inflammatory drug use, discussed earlier in this Series, though reflecting a somewhat different balance of mucosal injury mechanisms compared with duodenal ulcer.

Clinically, gastric ulcer characteristically presents with epigastric pain that may be **worsened** by eating, in contrast to the relief typically experienced with duodenal ulcer, discussed earlier in this Series, together with a somewhat greater association with weight loss given reduced oral intake resulting from meal-associated **discomfort**.

Fill in the blank: Gastric ulcer characteristically presents with epigastric pain that may be worsened by eating, in contrast to the relief typically experienced with ________ ulcer.

2.2.2 barium meal features of gastric ulcer

On barium meal, a benign gastric ulcer typically appears as a discrete niche projecting beyond the expected gastric contour, most commonly along the lesser curvature, discussed earlier in this Part, with **Hampton's line**, a thin, lucent line at the ulcer's base representing undermined, overhanging mucosa, considered a reliable sign of benignity.

Further reliable signs of a benign gastric ulcer include a smooth, regular ulcer **mound** surrounding the niche, and radiating mucosal folds reaching directly to the ulcer edge without interruption, discussed further in the next sub-Part in relation to the contrasting features of malignant **ulceration**.

Fill in the blank: Hampton's line, a thin, lucent line at the ulcer's base representing undermined, overhanging mucosa, is considered a reliable sign of ________.

2.2.3 distinguishing benign from malignant gastric ulcer on contrast studies

A **malignant** gastric ulcer typically appears as an irregular, shallow niche located **within** the confines of an irregular mass, rather than projecting cleanly beyond the normal gastric contour, with surrounding mucosal folds that are **nodular**, clubbed, or that fail to reach the ulcer edge, in direct contrast to the benign features discussed in the previous sub-Part.

Further features suggesting malignancy include an eccentric location of the ulcer within a larger mass, an irregular, thickened ulcer mound, and rigidity or lack of normal peristalsis in the adjacent gastric wall, meaning any ulcer demonstrating these atypical features generally warrants **endoscopic** biopsy for definitive tissue diagnosis regardless of the barium appearance alone.

Fill in the blank: Any gastric ulcer demonstrating atypical features suggesting malignancy generally warrants ________ biopsy for definitive tissue diagnosis.

Table 2.2: Comparing benign and malignant gastric ulcer features on barium meal.

Feature	Benign gastric ulcer	Malignant gastric ulcer
Niche location	Projects beyond the gastric contour	Located within an irregular mass
Ulcer mound	Smooth, regular	Irregular, thickened, or nodular
Radiating folds	Reach directly to the ulcer edge	Nodular, clubbed, or fail to reach the edge

Pilot questions 2.2

1. Describe the typical location and clinical pain pattern of gastric ulcer. (Linked to SLO 2.3)
2. Describe the barium meal appearance of a benign gastric ulcer. (Linked to SLO 2.3)
3. Define Hampton's line and explain its significance. (Linked to SLO 2.3)
4. Describe the features suggesting malignancy in a gastric ulcer on barium meal. (Linked to SLO 2.4)
5. Explain why an atypical gastric ulcer warrants endoscopic biopsy regardless of barium appearance. (Linked to SLO 2.4)

2.3 Gastric Tumours

2.3.1 gastric carcinoma: clinical features

The most common gastric malignancy, often presenting late

Gastric carcinoma, most commonly **adenocarcinoma**, is the most common gastric malignancy, generally presenting with non-specific symptoms including weight loss, early satiety, and epigastric discomfort, discussed in relation to gastric ulcer symptoms earlier in this Series, meaning presentation frequently occurs at a relatively **advanced** stage.

Recognised risk factors include chronic Helicobacter pylori infection, discussed earlier in this Series, dietary factors such as high salt or smoked food intake, and certain precursor conditions including chronic atrophic gastritis, meaning careful clinical and endoscopic evaluation is particularly warranted in patients with relevant risk **factors** and persistent symptoms.

Fill in the blank: Gastric carcinoma generally presents with non-specific symptoms including weight loss, early satiety, and epigastric discomfort, meaning presentation frequently occurs at a relatively ________ stage.

2.3.2 barium meal features of gastric carcinoma

Gastric carcinoma on barium meal may present as an irregular, polypoid, intraluminal filling defect, an ulcerating mass, discussed in relation to malignant ulcer features earlier in this Series, or, in its infiltrative form, as **linitis plastica**, a diffusely thickened, rigid, narrowed stomach wall with markedly reduced distensibility.

Linitis plastica, sometimes described radiologically as a **leather bottle stomach**, reflects extensive submucosal infiltration by tumour, producing a characteristically narrowed gastric lumen with loss of normal mucosal folds and peristaltic activity, generally carrying a particularly poor **prognosis**.

Fill in the blank: Linitis plastica is sometimes described radiologically as a leather bottle stomach, reflecting extensive ________ infiltration by tumour.

2.3.3 gastric lymphoma and gastrointestinal stromal tumour

Gastric lymphoma, generally arising from mucosa-associated lymphoid tissue, discussed in relation to gastric mucosal immunology in an earlier related course, typically produces diffuse or multifocal mucosal thickening and, at times, giant, thickened folds, occasionally mimicking benign inflammatory change rather than the more discrete mass appearance typical of adenocarcinoma.

Gastrointestinal stromal tumour, or **GIST**, arising from the interstitial cells of Cajal, typically presents as a discrete, well defined, often exophytic mass projecting outward from the gastric wall, distinct from the mucosal-based appearance of adenocarcinoma discussed earlier in this Part, occasionally demonstrating central ulceration or **necrosis** on imaging.

Fill in the blank: Gastrointestinal stromal tumour typically presents as a discrete, well defined, often exophytic mass projecting outward from the gastric ________.

Table 2.3: Comparing common gastric tumour types on imaging.

Tumour type	**Typical growth pattern**	**Characteristic imaging appearance**
Gastric adenocarcinoma	Mucosal, infiltrative, or ulcerating	Polypoid mass, ulcerating lesion, or linitis plastica
Gastric lymphoma	Diffuse mucosal or submucosal	Diffuse thickening or giant, thickened folds
Gastrointestinal stromal tumour (GIST)	Exophytic, from the gastric wall	Discrete, well defined mass, sometimes with central ulceration

Pilot questions 2.3

1. Describe the typical clinical presentation and risk factors of gastric carcinoma. (Linked to SLO 2.5)
2. Describe the barium meal features of gastric carcinoma. (Linked to SLO 2.5)
3. Define linitis plastica and describe its imaging appearance. (Linked to SLO 2.5)
4. Describe the typical imaging appearance of gastric lymphoma. (Linked to SLO 2.6)
5. Describe the typical imaging appearance of a gastrointestinal stromal tumour. (Linked to SLO 2.6)

2.4 Comparative Features and Differential Diagnosis

2.4.1 comparing duodenal ulcer, gastric ulcer, and gastric carcinoma on imaging

Applying accumulated imaging signs to reach a confident differential

Distinguishing duodenal ulcer, benign gastric ulcer, and gastric carcinoma on barium meal relies on careful, systematic application of the specific signs discussed throughout this Series, including ulcer **location**, the presence or absence of Hampton's line, discussed earlier in this Series, and the character of surrounding mucosal folds and gastric wall distensibility.

In practice, no single imaging sign is entirely reliable in isolation, meaning a **combination** of supporting features, together with the specific clinical context, discussed throughout this Series, generally guides the overall level of suspicion for malignancy and the corresponding need for further endoscopic **evaluation**.

Fill in the blank: No single imaging sign is entirely reliable in isolation, meaning a combination of supporting features generally guides the overall level of suspicion for ________.

2.4.2 the role of endoscopy relative to barium studies in diagnosis

Endoscopy offers the considerable additional advantage of direct mucosal visualisation and the ability to obtain **biopsy** samples for definitive histological diagnosis, discussed in relation to malignant ulcer features earlier in this Series, representing the current preferred initial investigation for suspected peptic ulcer disease or gastric malignancy in most contemporary practice settings.

Barium meal retains genuine practical value, however, particularly where endoscopy is unavailable, incompletely tolerated, or technically limited by anatomical factors, and remains valuable for assessing gastric outlet obstruction and overall gastric **distensibility** and motility, information not always readily obtained through endoscopy alone.

Fill in the blank: Barium meal remains valuable for assessing gastric outlet obstruction and overall gastric distensibility and ________, information not always readily obtained through endoscopy alone.

2.4.3 complications common to peptic ulcer disease and gastric tumours

Haemorrhage, presenting as haematemesis or melaena, represents a recognised complication common to both peptic ulcer disease and gastric tumours, discussed throughout this Series, generally requiring urgent endoscopic assessment and, where necessary, endoscopic or, less commonly, surgical **intervention**.

Perforation, discussed in relation to duodenal ulcer earlier in this Series, may similarly complicate gastric ulcer or, less commonly, an ulcerating gastric tumour, while **obstruction**, whether at the gastric outlet from chronic ulcer scarring or from a large obstructing tumour mass, represents a further shared potential **complication** requiring appropriate clinical recognition.

Fill in the blank: Obstruction, whether at the gastric outlet from chronic ulcer scarring or from a large obstructing tumour mass, represents a further shared potential ________ requiring appropriate clinical recognition.

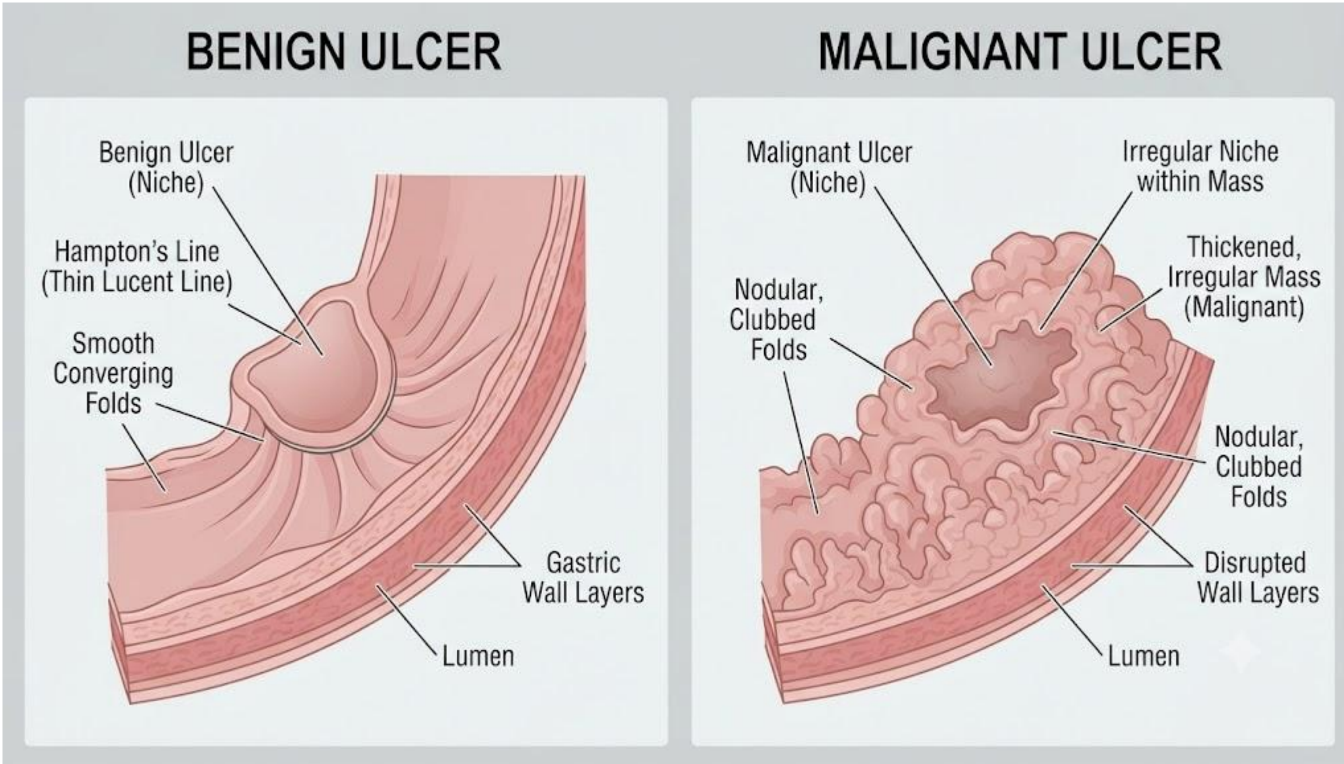

Figure 2.4: A comparative diagram summarising the key distinguishing barium meal features of benign gastric ulcer versus malignant gastric ulcer or tumour.

Pilot questions 2.4

1. Describe the systematic approach to distinguishing duodenal ulcer, gastric ulcer, and gastric carcinoma on imaging. (Linked to SLO 2.7)
2. Explain why no single barium meal sign is entirely reliable in isolation for excluding malignancy. (Linked to SLO 2.7)
3. Describe the advantages of endoscopy over barium meal in evaluating suspected peptic ulcer disease. (Linked to SLO 2.8)
4. Describe a situation in which barium meal retains genuine practical value over endoscopy. (Linked to SLO 2.8)
5. List three complications common to peptic ulcer disease and gastric tumours. (Linked to SLO 2.8)

Series Summary

This Series examined **peptic ulcer disease and gastric pathology on contrast studies**, beginning with **duodenal ulcer**, its pathophysiology, clinical features, barium meal appearance, and complications, before turning to **gastric ulcer**, its features and the essential distinction between benign and malignant appearance.

We then examined **gastric tumours**, gastric carcinoma, linitis plastica, gastric lymphoma, and gastrointestinal stromal tumour, concluding with **comparative features and differential diagnosis**, bringing together the specific imaging signs discussed throughout this Series and the complementary role of endoscopy. Having worked through this Series, you should now be equipped to understand chest radiograph interpretation examined in the next Series of this course.

Glossary of Terms

1. **Duodenal ulcer:** a mucosal defect of the duodenal cap, strongly associated with Helicobacter pylori.
2. **Trefoil deformity:** a cloverleaf-shaped scarring deformity of the duodenal cap from chronic ulceration.
3. **Gastric ulcer:** a mucosal defect most commonly occurring along the gastric lesser curvature.
4. **Hampton's line:** a thin, lucent line at the base of a gastric ulcer, indicating benignity.
5. **Linitis plastica:** a diffusely thickened, rigid, narrowed stomach from infiltrative gastric carcinoma.
6. **Gastric adenocarcinoma:** the most common gastric malignancy, typically arising from the gastric mucosa.
7. **Gastric lymphoma:** a gastric malignancy arising from mucosa-associated lymphoid tissue.
8. **Gastrointestinal stromal tumour (GIST):** a tumour arising from the interstitial cells of Cajal, typically exophytic.
9. **Ulcer niche:** the projecting or embedded barium-filled defect representing an ulcer crater on contrast study.
10. **Gastric outlet obstruction:** obstruction to gastric emptying from chronic scarring or a mass near the pylorus.
11. **String sign:** a thin, elongated column of barium passing through a severely narrowed channel.
12. **Haematemesis:** vomiting of blood, a recognised complication of peptic ulcer disease and gastric tumours.

Concept Check Questions [Series 2]

Objective questions

- Duodenal ulcer classically presents with epigastric pain relieved by eating, occurring more frequently at ________.
- Chronic or recurrent duodenal ulceration may produce a trefoil or ________ deformity of the duodenal cap.
- Hampton's line, a thin, lucent line at the base of an ulcer, is considered a reliable sign of ________.
- Linitis plastica is sometimes described as a leather bottle stomach, reflecting extensive ________ infiltration by tumour.
- No single barium meal sign is entirely reliable in isolation, meaning a combination of features generally guides the level of suspicion for ________.

Short-answer questions

1. Describe the barium meal appearance of a duodenal ulcer niche.
2. Describe the barium meal appearance of a benign gastric ulcer.
3. Describe the features suggesting malignancy in a gastric ulcer on barium meal.
4. Describe the typical imaging appearance of a gastrointestinal stromal tumour.
5. List three complications common to peptic ulcer disease and gastric tumours.

Long-answer questions

6. Discuss the pathophysiology, clinical features, barium meal features, and complications of duodenal ulcer. (Linked to SLO 2.1, SLO 2.2)
7. Discuss the pathophysiology, clinical features, and barium meal features of gastric ulcer, and how benign is distinguished from malignant ulceration. (Linked to SLO 2.3, SLO 2.4)
8. Discuss the clinical and barium meal features of gastric carcinoma, gastric lymphoma, and gastrointestinal stromal tumour. (Linked to SLO 2.5, SLO 2.6)
9. Discuss the comparative imaging features of duodenal ulcer, gastric ulcer, and gastric carcinoma. (Linked to SLO 2.7)
10. Discuss the complementary role of endoscopy and barium studies, and complications common to peptic ulcer disease and gastric tumours. (Linked to SLO 2.8)

Answers to Concept Check Questions [Series 2]

Objective questions

11. Night.
12. Cloverleaf.
13. Benignity.
14. Submucosal.
15. Malignancy.

Short-answer questions

16. A discrete, well defined niche of barium projecting beyond the duodenal contour with surrounding radiating mucosal folds.
17. A discrete niche projecting beyond the gastric contour, most commonly on the lesser curvature, with Hampton's line and smooth radiating folds reaching the edge.
18. An irregular, shallow niche within an irregular mass, with nodular, clubbed, or interrupted folds, an eccentric location, and wall rigidity.
19. A discrete, well defined, often exophytic mass projecting outward from the gastric wall, sometimes with central ulceration.
20. Haemorrhage, perforation, and obstruction.

Long-answer questions

21. **Basic response:** Duodenal ulcer arises from acid-peptic imbalance strongly linked to Helicobacter pylori, presenting with pain relieved by eating and appearing as a projecting niche with radiating folds on barium meal.

Value-added response: Complications include perforation, identified by free intraperitoneal air, and gastric outlet obstruction from chronic scarring, producing a dilated, poorly emptying stomach.

22. **Basic response:** Gastric ulcer occurs most commonly on the lesser curvature, presenting with pain often worsened by eating, with benign features including Hampton's line and smooth radiating folds reaching the ulcer edge.

Value-added response: Malignant ulceration shows an irregular niche within a mass, nodular folds, and wall rigidity, warranting endoscopic biopsy regardless of the barium appearance.

23. **Basic response:** Gastric carcinoma presents with non-specific symptoms often at an advanced stage, appearing as a polypoid mass, ulcerating lesion, or linitis plastica on barium meal.

Value-added response: Gastric lymphoma produces diffuse mucosal thickening, while gastrointestinal stromal tumour presents as a discrete, exophytic mass, each requiring careful imaging characterisation.

24. **Basic response:** Comparing duodenal ulcer, gastric ulcer, and gastric carcinoma relies on ulcer location, Hampton's line presence, and mucosal fold character.

Value-added response: No single sign is fully reliable alone, so a combination of features together with clinical context guides the overall assessment of malignant risk.

25. **Basic response:** Endoscopy offers direct visualisation and biopsy capability, representing the preferred initial investigation in most settings, while barium meal retains value where endoscopy is unavailable or limited.

Value-added response: Both peptic ulcer disease and gastric tumours share potential complications including haemorrhage, perforation, and obstruction, each requiring prompt recognition and management.

Answers to Pilot Questions [Series 2]

Part 2.1

1. An imbalance between mucosal protective factors and acid-peptic damage, strongly associated with Helicobacter pylori infection.
2. Epigastric pain characteristically relieved by eating and occurring more frequently at night.
3. A discrete, well defined niche projecting beyond the duodenal contour with surrounding radiating mucosal folds.
4. A cloverleaf-shaped scarring deformity of the duodenal cap resulting from chronic or recurrent ulceration.
5. Perforation shows free intraperitoneal air on erect radiography; obstruction shows a dilated, fluid-filled stomach with delayed emptying.

Part 2.2

6. Most commonly the lesser curvature; pain may be worsened by eating, unlike duodenal ulcer.
7. A discrete niche projecting beyond the gastric contour, generally on the lesser curvature.

8. A thin, lucent line at the ulcer base representing undermined mucosa, considered a reliable sign of benignity.
9. An irregular niche within a mass, nodular or interrupted folds, an eccentric location, and gastric wall rigidity.
10. Because atypical features carry sufficient risk of underlying malignancy that tissue diagnosis is required regardless of imaging appearance.

Part 2.3

11. Non-specific symptoms including weight loss, early satiety, and epigastric discomfort, associated with Helicobacter pylori and dietary risk factors.
12. A polypoid intraluminal filling defect, an ulcerating mass, or, in infiltrative form, linitis plastica.
13. A diffusely thickened, rigid, narrowed stomach from extensive submucosal tumour infiltration.
14. Diffuse or multifocal mucosal thickening, at times with giant, thickened folds.
15. A discrete, well defined, often exophytic mass projecting from the gastric wall, sometimes with central ulceration.

Part 2.4

1. Systematically applying signs including ulcer location, Hampton's line presence, and mucosal fold character.
2. Because features can overlap between benign and malignant disease, so a combination with clinical context is needed.
3. Direct mucosal visualisation and the ability to obtain biopsy for definitive histological diagnosis.
4. When endoscopy is unavailable or limited, or when assessing gastric outlet obstruction and overall distensibility or motility.
5. Haemorrhage, perforation, and obstruction.

References and Attributions [Series 2]

1. Chapman, S., & Nakielny, R. (2014). Aids to Radiological Differential Diagnosis (6th ed.). Elsevier.
2. Sutton, D. (Ed.). (2015). Textbook of Radiology and Imaging (7th ed.). Churchill Livingstone.

3. Levine, M. S., & Rubesin, S. E. (2011). Diseases of the Esophagus, Stomach, and Duodenum: Radiologic Diagnosis. Radiological Society of North America (RSNA) education series.
4. Whitehouse, R. W., & Adams, J. E. (Eds.). (2016). Clinical Radiology: A Guide for Practitioners (5th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

1. Figure 2.1: Diagram illustrating a duodenal ulcer niche with radiating mucosal folds on barium meal. AI-generated using the prompt: "A single clean, accurate schematic diagram of the duodenal cap outline on a barium study, showing a small rounded projection of contrast beyond the normal contour with labelled radiating fold lines converging toward it, radiology teaching diagram style, neutral background, no photographic realism, no other panels."
2. Table 2.2: Comparing benign and malignant gastric ulcer features on barium meal. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Benign and Malignant Gastric Ulcer Features, listing feature, benign gastric ulcer, and malignant gastric ulcer. Radiology reference table style with outside border, no photographic elements."
3. Table 2.3: Comparing common gastric tumour types on imaging. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Common Gastric Tumour Types, listing tumour type, typical growth pattern, and characteristic imaging appearance. Radiology reference table style with outside border, no photographic elements."
4. Figure 2.4: A comparative diagram summarising the key distinguishing barium meal features of benign gastric ulcer versus malignant gastric ulcer or tumour. AI-generated using the prompt: "A single clean, accurate two-panel schematic diagram of the stomach wall in cross-section, one panel labelled benign ulcer showing a clean projecting niche with a thin lucent line at its base and smooth converging folds, the other labelled malignant ulcer showing an irregular niche within a thickened, irregular mass with nodular folds, radiology teaching diagram style, neutral background, no photographic realism."

Course code: RAD 603

Course title: Radiology Procedures and Results Interpretation

Course credit load: 2 Units

Series 3: Chest Radiograph Interpretation

- **Part 3.1: Systematic Approach to Chest Radiograph Interpretation**
    - Sub Part 3.1.1: Patient and technical factors before interpretation
    - Sub Part 3.1.2: A systematic reading sequence for the chest radiograph
    - Sub Part 3.1.3: Identifying common focal lesions
- **Part 3.2: Consolidation on the Chest Radiograph**
    - Sub Part 3.2.1: Recognising consolidation
    - Sub Part 3.2.2: The silhouette sign and lobar localisation
    - Sub Part 3.2.3: Differentiating consolidation from other opacities
- **Part 3.3: Pleural Fluid Collections and Pneumothorax**
    - Sub Part 3.3.1: Identifying pleural fluid collections
    - Sub Part 3.3.2: Identifying pneumothorax
    - Sub Part 3.3.3: Distinguishing pleural fluid from pneumothorax
- **Part 3.4: Mediastinal Shift and Its Interpretation**
    - Sub Part 3.4.1: Recognising mediastinal shift
    - Sub Part 3.4.2: Causes of mediastinal shift toward the abnormal side
    - Sub Part 3.4.3: Causes of mediastinal shift away from the abnormal side

Introduction

In the last Series, we examined peptic ulcer disease and gastric pathology on contrast studies. We now turn to the essential practical skill of **chest radiograph interpretation**, applying a systematic reading approach to reliably identify common focal lesions, consolidation, pleural fluid collections, pneumothorax, and mediastinal shift, the core interpretive competencies expected of every practitioner reviewing a chest radiograph.

The aim of this Series is to equip you with a thorough, practical understanding of how to systematically interpret chest radiographs to identify common lesions, consolidation, pleural fluid collections, pneumothorax, and mediastinal shift.

This Series begins with a **systematic approach to chest radiograph interpretation**, before examining **consolidation on the chest radiograph**. We then turn to **pleural fluid collections and pneumothorax**, concluding with **mediastinal shift and its interpretation**.

Series Learning Outcomes

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

- **SLO 3.1:** assess patient and technical factors relevant to chest radiograph interpretation
- **SLO 3.2:** apply a systematic reading sequence to a chest radiograph and identify common focal lesions
- **SLO 3.3:** recognise consolidation on a chest radiograph
- **SLO 3.4:** apply the silhouette sign to localise consolidation and differentiate it from other opacities
- **SLO 3.5:** identify pleural fluid collections on a chest radiograph
- **SLO 3.6:** identify pneumothorax on a chest radiograph and distinguish it from pleural fluid
- **SLO 3.7:** recognise mediastinal shift on a chest radiograph, and
- **SLO 3.8:** distinguish causes of mediastinal shift toward the abnormal side from causes of shift away from it.

3.1 Systematic Approach to Chest Radiograph Interpretation

3.1.1 patient and technical factors before interpretation

Confirming an adequate, correctly labelled examination before diagnosis

Before interpreting any chest radiograph, the reader should confirm correct **patient identification**, the date and time of the examination, and the specific **projection** obtained, generally posteroanterior or, in less mobile patients, anteroposterior, since this distinction directly affects apparent cardiac size and overall image interpretation.

Technical adequacy should additionally be assessed, including appropriate **penetration**, allowing faint visualisation of the thoracic vertebrae through the cardiac shadow, adequate **inspiration**, generally with the diaphragm visible at or below the level of the tenth posterior rib, and correct patient **rotation**, assessed by symmetry of the medial clavicular ends relative to the spinous processes.

Fill in the blank: Technical adequacy should include assessment of correct patient rotation, assessed by symmetry of the medial clavicular ends relative to the ________ processes.

3.1.2 a systematic reading sequence for the chest radiograph

A systematic reading sequence helps ensure no abnormality is inadvertently overlooked, generally beginning with review of soft tissues and bones, discussed in relation to rib and sternal fractures in an earlier related course, before proceeding to the **cardiac silhouette** and mediastinal contours, discussed further later in this Series.

The sequence then generally proceeds to the **pulmonary hila** and lung fields themselves, assessed systematically zone by zone, and finally the **pleural spaces** and diaphragmatic contours, discussed further later in this Series, with consistent application of the same reading sequence regardless of the specific clinical indication reducing the risk of missed **findings**.

Fill in the blank: A systematic reading sequence generally proceeds from soft tissues and bones, to the cardiac silhouette, to the pulmonary hila and lung fields, and finally the pleural spaces and diaphragmatic ________.

3.1.3 identifying common focal lesions

A **focal lesion** on chest radiography, discussed in relation to nodules in an earlier related course, should be assessed for its precise **location**, size, margin characteristics, and internal density, including the presence or absence of calcification or cavitation, each contributing important information toward the likely underlying **diagnosis**.

Comparison with any available prior imaging represents an essential component of lesion assessment, since **interval change**, discussed in relation to malignancy risk in an earlier related course, or stability over a prolonged period, carries direct diagnostic significance that a single isolated radiograph alone cannot reliably **provide**.

Fill in the blank: Comparison with any available prior imaging is essential, since interval change or stability over a prolonged period carries direct diagnostic ________.

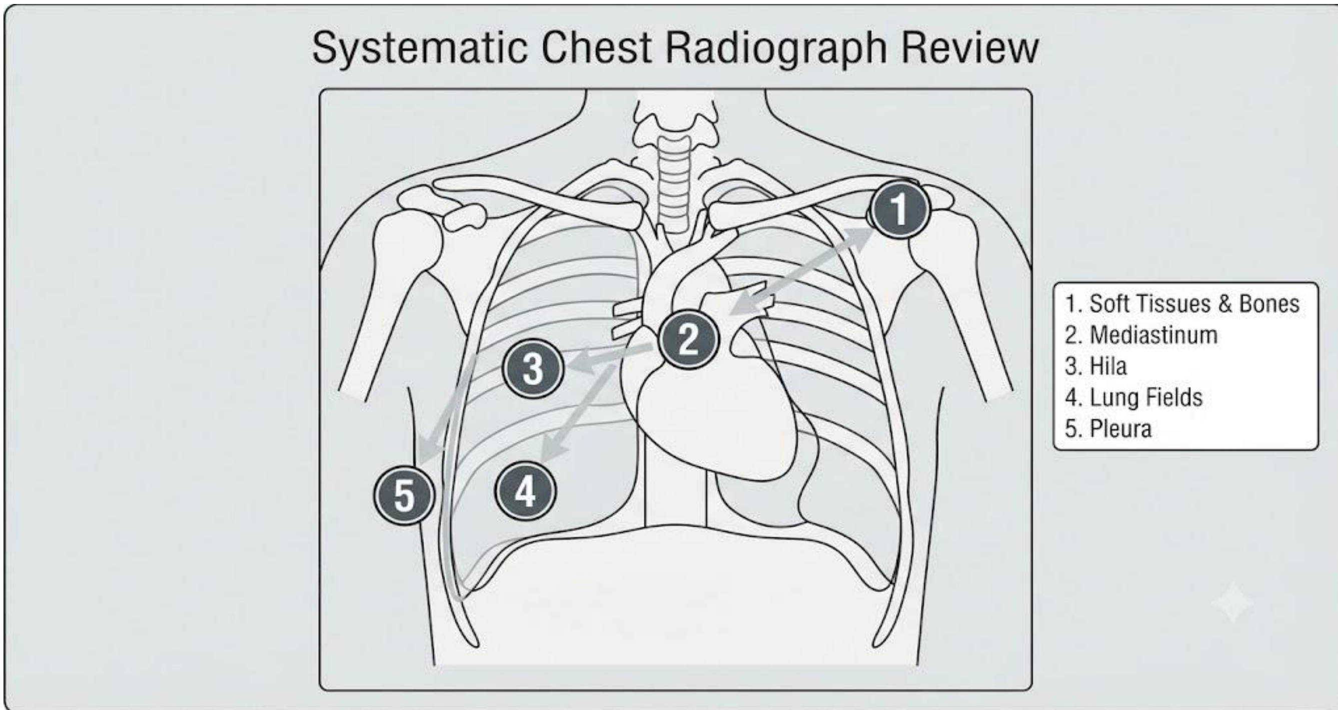

Figure 3.1: Diagram illustrating a systematic chest radiograph reading sequence proceeding from soft tissues and bones through the mediastinum, hila, lungs, and pleura.

Pilot questions 3.1

- List three technical adequacy factors that should be assessed before interpreting a chest radiograph. (Linked to SLO 3.1)
- Describe how correct patient rotation is assessed on a chest radiograph. (Linked to SLO 3.1)
- Describe a systematic reading sequence for chest radiograph interpretation. (Linked to SLO 3.2)
- List the features that should be assessed in a focal chest lesion. (Linked to SLO 3.2)
- Explain why comparison with prior imaging is important when assessing a focal lesion. (Linked to SLO 3.2)

3.2 Consolidation on the Chest Radiograph

3.2.1 recognising consolidation

Homogeneous opacity replacing normal aerated lung

Consolidation, discussed in relation to pneumonia in an earlier related course, appears as a homogeneous area of increased opacity replacing normal air-containing lung, generally with **ill-defined** margins where it abuts normally aerated lung, often containing visible **air bronchograms**, air-filled bronchi outlined against the surrounding opacified parenchyma.

Consolidation typically respects **anatomical boundaries**, such as a lobar fissure, producing a sharply demarcated edge where it meets the fissure while remaining ill-defined elsewhere, a pattern reflecting the underlying alveolar filling process rather than a discrete mass or nodule with a genuinely rounded, well defined **margin**.

Fill in the blank: Consolidation typically respects anatomical boundaries, such as a lobar fissure, producing a sharply demarcated edge where it meets the fissure while remaining ill-defined ________.

3.2.2 the silhouette sign and lobar localisation

The **silhouette sign** describes loss of a normally visible anatomical border, such as the right heart border or a hemidiaphragm contour, discussed in relation to systematic reading sequence earlier in this Series, when consolidation of the same **radiographic density** lies in direct anatomical contact with that structure, obliterating its normal silhouette.

Applying the silhouette sign allows relatively precise **lobar localisation** of consolidation without necessarily requiring a lateral radiograph, since loss of the right heart border specifically indicates right middle lobe consolidation, while loss of a hemidiaphragm contour indicates consolidation of the corresponding lower **lobe**.

Fill in the blank: Loss of the right heart border on the silhouette sign specifically indicates consolidation of the right middle ________.

3.2.3 differentiating consolidation from other opacities

Consolidation should be distinguished from **lung collapse**, discussed in an earlier related course, which characteristically produces volume loss signs, including fissural displacement and mediastinal shift toward the affected side, discussed further later in this Series, features generally absent in simple consolidation without associated collapse.

Consolidation should additionally be distinguished from a discrete **pulmonary mass**, discussed earlier in this Series, which typically demonstrates a genuinely rounded, well defined margin rather than the ill-defined, air bronchogram-containing pattern of consolidation, with careful attention to these distinguishing features supporting accurate radiographic **interpretation**.

Fill in the blank: Consolidation should be distinguished from lung collapse, which characteristically produces volume loss signs including fissural displacement and mediastinal shift toward the affected ________.

Table 3.2: Comparing consolidation, lung collapse, and a discrete pulmonary mass.

Feature	Consolidation	Lung collapse / Pulmonary mass
Margin	Ill-defined	Collapse: ill-defined with volume loss / Mass: rounded, well defined
Air bronchograms	Often present	Generally absent in both
Mediastinal shift	Absent (unless with collapse)	Collapse: toward affected side / Mass: generally absent

Pilot questions 3.2

1. Describe the typical radiographic appearance of consolidation. (Linked to SLO 3.3)
2. Define the silhouette sign. (Linked to SLO 3.4)
3. Explain how the silhouette sign is used to localise consolidation to a specific lobe. (Linked to SLO 3.4)
4. Distinguish consolidation from lung collapse in terms of volume loss signs. (Linked to SLO 3.4)
5. Distinguish consolidation from a discrete pulmonary mass in terms of margin characteristics. (Linked to SLO 3.4)

3.3 Pleural Fluid Collections and Pneumothorax

3.3.1 identifying pleural fluid collections

Fluid within the pleural space producing a rising, curved border

A **pleural effusion**, discussed in relation to its causes in an earlier related course, on an erect chest radiograph characteristically produces a homogeneous opacity at the lung base with a curved, concave upper border rising laterally, termed the **meniscus sign**, reflecting the physical behaviour of free fluid within the pleural space.

Small effusions may initially only blunt the normally sharp **costophrenic angle**, while larger effusions progressively obscure more of the hemidiaphragm and lower lung field, with a genuinely massive effusion capable of producing complete **opacification** of a hemithorax together with mediastinal shift away from the affected side, discussed further later in this Series.

Fill in the blank: Small pleural effusions may initially only blunt the normally sharp ________ angle.

3.3.2 identifying pneumothorax

A **pneumothorax**, discussed in relation to its causes in an earlier related course, appears radiographically as a thin, curvilinear **visceral pleural line**, with a complete absence of normal 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 radiograph.

A **tension pneumothorax**, a genuine radiological and clinical emergency, additionally demonstrates **mediastinal shift** away from the affected side, discussed further later in this Series, and, in more severe cases, flattening or inversion of the ipsilateral hemidiaphragm, reflecting progressively rising intrapleural **pressure**.

Fill in the blank: A pneumothorax appears radiographically as a thin, curvilinear visceral pleural line, with a complete absence of normal lung markings peripheral to this line, most easily identified toward the lung ________.

3.3.3 distinguishing pleural fluid from pneumothorax

Pleural fluid and pneumothorax can generally be reliably distinguished by their characteristic radiographic **pattern**, fluid producing a homogeneous, upward-curving opacity at the lung base, discussed earlier in this Part, and air producing a thin, sharply defined pleural line with absent peripheral lung markings, typically most apparent toward the lung apex.

Where both fluid and air coexist within the same pleural space, termed a **hydropneumothorax**, an erect radiograph characteristically demonstrates a horizontal **air-fluid level**, discussed in relation to fluid behaviour in an earlier related course, distinct from the curved meniscus of fluid alone, providing a further reliable distinguishing radiographic sign.

Fill in the blank: Where both fluid and air coexist within the same pleural space, termed a hydropneumothorax, an erect radiograph characteristically demonstrates a horizontal air-fluid ________.

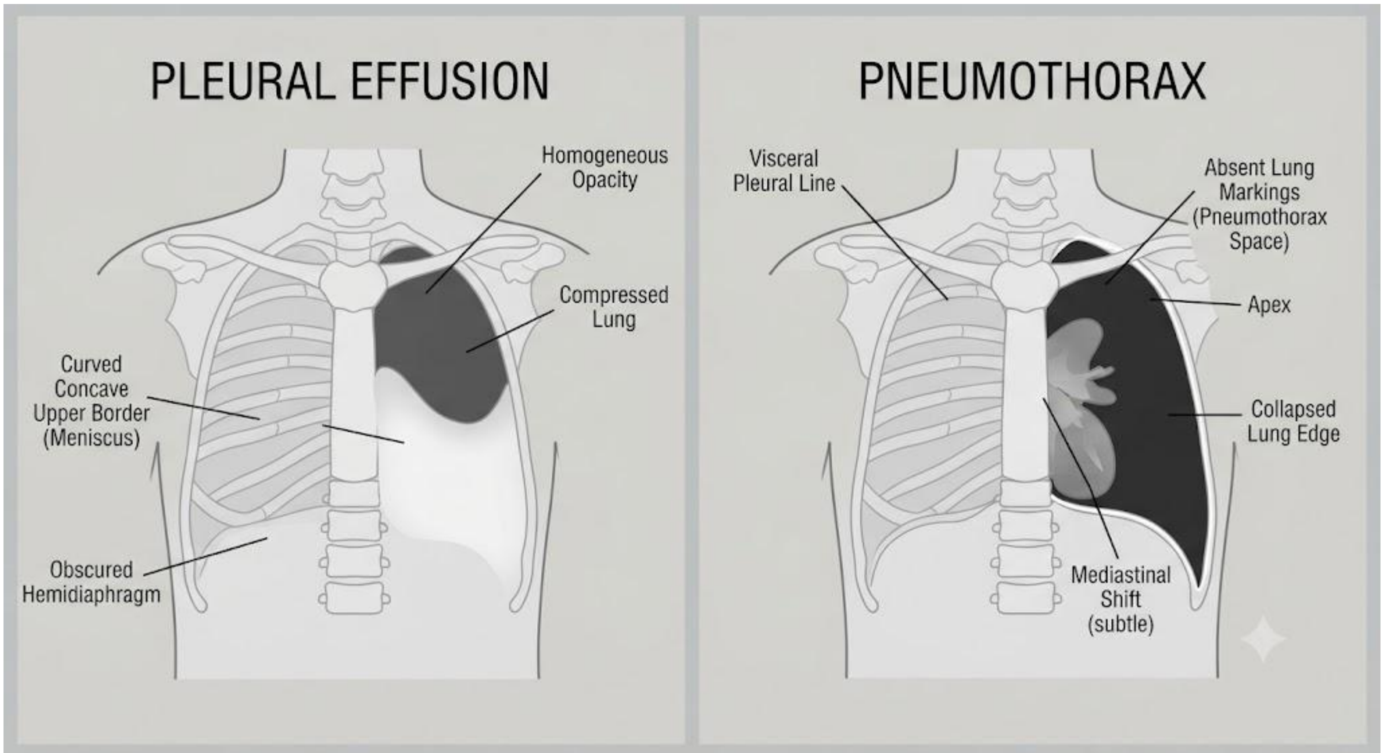

Figure 3.3: Diagram comparing the meniscus sign of pleural effusion with the visceral pleural line of pneumothorax on an erect chest radiograph.

Pilot questions 3.3

1. Describe the meniscus sign of pleural effusion. (Linked to SLO 3.5)
2. Describe how a small pleural effusion first becomes apparent radiographically. (Linked to SLO 3.5)
3. Describe the radiographic appearance of a pneumothorax. (Linked to SLO 3.6)
4. Describe the additional radiographic findings of tension pneumothorax. (Linked to SLO 3.6)
5. Define hydropneumothorax and describe its characteristic radiographic sign. (Linked to SLO 3.6)

3.4 Mediastinal Shift and Its Interpretation

3.4.1 recognising mediastinal shift

Displacement of central structures indicating a volume or pressure imbalance

Mediastinal shift refers to displacement of central mediastinal structures, most readily assessed by the position of the **trachea** and cardiac silhouette, discussed in relation to the systematic reading sequence earlier in this Series, away from their expected central position, reflecting an underlying volume or pressure imbalance between the two hemithoraces.

Careful assessment for mediastinal shift represents an essential component of chest radiograph interpretation, discussed throughout this Series, since its presence or absence, and its specific **direction**, carries direct diagnostic significance in distinguishing between several important differential diagnoses discussed further in this Part.

Fill in the blank: Mediastinal shift refers to displacement of central mediastinal structures away from their expected central position, reflecting an underlying volume or pressure ________ between the two hemithoraces.

3.4.2 causes of mediastinal shift toward the abnormal side

Mediastinal shift **toward** the abnormal side generally reflects volume loss within that hemithorax, most commonly **lung collapse**, discussed earlier in this Series, or, less commonly, surgical **pneumonectomy**, with the mediastinum drawn toward the smaller, volume-reduced side to occupy the resulting available space.

Further causes of shift toward the abnormal side include extensive **pulmonary fibrosis**, producing chronic volume loss within the affected lung, meaning shift toward a specific side should prompt careful consideration of these volume-loss processes rather than the volume-excess processes discussed in the next sub-Part.

Fill in the blank: Mediastinal shift toward the abnormal side generally reflects volume loss within that hemithorax, most commonly lung ________.

3.4.3 causes of mediastinal shift away from the abnormal side

Mediastinal shift **away** from the abnormal side generally reflects a space-occupying or volume-excess process within that hemithorax, most commonly a large **pleural effusion**, discussed earlier in this Series, or **tension pneumothorax**, discussed earlier in this Series, both displacing the mediastinum toward the contralateral, unaffected side.

Further causes of shift away from the abnormal side include a large intrathoracic **mass**, discussed earlier in this Series, sufficiently large to displace mediastinal structures through direct mass effect, meaning the specific direction of mediastinal shift, together with the accompanying radiographic findings discussed throughout this Series, generally allows confident distinction between these volume-loss and volume-excess differential **diagnoses**.

Fill in the blank: Mediastinal shift away from the abnormal side generally reflects a space-occupying or volume-excess process, most commonly a large pleural effusion or tension ________.

Table 3.4: Comparing causes of mediastinal shift by direction.

Direction of shift	Underlying process	Example causes
Toward the abnormal side	Volume loss	Lung collapse, pneumonectomy, pulmonary fibrosis
Away from the abnormal side	Volume excess or space-occupying process	Large pleural effusion, tension pneumothorax, large mass

Pilot questions 3.4

1. Define mediastinal shift and describe how it is assessed on a chest radiograph. (Linked to SLO 3.7)
2. List two causes of mediastinal shift toward the abnormal side. (Linked to SLO 3.8)
3. Explain why lung collapse produces shift toward, rather than away from, the affected side. (Linked to SLO 3.8)
4. List two causes of mediastinal shift away from the abnormal side. (Linked to SLO 3.8)
5. Explain how the direction of mediastinal shift assists in differential diagnosis. (Linked to SLO 3.8)

Series Summary

This Series examined **chest radiograph interpretation**, beginning with a **systematic approach to chest radiograph interpretation**, patient and technical factors, a consistent reading sequence, and identification of common focal lesions, before turning to **consolidation on the chest radiograph**, its recognition, the silhouette sign, and its differentiation from lung collapse and pulmonary mass.

We then examined **pleural fluid collections and pneumothorax**, their identification and distinguishing features, concluding with **mediastinal shift and its interpretation**, its recognition and the contrasting causes of shift toward and away from the abnormal side. Having worked through this Series, you should now be equipped to understand ultrasound of abdominal organs and lesion characterisation examined in the next Series of this course.

Glossary of Terms

1. **Adequate penetration:** correct radiographic exposure allowing faint visualisation of vertebrae through the cardiac shadow.
2. **Silhouette sign:** loss of a normal anatomical border when an adjacent structure of the same radiographic density lies in contact with it.
3. **Air bronchogram:** air-filled bronchi visible against surrounding consolidated lung.
4. **Meniscus sign:** the curved, concave upper border of pleural fluid on an erect chest radiograph.
5. **Costophrenic angle:** the angle between the diaphragm and chest wall, an early site of blunting in small effusions.
6. **Visceral pleural line:** the thin line marking the edge of collapsed lung in pneumothorax.
7. **Hydropneumothorax:** the coexistence of both fluid and air within the pleural space.
8. **Air-fluid level:** a horizontal interface visible where both fluid and air are present within a space.
9. **Mediastinal shift:** displacement of central mediastinal structures from their expected midline position.
10. **Lung collapse (atelectasis):** loss of lung volume, typically shifting the mediastinum toward the affected side.
11. **Tension pneumothorax:** a pneumothorax with rising intrapleural pressure shifting the mediastinum away from the affected side.
12. **Interval change:** a difference in appearance between a current and prior imaging study of the same region.

Concept Check Questions [Series 3]

Objective questions

- Correct patient rotation on a chest radiograph is assessed by symmetry of the medial clavicular ends relative to the spinous ________.

- Loss of the right heart border on the silhouette sign specifically indicates consolidation of the right middle ________.
- Small pleural effusions may initially only blunt the normally sharp ________ angle.
- A pneumothorax is most easily identified toward the lung ________ on an erect radiograph.
- Mediastinal shift toward the abnormal side generally reflects volume loss, most commonly lung ________.

Short-answer questions

1. Describe a systematic reading sequence for chest radiograph interpretation.
2. Define the silhouette sign.
3. Distinguish consolidation from lung collapse in terms of volume loss signs.
4. Define hydropneumothorax and describe its characteristic radiographic sign.
5. List two causes of mediastinal shift away from the abnormal side.

Long-answer questions

6. Discuss patient and technical factors, a systematic reading sequence, and identification of common focal lesions on chest radiography. (Linked to SLO 3.1, SLO 3.2)
7. Discuss consolidation, the silhouette sign, and its differentiation from lung collapse and pulmonary mass. (Linked to SLO 3.3, SLO 3.4)
8. Discuss the identification of pleural fluid collections and pneumothorax, and how they are distinguished. (Linked to SLO 3.5, SLO 3.6)
9. Discuss the recognition of mediastinal shift on chest radiography. (Linked to SLO 3.7)
10. Discuss the causes of mediastinal shift toward and away from the abnormal side. (Linked to SLO 3.8)

Answers to Concept Check Questions [Series 3]

Objective questions

11. Processes.
12. Lobe.
13. Costophrenic.
14. Apex.
15. Collapse.

Short-answer questions

16. Beginning with soft tissues and bones, then the cardiac silhouette and mediastinum, then the hila and lung fields, then the pleural spaces and diaphragm.
17. Loss of a normal anatomical border when an adjacent structure of the same radiographic density lies in direct contact with it.
18. Consolidation generally lacks volume loss signs; lung collapse shows fissural displacement and mediastinal shift toward the affected side.
19. The coexistence of fluid and air within the pleural space; it shows a characteristic horizontal air-fluid level.
20. A large pleural effusion and tension pneumothorax, among others such as a large intrathoracic mass.

Long-answer questions

21. **Basic response:** Chest radiograph interpretation begins with confirming patient details, projection, and technical adequacy, followed by a consistent reading sequence covering soft tissue, mediastinum, hila, lungs, and pleura.

Value-added response: Focal lesions are assessed for location, size, margin, and density, with comparison to prior imaging providing essential information on interval change.

22. **Basic response:** Consolidation appears as ill-defined opacity with air bronchograms, localised using the silhouette sign, which identifies the specific lobe involved based on which border is obscured.

Value-added response: Consolidation is distinguished from lung collapse, which shows volume loss signs, and from a discrete mass, which shows a rounded, well defined margin.

23. **Basic response:** Pleural effusion produces a meniscus sign at the lung base, while pneumothorax produces a visceral pleural line with absent peripheral markings toward the apex.

Value-added response: Where both coexist, a hydropneumothorax produces a characteristic horizontal air-fluid level, distinguishing it from either finding alone.

24. **Basic response:** Mediastinal shift is assessed by tracheal and cardiac position relative to the midline, reflecting an underlying volume or pressure imbalance between hemithoraces.

Value-added response: Recognising its presence and direction is an essential, systematic step in chest radiograph interpretation.

25. **Basic response:** Shift toward the abnormal side reflects volume loss, such as lung collapse or pneumonectomy, while shift away from the abnormal side reflects volume-excess processes, such as large effusion or tension pneumothorax.

Value-added response: This directional distinction provides a powerful and reliable tool for narrowing the differential diagnosis based on chest radiograph findings alone.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Penetration, inspiration, and rotation.
2. By symmetry of the medial clavicular ends relative to the spinous processes.
3. Soft tissues and bones, then cardiac silhouette and mediastinum, then hila and lung fields, then pleural spaces and diaphragm.
4. Location, size, margin characteristics, and internal density including calcification or cavitation.
5. Because interval change or stability carries direct diagnostic significance not available from a single isolated radiograph.

Part 3.2

6. A homogeneous, ill-defined area of increased opacity, often with visible air bronchograms.
7. Loss of a normal anatomical border when an adjacent structure of the same radiographic density is in direct contact with it.
8. Loss of the right heart border indicates right middle lobe consolidation; loss of a hemidiaphragm contour indicates the corresponding lower lobe.
9. Consolidation generally lacks volume loss signs; lung collapse shows fissural displacement and shift toward the affected side.
10. Consolidation is ill-defined with air bronchograms; a mass is rounded and well defined without air bronchograms.

Part 3.3

11. A homogeneous opacity at the lung base with a curved, concave upper border rising laterally.
12. By blunting the normally sharp costophrenic angle.

13. A thin, curvilinear visceral pleural line with absent lung markings peripheral to it, most apparent toward the apex.
14. Mediastinal shift away from the affected side and flattening or inversion of the ipsilateral hemidiaphragm.
15. Coexistence of fluid and air in the pleural space; a horizontal air-fluid level on an erect radiograph.

Part 3.4

1. Displacement of central mediastinal structures from the midline, assessed by tracheal and cardiac position.
2. Lung collapse and pneumonectomy, among others such as pulmonary fibrosis.
3. Because the mediastinum is drawn toward the smaller, volume-reduced side to occupy the available space.
4. Large pleural effusion and tension pneumothorax, among others such as a large intrathoracic mass.
5. The direction distinguishes volume-loss processes (shift toward) from volume-excess or space-occupying processes (shift away), narrowing the differential diagnosis.

References and Attributions [Series 3]

1. Corne, J., Carroll, M., Brown, I., & Delany, D. (2011). Chest X-Ray Made Easy (3rd ed.). Churchill Livingstone.
2. Chapman, S., & Nakielny, R. (2014). Aids to Radiological Differential Diagnosis (6th ed.). Elsevier.
3. Hansell, D. M., Lynch, D. A., McAdams, H. P., & Bankier, A. A. (2019). Imaging of Diseases of the Chest (6th ed.). Elsevier.
4. Whitehouse, R. W., & Adams, J. E. (Eds.). (2016). Clinical Radiology: A Guide for Practitioners (5th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: Diagram illustrating a systematic chest radiograph reading sequence proceeding from soft tissues and bones through the mediastinum, hila, lungs, and pleura.

AI-generated using the prompt: "A single clean, accurate schematic chest radiograph diagram with numbered circular labels (1 through 5) placed over soft tissue/bone, mediastinum, hila, lung fields, and pleura in sequence, connected by faint directional arrows, radiology teaching diagram style, neutral background, no photographic realism, no other panels."

2. Table 3.2: Comparing consolidation, lung collapse, and a discrete pulmonary mass. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Consolidation, Lung Collapse, and Pulmonary Mass, listing feature, consolidation, lung collapse, and pulmonary mass. Radiology reference table style with outside border, no photographic elements."
3. Figure 3.3: Diagram comparing the meniscus sign of pleural effusion with the visceral pleural line of pneumothorax on an erect chest radiograph. 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 border at the lung base, 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 causes of mediastinal shift by direction. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Causes of Mediastinal Shift by Direction, listing direction of shift, underlying process, and example causes. Radiology reference table style with outside border, no photographic elements."

Course code: RAD 603

Course title: Radiology Procedures and Results Interpretation

Course credit load: 2 Units

Series 4: Ultrasound of Abdominal Organs and Lesion Characterisation

- **Part 4.1: Ultrasound of the Liver**
  - Sub Part 4.1.1: Normal liver ultrasound appearance
  - Sub Part 4.1.2: Ultrasound features of diffuse liver disease
  - Sub Part 4.1.3: Ultrasound features of focal liver lesions
- **Part 4.2: Ultrasound of the Pancreas and Gallbladder**
  - Sub Part 4.2.1: Ultrasound features of pancreatic disease
  - Sub Part 4.2.2: Ultrasound features of gallstones and cholecystitis
  - Sub Part 4.2.3: Ultrasound features of biliary obstruction
- **Part 4.3: Ultrasound of the Appendix and Colon**
  - Sub Part 4.3.1: Ultrasound features of acute appendicitis
  - Sub Part 4.3.2: Ultrasound features of colonic tumours
  - Sub Part 4.3.3: Limitations of ultrasound in bowel imaging
- **Part 4.4: Differentiating Cystic from Solid Lesions on Ultrasound**
  - Sub Part 4.4.1: Ultrasound features of a cystic lesion
  - Sub Part 4.4.2: Ultrasound features of a solid lesion
  - Sub Part 4.4.3: Pitfalls in differentiating cystic from solid lesions

Introduction

In the last Series, we established a systematic approach to chest radiograph interpretation. We now turn to **abdominal ultrasound**, applying the physical principles of ultrasound imaging to the specific interpretation of disease affecting the liver, pancreas, gallbladder, appendix, and colon, together with the essential practical skill of **differentiating cystic from solid lesions**, a fundamental distinction underlying almost every ultrasound abdominal report.

The aim of this Series is to equip you with a thorough understanding of the ultrasound features of diseases affecting the liver, pancreas, gallbladder, appendix, and colon, and the ability to differentiate cystic lesions from solid lesions on ultrasound scan.

This Series begins with **ultrasound of the liver**, before turning to **ultrasound of the pancreas and gallbladder**. We then examine **ultrasound of the appendix and colon**, concluding with **differentiating cystic from solid lesions on ultrasound**.

Series Learning Outcomes

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

- **SLO 4.1:** describe the normal ultrasound appearance of the liver and the ultrasound features of diffuse liver disease
- **SLO 4.2:** describe the ultrasound features of common focal liver lesions
- **SLO 4.3:** describe the ultrasound features of pancreatic disease
- **SLO 4.4:** describe the ultrasound features of gallstones, cholecystitis, and biliary obstruction
- **SLO 4.5:** describe the ultrasound features of acute appendicitis
- **SLO 4.6:** describe the ultrasound features of colonic tumours and the limitations of ultrasound in bowel imaging
- **SLO 4.7:** describe the ultrasound features of a cystic lesion, and
- **SLO 4.8:** describe the ultrasound features of a solid lesion and pitfalls in differentiating cystic from solid lesions.

4.1 Ultrasound of the Liver

4.1.1 normal liver ultrasound appearance

A homogeneous, moderately echogenic parenchyma

The **normal liver** on ultrasound demonstrates homogeneous, moderately echogenic parenchyma, discussed in relation to ultrasound tissue properties in an earlier related course, generally slightly more echogenic than the adjacent renal cortex, with a smooth, well defined capsular **margin** and clearly visualised portal and hepatic venous branches.

Systematic assessment of the liver additionally includes measurement of overall liver **size**, assessment of the intrahepatic and extrahepatic bile ducts for dilatation, discussed further later in this Series, and evaluation of the hepatic vasculature, including portal vein calibre and **flow direction**, using Doppler ultrasound, discussed in an earlier related course.

Fill in the blank: The normal liver demonstrates homogeneous, moderately echogenic parenchyma, generally slightly more echogenic than the adjacent renal ________.

4.1.2 ultrasound features of diffuse liver disease

Hepatic steatosis, or fatty liver, produces diffusely increased liver echogenicity, discussed earlier in this Part, often described as a **bright liver**, with reduced through-transmission of the ultrasound beam and, in more severe cases, obscuration of the normal portal vein wall **definition**.

Cirrhosis produces a coarsened, heterogeneous liver echotexture with an irregular, nodular surface contour, often accompanied by relative shrinkage of the right lobe with compensatory enlargement of the left lobe and caudate lobe, together with signs of portal hypertension, including splenomegaly and portal vein **dilatation**.

Fill in the blank: Cirrhosis produces a coarsened, heterogeneous liver echotexture with an irregular, nodular surface contour, often accompanied by signs of portal hypertension including splenomegaly and portal vein ________.

4.1.3 ultrasound features of focal liver lesions

A **simple hepatic cyst**, discussed further in relation to cystic lesion features later in this Series, appears as a well defined, anechoic structure with posterior acoustic enhancement, representing an extremely common, generally clinically insignificant incidental finding, in contrast to solid focal lesions discussed below.

Hepatocellular carcinoma typically presents as a solid mass with variable, often heterogeneous, echogenicity, while metastatic liver deposits, discussed in relation to haematogenous spread in an earlier related course, frequently demonstrate a characteristic **target**, or bull's-eye, appearance, with a relatively hypoechoic peripheral halo surrounding a more echogenic **centre**.

Fill in the blank: Metastatic liver deposits frequently demonstrate a characteristic target, or bull's-eye, appearance, with a relatively hypoechoic peripheral halo surrounding a more echogenic ________.

Table 4.1: Comparing key liver ultrasound findings.

Finding	Ultrasound appearance	Clinical significance
Hepatic steatosis	Diffusely increased echogenicity (bright liver)	Fatty liver disease
Cirrhosis	Coarsened, nodular echotexture with portal hypertension signs	Chronic liver disease
Metastases	Target (bull's-eye) appearance	Secondary malignant deposits

Pilot questions 4.1

- Describe the normal ultrasound appearance of the liver. (Linked to SLO 4.1)
- Describe the ultrasound features of hepatic steatosis. (Linked to SLO 4.1)
- Describe the ultrasound features of cirrhosis. (Linked to SLO 4.1)
- Describe the ultrasound appearance of a simple hepatic cyst. (Linked to SLO 4.2)
- Describe the target (bull's-eye) appearance of liver metastases. (Linked to SLO 4.2)

4.2 Ultrasound of the Pancreas and Gallbladder

4.2.1 ultrasound features of pancreatic disease

A retroperitoneal organ often partly obscured by overlying bowel gas

Acute pancreatitis on ultrasound typically demonstrates a diffusely enlarged, hypoechoic pancreas, discussed in relation to inflammatory oedema earlier in this Series, though the pancreas may be incompletely visualised given frequent obscuration by overlying bowel gas, a recognised practical **limitation** of ultrasound in this anatomical region.

Pancreatic carcinoma, most commonly arising in the pancreatic head, typically presents as a focal, hypoechoic mass, frequently associated with secondary dilatation of the pancreatic **duct**

and, where the tumour obstructs the distal common bile duct, dilatation of the intrahepatic and extrahepatic biliary tree, discussed further in the next sub-Part.

Fill in the blank: Acute pancreatitis on ultrasound typically demonstrates a diffusely enlarged, ________ pancreas.

4.2.2 ultrasound features of gallstones and cholecystitis

Gallstones appear as echogenic, mobile structures within the gallbladder lumen, characteristically demonstrating **posterior acoustic shadowing**, discussed in relation to ultrasound tissue properties in an earlier related course, a reliable feature distinguishing calculi from other non-shadowing intraluminal findings such as sludge or polyps.

Acute cholecystitis demonstrates gallbladder wall thickening, generally exceeding 3 millimetres, pericholecystic fluid, and a positive **sonographic Murphy's sign**, focal tenderness directly over the ultrasound-visualised gallbladder, together with the presence of gallstones in the majority of affected **patients**.

Fill in the blank: Gallstones characteristically demonstrate posterior acoustic ________, a reliable feature distinguishing calculi from other non-shadowing intraluminal findings.

4.2.3 ultrasound features of biliary obstruction

Biliary obstruction produces dilatation of the intrahepatic bile ducts, discussed in relation to normal biliary anatomy earlier in this Series, appearing as tubular, anechoic structures running parallel to the adjacent portal venous branches, sometimes described as a **parallel channel**, or shotgun, appearance.

Common bile duct **dilatation**, generally exceeding 6 to 7 millimetres in an adult, together with the specific level of obstruction identified along its course, provides essential diagnostic information regarding the likely underlying cause, whether choledocholithiasis or an obstructing **mass**, discussed earlier in this Part, guiding further management.

Fill in the blank: Dilated intrahepatic bile ducts running parallel to adjacent portal venous branches are sometimes described as a parallel channel, or shotgun, ________.

Table 4.2: Comparing key gallbladder and biliary ultrasound findings.

Finding	Ultrasound appearance	Clinical significance

Gallstone	Echogenic, mobile focus with posterior acoustic shadowing	Cholelithiasis
Acute cholecystitis	Wall thickening, pericholecystic fluid, positive sonographic Murphy's sign	Gallbladder inflammation
Biliary obstruction	Dilated parallel-channel intrahepatic ducts	Obstructive biliary pathology

Pilot questions 4.2

1. Describe the ultrasound appearance of acute pancreatitis. (Linked to SLO 4.3)
2. Describe the ultrasound appearance of pancreatic carcinoma. (Linked to SLO 4.3)
3. Describe the ultrasound features of gallstones. (Linked to SLO 4.4)
4. Describe the ultrasound features of acute cholecystitis. (Linked to SLO 4.4)
5. Describe the parallel channel appearance of biliary obstruction. (Linked to SLO 4.4)

4.3 Ultrasound of the Appendix and Colon

4.3.1 ultrasound features of acute appendicitis

A non-compressible, thickened tubular structure

Acute appendicitis on ultrasound, generally assessed using a graded compression technique, demonstrates a **non-compressible**, blind-ending tubular structure exceeding **6 millimetres** in outer diameter, discussed in relation to graded compression technique earlier in this sub-Part, representing the primary sonographic criterion for diagnosis.

Further supportive ultrasound findings include a target-like appearance on transverse imaging, discussed in relation to the target appearance of liver metastases earlier in this Series, periappendiceal fat stranding, and, where present, a visible **appendicolith**, an echogenic, shadowing structure within the appendiceal lumen, together with localised free fluid supporting the diagnosis.

Fill in the blank: Acute appendicitis on ultrasound demonstrates a non-compressible, blind-ending tubular structure exceeding 6 millimetres in outer ________.

4.3.2 ultrasound features of colonic tumours

Colonic tumours on ultrasound may produce a characteristic **pseudokidney sign**, a target-like appearance resulting from circumferential tumour infiltration of the bowel wall surrounding a central echogenic mucosal lumen, superficially resembling the appearance of a kidney in cross-section.

This appearance reflects marked, asymmetric bowel wall thickening at the site of tumour involvement, discussed in relation to the target sign appearance earlier in this Series, though ultrasound generally plays a secondary, complementary role to colonoscopy and cross-sectional imaging, discussed further in the next sub-Part, for definitive colonic tumour **characterisation**.

Fill in the blank: Colonic tumours may produce a characteristic pseudokidney sign, resulting from circumferential tumour infiltration of the bowel wall surrounding a central echogenic mucosal ________.

4.3.3 limitations of ultrasound in bowel imaging

Ultrasound assessment of the bowel is generally limited by overlying **gas**, discussed in relation to acoustic impedance in an earlier related course, which strongly reflects the ultrasound beam and obscures deeper structures, meaning bowel gas represents a genuine, frequently encountered practical obstacle to complete abdominal ultrasound assessment.

Further limitations include **operator dependence**, with image quality and diagnostic accuracy varying considerably according to the specific examiner's technique and experience, and the generally more limited ability of ultrasound, compared with CT, discussed in an earlier related course, to comprehensively stage colonic malignancy for distant **metastatic** spread.

Fill in the blank: Ultrasound assessment of the bowel is generally limited by overlying gas, which strongly reflects the ultrasound beam and obscures ________ structures.

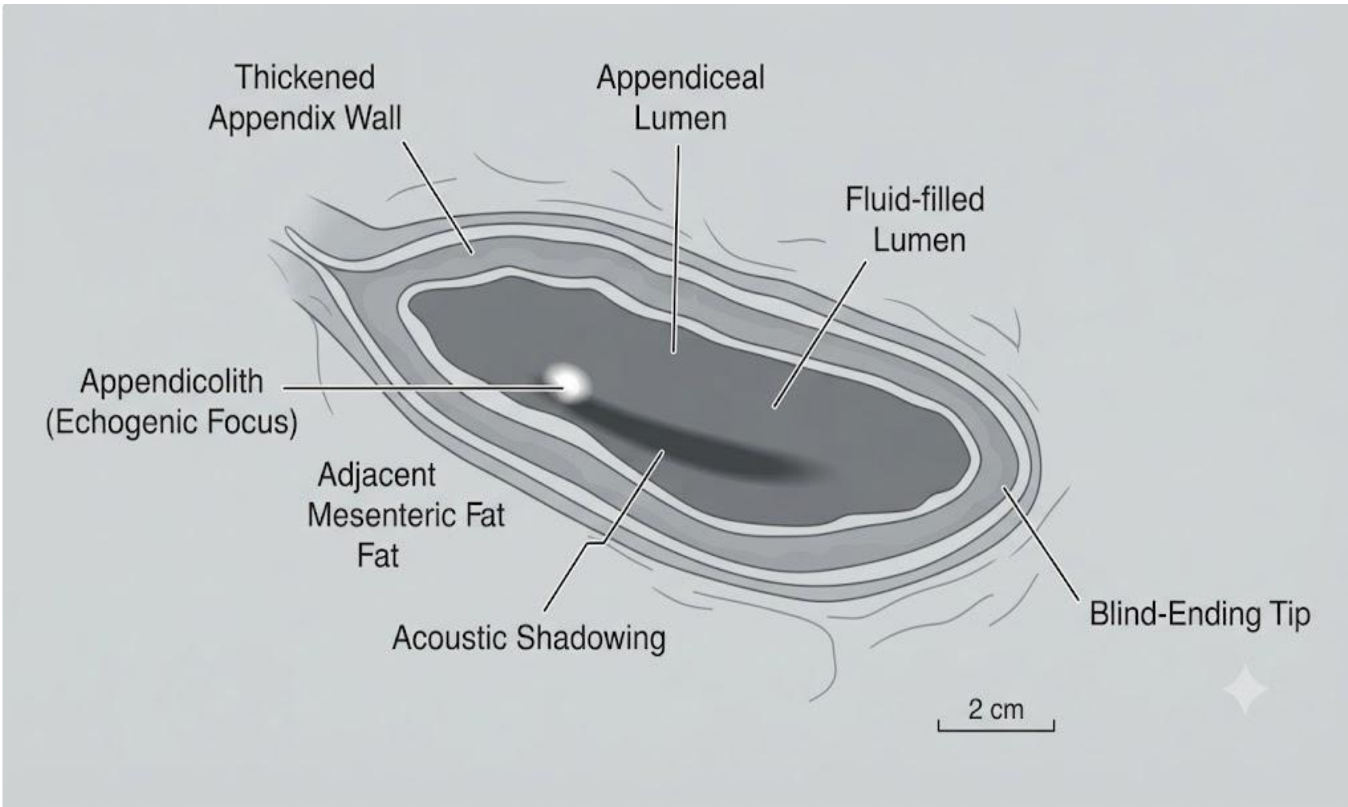

Figure 4.3: Diagram illustrating a non-compressible, thickened appendix on graded compression ultrasound with a visible appendicolith.

Pilot questions 4.3

1. Describe the primary sonographic criterion for diagnosing acute appendicitis. (Linked to SLO 4.5)
2. List two supportive ultrasound findings in acute appendicitis. (Linked to SLO 4.5)
3. Describe the pseudokidney sign of a colonic tumour. (Linked to SLO 4.6)
4. Explain why ultrasound plays only a secondary role in colonic tumour characterisation. (Linked to SLO 4.6)
5. List two general limitations of ultrasound in bowel imaging. (Linked to SLO 4.6)

4.4 Differentiating Cystic from Solid Lesions on Ultrasound

4.4.1 ultrasound features of a cystic lesion

Fluid-filled structures with characteristic transmission properties

A **cystic lesion** on ultrasound is generally characterised by an **anechoic** internal appearance, discussed in relation to tissue homogeneity in an earlier related course, reflecting the absence of internal reflecting interfaces within uniform fluid content, together with a thin, well defined **wall** and smooth, rounded overall contour.

A further essential, highly reliable feature of a simple cystic lesion is **posterior acoustic enhancement**, increased echogenicity of tissue immediately deep to the lesion, resulting from relatively reduced sound beam attenuation while passing through the fluid-filled structure compared with surrounding solid **tissue**.

Fill in the blank: A further essential, highly reliable feature of a simple cystic lesion is posterior acoustic enhancement, resulting from relatively reduced sound beam attenuation while passing through the fluid-filled structure compared with surrounding solid ________.

4.4.2 ultrasound features of a solid lesion

A **solid lesion** on ultrasound demonstrates internal **echoes**, reflecting the presence of multiple internal tissue interfaces, discussed in relation to acoustic impedance in an earlier related course, with echogenicity potentially hypoechoic, isoechoic, or hyperechoic relative to surrounding normal tissue depending on the specific lesion's internal composition.

Solid lesions generally lack the posterior acoustic enhancement characteristic of cystic lesions, discussed in the previous sub-Part, and, depending on their internal composition, may instead demonstrate posterior acoustic **shadowing**, particularly where dense, calcified, or fibrous content substantially attenuates the transmitted ultrasound **beam**.

Fill in the blank: Solid lesions generally lack posterior acoustic enhancement and may instead demonstrate posterior acoustic ________, particularly where dense or calcified content substantially attenuates the beam.

4.4.3 pitfalls in differentiating cystic from solid lesions

A **complex cystic lesion**, containing internal septations, debris, or a solid mural component, discussed in relation to the Bosniak classification of renal cystic lesions in an earlier related course, may demonstrate features overlapping with those of a solid lesion, requiring careful, systematic assessment of all internal characteristics rather than a single simplified anechoic-versus-echogenic distinction.

Technical factors, including inappropriate gain settings or **focal zone** positioning, discussed in relation to ultrasound image formation in an earlier related course, can additionally introduce artefactual internal echoes within a genuinely simple cyst, or conversely obscure genuine internal echoes within a solid lesion, meaning correct technical optimisation remains essential to reliable lesion **characterisation**.

Fill in the blank: Technical factors, including inappropriate gain settings or focal zone positioning, can introduce artefactual internal echoes within a genuinely simple ________.

Table 4.4: Comparing cystic and solid lesion features on ultrasound.

Feature	Cystic lesion	Solid lesion
Internal echoes	Anechoic (echo-free)	Present, variable echogenicity
Posterior acoustic feature	Enhancement	Shadowing (if dense) or none
Wall and contour	Thin, well defined, smooth	Variable, may be irregular

Pilot questions 4.4

1. List the characteristic ultrasound features of a simple cystic lesion. (Linked to SLO 4.7)
2. Define posterior acoustic enhancement and explain its relevance to cystic lesion diagnosis. (Linked to SLO 4.7)
3. List the characteristic ultrasound features of a solid lesion. (Linked to SLO 4.8)
4. Describe a complex cystic lesion and explain why it can be diagnostically challenging. (Linked to SLO 4.8)
5. Describe two technical factors that can affect reliable differentiation of cystic from solid lesions. (Linked to SLO 4.8)

Series Summary

This Series examined **ultrasound of abdominal organs and lesion characterisation**, beginning with **ultrasound of the liver**, normal appearance, diffuse disease, and focal lesions, before turning to **ultrasound of the pancreas and gallbladder**, pancreatic disease, gallstones, cholecystitis, and biliary obstruction.

We then examined **ultrasound of the appendix and colon**, acute appendicitis, colonic tumours, and the limitations of ultrasound in bowel imaging, concluding with **differentiating cystic from solid lesions on ultrasound**, the characteristic features of each and recognised diagnostic pitfalls. Having worked through this Series, you should now be equipped to understand neuroimaging and interventional radiology techniques examined in the final Series of this course.

Glossary of Terms

1. **Hepatic steatosis:** fatty infiltration of the liver, producing diffusely increased echogenicity on ultrasound.
2. **Cirrhosis:** chronic liver disease producing coarsened, nodular echotexture and portal hypertension signs.
3. **Target (bull's-eye) sign:** a hypoechoic halo surrounding a more echogenic centre, characteristic of liver metastases.
4. **Sonographic Murphy's sign:** focal tenderness directly over an ultrasound-visualised inflamed gallbladder.
5. **Parallel channel sign:** dilated intrahepatic bile ducts running alongside portal venous branches, indicating obstruction.
6. **Graded compression technique:** an ultrasound technique applying gradual pressure to assess bowel compressibility.
7. **Appendicolith:** an echogenic, shadowing calcified structure within the appendiceal lumen.
8. **Pseudokidney sign:** a target-like ultrasound appearance from circumferential bowel wall tumour infiltration.
9. **Anechoic:** producing no internal echoes, characteristic of simple fluid-filled structures.
10. **Posterior acoustic enhancement:** increased echogenicity deep to a structure with low sound attenuation, typical of cysts.
11. **Posterior acoustic shadowing:** reduced echogenicity deep to a structure with high sound attenuation, typical of calculi or dense tissue.
12. **Complex cystic lesion:** a cystic lesion containing septations, debris, or a solid component, overlapping with solid lesion features.

Concept Check Questions [Series 4]

Objective questions

- The normal liver demonstrates homogeneous, moderately echogenic parenchyma, generally slightly more echogenic than the adjacent renal ________.
- Gallstones characteristically demonstrate posterior acoustic ________.
- Acute appendicitis on ultrasound demonstrates a non-compressible, blind-ending tubular structure exceeding 6 millimetres in outer ________.
- A cystic lesion is characterised by posterior acoustic enhancement, resulting from reduced sound beam attenuation compared with surrounding solid ________.
- Solid lesions may instead demonstrate posterior acoustic ________, particularly where dense or calcified content attenuates the beam.

Short-answer questions

1. Describe the ultrasound features of cirrhosis.
2. Describe the ultrasound features of acute cholecystitis.
3. Describe the pseudokidney sign of a colonic tumour.
4. Define posterior acoustic enhancement and explain its relevance to cystic lesion diagnosis.
5. Describe a complex cystic lesion and explain why it can be diagnostically challenging.

Long-answer questions

6. Discuss the normal ultrasound appearance of the liver and the ultrasound features of diffuse and focal liver disease. (Linked to SLO 4.1, SLO 4.2)
7. Discuss the ultrasound features of pancreatic disease, gallstones, cholecystitis, and biliary obstruction. (Linked to SLO 4.3, SLO 4.4)
8. Discuss the ultrasound features of acute appendicitis and colonic tumours, and the limitations of ultrasound in bowel imaging. (Linked to SLO 4.5, SLO 4.6)
9. Discuss the ultrasound features distinguishing cystic from solid lesions. (Linked to SLO 4.7, SLO 4.8)
10. Discuss the pitfalls in differentiating cystic from solid lesions on ultrasound. (Linked to SLO 4.8)

Answers to Concept Check Questions [Series 4]

Objective questions

11. Cortex.
12. Shadowing.
13. Diameter.
14. Tissue.
15. Shadowing.

Short-answer questions

16. A coarsened, heterogeneous echotexture with an irregular, nodular surface and signs of portal hypertension such as splenomegaly.
17. Gallbladder wall thickening exceeding 3 millimetres, pericholecystic fluid, and a positive sonographic Murphy's sign.
18. A target-like appearance from circumferential tumour infiltration of the bowel wall surrounding a central echogenic mucosal lumen.
19. Increased echogenicity deep to a lesion from reduced sound attenuation; it is a highly reliable feature confirming a simple cystic lesion.
20. A cystic lesion with septations, debris, or a solid component; it can overlap with solid lesion features, complicating diagnosis.

Long-answer questions

21. **Basic response:** The normal liver shows homogeneous, moderately echogenic parenchyma, while steatosis shows diffusely increased echogenicity and cirrhosis shows coarsened, nodular echotexture with portal hypertension signs.

Value-added response: Focal lesions range from simple anechoic cysts to solid masses such as hepatocellular carcinoma or the characteristic target appearance of metastases.

22. **Basic response:** Pancreatic disease includes diffusely enlarged, hypoechoic acute pancreatitis and focal hypoechoic pancreatic carcinoma, often with ductal dilatation.

Value-added response: Gallstones show echogenic, shadowing foci, cholecystitis shows wall thickening and a positive Murphy's sign, and biliary obstruction shows the parallel channel sign of dilated ducts.

23. **Basic response:** Acute appendicitis shows a non-compressible, thickened tubular structure exceeding 6mm, sometimes with an appendicolith, while colonic tumours may show the pseudokidney sign.

Value-added response: Ultrasound is limited in bowel imaging by overlying gas, operator dependence, and reduced staging capability compared with CT.

24. **Basic response:** Cystic lesions show an anechoic appearance, thin walls, and posterior acoustic enhancement, while solid lesions show internal echoes and variable echogenicity without this enhancement.

Value-added response: These features together form the fundamental basis for lesion characterisation across nearly every abdominal ultrasound examination.

25. **Basic response:** Complex cystic lesions with septations or solid components can overlap with solid lesion appearance, requiring careful systematic assessment.

Value-added response: Technical factors, including gain and focal zone settings, can introduce artefactual echoes or obscure genuine ones, meaning correct technique remains essential to reliable characterisation.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Homogeneous, moderately echogenic parenchyma, slightly more echogenic than the renal cortex, with a smooth capsular margin.
2. Diffusely increased echogenicity, often described as a bright liver, with reduced through-transmission.
3. Coarsened, heterogeneous echotexture with an irregular, nodular surface and signs of portal hypertension.
4. A well defined, anechoic structure with posterior acoustic enhancement.
5. A hypoechoic peripheral halo surrounding a more echogenic centre.

Part 4.2

6. A diffusely enlarged, hypoechoic pancreas, sometimes incompletely visualised due to overlying bowel gas.
7. A focal, hypoechoic mass, often with secondary pancreatic duct dilatation and, where obstructing, biliary dilatation.

8. Echogenic, mobile intraluminal structures demonstrating posterior acoustic shadowing.
9. Gallbladder wall thickening, pericholecystic fluid, and a positive sonographic Murphy's sign.
10. Dilated intrahepatic bile ducts running parallel to adjacent portal venous branches, resembling a shotgun pattern.

Part 4.3

11. A non-compressible, blind-ending tubular structure exceeding 6 millimetres in outer diameter.
12. A target-like transverse appearance and periappendiceal fat stranding, among others such as a visible appendicolith.
13. A target-like appearance from circumferential tumour infiltration of the bowel wall surrounding a central echogenic lumen.
14. Because ultrasound has more limited capability for comprehensive staging of distant metastatic spread compared with CT and colonoscopy.
15. Obscuration by overlying bowel gas, and operator dependence affecting image quality and accuracy.

Part 4.4

1. Anechoic internal appearance, thin well defined wall, smooth contour, and posterior acoustic enhancement.
2. Increased echogenicity deep to the lesion from reduced attenuation; it reliably confirms a simple fluid-filled structure.
3. Internal echoes of variable echogenicity, absence of posterior enhancement, and possible posterior shadowing if dense.
4. A cystic lesion containing septations, debris, or a solid mural component; it can overlap with solid lesion features, complicating diagnosis.
5. Inappropriate gain settings and incorrect focal zone positioning, which can introduce or obscure internal echoes.

References and Attributions [Series 4]

1. Hoskins, P. R., Martin, K., & Thrush, A. (Eds.). (2019). Diagnostic Ultrasound: Physics and Equipment (3rd ed.). Cambridge University Press.
2. Chapman, S., & Nakielny, R. (2014). Aids to Radiological Differential Diagnosis (6th ed.). Elsevier.
3. Rumack, C. M., & Levine, D. (Eds.). (2017). Diagnostic Ultrasound (5th ed.). Elsevier.
4. Whitehouse, R. W., & Adams, J. E. (Eds.). (2016). Clinical Radiology: A Guide for Practitioners (5th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

1. Table 4.1: Comparing key liver ultrasound findings. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Liver Ultrasound Findings, listing finding, ultrasound appearance, and clinical significance. Radiology reference table style with outside border, no photographic elements."
2. Table 4.2: Comparing key gallbladder and biliary ultrasound findings. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Gallbladder and Biliary Ultrasound Findings, listing finding, ultrasound appearance, and clinical significance. Radiology reference table style with outside border, no photographic elements."
3. Figure 4.3: Diagram illustrating a non-compressible, thickened appendix on graded compression ultrasound with a visible appendicolith. AI-generated using the prompt: "A single clean, accurate schematic ultrasound diagram showing a thickened, tubular, blind-ending structure in longitudinal section with a small labelled echogenic shadowing focus within the lumen representing an appendicolith, radiology teaching diagram style, neutral background, no photographic realism, no other panels."
4. Table 4.4: Comparing cystic and solid lesion features on ultrasound. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Cystic and Solid Lesion Features on Ultrasound, listing feature, cystic lesion, and solid lesion. Radiology reference table style with outside border, no photographic elements."

Course code: RAD 603

Course title: Radiology Procedures and Results Interpretation

Course credit load: 2 Units

Series 5: Neuroimaging and Interventional Radiology Techniques

- **Part 5.1: Head Injury Imaging and Skull Fractures**
  - Sub Part 5.1.1: Indications for neuroimaging in head injury
  - Sub Part 5.1.2: Types of skull fracture
  - Sub Part 5.1.3: Imaging features distinguishing fracture types
- **Part 5.2: Intracranial Haematoma**
  - Sub Part 5.2.1: Extradural haematoma
  - Sub Part 5.2.2: Subdural haematoma
  - Sub Part 5.2.3: Intracerebral and subarachnoid haemorrhage
- **Part 5.3: Mass Effect on CT**
  - Sub Part 5.3.1: The concept of mass effect
  - Sub Part 5.3.2: Signs of mass effect on CT
  - Sub Part 5.3.3: Clinical significance of mass effect
- **Part 5.4: Interventional Radiology Instruments and Techniques**
  - Sub Part 5.4.1: The cannula and guide wire
  - Sub Part 5.4.2: Stents and coils
  - Sub Part 5.4.3: Basic technique for ultrasound-guided biopsy and drainage

Introduction

In the last Series, we established ultrasound interpretation across the liver, pancreas, gallbladder, appendix, and colon, together with the essential distinction between cystic and solid lesions. We now conclude this course with **neuroimaging** in head injury, skull fractures, intracranial haematoma, and **mass effect** on CT, together with the essential **instruments** and **basic techniques** underlying interventional radiology practice.

The aim of this Series is to equip you with a thorough understanding of the indications and interpretation of common neurological disorders and head injury, different types of skull fracture and intracranial haematoma, mass effect on CT scan images, instruments used in interventional radiology, and the basic technique for ultrasound-guided biopsies and drainage procedures.

This Series begins with **head injury imaging and skull fractures**, before turning to **intracranial haematoma**. We then examine **mass effect on CT**, concluding with **interventional radiology instruments and techniques**.

Series Learning Outcomes

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

- **SLO 5.1:** list the indications for neuroimaging in head injury and describe the types of skull fracture
- **SLO 5.2:** describe the imaging features distinguishing different types of skull fracture
- **SLO 5.3:** describe the imaging features of extradural haematoma
- **SLO 5.4:** describe the imaging features of subdural haematoma, intracerebral haemorrhage, and subarachnoid haemorrhage
- **SLO 5.5:** explain the concept of mass effect on CT scan images
- **SLO 5.6:** describe the signs of mass effect on CT and their clinical significance
- **SLO 5.7:** list instruments used in interventional radiology, including the cannula, guide wires, stents, and coils, and
- **SLO 5.8:** describe the basic technique for ultrasound-guided biopsies and drainage procedures.

5.1 Head Injury Imaging and Skull Fractures

5.1.1 indications for neuroimaging in head injury

Selecting patients warranting urgent CT after head trauma

Neuroimaging, generally **CT**, discussed in relation to CT physical principles in an earlier related course, is indicated following head injury where specific clinical warning features are present, including loss of consciousness, persistent or worsening headache, vomiting, focal neurological deficit, or a deteriorating conscious level.

Further recognised indications include suspected open or depressed skull fracture, discussed further in the next sub-Part, clinical signs suggestive of a base of skull fracture, such as **cerebrospinal fluid otorrhoea** or periorbital bruising, and any coagulopathy or anticoagulant use given the increased risk of clinically significant intracranial **haemorrhage**, discussed further later in this Series.

Fill in the blank: Indications for neuroimaging following head injury include clinical signs suggestive of a base of skull fracture, such as cerebrospinal fluid ________.

5.1.2 types of skull fracture

Linear skull fractures appear as a sharply defined lucent line without displacement of fracture fragments, discussed in relation to bony detail on CT in an earlier related course, generally the least clinically significant fracture type in isolation, though still warranting assessment for any associated intracranial injury.

Depressed skull fractures, in which a fracture fragment is displaced inward relative to the adjacent skull table, carry increased risk of direct underlying brain injury, while **basal skull fractures**, involving the skull base, discussed earlier in this Part, may be more subtle on direct visualisation, often inferred instead from secondary signs such as air-fluid levels within the adjacent paranasal **sinuses**.

Fill in the blank: Depressed skull fractures, in which a fracture fragment is displaced inward relative to the adjacent skull table, carry increased risk of direct underlying brain ________.

5.1.3 imaging features distinguishing fracture types

A **linear fracture** should be distinguished from a normal cranial **suture**, discussed in relation to normal skull anatomy in an earlier related course, based on its typically straighter course, sharper margins, and lack of the characteristic serrated, interdigitating appearance and symmetrical location characteristic of normal sutures.

Diastatic fractures, in which a fracture line traverses and widens an existing cranial suture, and **comminuted fractures**, comprising multiple fracture fragments, discussed in relation to depressed fractures earlier in this Part, represent further recognised fracture patterns each carrying distinct implications for the likely severity of the underlying head **injury**.

Fill in the blank: A diastatic fracture is one in which a fracture line traverses and widens an existing cranial ________.

Table 5.1: Comparing types of skull fracture.

Fracture type	Key feature	Clinical significance
Linear	Sharply defined lucent line, no displacement	Generally least clinically significant in isolation
Depressed	Fragment displaced inward	Increased risk of underlying brain injury
Basal (skull base)	Often subtle; inferred from sinus air-fluid levels	Risk of CSF leak and meningitis

Pilot questions 5.1

- List three indications for neuroimaging following head injury. (Linked to SLO 5.1)
- Describe the imaging appearance of a linear skull fracture. (Linked to SLO 5.1)
- Describe a depressed skull fracture and its clinical significance. (Linked to SLO 5.1)
- Explain how a linear fracture is distinguished from a normal cranial suture. (Linked to SLO 5.2)
- Define a diastatic fracture. (Linked to SLO 5.2)

5.2 Intracranial Haematoma

5.2.1 extradural haematoma

A biconvex collection typically limited by cranial sutures

Extradural haematoma, generally resulting from arterial injury, most commonly the **middle meningeal artery**, discussed in relation to skull fracture earlier in this Series, appears on CT as a **biconvex**, or lens-shaped, hyperdense collection between the skull and dura mater.

Extradural haematomas characteristically do **not cross cranial suture lines**, since the dura remains firmly adherent to the skull at these specific points, in direct contrast to subdural haematoma, discussed further in the next sub-Part, providing an important distinguishing imaging **feature**.

Fill in the blank: Extradural haematomas characteristically do not cross cranial suture lines, since the dura remains firmly adherent to the skull at these specific ________.

5.2.2 subdural haematoma

Subdural haematoma, generally resulting from tearing of **bridging veins**, discussed in relation to venous injury mechanisms in an earlier related course, appears on CT as a **crescent-shaped**, or concave, hyperdense collection between the dura mater and underlying arachnoid membrane.

Unlike extradural haematoma, discussed earlier in this Part, subdural haematoma **can cross cranial suture lines**, since it is not constrained by dural attachment at these points, though it cannot cross the midline dural reflections, such as the falx cerebri, providing a further useful distinguishing **feature**.

Fill in the blank: Unlike extradural haematoma, subdural haematoma can cross cranial suture lines, though it cannot cross the ________ dural reflections, such as the falx cerebri.

5.2.3 intracerebral and subarachnoid haemorrhage

Intracerebral haemorrhage appears as a hyperdense collection located directly within the brain parenchyma itself, discussed in relation to normal brain anatomy in an earlier related course, generally resulting from direct traumatic contusion or, in non-traumatic cases, hypertensive vascular rupture or an underlying vascular malformation.

Subarachnoid haemorrhage appears as hyperdense material filling the normally low-density cerebrospinal fluid spaces, discussed in relation to cerebrospinal fluid earlier in this Series, including the basal cisterns and cortical sulci, generally resulting from trauma or, non-traumatically, rupture of an intracranial **aneurysm**.

Fill in the blank: Subarachnoid haemorrhage appears as hyperdense material filling the normally low-density cerebrospinal fluid spaces, generally resulting from trauma or, non-traumatically, rupture of an intracranial ________.

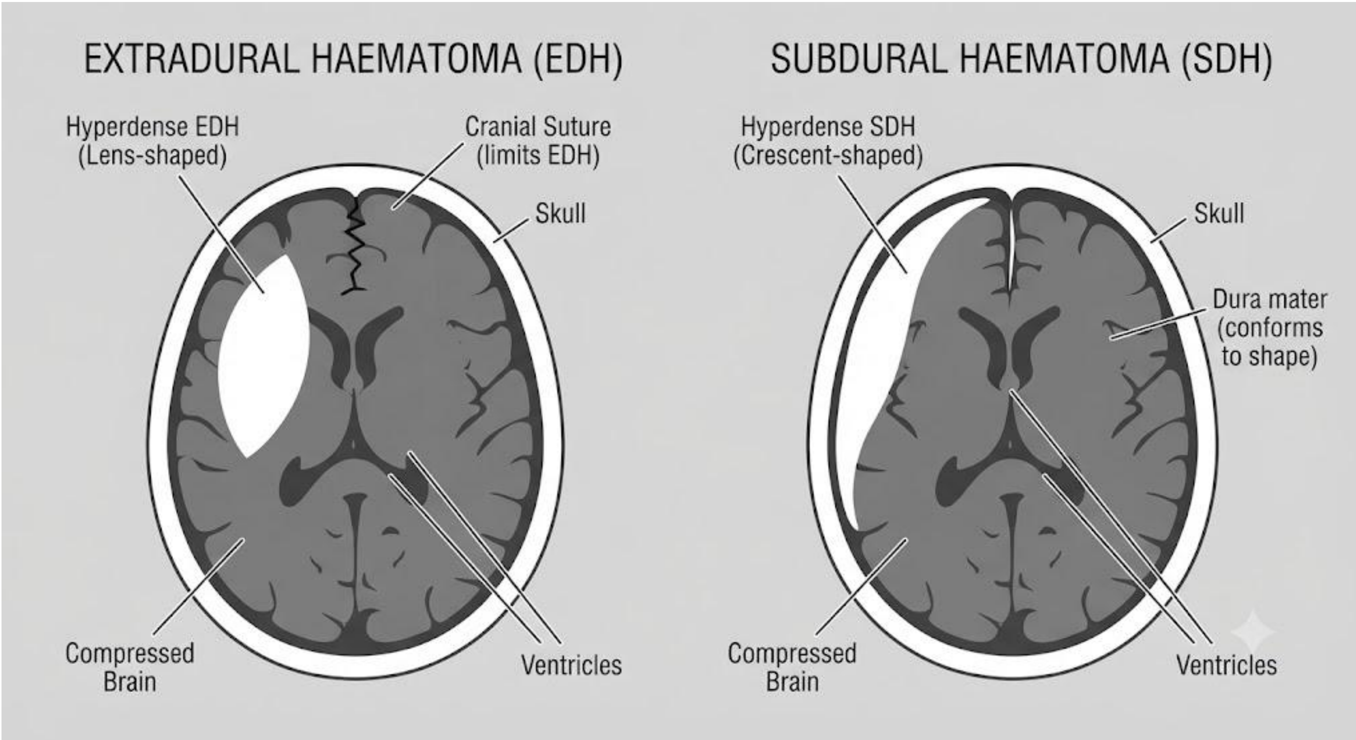

Figure 5.2: Diagram comparing the biconvex, suture-limited shape of extradural haematoma with the crescent-shaped, suture-crossing appearance of subdural haematoma on CT.

Pilot questions 5.2

1. Describe the typical CT appearance and causative vessel of extradural haematoma. (Linked to SLO 5.3)
2. Explain why extradural haematoma does not cross cranial suture lines. (Linked to SLO 5.3)
3. Describe the typical CT appearance and causative structure of subdural haematoma. (Linked to SLO 5.4)
4. Explain why subdural haematoma can cross suture lines but not the midline. (Linked to SLO 5.4)
5. Distinguish intracerebral haemorrhage from subarachnoid haemorrhage in terms of location. (Linked to SLO 5.4)

5.3 Mass Effect on CT

5.3.1 the concept of mass effect

Physical displacement of normal structures by an expanding lesion

Mass effect refers to the physical displacement of normal anatomical structures resulting from an expanding lesion, whether haematoma, discussed earlier in this Series, tumour, or oedema, occupying space within the relatively fixed, confined volume of the **cranial cavity**.

Because the skull represents a rigid, essentially non-expansile container, any significant space-occupying process must displace or compress adjacent normal structures, meaning recognising mass effect represents an essential component of CT interpretation directly relevant to assessing overall clinical **severity**.

Fill in the blank: Because the skull represents a rigid, essentially non-expansile container, any significant space-occupying process must displace or ________ adjacent normal structures.

5.3.2 signs of mass effect on ct

Recognised signs of mass effect include **midline shift**, displacement of central structures such as the septum pellucidum or third ventricle away from the midline, discussed in relation to mediastinal shift principles in an earlier related course, and effacement, or loss of visibility, of the normal cortical **sulci** adjacent to the lesion.

Further recognised signs include compression or effacement of the adjacent lateral **ventricle**, and, in more severe cases, **herniation**, displacement of brain tissue across a normal anatomical boundary, such as uncal or tonsillar herniation, representing the most severe manifestation of mass effect with direct life-threatening **implications**.

Fill in the blank: Further recognised signs of mass effect include compression or effacement of the adjacent lateral ________.

5.3.3 clinical significance of mass effect

The presence and **degree** of mass effect carries direct clinical significance, since even a relatively small lesion producing substantial midline shift or early herniation, discussed earlier in this Part, may represent a genuine neurosurgical emergency requiring urgent intervention, regardless of the lesion's absolute size alone.

Conversely, a larger lesion producing minimal mass effect, reflecting either slow growth allowing physiological **compensation** or a relatively non-eloquent anatomical location, may be managed less urgently, meaning careful assessment of mass effect, rather than lesion size in isolation, represents an essential determinant of appropriate clinical **urgency**.

Fill in the blank: A larger lesion producing minimal mass effect may reflect slow growth allowing physiological ________, meaning careful assessment of mass effect represents an essential determinant of clinical urgency.

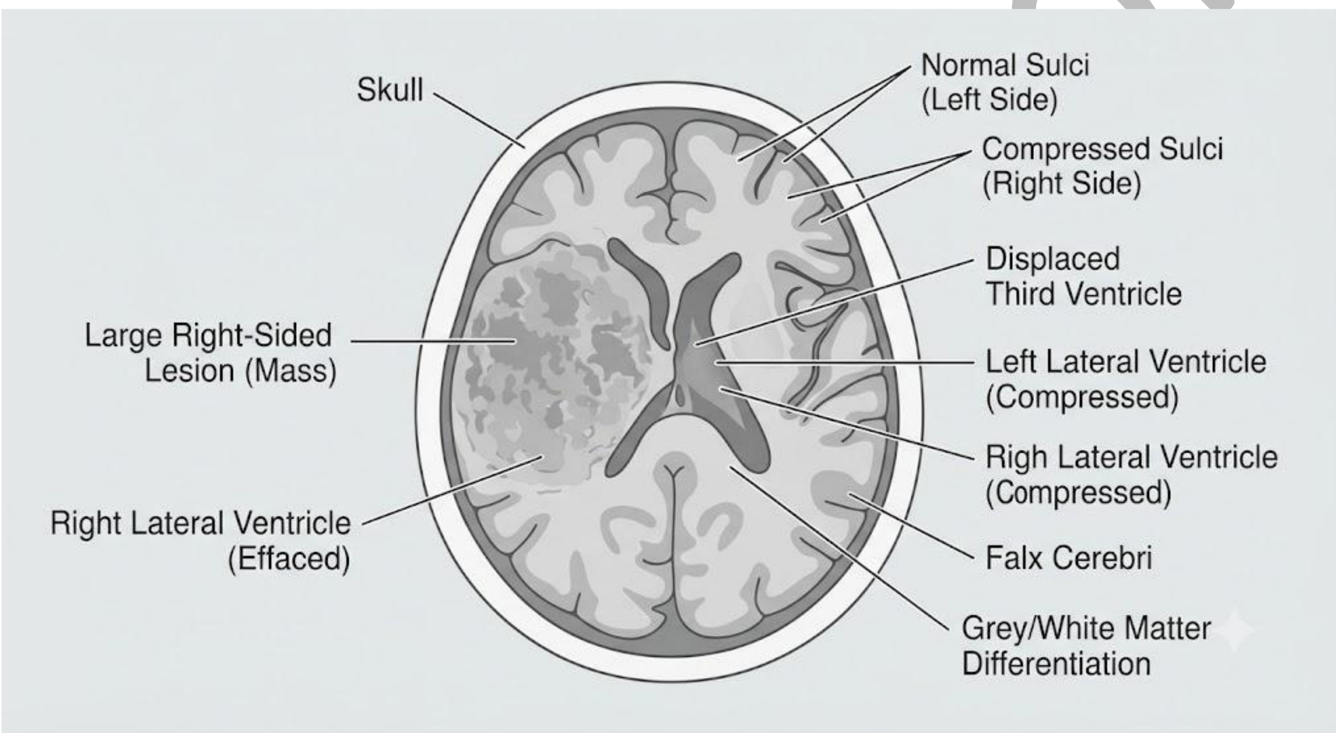

Figure 5.3: Diagram illustrating midline shift and sulcal effacement as CT signs of mass effect from a space-occupying lesion.

Pilot questions 5.3

1. Define mass effect on CT. (Linked to SLO 5.5)
2. Explain why the rigid skull produces mass effect from any significant space-occupying process. (Linked to SLO 5.5)
3. List three recognised signs of mass effect on CT. (Linked to SLO 5.6)
4. Define herniation and explain its clinical significance. (Linked to SLO 5.6)
5. Explain why the degree of mass effect, rather than lesion size alone, determines clinical urgency. (Linked to SLO 5.6)

5.4 Interventional Radiology Instruments and Techniques

5.4.1 the cannula and guide wire

The essential first tools establishing vascular or percutaneous access

The **cannula**, or needle-sheath device, discussed in relation to interventional radiology principles in an earlier related course, provides the initial percutaneous access point into a vessel or body cavity, generally the first instrument used in any interventional radiological procedure requiring subsequent instrument passage.

The **guide wire**, a thin, flexible wire advanced through the cannula, discussed earlier in this Part, provides a stable, steerable pathway along which subsequent catheters or other devices can be safely advanced, with guide wires available in varying stiffness and tip configuration **suited** to navigating different vascular anatomy or degrees of tortuosity.

Fill in the blank: The guide wire provides a stable, steerable pathway along which subsequent catheters or other devices can be safely ________.

5.4.2 stents and coils

A **stent** is a tubular, generally expandable metallic or polymer device, discussed in relation to ureteral stenting in an earlier related course, deployed to maintain patency of a vessel or duct narrowed by stricture, tumour compression, or atherosclerotic disease, providing durable, long-term structural **support**.

Coils, small metallic devices deployed through a catheter, discussed earlier in this Part, achieve controlled, targeted vessel **occlusion**, generally used to treat aneurysms or to control active haemorrhage by promoting thrombosis within the specific targeted vessel or vascular abnormality.

Fill in the blank: Coils achieve controlled, targeted vessel occlusion, generally used to treat aneurysms or to control active haemorrhage by promoting ________ within the targeted vessel.

5.4.3 basic technique for ultrasound-guided biopsy and drainage

Ultrasound-guided biopsy involves real-time ultrasound visualisation, discussed in the previous Series of this course, of both the target lesion and the advancing biopsy **needle**, allowing precise, continuously monitored needle placement while avoiding injury to adjacent critical structures throughout the procedure.

Ultrasound-guided drainage similarly uses real-time guidance to direct a drainage catheter into a target fluid collection, discussed in relation to abscess drainage in an earlier related course, generally using either a direct trocar technique or a **Seldinger technique**, employing an initial needle, guide wire, and subsequent catheter exchange over the wire, discussed earlier in this Part.

Fill in the blank: Ultrasound-guided drainage generally uses either a direct trocar technique or a Seldinger technique, employing an initial needle, guide wire, and subsequent catheter ________ over the wire.

Table 5.4: Comparing key interventional radiology instruments.

Instrument	Function	Typical use
Cannula	Establishes initial percutaneous access	First step of most interventional procedures
Guide wire	Provides a steerable pathway for catheter passage	Navigating vessels or ducts to the target site
Stent	Maintains structural patency	Strictures, tumour compression, or atherosclerotic narrowing
Coil	Achieves targeted vessel occlusion	Aneurysm treatment or haemorrhage control

Pilot questions 5.4

1. Describe the function of the cannula in interventional radiology. (Linked to SLO 5.7)
2. Describe the function of the guide wire. (Linked to SLO 5.7)
3. Describe the function and typical use of a stent. (Linked to SLO 5.7)
4. Describe the function and typical use of a coil. (Linked to SLO 5.7)
5. Describe the basic technique for ultrasound-guided biopsy and drainage, including the Seldinger technique. (Linked to SLO 5.8)

Series Summary

This final Series examined **neuroimaging and interventional radiology techniques**, beginning with **head injury imaging and skull fractures**, the indications for neuroimaging and the imaging features distinguishing linear, depressed, basal, and diastatic fractures, before turning to **intracranial haematoma**, extradural, subdural, intracerebral, and subarachnoid haemorrhage.

We then examined **mass effect on CT**, its concept, recognised signs, and clinical significance, concluding with **interventional radiology instruments and techniques**, the cannula, guide wire, stents, coils, and the basic technique for ultrasound-guided biopsy and drainage. Having worked through this Series, and indeed this entire course, you should now possess a comprehensive, practically grounded foundation in radiology procedures and results interpretation, from contrast study technique through peptic ulcer and gastric pathology, chest radiograph interpretation, abdominal ultrasound, and, finally, neuroimaging and interventional radiology addressed throughout RAD 603.

Glossary of Terms

1. **Linear skull fracture:** a sharply defined lucent fracture line without fragment displacement.
2. **Depressed skull fracture:** a fracture in which a fragment is displaced inward relative to the skull table.
3. **Diastatic fracture:** a fracture that traverses and widens an existing cranial suture.
4. **Extradural haematoma:** a biconvex hyperdense collection between the skull and dura, not crossing sutures.
5. **Subdural haematoma:** a crescent-shaped hyperdense collection between the dura and arachnoid, crossing sutures but not the midline.
6. **Subarachnoid haemorrhage:** hyperdense blood filling the cerebrospinal fluid spaces, including cisterns and sulci.
7. **Mass effect:** physical displacement of normal structures by an expanding intracranial lesion.
8. **Midline shift:** displacement of central brain structures away from the midline, a sign of mass effect.
9. **Herniation:** displacement of brain tissue across a normal anatomical boundary, a severe form of mass effect.
10. **Guide wire:** a thin, flexible wire providing a steerable pathway for catheter or device passage.
11. **Stent:** a tubular device maintaining patency of a narrowed vessel or duct.
12. **Seldinger technique:** an access technique using an initial needle, guide wire, and catheter exchange over the wire.

Concept Check Questions [Series 5]

Objective questions

- Depressed skull fractures, in which a fragment is displaced inward, carry increased risk of direct underlying brain ________.
- Extradural haematoma does not cross cranial suture lines, since the dura remains firmly adherent to the skull at these ________.
- Subdural haematoma can cross cranial suture lines, though it cannot cross the ________ dural reflections, such as the falx cerebri.
- Because the skull is a rigid, non-expansile container, any significant space-occupying process must displace or ________ adjacent normal structures.
- Ultrasound-guided drainage may use a Seldinger technique, employing an initial needle, guide wire, and catheter ________ over the wire.

Short-answer questions

1. List three indications for neuroimaging following head injury.
2. Describe the typical CT appearance and causative vessel of extradural haematoma.
3. Distinguish intracerebral haemorrhage from subarachnoid haemorrhage in terms of location.
4. List three recognised signs of mass effect on CT.
5. Describe the function of a stent and a coil in interventional radiology.

Long-answer questions

6. Discuss the indications for neuroimaging in head injury and the types and distinguishing imaging features of skull fracture. (Linked to SLO 5.1, SLO 5.2)
7. Discuss the imaging features of extradural haematoma, subdural haematoma, intracerebral haemorrhage, and subarachnoid haemorrhage. (Linked to SLO 5.3, SLO 5.4)
8. Discuss the concept of mass effect, its signs on CT, and its clinical significance. (Linked to SLO 5.5, SLO 5.6)
9. Discuss instruments used in interventional radiology, including the cannula, guide wires, stents, and coils. (Linked to SLO 5.7)
10. Discuss the basic technique for ultrasound-guided biopsies and drainage procedures. (Linked to SLO 5.8)

Answers to Concept Check Questions [Series 5]

Objective questions

11. Injury.
12. Points.
13. Midline.
14. Compress.
15. Exchange.

Short-answer questions

16. Loss of consciousness, persistent or worsening headache, vomiting, focal neurological deficit, or deteriorating conscious level.
17. A biconvex, hyperdense collection between the skull and dura; generally caused by middle meningeal artery injury.
18. Intracerebral haemorrhage lies within the brain parenchyma; subarachnoid haemorrhage fills the cerebrospinal fluid spaces including cisterns and sulci.
19. Midline shift, sulcal effacement, and ventricular compression, among others such as herniation.
20. A stent maintains structural patency of a narrowed vessel or duct; a coil achieves targeted vessel occlusion, used for aneurysms or haemorrhage control.

Long-answer questions

21. **Basic response:** Neuroimaging after head injury is indicated for loss of consciousness, worsening symptoms, focal deficit, or signs of basal skull fracture.

Value-added response: Skull fractures are classified as linear, depressed, basal, or diastatic, each distinguished by specific imaging features and carrying different clinical implications.

22. **Basic response:** Extradural haematoma appears biconvex and suture-limited from arterial injury, while subdural haematoma appears crescentic and can cross sutures but not the midline from venous injury.

Value-added response: Intracerebral haemorrhage lies within the brain parenchyma, while subarachnoid haemorrhage fills the cerebrospinal fluid spaces, each with distinct causes and imaging appearances.

23. **Basic response:** Mass effect reflects displacement of normal structures by an expanding lesion within the rigid cranial cavity, recognised by midline shift, sulcal effacement, and ventricular compression.

Value-added response: The degree of mass effect, rather than lesion size alone, determines clinical urgency, with herniation representing its most severe, life-threatening manifestation.

24. **Basic response:** The cannula establishes initial access, the guide wire provides a steerable pathway, the stent maintains structural patency, and the coil achieves targeted vessel occlusion.

Value-added response: Together these instruments form the essential basic toolkit underlying most interventional radiology procedures.

25. **Basic response:** Ultrasound-guided biopsy and drainage use real-time imaging to precisely direct a needle or catheter to the target, using direct trocar or Seldinger technique.

Value-added response: This image-guided approach minimises injury to adjacent structures while achieving diagnostic or therapeutic goals with minimally invasive access.

Answers to Pilot Questions [Series 5]

Part 5.1

1. Loss of consciousness, persistent or worsening headache, and focal neurological deficit.
2. A sharply defined lucent line without displacement of fracture fragments.
3. A fracture with a fragment displaced inward relative to the skull table; increased risk of underlying brain injury.
4. By its straighter course, sharper margins, and lack of the serrated, symmetrical appearance of a normal suture.
5. A fracture that traverses and widens an existing cranial suture.

Part 5.2

6. A biconvex, hyperdense collection between the skull and dura; generally caused by middle meningeal artery injury.
7. Because the dura remains firmly adherent to the skull at suture lines, limiting spread beyond them.

8. A crescent-shaped, hyperdense collection between the dura and arachnoid; generally caused by bridging vein tearing.
9. Because it is not constrained by dural attachment at sutures but is constrained by the dural reflection at the midline.
10. Intracerebral haemorrhage lies within the brain parenchyma; subarachnoid haemorrhage fills the cerebrospinal fluid spaces.

Part 5.3

11. The physical displacement of normal structures resulting from an expanding lesion within the cranial cavity.
12. Because the skull cannot expand, any significant space-occupying lesion must displace or compress adjacent structures.
13. Midline shift, sulcal effacement, and ventricular compression.
14. Displacement of brain tissue across an anatomical boundary; it represents the most severe, life-threatening form of mass effect.
15. Because a small lesion with substantial mass effect may be more urgent than a larger lesion with minimal mass effect due to compensation.

Part 5.4

1. It provides the initial percutaneous access point into a vessel or body cavity.
2. It provides a stable, steerable pathway along which catheters or devices can be safely advanced.
3. It maintains patency of a vessel or duct narrowed by stricture, tumour, or atherosclerosis, providing structural support.
4. It achieves controlled, targeted vessel occlusion, used to treat aneurysms or control haemorrhage.
5. Real-time ultrasound guides needle or catheter placement, using direct trocar or Seldinger technique with needle, guide wire, and catheter exchange.

References and Attributions [Series 5]

1. Osborn, A. G., et al. (2017). Osborn's Brain: Imaging, Pathology, and Anatomy (2nd ed.). Elsevier.
2. National Institute for Health and Care Excellence (2023). Head injury: assessment and early management (NG232).

3. Kandarpa, K., Machan, L., & Durham, J. (Eds.). (2016). Handbook of Interventional Radiologic Procedures (5th ed.). Wolters Kluwer.
4. Chapman, S., & Nakielny, R. (2014). Aids to Radiological Differential Diagnosis (6th ed.). Elsevier.

Figures, Plates, Tables, and Boxes

1. Table 5.1: Comparing types of skull fracture. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Types of Skull Fracture, listing fracture type, key feature, and clinical significance. Radiology reference table style with outside border, no photographic elements."
2. Figure 5.2: Diagram comparing the biconvex, suture-limited shape of extradural haematoma with the crescent-shaped, suture-crossing appearance of subdural haematoma on CT. AI-generated using the prompt: "A single clean, accurate two-panel schematic axial brain CT diagram, one panel labelled extradural haematoma showing a lens-shaped hyperdense collection abruptly ending at a suture line, the other panel labelled subdural haematoma showing a crescent-shaped hyperdense collection extending more broadly along the skull but stopping at the midline, radiology teaching diagram style, neutral background, no photographic realism."
3. Figure 5.3: Diagram illustrating midline shift and sulcal effacement as CT signs of mass effect from a space-occupying lesion. AI-generated using the prompt: "A single clean, accurate schematic axial brain CT diagram showing a labelled lesion on one side, with midline structures displaced toward the opposite side and the sulci near the lesion appearing flattened or absent compared with the normal contralateral side, radiology teaching diagram style, neutral background, no photographic realism, no other panels."
4. Table 5.4: Comparing key interventional radiology instruments. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Key Interventional Radiology Instruments, listing instrument, function, and typical use. Radiology reference table style with outside border, no photographic elements."