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SUG 603

CARDIOTHORACIC INCLUDING VASCULAR SURGERY

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Course code: SUG 603

Course title: Cardiothoracic including Vascular Surgery

Course credit load: 2 Units

Series 1: Symptoms and Signs of Common Lesions in Cardiothoracic and Vascular Surgery

- **Part 1.1: Approach to Cardiothoracic and Vascular Symptoms**
    - Sub Part 1.1.1: Principles of cardiothoracic and vascular history and examination
    - Sub Part 1.1.2: Interpreting cardiac symptoms
    - Sub Part 1.1.3: Interpreting respiratory and chest symptoms
- **Part 1.2: Signs and Symptoms of Common Cardiac Lesions**
    - Sub Part 1.2.1: Valvular heart disease: symptoms and signs
    - Sub Part 1.2.2: Ischaemic heart disease: symptoms and signs
    - Sub Part 1.2.3: Pericardial disease: symptoms and signs
- **Part 1.3: Signs and Symptoms of Common Thoracic Lesions**
    - Sub Part 1.3.1: Lung masses and pulmonary lesions
    - Sub Part 1.3.2: Mediastinal masses
    - Sub Part 1.3.3: Pleural disease: symptoms and signs
- **Part 1.4: Signs and Symptoms of Common Vascular Lesions**
    - Sub Part 1.4.1: Arterial disease: symptoms and signs
    - Sub Part 1.4.2: Aneurysmal disease: symptoms and signs
    - Sub Part 1.4.3: Venous disease: symptoms and signs

Introduction

Chest pain radiating to the jaw, a leg that turns pale and cold on exertion, a persistent cough that will not resolve, each of these everyday complaints could point towards a cardiac, thoracic, or vascular cause, and correctly distinguishing between them from the very first consultation is the essential starting skill this opening Series sets out to build. **Cardiothoracic and vascular**

surgery covers an unusually wide anatomical territory, from the heart and great vessels through the lungs and mediastinum to the peripheral arterial and venous systems, and each region produces its own recognisable pattern of symptoms and signs.

The aim of this Series is to equip you with the ability to enumerate and interpret the symptoms and signs of common lesions across this specialty, covering the general approach to cardiothoracic and vascular assessment, common cardiac lesions, common thoracic lesions, and common vascular lesions. Building this recognition skill early gives you the foundation needed for everything that follows in this course, from chest trauma through to definitive surgical management.

This Series opens with the **general approach to cardiothoracic and vascular symptoms**, moves through **common cardiac lesions** and **common thoracic lesions**, and closes with **common vascular lesions**, building a comprehensive picture of symptom and sign recognition across the whole specialty.

Series Learning Outcomes

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

- **SLO 1.1:** describe the principles of history taking and examination in cardiothoracic and vascular surgery
- **SLO 1.2:** interpret common cardiac symptoms and respiratory symptoms
- **SLO 1.3:** describe the symptoms and signs of valvular and ischaemic heart disease
- **SLO 1.4:** describe the symptoms and signs of pericardial disease
- **SLO 1.5:** describe the symptoms and signs of common thoracic lesions, including lung and mediastinal masses
- **SLO 1.6:** interpret the symptoms and signs of pleural disease
- **SLO 1.7:** describe the symptoms and signs of arterial and aneurysmal disease
- **SLO 1.8:** describe the symptoms and signs of venous disease

1.1 Approach to Cardiothoracic and Vascular Symptoms

1.1.1 principles of cardiothoracic and vascular history and examination

A wide territory demanding a structured approach

A thorough **cardiothoracic and vascular history** covers the character, onset, and triggers of chest pain, breathlessness and its relationship to exertion, palpitations, cough and haemoptysis, and limb symptoms such as claudication or swelling, alongside relevant risk factors including smoking, hypertension, diabetes, hyperlipidaemia, and family history of cardiovascular disease, since these risk factors shape the probability of one diagnosis over another before examination even begins.

Examination follows a structured sequence: general inspection for cyanosis, clubbing, or peripheral oedema, examination of the pulse and jugular venous pressure, palpation and auscultation of the praecordium, examination of the chest for respiratory signs, and, where relevant, examination of the peripheral pulses and limbs for vascular signs, a comprehensive approach that reflects the genuinely wide anatomical territory this specialty covers compared with many others.

Fill in the blank: Risk factors such as smoking and hypertension shape the _____ of one diagnosis over another before examination begins.

1.1.2 interpreting cardiac symptoms

What the heart tells the patient, and what the patient tells you

Chest pain of cardiac origin classically presents as a central, crushing or tight sensation, often radiating to the jaw, neck, or left arm, and precipitated or worsened by exertion and relieved by rest, though atypical presentations, particularly in women, older adults, and diabetic patients, are common enough that a normal or unusual pain character should never be used alone to exclude a cardiac cause.

Palpitations, an unpleasant awareness of the heartbeat, and **syncope**, transient loss of consciousness, both warrant careful characterisation, since palpitations occurring with exertion or associated with syncope carry considerably greater diagnostic weight than brief, isolated palpitations at rest, and syncope during exertion in particular should always raise concern for a significant underlying structural or rhythm abnormality requiring prompt further evaluation.

Fill in the blank: Syncope occurring during exertion should always raise concern for a significant underlying structural or _____ abnormality.

1.1.3 interpreting respiratory and chest symptoms

Reading breathlessness, cough, and chest pain together

Breathlessness should be characterised by its onset, whether acute or gradual, its relationship to exertion, and whether it is positional, since orthopnoea, breathlessness when lying flat, and paroxysmal nocturnal dyspnoea, sudden breathlessness waking the patient from sleep, both point towards a cardiac rather than purely respiratory cause and should prompt specific direct questioning during history taking.

Cough and **haemoptysis**, coughing up blood, each carry distinct diagnostic significance, with haemoptysis in particular warranting careful further evaluation regardless of volume, since even small-volume haemoptysis can herald a serious underlying thoracic pathology, and chest pain that varies with respiration or position, referred to as pleuritic chest pain, points towards a pleural or musculoskeletal cause rather than a cardiac one.

Fill in the blank: Chest pain that varies with respiration or position is referred to as _____ chest pain.

Figure 1.1: A clinician examining jugular venous pressure with the patient positioned at forty-five degrees.

Pilot questions 1.1

1. List the key elements of a cardiothoracic and vascular history. (Linked to SLO 1.1)
2. Describe the structured sequence followed during cardiothoracic examination. (Linked to SLO 1.1)
3. Describe the classic presentation of cardiac chest pain. (Linked to SLO 1.2)
4. Explain why syncope during exertion is particularly concerning. (Linked to SLO 1.2)
5. Distinguish orthopnoea from paroxysmal nocturnal dyspnoea. (Linked to SLO 1.2)

1.2 Signs and Symptoms of Common Cardiac Lesions

1.2.1 valvular heart disease: symptoms and signs

Murmurs and the symptoms they produce

Valvular heart disease presents with symptoms reflecting the specific valve affected and whether it is stenotic or regurgitant, with aortic stenosis classically producing exertional syncope, angina, and breathlessness, and mitral regurgitation producing breathlessness and fatigue as the heart compensates for the regurgitant volume, symptoms that typically progress gradually as the underlying valvular lesion worsens over time.

The corresponding sign, a **murmur**, is characterised by its timing in the cardiac cycle, location where it is best heard, radiation, and character, with aortic stenosis producing an ejection systolic murmur radiating to the carotids, and mitral regurgitation producing a pansystolic murmur radiating to the axilla, distinguishing features that, together with the associated symptoms, allow a confident clinical diagnosis to be reached before any imaging is performed.

Fill in the blank: Aortic stenosis classically produces an ejection systolic murmur radiating to the _____.

1.2.2 ischaemic heart disease: symptoms and signs

From stable angina to the acute coronary syndrome

Ischaemic heart disease ranges from stable angina, predictable exertional chest pain relieved by rest, to **acute coronary syndrome**, encompassing unstable angina and myocardial infarction, presenting with more severe, often unprovoked chest pain that may be accompanied by breathlessness, sweating, nausea, and a sense of impending doom, a symptom cluster that should always be treated as a genuine emergency until proven otherwise.

Physical examination in ischaemic heart disease can be entirely normal between episodes, or reveal signs of an associated complication, such as a new murmur suggesting acute mitral regurgitation from papillary muscle dysfunction, or signs of heart failure following significant myocardial damage, underlining why a normal examination alone should never be used to exclude a significant ischaemic event when the history is otherwise suggestive.

Fill in the blank: Acute coronary syndrome encompasses unstable angina and myocardial _____.

1.2.3 pericardial disease: symptoms and signs

A distinct pain pattern and a distinctive sound

Pericarditis classically presents with sharp, pleuritic chest pain that characteristically improves on sitting forward and worsens on lying flat, a positional pattern that helps distinguish it from typical ischaemic cardiac pain, and the corresponding sign, a **pericardial friction rub**, a scratchy sound heard on auscultation independent of respiration, is highly specific when present, though its absence does not exclude the diagnosis.

Pericardial effusion, fluid accumulation within the pericardial sac, can progress to **cardiac tamponade** if it accumulates rapidly or in sufficient volume, presenting with the classical triad of hypotension, raised jugular venous pressure, and muffled heart sounds, a genuine surgical emergency requiring immediate recognition, since tamponade can progress rapidly to cardiovascular collapse if left untreated.

Fill in the blank: Pericarditis pain characteristically improves on sitting forward and worsens on lying _____.

Table 1.1: Comparing common cardiac lesions by symptom and sign

Condition	Key symptom	Key sign
Aortic stenosis	Exertional syncope, angina, breathlessness	Ejection systolic murmur radiating to carotids
Acute coronary syndrome	Severe, unprovoked chest pain	Examination may be normal or show complications
Cardiac tamponade	Hypotension, breathlessness	Raised jugular venous pressure, muffled heart sounds

Pilot questions 1.2

1. Describe the classic symptom of aortic stenosis. (Linked to SLO 1.3)
2. Describe the murmur associated with mitral regurgitation. (Linked to SLO 1.3)
3. Distinguish stable angina from acute coronary syndrome. (Linked to SLO 1.3)
4. Describe the positional pattern of pericarditic chest pain. (Linked to SLO 1.4)
5. List the classical triad of cardiac tamponade. (Linked to SLO 1.4)

1.3 Signs and Symptoms of Common Thoracic Lesions

1.3.1 lung masses and pulmonary lesions

Symptoms that develop slowly, or not at all

Lung masses are frequently asymptomatic in their early stages and identified incidentally on imaging performed for another reason, but as they grow can produce cough, haemoptysis, breathlessness, and, when a mass involves the brachial plexus at the lung apex, characteristic arm pain and weakness known as **Pancoast syndrome**, alongside **Horner's syndrome**, a triad of ptosis, miosis, and anhidrosis, from involvement of the sympathetic chain.

Finger clubbing, a specific sign involving loss of the normal angle between the nail and nail bed alongside increased nail curvature, is classically associated with lung malignancy and several other pulmonary and cardiac conditions, and, while non-specific on its own, is an important sign to actively look for in any patient presenting with respiratory symptoms, since its presence raises the index of suspicion for significant underlying pathology.

Fill in the blank: Pancoast syndrome describes arm pain and weakness from a lung apex mass involving the brachial _____.

1.3.2 mediastinal masses

Symptoms determined by location and local compression

Mediastinal masses, arising in the anterior, middle, or posterior mediastinum, produce symptoms largely determined by which local structure is compressed, with anterior masses more likely to compress the trachea, causing breathlessness or stridor, and cause **superior vena cava obstruction**, presenting with facial swelling, distended neck veins, and breathlessness, while posterior masses are more likely to affect the oesophagus, causing dysphagia, or the sympathetic chain.

Many mediastinal masses, like lung masses, are identified incidentally, and the compartment of origin, anterior, middle, or posterior, considered alongside the patient's age, meaningfully narrows the differential diagnosis, since specific tumour types are characteristically associated with specific mediastinal compartments, a pattern that guides both further investigation and the eventual surgical approach.

Fill in the blank: Superior vena cava obstruction presents with facial swelling, distended neck veins, and _____.

1.3.3 pleural disease: symptoms and signs

Fluid, air, and thickening between the lung and chest wall

Pleural effusion, fluid accumulation within the pleural space, presents with breathlessness proportional to the volume of fluid present, and examination reveals reduced chest expansion, stony dull percussion, and reduced or absent breath sounds over the affected area, findings that together distinguish an effusion confidently from other causes of breathlessness on clinical examination alone.

Pneumothorax, air within the pleural space, presents with sudden-onset chest pain and breathlessness, and examination reveals hyper-resonant percussion and reduced breath sounds on the affected side, a picture that, particularly when the patient is haemodynamically unstable with signs suggesting a **tension pneumothorax**, such as tracheal deviation away from the affected side, constitutes a genuine emergency requiring immediate decompression rather than awaiting confirmatory imaging.

Fill in the blank: A tension pneumothorax can cause tracheal deviation _____ from the affected side.

Figure 1.2: Finger clubbing showing loss of the normal nail bed angle and increased nail curvature.

Pilot questions 1.3

1. Describe Pancoast syndrome. (Linked to SLO 1.5)
2. List the components of Horner's syndrome. (Linked to SLO 1.5)
3. Explain how the location of a mediastinal mass influences its symptoms. (Linked to SLO 1.5)
4. Describe the examination findings of a pleural effusion. (Linked to SLO 1.6)
5. Describe the signs suggesting a tension pneumothorax. (Linked to SLO 1.6)

1.4 Signs and Symptoms of Common Vascular Lesions

1.4.1 arterial disease: symptoms and signs

Reduced blood flow, told through pain and pulses

Peripheral arterial disease presents with **intermittent claudication**, cramping pain in the calf, thigh, or buttock brought on by walking a consistent distance and relieved promptly by rest, progressing in more severe disease to **critical limb ischaemia**, presenting with rest pain,

typically worse at night and relieved by hanging the leg over the side of the bed, alongside non-healing ulceration or frank tissue loss.

Examination reveals reduced or absent peripheral pulses, a cool limb with delayed capillary refill, and, in chronic severe disease, hair loss and shiny, thin skin over the affected limb, findings that together with the symptom pattern allow arterial disease to be confidently distinguished from other causes of leg pain, such as musculoskeletal or neurological conditions, without requiring immediate specialist investigation.

Fill in the blank: Critical limb ischaemia presents with rest pain typically worse at _____.

1.4.2 aneurysmal disease: symptoms and signs

A silent threat until it announces itself dramatically

Aneurysms, abnormal focal dilatations of an artery, are frequently asymptomatic and identified incidentally, most commonly affecting the abdominal aorta, though a large abdominal aortic aneurysm can sometimes be felt as a pulsatile, expansile mass on abdominal examination, a specific finding, expansile in all directions rather than simply pulsatile, that distinguishes a true aneurysm from a normal but prominent pulse transmitted through overlying structures.

Aneurysm rupture presents dramatically with sudden, severe abdominal or back pain, hypotension, and a pulsatile abdominal mass, a genuine surgical emergency with a very high mortality if not treated immediately, and the historical, often asymptomatic nature of an unruptured aneurysm underlines the value of screening programmes in detecting aneurysmal disease before this catastrophic complication occurs.

Fill in the blank: A true aneurysm produces a mass that is expansile in all directions rather than simply _____.

1.4.3 venous disease: symptoms and signs

From cosmetic concern to a genuine medical emergency

Varicose veins, dilated, tortuous superficial veins most commonly affecting the legs, present with aching, heaviness, and swelling that typically worsens through the day and improves with leg elevation, and, while often primarily a cosmetic concern for the patient, can progress to skin changes and venous ulceration in more advanced chronic venous insufficiency, as already discussed in the earlier Series of this course's companion module on ulcer management.

Deep vein thrombosis, clot formation within the deep venous system, presents with unilateral limb swelling, pain, warmth, and erythema, and, though examination findings alone are

notoriously unreliable for confidently confirming or excluding the diagnosis, a high index of clinical suspicion combined with recognised risk factors, such as recent surgery, immobility, or malignancy, should prompt urgent further investigation given the risk of life-threatening pulmonary embolism if the clot embolises.

Fill in the blank: Deep vein thrombosis carries the risk of life-threatening pulmonary _____ if the clot embolises.

Table 1.2: Comparing arterial and venous disease of the lower limb

Feature	Arterial disease	Venous disease
Pain pattern	Claudication or rest pain	Aching, heaviness, worse through the day
Limb temperature	Cool	Normal or warm
Skin findings	Hair loss, shiny thin skin	Pigmentation, eczema, varicosities

Pilot questions 1.4

1. Describe intermittent claudication. (Linked to SLO 1.7)
2. Distinguish critical limb ischaemia from intermittent claudication. (Linked to SLO 1.7)
3. Describe the examination finding of a true aneurysm. (Linked to SLO 1.7)
4. Describe the presentation of a ruptured aneurysm. (Linked to SLO 1.7)
5. List the clinical features of a deep vein thrombosis. (Linked to SLO 1.8)

Series Summary

This opening Series built the foundation of symptom and sign recognition across the wide territory of cardiothoracic and vascular surgery. Part 1.1 covered the general approach to history and examination and the interpretation of cardiac and respiratory symptoms, while Part 1.2 turned to common cardiac lesions, valvular disease, ischaemic heart disease, and pericardial disease. Part 1.3 covered common thoracic lesions, lung masses, mediastinal masses, and pleural disease, and Part 1.4 closed with common vascular lesions, arterial disease, aneurysms, and venous disease.

You should now be able to enumerate and interpret the symptoms and signs of common lesions across all four Parts of this Series, building the recognition skill that underpins the rest of this course, meeting the outcomes set for this Series. Series 2 turns next to chest trauma and chest wall tumours.

Glossary of Terms

- **Acute coronary syndrome:** unstable angina and myocardial infarction, presenting with severe, unprovoked chest pain.
- **Cardiac tamponade:** compression of the heart by pericardial fluid, presenting with hypotension and muffled heart sounds.
- **Critical limb ischaemia:** severe peripheral arterial disease presenting with rest pain and tissue loss.
- **Finger clubbing:** loss of the normal nail bed angle with increased nail curvature, associated with chronic disease.
- **Horner's syndrome:** a triad of ptosis, miosis, and anhidrosis from sympathetic chain involvement.
- **Intermittent claudication:** cramping limb pain brought on by walking and relieved by rest.
- **Pancoast syndrome:** arm pain and weakness from a lung apex mass involving the brachial plexus.
- **Pericardial friction rub:** a scratchy sound heard on auscultation in pericarditis, independent of respiration.
- **Pleural effusion:** fluid accumulation within the pleural space.
- **Pneumothorax:** air within the pleural space.
- **Superior vena cava obstruction:** compression of the superior vena cava, presenting with facial swelling and distended neck veins.
- **Tension pneumothorax:** a pneumothorax causing haemodynamic compromise, a surgical emergency.

Concept Check Questions [Series 1]

Objective questions

1. Syncope occurring during exertion should always raise concern for a significant underlying structural or _____ abnormality. (Linked to SLO 1.2)
2. Aortic stenosis classically produces an ejection systolic murmur radiating to the _____. (Linked to SLO 1.3)

3. Pancoast syndrome describes arm pain and weakness from a lung apex mass involving the brachial _____. (Linked to SLO 1.5)
4. A true aneurysm produces a mass that is expansile in all directions rather than simply _____. (Linked to SLO 1.7)
5. Deep vein thrombosis carries the risk of life-threatening pulmonary _____ if the clot embolises. (Linked to SLO 1.8)

Short-answer questions

6. Describe the classic presentation of cardiac chest pain. (Linked to SLO 1.2)
7. List the classical triad of cardiac tamponade. (Linked to SLO 1.4)
8. Describe the examination findings of a pleural effusion. (Linked to SLO 1.6)
9. Distinguish critical limb ischaemia from intermittent claudication. (Linked to SLO 1.7)
10. List the clinical features of a deep vein thrombosis. (Linked to SLO 1.8)

Long-answer questions

11. Discuss the general approach to cardiothoracic and vascular history and examination, including the interpretation of cardiac and respiratory symptoms. (Linked to SLO 1.1, 1.2)
12. Compare the symptoms and signs of valvular heart disease, ischaemic heart disease, and pericardial disease. (Linked to SLO 1.3, 1.4)
13. Discuss the symptoms and signs of lung masses, mediastinal masses, and pleural disease. (Linked to SLO 1.5, 1.6)
14. Describe the symptoms and signs of arterial and aneurysmal disease. (Linked to SLO 1.7)
15. Discuss the symptoms and signs of venous disease, including deep vein thrombosis. (Linked to SLO 1.8)

Answers to Concept Check Questions [Series 1]

Objective questions

1. Rhythm.
2. Carotids.
3. Plexus.
4. Pulsatile.
5. Embolism.

Short-answer questions

6. Cardiac chest pain is classically central, crushing or tight, radiating to the jaw, neck, or left arm, and worsened by exertion.
7. The classical triad is hypotension, raised jugular venous pressure, and muffled heart sounds.
8. Findings include reduced chest expansion, stony dull percussion, and reduced or absent breath sounds.
9. Critical limb ischaemia presents with rest pain and tissue loss, while claudication presents with pain only on walking.
10. Features include unilateral limb swelling, pain, warmth, and erythema.

Long-answer questions

11. **Basic response:** History covers chest pain, breathlessness, palpitations, cough, and limb symptoms with risk factors; examination follows inspection, pulse, jugular venous pressure, praecordium, chest, and peripheral examination in sequence.

    Value-added response: A value-added response notes that orthopnoea and paroxysmal nocturnal dyspnoea point towards a cardiac rather than purely respiratory cause of breathlessness.

12. **Basic response:** Valvular disease presents with murmurs and progressive breathlessness; ischaemic heart disease ranges from stable angina to acute coronary syndrome; pericardial disease presents with positional pain and a friction rub, progressing to tamponade if severe.

    Value-added response: A value-added response notes that examination can be entirely normal in ischaemic heart disease between episodes, so a normal examination should never exclude a suggestive history.

13. **Basic response:** Lung masses can cause Pancoast and Horner's syndromes and clubbing; mediastinal masses cause symptoms determined by compartment and local compression; pleural effusion and pneumothorax each produce distinct examination findings.

    Value-added response: A value-added response notes that tension pneumothorax with tracheal deviation is a genuine emergency requiring immediate decompression.

14. **Basic response:** Arterial disease presents with claudication or critical limb ischaemia with reduced pulses and skin changes; aneurysms are often asymptomatic until rupture, which presents with sudden pain, hypotension, and a pulsatile mass.

    Value-added response: A value-added response notes the value of screening programmes in detecting aneurysmal disease before catastrophic rupture occurs.

15. **Basic response:** Varicose veins present with aching and heaviness worsened through the day; deep vein thrombosis presents with unilateral swelling, pain, warmth, and erythema, carrying risk of pulmonary embolism.

    Value-added response: A value-added response notes that examination findings alone are unreliable for deep vein thrombosis, so a high index of suspicion with risk factors should prompt further investigation.

Answers to Pilot Questions [Series 1]

Part 1.1

1. Key elements include chest pain, breathlessness, palpitations, cough, haemoptysis, limb symptoms, and risk factors.
2. The sequence covers inspection, pulse, jugular venous pressure, praecordium, chest, and peripheral examination.
3. Cardiac chest pain is central, crushing or tight, radiating to the jaw, neck, or left arm, worsened by exertion.
4. Exertional syncope may indicate a significant structural or rhythm abnormality requiring urgent evaluation.
5. Orthopnoea is breathlessness lying flat, while paroxysmal nocturnal dyspnoea is sudden breathlessness waking the patient from sleep.

Part 1.2

1. Aortic stenosis classically presents with exertional syncope, angina, and breathlessness.
2. Mitral regurgitation produces a pansystolic murmur radiating to the axilla.
3. Stable angina is predictable and exertional, while acute coronary syndrome is more severe and often unprovoked.
4. Pericarditic pain improves on sitting forward and worsens on lying flat.
5. The triad is hypotension, raised jugular venous pressure, and muffled heart sounds.

Part 1.3

1. Pancoast syndrome is arm pain and weakness from a lung apex mass involving the brachial plexus.
2. Horner's syndrome comprises ptosis, miosis, and anhidrosis.
3. The compartment of origin, anterior, middle, or posterior, determines which local structure is compressed and the resulting symptoms.
4. Findings include reduced chest expansion, stony dull percussion, and reduced or absent breath sounds.
5. Signs include haemodynamic instability and tracheal deviation away from the affected side.

Part 1.4

1. Intermittent claudication is cramping limb pain brought on by walking a consistent distance and relieved by rest.
2. Critical limb ischaemia presents with rest pain and tissue loss, unlike claudication which occurs only on exertion.
3. A true aneurysm produces a pulsatile, expansile mass, expansile in all directions rather than simply pulsatile.
4. Rupture presents with sudden, severe abdominal or back pain, hypotension, and a pulsatile mass.
5. Features include unilateral limb swelling, pain, warmth, and erythema.

References and Attributions [Series 1]

- Sabiston, D. C., & Townsend, C. M. (2021). Sabiston Textbook of Surgery (21st ed.). Elsevier.
- Williams, N. S., Bulstrode, C. J. K., & O'Connell, P. R. (2018). Bailey and Love's Short Practice of Surgery (27th ed.). CRC Press.
- Rutherford, R. B. (2019). Rutherford's Vascular Surgery and Endovascular Therapy (9th ed.). Elsevier.
- Douglas, G., Nicol, F., & Robertson, C. (2013). Macleod's Clinical Examination (13th ed.). Churchill Livingstone.

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Series 2: Chest Trauma and Chest Wall Tumours

- **Part 2.1: Assessment of Chest Trauma**
  - Sub Part 2.1.1: Initial assessment of the trauma patient with chest injury
  - Sub Part 2.1.2: Rib fractures and flail chest
  - Sub Part 2.1.3: Recognising life-threatening chest injuries
- **Part 2.2: Specific Chest Injuries**
  - Sub Part 2.2.1: Pneumothorax and haemothorax in trauma
  - Sub Part 2.2.2: Cardiac tamponade and great vessel injury in trauma
  - Sub Part 2.2.3: Diaphragmatic and oesophageal injury
- **Part 2.3: Management of Chest Trauma**
  - Sub Part 2.3.1: Emergency management of chest trauma
  - Sub Part 2.3.2: Chest drain insertion
  - Sub Part 2.3.3: Indications for thoracotomy in trauma
- **Part 2.4: Chest Wall Tumours**
  - Sub Part 2.4.1: Benign chest wall tumours
  - Sub Part 2.4.2: Malignant chest wall tumours
  - Sub Part 2.4.3: Management of chest wall tumours

Introduction

A road traffic collision, a fall from height, a stab wound to the chest, these mechanisms of injury bring patients to the emergency department with chest injuries that can range from a simple, self-limiting rib fracture to a genuinely immediately life-threatening condition demanding intervention within minutes. This Series turns to **chest trauma**, building the assessment and

management skills this specific clinical scenario demands, before closing with **chest wall tumours**, a very different but anatomically related topic within cardiothoracic surgery.

The aim of this Series is to equip you with the ability to assess a patient with chest trauma, recognise life-threatening chest injuries, manage chest trauma appropriately including chest drain insertion, and describe the presentation and management of chest wall tumours. Chest trauma in particular demands rapid, structured clinical reasoning, since the difference between recognising and missing a life-threatening injury within the first few minutes of assessment can be the difference between a good and a catastrophic outcome.

This Series opens with the **assessment of chest trauma**, moves through **specific chest injuries** and **management of chest trauma**, and closes with **chest wall tumours**.

Series Learning Outcomes

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

- **SLO 2.1:** describe the initial assessment of a patient with chest trauma
- **SLO 2.2:** describe rib fractures and flail chest
- **SLO 2.3:** list the life-threatening chest injuries requiring immediate recognition
- **SLO 2.4:** describe the presentation of pneumothorax, haemothorax, and cardiac tamponade in trauma
- **SLO 2.5:** describe the emergency management of chest trauma, including chest drain insertion
- **SLO 2.6:** discuss the indications for thoracotomy in trauma
- **SLO 2.7:** describe the presentation of benign and malignant chest wall tumours
- **SLO 2.8:** discuss the management of chest wall tumours

2.1 Assessment of Chest Trauma

2.1.1 initial assessment of the trauma patient with chest injury

Applying trauma principles to the chest specifically

Initial assessment of chest trauma follows the standard **airway, breathing, circulation** trauma sequence, with the chest examined systematically during the primary survey for signs including asymmetrical chest movement, visible wounds or bruising, tracheal deviation, distended neck

veins, and abnormal breath sounds, findings that together guide the immediate priorities of resuscitation before any imaging is performed.

The mechanism of injury provides essential context, since blunt chest trauma, typically from road traffic collisions or falls, produces a different pattern of injury compared with penetrating trauma from a stab or gunshot wound, and this distinction should shape the index of suspicion for specific underlying injuries throughout the assessment, even before any single specific finding has been identified.

Fill in the blank: Blunt and penetrating chest trauma produce different patterns of injury, shaping the index of _____ throughout assessment.

2.1.2 rib fractures and flail chest

From a simple fracture to a genuinely unstable chest wall

Rib fractures are the most common chest injury, presenting with localised pain worsened by breathing, coughing, or movement, and tenderness on palpation, and, while often managed conservatively with analgesia and encouragement to breathe deeply to prevent secondary chest infection, multiple rib fractures carry a genuinely higher risk of underlying pulmonary contusion and other associated injuries that must be actively considered.

Flail chest occurs when three or more consecutive ribs are fractured in two or more places, creating a free-floating segment of chest wall that moves paradoxically, drawing inward during inspiration and outward during expiration rather than moving with the rest of the chest wall, a distinctive clinical sign that, combined with the frequently associated underlying pulmonary contusion, can produce significant respiratory compromise requiring close monitoring and, in more severe cases, ventilatory support.

Fill in the blank: A flail segment moves paradoxically, drawing inward during _____ rather than moving with the chest wall.

2.1.3 recognising life-threatening chest injuries

The injuries that must never be missed

Several chest injuries are considered genuinely immediately life-threatening and must be actively identified and addressed during the primary survey rather than left for later assessment: **tension pneumothorax**, **massive haemothorax**, **cardiac tamponade**, **open pneumothorax**, **flail chest** with significant pulmonary contusion, and **airway obstruction**, each requiring specific, prompt intervention rather than simply supportive observation.

A structured approach that actively searches for each of these conditions in every chest trauma patient, rather than waiting for them to become clinically obvious, considerably reduces the risk of a missed, potentially fatal injury, since several of these conditions can deteriorate with alarming speed once decompensation begins, leaving little margin for a delayed diagnosis.

Fill in the blank: A structured approach actively searches for life-threatening chest injuries rather than waiting for them to become clinically _____.

Figure 2.1: A patient's chest wall showing a paradoxically moving flail segment.

Pilot questions 2.1

- Describe the initial assessment sequence for a patient with chest trauma. (Linked to SLO 2.1)
- Explain why mechanism of injury matters in chest trauma assessment. (Linked to SLO 2.1)
- Describe the typical presentation of a simple rib fracture. (Linked to SLO 2.2)
- Define flail chest. (Linked to SLO 2.2)
- List the immediately life-threatening chest injuries that must be actively identified. (Linked to SLO 2.3)

2.2 Specific Chest Injuries

2.2.1 pneumothorax and haemothorax in trauma

Air and blood where neither belongs

Traumatic pneumothorax, air within the pleural space following chest injury, presents with breathlessness and reduced breath sounds on the affected side, and can progress to **tension pneumothorax** if air continues to accumulate under pressure, presenting additionally with tracheal deviation, distended neck veins, and haemodynamic compromise, a genuine emergency requiring immediate needle decompression rather than awaiting imaging confirmation.

Haemothorax, blood within the pleural space, presents similarly with breathlessness and reduced breath sounds, but with stony dull rather than hyper-resonant percussion, distinguishing it clinically from a simple pneumothorax, and a **massive haemothorax**, generally defined by a large initial blood loss into the chest or continued significant bleeding, is itself immediately life-threatening both from the blood loss and the resulting lung compression, requiring urgent chest drain insertion and, in some cases, surgical intervention.

Fill in the blank: Haemothorax presents with stony dull rather than hyper-resonant _____, distinguishing it from pneumothorax.

2.2.2 cardiac tamponade and great vessel injury in trauma

The most immediately fatal injuries in this Series

Traumatic cardiac tamponade, most commonly from penetrating chest injury, presents with the same classical triad discussed in Series 1, hypotension, raised jugular venous pressure, and muffled heart sounds, though this triad is not always fully present, and a high index of suspicion following any penetrating injury to the chest, particularly the precordial region, should prompt urgent assessment and, where indicated, emergency pericardiocentesis or thoracotomy.

Great vessel injury, involving the aorta or its major branches, is a leading cause of immediate death following severe blunt chest trauma, such as a high-speed deceleration injury, and survivors reaching hospital alive require urgent imaging and, where confirmed, emergency surgical or endovascular repair, since a contained injury can rupture catastrophically at any moment without warning.

Fill in the blank: Great vessel injury is a leading cause of immediate death following severe blunt chest _____.

2.2.3 diaphragmatic and oesophageal injury

Less common, but easily missed without active suspicion

Diaphragmatic injury, more commonly from penetrating trauma but also seen in severe blunt injury, can be genuinely difficult to detect on initial imaging and may present late with herniation of abdominal contents into the chest cavity, sometimes only becoming apparent months or even years after the original injury, underlining why any penetrating injury to the lower chest or upper abdomen should raise active suspicion for diaphragmatic involvement.

Oesophageal injury, though uncommon, carries a disproportionately high mortality if not identified and treated promptly, since leakage of oesophageal contents into the mediastinum causes severe mediastinitis, and any penetrating injury to the chest with a trajectory near the oesophagus should prompt specific investigation for this injury even in the absence of overt symptoms at initial presentation.

Fill in the blank: Oesophageal injury carries a disproportionately high mortality due to the risk of severe _____.

Table 2.1: The six immediately life-threatening chest injuries

Injury	Key clinical feature	Immediate action
Tension pneumothorax	Tracheal deviation, distended neck veins	Immediate needle decompression
Massive haemothorax	Stony dull percussion, hypotension	Urgent chest drain, consider surgery
Cardiac tamponade	Hypotension, muffled heart sounds	Urgent pericardiocentesis or thoracotomy

Pilot questions 2.2

1. Distinguish pneumothorax from haemothorax on percussion. (Linked to SLO 2.4)
2. Describe the immediate management of tension pneumothorax. (Linked to SLO 2.4)
3. Describe traumatic cardiac tamponade and its immediate management. (Linked to SLO 2.4)
4. Explain why great vessel injury is so often immediately fatal. (Linked to SLO 2.4)
5. Explain why diaphragmatic injury can present late. (Linked to SLO 2.4)

2.3 Management of Chest Trauma

2.3.1 emergency management of chest trauma

Treating what is found, in the order it is found

Emergency management of chest trauma follows the same airway, breathing, circulation sequence used in assessment, treating each identified life-threatening injury as it is found rather than completing a full assessment before beginning treatment, since a patient with tension pneumothorax, for example, requires immediate needle decompression the moment the diagnosis is suspected, not after imaging has confirmed it.

Supportive management, including supplemental oxygen, adequate analgesia to support effective breathing and coughing, and close monitoring of respiratory and haemodynamic status, runs alongside the treatment of any specific identified injury, and adequate pain control in particular is genuinely important in chest trauma, since poorly controlled pain leads to shallow breathing and inadequate coughing, increasing the risk of secondary chest infection and respiratory compromise.

Fill in the blank: Poorly controlled pain in chest trauma leads to shallow breathing and inadequate _____.

2.3.2 chest drain insertion

A core practical skill in managing chest trauma

Chest drain insertion is indicated for pneumothorax, haemothorax, or both, and is typically performed through the **triangle of safety**, bordered by the anterior border of latissimus dorsi, the lateral border of pectoralis major, and a horizontal line at the level of the nipple, a location chosen to avoid injury to underlying structures such as the internal mammary artery and to minimise the risk of damaging the long thoracic nerve.

Following insertion, correct chest drain position and function is confirmed by observing appropriate swinging of the fluid column with respiration and bubbling if air is being drained, and the drain is connected to an underwater seal system that allows air and fluid to exit the pleural space while preventing air from re-entering, a simple but genuinely effective mechanical principle underlying this widely used device.

Fill in the blank: A chest drain is typically inserted through the triangle of _____.

2.3.3 indications for thoracotomy in trauma

When the chest itself must be opened

Emergency department thoracotomy, opening the chest immediately at the bedside rather than in an operating theatre, is reserved for a very specific, narrow group of patients, typically those with penetrating chest trauma who arrest or lose vital signs shortly before or immediately upon arrival, since this dramatic intervention offers a realistic chance of survival essentially only in this specific clinical scenario.

Formal thoracotomy in the operating theatre is indicated for ongoing significant haemorrhage, such as an initial or continued high-volume chest drain output, confirmed great vessel or cardiac injury, or other injuries identified on imaging requiring direct surgical repair, and recognising the specific indication and correct setting for thoracotomy, emergency department versus operating theatre, is an essential distinction for any trainee managing chest trauma.

Fill in the blank: Emergency department thoracotomy is reserved for penetrating trauma patients who arrest shortly before or upon _____.

Figure 2.2: A clinician inserting a chest drain through the triangle of safety.

Pilot questions 2.3

1. Explain why treatment should begin as soon as a life-threatening injury is suspected. (Linked to SLO 2.5)
2. Explain the importance of adequate analgesia in chest trauma. (Linked to SLO 2.5)
3. Describe the anatomical boundaries of the triangle of safety. (Linked to SLO 2.5)
4. Describe how correct chest drain function is confirmed after insertion. (Linked to SLO 2.5)
5. Distinguish the indications for emergency department thoracotomy from formal thoracotomy. (Linked to SLO 2.6)

2.4 Chest Wall Tumours

2.4.1 benign chest wall tumours

Slow-growing lesions of bone and cartilage

Benign chest wall tumours, including osteochondroma and chondroma, typically present as a slow-growing, painless mass, often noticed incidentally or as a cosmetic concern, and generally arise from the ribs or costal cartilage, with imaging showing well-defined margins and features characteristic of a benign process rather than the irregular, poorly defined appearance more typical of malignancy.

Although generally slow-growing and asymptomatic, benign chest wall tumours can occasionally cause local symptoms through pressure on adjacent structures, and any lesion showing atypical features, such as rapid growth, pain, or an irregular margin on imaging, should be reassessed and biopsied to exclude malignant transformation rather than assumed to remain benign indefinitely without further evaluation.

Fill in the blank: Benign chest wall tumours typically present as a slow-growing, _____ mass.

2.4.2 malignant chest wall tumours

Primary bone tumours and metastatic disease

Malignant chest wall tumours include primary tumours such as chondrosarcoma, the most common primary malignant chest wall tumour in adults, and Ewing sarcoma, more common in

children and young adults, alongside metastatic disease from a distant primary tumour, which is actually more common overall than a primary chest wall malignancy in an adult population.

Malignant chest wall tumours typically present with a growing, often painful mass, and imaging characteristically shows irregular margins, bone destruction, and, in aggressive lesions, extension into surrounding soft tissue, features that together with the growth pattern and pain should prompt urgent biopsy and staging investigation rather than reassurance and simple observation.

Fill in the blank: Metastatic disease is actually more common overall than a primary chest wall _____ in an adult population.

2.4.3 management of chest wall tumours

Excision, reconstruction, and adjuvant treatment

Management of confirmed malignant chest wall tumours centres on **wide surgical excision** with a clear margin of normal tissue, since inadequate excision carries a genuine risk of local recurrence, and the resulting chest wall defect frequently requires **reconstruction** using synthetic mesh, tissue flaps, or a combination of both, to restore both structural integrity and adequate protection of the underlying thoracic organs.

Adjuvant chemotherapy or radiotherapy is used for specific tumour types, such as Ewing sarcoma, according to established oncological protocols, and management of benign tumours is generally more conservative, with excision reserved for symptomatic lesions, diagnostic uncertainty, or genuine cosmetic concern rather than performed routinely for every incidentally identified benign lesion.

Fill in the blank: Wide surgical excision aims for a clear margin of normal tissue to reduce the risk of local _____.

Table 2.2: Comparing benign and malignant chest wall tumours

Feature	Benign tumour	Malignant tumour
Growth rate	Slow	Faster, progressive
Pain	Usually absent	Often present
Imaging margin	Well-defined	Irregular, may show bone destruction

Pilot questions 2.4

1. Describe the typical presentation of a benign chest wall tumour. (Linked to SLO 2.7)
2. List two primary malignant chest wall tumours. (Linked to SLO 2.7)
3. Explain why metastatic disease should be considered in a malignant-appearing chest wall mass. (Linked to SLO 2.7)
4. Describe the surgical principle underlying management of a malignant chest wall tumour. (Linked to SLO 2.8)
5. Explain when excision of a benign chest wall tumour is indicated. (Linked to SLO 2.8)

Series Summary

This Series covered chest trauma from initial assessment through to management, before closing with chest wall tumours. Part 2.1 covered the initial assessment of chest trauma, rib fractures, flail chest, and the life-threatening injuries requiring immediate recognition, while Part 2.2 turned to specific injuries, pneumothorax, haemothorax, cardiac tamponade, great vessel injury, and diaphragmatic and oesophageal injury. Part 2.3 covered the emergency management of chest trauma, chest drain insertion, and the indications for thoracotomy, and Part 2.4 closed with benign and malignant chest wall tumours and their management.

You should now be able to assess and manage a patient with chest trauma, recognise the immediately life-threatening chest injuries, and describe the presentation and management of chest wall tumours, meeting the outcomes set for this Series. Series 3 turns next to the principles of management of common lesions in cardiothoracic surgery.

Glossary of Terms

1. **Chondrosarcoma:** the most common primary malignant chest wall tumour in adults.
2. **Emergency department thoracotomy:** immediate bedside thoracotomy reserved for a narrow group of arresting trauma patients.
3. **Flail chest:** three or more consecutive ribs fractured in two or more places, creating paradoxical movement.
4. **Great vessel injury:** injury to the aorta or its major branches, a leading cause of immediate trauma death.

5. **Haemothorax:** blood within the pleural space.
6. **Massive haemothorax:** a large volume of blood loss into the pleural space, immediately life-threatening.
7. **Mediastinitis:** severe inflammation of the mediastinum, a complication of oesophageal injury.
8. **Osteochondroma:** a common benign chest wall tumour arising from bone or cartilage.
9. **Tension pneumothorax:** a pneumothorax causing haemodynamic compromise, a surgical emergency.
10. **Thoracotomy:** surgical opening of the chest cavity.
11. **Triangle of safety:** the anatomical area used for safe chest drain insertion.
12. **Wide surgical excision:** removal of a tumour with a clear margin of surrounding normal tissue.

Concept Check Questions [Series 2]

Objective questions

- A flail segment moves paradoxically, drawing inward during _____ rather than moving with the chest wall. (Linked to SLO 2.2)
- Haemothorax presents with stony dull rather than hyper-resonant _____, distinguishing it from pneumothorax. (Linked to SLO 2.4)
- A chest drain is typically inserted through the triangle of _____. (Linked to SLO 2.5)
- Emergency department thoracotomy is reserved for penetrating trauma patients who arrest shortly before or upon _____. (Linked to SLO 2.6)
- Metastatic disease is actually more common overall than a primary chest wall _____ in an adult population. (Linked to SLO 2.7)

Short-answer questions

1. Define flail chest. (Linked to SLO 2.2)
2. List the immediately life-threatening chest injuries that must be actively identified. (Linked to SLO 2.3)
3. Describe the anatomical boundaries of the triangle of safety. (Linked to SLO 2.5)
4. Distinguish the indications for emergency department thoracotomy from formal thoracotomy. (Linked to SLO 2.6)
5. Describe the surgical principle underlying management of a malignant chest wall tumour. (Linked to SLO 2.8)

Long-answer questions

6. Discuss the initial assessment of chest trauma and the recognition of life-threatening chest injuries. (Linked to SLO 2.1, 2.3)
7. Describe the presentation of pneumothorax, haemothorax, cardiac tamponade, and great vessel injury in trauma. (Linked to SLO 2.4)
8. Discuss the emergency management of chest trauma, including chest drain insertion and the indications for thoracotomy. (Linked to SLO 2.5, 2.6)
9. Describe the presentation and differentiation of benign and malignant chest wall tumours. (Linked to SLO 2.7)
10. Discuss the management of chest wall tumours. (Linked to SLO 2.8)

Answers to Concept Check Questions [Series 2]

Objective questions

11. Inspiration.
12. Percussion.
13. Safety.
14. Arrival.
15. Malignancy.

Short-answer questions

16. Flail chest is three or more consecutive ribs fractured in two or more places, creating a paradoxically moving segment.
17. The six injuries are tension pneumothorax, massive haemothorax, cardiac tamponade, open pneumothorax, flail chest, and airway obstruction.
18. The triangle is bordered by latissimus dorsi, pectoralis major, and a horizontal line at the level of the nipple.
19. Emergency department thoracotomy is for penetrating trauma patients arresting near arrival, while formal thoracotomy is for ongoing haemorrhage or confirmed injury requiring repair.
20. Management centres on wide surgical excision with a clear margin, often followed by chest wall reconstruction.

Long-answer questions

21. **Basic response:** Assessment follows airway, breathing, circulation with systematic chest examination; life-threatening injuries include tension pneumothorax, massive haemothorax, cardiac tamponade, open pneumothorax, flail chest, and airway obstruction, each requiring active identification.

Value-added response: A value-added response notes that mechanism of injury, blunt versus penetrating, shapes the index of suspicion throughout assessment.

22. **Basic response:** Pneumothorax presents with breathlessness and reduced breath sounds; haemothorax adds stony dull percussion; cardiac tamponade presents with the classical triad; great vessel injury is a leading cause of immediate death after severe deceleration trauma.

    Value-added response: A value-added response notes that a contained great vessel injury can rupture catastrophically without warning, requiring urgent imaging in survivors.

23. **Basic response:** Management treats each life-threatening injury as identified, with chest drains inserted through the triangle of safety for pneumothorax or haemothorax; thoracotomy is reserved for specific indications, differing between the emergency department and operating theatre.

    Value-added response: A value-added response notes that adequate analgesia is genuinely important, since poorly controlled pain leads to shallow breathing and secondary chest infection.

24. **Basic response:** Benign tumours present as slow-growing, painless masses with well-defined imaging margins; malignant tumours present with growing, painful masses showing irregular margins and bone destruction.

    Value-added response: A value-added response notes that metastatic disease is actually more common than primary chest wall malignancy in adults.

25. **Basic response:** Malignant tumours are managed with wide surgical excision and reconstruction, with adjuvant chemotherapy or radiotherapy for specific tumour types; benign tumours are managed conservatively, with excision reserved for symptomatic or uncertain lesions.

    Value-added response: A value-added response notes that inadequate excision margins carry a genuine risk of local recurrence, underlining the importance of adequate margin planning.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Initial assessment follows the airway, breathing, circulation sequence with systematic chest examination.
2. Mechanism of injury, blunt versus penetrating, shapes the pattern of injury and the index of suspicion.
3. A simple rib fracture presents with localised pain worsened by breathing or movement and tenderness on palpation.
4. Flail chest is three or more consecutive ribs fractured in two or more places, creating paradoxical chest wall movement.
5. The life-threatening injuries are tension pneumothorax, massive haemothorax, cardiac tamponade, open pneumothorax, flail chest, and airway obstruction.

Part 2.2

6. Pneumothorax shows hyper-resonant percussion, while haemothorax shows stony dull percussion.
7. Tension pneumothorax requires immediate needle decompression.
8. Traumatic cardiac tamponade presents with the classical triad and is managed with urgent pericardiocentesis or thoracotomy.
9. Great vessel injury causes rapid, catastrophic blood loss, making it a leading cause of immediate death.
10. Diaphragmatic injury can be difficult to detect on initial imaging and may only become apparent once herniation develops later.

Part 2.3

11. Treatment begins immediately because several life-threatening injuries can deteriorate rapidly, leaving little margin for delay.
12. Poorly controlled pain leads to shallow breathing and inadequate coughing, increasing infection risk.
13. The triangle is bordered by latissimus dorsi, pectoralis major, and a horizontal line at the nipple level.
14. Correct function is confirmed by swinging of the fluid column and bubbling if air is present.
15. Emergency department thoracotomy is for arresting penetrating trauma patients, while formal thoracotomy addresses ongoing haemorrhage or confirmed injury.

Part 2.4

1. A benign chest wall tumour typically presents as a slow-growing, painless mass with well-defined margins.
2. Chondrosarcoma and Ewing sarcoma are two primary malignant chest wall tumours.
3. Metastatic disease is actually more common overall than primary chest wall malignancy in adults.
4. Management centres on wide surgical excision with a clear margin, often requiring reconstruction.
5. Excision is indicated for symptomatic lesions, diagnostic uncertainty, or genuine cosmetic concern.

References and Attributions [Series 2]

1. American College of Surgeons (2018). Advanced Trauma Life Support Student Course Manual (10th ed.). American College of Surgeons.
2. Sabiston, D. C., & Townsend, C. M. (2021). Sabiston Textbook of Surgery (21st ed.). Elsevier.
3. Williams, N. S., Bulstrode, C. J. K., & O'Connell, P. R. (2018). Bailey and Love's Short Practice of Surgery (27th ed.). CRC Press.
4. Shields, T. W. (2019). General Thoracic Surgery (8th ed.). Wolters Kluwer.

Figures, Plates, Tables, and Boxes

1. Figure 2.1: A patient's chest wall showing a paradoxically moving flail segment. AI-generated using the prompt: "Create a realistic clinical illustration titled Flail Chest Presentation, showing a trauma patient's bare chest with a visibly depressed segment on one side indicating a flail segment, bruising over the affected area, emergency department setting. Clean clinical illustration style, no text."
2. Table 2.1: The six immediately life-threatening chest injuries. AI-generated using the prompt: "Create a clean reference table titled The Six Immediately Life-Threatening Chest Injuries, listing injury, key clinical feature, and immediate action. Simple clinical reference table style with outside border."
3. Figure 2.2: A clinician inserting a chest drain through the triangle of safety. AI-generated using the prompt: "Create a realistic clinical illustration titled Chest Drain Insertion,

showing a clinician in gloves inserting a chest drain into a patient's lateral chest wall at the level of the nipple, sterile drapes and equipment visible, emergency department setting. Clean clinical illustration style, no text."

4. Table 2.2: Comparing benign and malignant chest wall tumours. AI-generated using the prompt: "Create a clean reference table titled Comparing Benign and Malignant Chest Wall Tumours, listing feature, benign tumour, and malignant tumour. Simple clinical reference table style with outside border."

Course code: SUG 603

Course title: Cardiothoracic including Vascular Surgery

Course credit load: 2 Units

Series 3: Principles of Management of Common Lesions in Cardiothoracic Surgery

- **Part 3.1: Principles of Surgical Access in Cardiothoracic Surgery**
  - Sub Part 3.1.1: Median sternotomy
  - Sub Part 3.1.2: Thoracotomy approaches
  - Sub Part 3.1.3: Minimally invasive and video-assisted approaches
- **Part 3.2: Principles of Cardiac Surgical Management**
  - Sub Part 3.2.1: Cardiopulmonary bypass
  - Sub Part 3.2.2: Principles of valve surgery
  - Sub Part 3.2.3: Principles of coronary artery bypass surgery
- **Part 3.3: Principles of Thoracic Surgical Management**
  - Sub Part 3.3.1: Principles of lung resection surgery
  - Sub Part 3.3.2: Principles of mediastinal mass management
  - Sub Part 3.3.3: Principles of pleural disease management
- **Part 3.4: Principles of Vascular Surgical Management**
  - Sub Part 3.4.1: Principles of open vascular surgery
  - Sub Part 3.4.2: Principles of endovascular surgery
  - Sub Part 3.4.3: Principles of perioperative care in cardiothoracic and vascular surgery

Introduction

Recognising a lesion, as covered in Series 1, and managing trauma, as covered in Series 2, are only part of the picture, since definitive treatment in cardiothoracic and vascular surgery ultimately depends on choosing the right surgical approach and applying it according to sound underlying principles. This Series turns to the **principles of management** of common lesions across this specialty, working through surgical access, cardiac surgical management, thoracic surgical management, and vascular surgical management in turn.

The aim of this Series is to equip you with an understanding of the surgical approaches used in cardiothoracic surgery, the principles underlying cardiac, thoracic, and vascular surgical management, and the perioperative care that supports a good outcome regardless of the specific procedure performed. Each subspecialty within this field has developed its own characteristic approaches and techniques, but the underlying surgical logic, exposing the pathology adequately, treating it definitively, and supporting the patient safely through the perioperative period, remains genuinely consistent across all of them.

This Series opens with **principles of surgical access**, moves through **cardiac surgical management** and **thoracic surgical management**, and closes with **vascular surgical management**.

Series Learning Outcomes

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

- **SLO 3.1:** describe the surgical approaches used in cardiothoracic surgery
- **SLO 3.2:** discuss minimally invasive and video-assisted approaches in cardiothoracic surgery
- **SLO 3.3:** describe the principles of cardiopulmonary bypass and valve surgery
- **SLO 3.4:** describe the principles of coronary artery bypass surgery
- **SLO 3.5:** describe the principles of lung resection and mediastinal mass management
- **SLO 3.6:** discuss the principles of pleural disease management
- **SLO 3.7:** compare open and endovascular approaches in vascular surgery
- **SLO 3.8:** describe the principles of perioperative care in cardiothoracic and vascular surgery

3.1 Principles of Surgical Access in Cardiothoracic Surgery

3.1.1 median sternotomy

The workhorse incision for cardiac surgery

Median sternotomy, a vertical incision through the midline of the sternum, is the standard approach for most cardiac surgical procedures, providing excellent, symmetrical access to the heart and great vessels and allowing straightforward institution of cardiopulmonary bypass, since the major vessels required for cannulation are readily accessible through this single, central incision.

Following the procedure, the sternum is reapproximated with wire sutures, and adequate sternal healing over the following weeks is essential to avoid the significant complication of **sternal dehiscence** or **mediastinitis**, making postoperative activity restriction, such as avoiding heavy lifting and specific movements that place strain on the healing sternum, a genuinely important part of the patient's early recovery instructions.

Fill in the blank: Following median sternotomy, the sternum is reapproximated with _____ sutures.

3.1.2 thoracotomy approaches

Accessing one side of the chest specifically

Thoracotomy, an incision into the chest wall between the ribs, provides access to one hemithorax and is the standard approach for most lung resections and many oesophageal and great vessel procedures, with the specific intercostal space chosen depending on the target structure, a **posterolateral thoracotomy** commonly used for lung resections and a more anterior approach sometimes preferred for other indications.

Thoracotomy is associated with significant postoperative pain given the extensive muscle division and rib spreading involved, making effective analgesia, frequently including regional techniques such as an epidural or paravertebral block, a genuinely important component of the perioperative plan, since inadequately controlled pain after thoracotomy leads to shallow breathing and an increased risk of postoperative chest infection.

Fill in the blank: Thoracotomy is associated with significant postoperative pain, making effective _____ a key component of the perioperative plan.

3.1.3 minimally invasive and video-assisted approaches

Smaller incisions, comparable results

Video-assisted thoracoscopic surgery, performed through several small incisions using a camera and specialised instruments rather than a single large open incision, has become the preferred approach for many lung resections and pleural procedures where anatomically and technically appropriate, offering reduced postoperative pain, shorter hospital stay, and faster recovery compared with open thoracotomy for comparable procedures.

Minimally invasive cardiac surgery, performed through smaller incisions than a full median sternotomy, is similarly increasingly used for selected valve and other cardiac procedures in appropriately selected patients, though these techniques demand specific additional surgical expertise and are not universally appropriate for every patient or every procedure, particularly complex cases where the superior exposure of a full sternotomy remains genuinely preferable.

Fill in the blank: Video-assisted thoracoscopic surgery offers reduced pain, shorter stay, and faster _____ compared with open thoracotomy.

Figure 3.1: A surgical team performing a median sternotomy at the start of cardiac surgery.

Pilot questions 3.1

- Describe median sternotomy and its main advantage. (Linked to SLO 3.1)
- Explain why sternal healing matters following sternotomy. (Linked to SLO 3.1)
- Describe the standard approach for most lung resections. (Linked to SLO 3.1)
- Explain why effective analgesia is particularly important after thoracotomy. (Linked to SLO 3.1)
- List the benefits of video-assisted thoracoscopic surgery over open thoracotomy. (Linked to SLO 3.2)

3.2 Principles of Cardiac Surgical Management

3.2.1 cardiopulmonary bypass

Taking over the work of the heart and lungs temporarily

Cardiopulmonary bypass temporarily takes over the function of the heart and lungs during cardiac surgery, diverting venous blood away from the heart to an external machine that oxygenates it and returns it to the arterial circulation, allowing the surgeon to operate on a still, bloodless heart while the rest of the body continues to receive adequately oxygenated blood throughout the procedure.

While generally very safe, cardiopulmonary bypass carries its own specific physiological effects, including a systemic inflammatory response, and requires careful anticoagulation with heparin throughout the period of bypass to prevent clot formation within the circuit, with this anticoagulation carefully reversed with protamine once bypass is discontinued at the end of the procedure, a precisely timed pharmacological sequence essential to the safety of the whole technique.

Fill in the blank: Anticoagulation during cardiopulmonary bypass is reversed with _____ once bypass is discontinued.

3.2.2 principles of valve surgery

Repairing or replacing a damaged valve

Valve surgery offers two broad options depending on the specific valve, the nature of the pathology, and patient factors: **valve repair**, preserving the patient's own valve tissue where technically feasible, and **valve replacement**, using either a mechanical or a biological prosthetic

valve, with repair generally preferred where achievable given the avoidance of long-term anticoagulation and prosthesis-related complications that replacement carries.

Mechanical valves offer greater durability but require lifelong anticoagulation given their inherent thrombogenicity, while **biological valves** avoid this requirement for long-term anticoagulation but have a more limited durability, particularly in younger patients, and choosing between these two options requires careful discussion with the patient about their individual priorities, age, and willingness to accept lifelong anticoagulation, rather than a decision made by the surgeon alone.

Fill in the blank: Mechanical valves require lifelong _____ given their inherent thrombogenicity.

3.2.3 principles of coronary artery bypass surgery

Rerouting blood flow around a blocked coronary artery

Coronary artery bypass grafting restores blood flow beyond a significant coronary artery blockage by using a graft, most commonly the internal mammary artery or a segment of the saphenous vein, to create a new conduit connecting the aorta, or another suitable vessel, to the coronary artery beyond the site of blockage, effectively bypassing the diseased segment rather than attempting to open or remove it directly.

The **internal mammary artery** is generally the preferred conduit given its excellent long-term patency compared with venous grafts, and the number of grafts performed in a single operation depends on the extent and distribution of coronary disease identified on preoperative angiography, with the overall surgical strategy planned collaboratively between the surgeon and cardiologist based on the specific pattern of disease present in the individual patient.

Fill in the blank: The internal mammary artery is generally preferred given its excellent long-term _____ compared with venous grafts.

Table 3.1: Comparing mechanical and biological heart valves

Feature	Mechanical valve	Biological valve
Durability	High, generally lifelong	Limited, particularly in younger patients
Anticoagulation	Lifelong required	Not typically required long-term

Preferred patient group	Younger patients accepting anticoagulation	Older patients or those avoiding anticoagulation

Pilot questions 3.2

1. Describe the function of cardiopulmonary bypass during cardiac surgery. (Linked to SLO 3.3)
2. Explain the anticoagulation sequence required during cardiopulmonary bypass. (Linked to SLO 3.3)
3. Distinguish valve repair from valve replacement. (Linked to SLO 3.3)
4. Distinguish mechanical from biological heart valves. (Linked to SLO 3.3)
5. Describe the principle underlying coronary artery bypass grafting. (Linked to SLO 3.4)

3.3 Principles of Thoracic Surgical Management

3.3.1 principles of lung resection surgery

Matching the extent of resection to the disease

Lung resection ranges in extent from a small wedge resection, removing a limited area of lung tissue, through lobectomy, removing an entire lobe, to pneumonectomy, removing an entire lung, with the extent of resection chosen based on the size, location, and nature of the lesion, alongside the patient's underlying lung function and physiological reserve to tolerate the resulting loss of functioning lung tissue.

Lobectomy is generally the standard resection for early-stage lung cancer where the patient's lung function permits, since it removes the tumour with an adequate margin while preserving more functioning lung tissue than pneumonectomy, and preoperative assessment of lung function is therefore a genuinely essential step in planning any lung resection, directly influencing both the extent of resection considered safe and the patient's expected postoperative respiratory function.

Fill in the blank: Preoperative assessment of lung function directly influences the extent of resection considered _____.

3.3.2 principles of mediastinal mass management

Access and excision guided by location and diagnosis

Management of a **mediastinal mass** depends heavily on its compartment of origin and likely diagnosis, with surgical approach ranging from median sternotomy for selected anterior masses, to a lateral thoracotomy or video-assisted thoracoscopic approach for masses in other locations, chosen according to the specific anatomical access each mass requires for safe, complete resection.

Tissue diagnosis, whether through image-guided biopsy or, where a definitive tissue diagnosis cannot be reached safely beforehand, surgical excision itself, guides the subsequent management plan, since some mediastinal masses, such as lymphoma, are managed primarily with chemotherapy or radiotherapy rather than surgery, making an accurate diagnosis before committing to a surgical approach a genuinely important preliminary step wherever it can be safely obtained.

Fill in the blank: Some mediastinal masses, such as lymphoma, are managed primarily with chemotherapy rather than _____.

3.3.3 principles of pleural disease management

From simple drainage to definitive pleurodesis

Management of a **pleural effusion** ranges from simple therapeutic aspiration for symptomatic relief, through chest drain insertion for larger or recurrent effusions, to **pleurodesis**, a procedure deliberately causing adhesion between the visceral and parietal pleura to prevent fluid or air from reaccumulating, typically used for recurrent malignant effusions or recurrent pneumothorax where a definitive solution is required.

Video-assisted thoracoscopic pleurodesis, combining direct visualisation of the pleural cavity with instillation of a sclerosing agent such as talc, offers a more definitive and reliable approach than a simple chest drain alone for recurrent pleural pathology, and selecting the appropriate level of intervention, from simple aspiration through to definitive pleurodesis, depends on the underlying cause, the patient's overall prognosis, and the likelihood of recurrence with a less invasive approach.

Fill in the blank: Pleurodesis deliberately causes adhesion between the visceral and parietal _____ to prevent recurrence.

Figure 3.2: A surgeon performing video-assisted thoracoscopic surgery guided by a screen.

Pilot questions 3.3

1. List the range of lung resection extent from smallest to largest. (Linked to SLO 3.5)
2. Explain why lobectomy is generally preferred over pneumonectomy where possible. (Linked to SLO 3.5)
3. Explain how the compartment of origin influences mediastinal mass management. (Linked to SLO 3.5)
4. Define pleurodesis and its purpose. (Linked to SLO 3.6)
5. Explain the benefit of video-assisted thoracoscopic pleurodesis over simple chest drain alone. (Linked to SLO 3.6)

3.4 Principles of Vascular Surgical Management

3.4.1 principles of open vascular surgery

Direct surgical access to the diseased vessel

Open vascular surgery, directly exposing and repairing or bypassing a diseased artery, remains the definitive approach for many vascular conditions, offering durable, long-term results and direct visual and tactile assessment of the vessel, though at the cost of a larger incision, longer

recovery, and generally higher perioperative risk compared with an equivalent endovascular alternative where one exists.

Bypass grafting, using either a prosthetic graft or the patient's own vein, remains a core open vascular technique for restoring blood flow around a significant arterial blockage, conceptually similar to coronary artery bypass grafting already discussed, and choosing the correct conduit and bypass route requires careful consideration of the specific vessel involved and the availability of suitable autologous vein.

Fill in the blank: Open vascular surgery offers durable results but generally carries higher perioperative _____ than an equivalent endovascular alternative.

3.4.2 principles of endovascular surgery

Treating vessels from the inside, through a small puncture

Endovascular surgery, accessing and treating the diseased vessel from within, typically through a small puncture in a peripheral artery under imaging guidance, includes techniques such as angioplasty, stenting, and **endovascular aneurysm repair**, offering reduced recovery time, lower immediate perioperative risk, and shorter hospital stay compared with equivalent open surgery, though generally requiring more frequent long-term surveillance imaging to detect any late complication.

The suitability of a lesion for endovascular treatment depends on its specific anatomy, and not every lesion is technically suitable for an endovascular approach, meaning the choice between open and endovascular treatment genuinely requires careful individual patient and anatomical assessment rather than defaulting automatically to the less invasive option in every case regardless of anatomical suitability.

Fill in the blank: Endovascular surgery generally requires more frequent long-term _____ imaging than open surgery.

3.4.3 principles of perioperative care in cardiothoracic and vascular surgery

Supporting the patient before, during, and after surgery

Perioperative care in cardiothoracic and vascular surgery begins well before the operating theatre, with preoperative optimisation of cardiovascular risk factors, correction of any reversible medical condition, and thorough patient counselling about the planned procedure and its risks, continues through careful intraoperative monitoring and physiological support, and extends into structured postoperative recovery with early mobilisation and complication surveillance.

Multidisciplinary input, drawing on anaesthetists, intensivists, physiotherapists, and specialist nurses alongside the surgical team, genuinely improves outcomes across this entire perioperative journey, and structured enhanced recovery protocols, applying evidence-based principles to minimise physiological stress and support faster recovery, are increasingly used across cardiothoracic and vascular surgery to improve both outcomes and the patient's overall experience of care.

Fill in the blank: Structured enhanced recovery protocols aim to minimise physiological stress and support faster _____.

Table 3.2: Comparing open and endovascular vascular surgery

Feature	Open surgery	Endovascular surgery
Durability	Generally more durable long-term	May require reintervention
Recovery time	Longer	Shorter
Surveillance need	Less frequent	More frequent long-term imaging

Pilot questions 3.4

1. Describe the main advantage of open vascular surgery. (Linked to SLO 3.7)
2. Describe bypass grafting as an open vascular technique. (Linked to SLO 3.7)
3. List the advantages of endovascular surgery compared with open surgery. (Linked to SLO 3.7)
4. Explain why not every vascular lesion is suitable for endovascular treatment. (Linked to SLO 3.7)
5. Describe the components of perioperative care in cardiothoracic and vascular surgery. (Linked to SLO 3.8)

Series Summary

This Series worked through the principles underlying surgical management across cardiothoracic and vascular surgery. Part 3.1 covered surgical access, median sternotomy, thoracotomy, and minimally invasive approaches, while Part 3.2 turned to cardiac surgical management, cardiopulmonary bypass, valve surgery, and coronary artery bypass grafting. Part 3.3 covered

thoracic surgical management, lung resection, mediastinal mass management, and pleural disease management, and Part 3.4 closed with vascular surgical management, open and endovascular approaches, and perioperative care.

You should now be able to describe the surgical approaches and principles underlying management across all four Parts of this Series, meeting the outcomes set for this Series. Series 4 turns next to investigation, treatment, and management of complications in cardiothoracic surgery.

Glossary of Terms

1. **Cardiopulmonary bypass:** a technique temporarily taking over heart and lung function during cardiac surgery.
2. **Coronary artery bypass grafting:** surgery restoring blood flow beyond a coronary artery blockage using a graft.
3. **Endovascular aneurysm repair:** minimally invasive repair of an aneurysm from within the vessel.
4. **Enhanced recovery protocol:** structured, evidence-based perioperative care to support faster recovery.
5. **Lobectomy:** surgical removal of an entire lobe of the lung.
6. **Mechanical valve:** a prosthetic heart valve requiring lifelong anticoagulation.
7. **Median sternotomy:** a vertical incision through the sternum, the standard approach for most cardiac surgery.
8. **Perioperative care:** structured patient care spanning the period before, during, and after surgery.
9. **Pleurodesis:** a procedure causing adhesion between pleural layers to prevent fluid or air recurrence.
10. **Pneumonectomy:** surgical removal of an entire lung.
11. **Thoracotomy:** an incision into the chest wall between the ribs, providing access to one hemithorax.
12. **Video-assisted thoracoscopic surgery:** minimally invasive thoracic surgery using a camera and small incisions.

Concept Check Questions [Series 3]

Objective questions

- Following median sternotomy, the sternum is reapproximated with _____ sutures. (Linked to SLO 3.1)
- Anticoagulation during cardiopulmonary bypass is reversed with _____ once bypass is discontinued. (Linked to SLO 3.3)
- The internal mammary artery is generally preferred given its excellent long-term _____ compared with venous grafts. (Linked to SLO 3.4)
- Pleurodesis deliberately causes adhesion between the visceral and parietal _____ to prevent recurrence. (Linked to SLO 3.6)
- Endovascular surgery generally requires more frequent long-term _____ imaging than open surgery. (Linked to SLO 3.7)

Short-answer questions

1. Describe median sternotomy and its main advantage. (Linked to SLO 3.1)
2. Distinguish mechanical from biological heart valves. (Linked to SLO 3.3)
3. Explain why lobectomy is generally preferred over pneumonectomy where possible. (Linked to SLO 3.5)
4. Define pleurodesis and its purpose. (Linked to SLO 3.6)
5. List the advantages of endovascular surgery compared with open surgery. (Linked to SLO 3.7)

Long-answer questions

6. Discuss the surgical approaches used in cardiothoracic surgery, including minimally invasive options. (Linked to SLO 3.1, 3.2)
7. Describe the principles of cardiopulmonary bypass, valve surgery, and coronary artery bypass grafting. (Linked to SLO 3.3, 3.4)
8. Discuss the principles of lung resection, mediastinal mass management, and pleural disease management. (Linked to SLO 3.5, 3.6)
9. Compare open and endovascular approaches in vascular surgery. (Linked to SLO 3.7)
10. Describe the principles of perioperative care in cardiothoracic and vascular surgery. (Linked to SLO 3.8)

Answers to Concept Check Questions [Series 3]

Objective questions

11. Wire.
12. Protamine.
13. Patency.
14. Pleura.
15. Surveillance.

Short-answer questions

16. Median sternotomy is a vertical sternal incision offering excellent, symmetrical access to the heart and great vessels.
17. Mechanical valves are durable but require lifelong anticoagulation, while biological valves avoid this but have limited durability.
18. Lobectomy removes the tumour with adequate margin while preserving more functioning lung tissue than pneumonectomy.
19. Pleurodesis causes adhesion between pleural layers to prevent recurrent fluid or air accumulation.
20. Endovascular surgery offers reduced recovery time, lower immediate perioperative risk, and shorter hospital stay.

Long-answer questions

21. **Basic response:** Median sternotomy is standard for most cardiac surgery; thoracotomy provides access to one hemithorax for lung resections; video-assisted and minimally invasive approaches offer reduced pain and faster recovery where anatomically appropriate.

    Value-added response: A value-added response notes that minimally invasive techniques demand specific additional expertise and are not universally suitable for every patient or procedure.

22. **Basic response:** Cardiopulmonary bypass diverts blood through an external machine during surgery; valve surgery offers repair or replacement with mechanical or biological options; coronary artery bypass grafting reroutes blood flow around blocked coronary arteries.

    Value-added response: A value-added response notes that the internal mammary artery is preferred for coronary bypass given its superior long-term patency compared with venous grafts.

23. **Basic response:** Lung resection ranges from wedge resection to pneumonectomy depending on disease extent and lung function; mediastinal mass management depends on compartment and diagnosis; pleural disease management ranges from aspiration to definitive pleurodesis.

    Value-added response: A value-added response notes that some mediastinal masses, such as lymphoma, are managed primarily with chemotherapy rather than surgery.

24. **Basic response:** Open surgery offers durable, long-term results with direct vessel access but higher perioperative risk; endovascular surgery offers reduced recovery time and lower immediate risk but requires more frequent surveillance and is not suitable for every anatomy.

    Value-added response: A value-added response notes that lesion anatomy genuinely determines suitability for endovascular treatment, rather than the less invasive option being automatically preferred.

25. **Basic response:** Perioperative care spans preoperative optimisation, intraoperative monitoring, and structured postoperative recovery with early mobilisation and complication surveillance.

    Value-added response: A value-added response notes that multidisciplinary input and enhanced recovery protocols genuinely improve outcomes and patient experience across this journey.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Median sternotomy is a vertical sternal incision offering excellent, symmetrical access to the heart and great vessels.
2. Adequate sternal healing avoids sternal dehiscence and mediastinitis, serious postoperative complications.
3. Thoracotomy, most commonly posterolateral, is the standard approach for most lung resections.
4. Effective analgesia prevents shallow breathing and reduces the risk of postoperative chest infection.
5. Video-assisted thoracoscopic surgery offers reduced pain, shorter hospital stay, and faster recovery.

Part 3.2

6. Cardiopulmonary bypass diverts blood through an external machine, allowing surgery on a still, bloodless heart.
7. Heparin is used for anticoagulation during bypass, reversed with protamine once bypass ends.
8. Valve repair preserves the patient's own tissue, while valve replacement uses a mechanical or biological prosthesis.
9. Mechanical valves are durable but require lifelong anticoagulation, while biological valves have limited durability without this requirement.
10. Coronary artery bypass grafting reroutes blood flow around a blocked coronary artery using a graft such as the internal mammary artery.

Part 3.3

11. The range is wedge resection, lobectomy, and pneumonectomy.
12. Lobectomy preserves more functioning lung tissue than pneumonectomy while still achieving adequate tumour margins.
13. The compartment of origin determines the surgical approach and access required for safe resection.
14. Pleurodesis causes adhesion between pleural layers to prevent recurrent fluid or air accumulation.
15. Video-assisted thoracoscopic pleurodesis offers direct visualisation and more reliable, definitive results than a simple drain alone.

Part 3.4

1. Open vascular surgery offers durable, long-term results with direct vessel access.
2. Bypass grafting uses a prosthetic graft or the patient's own vein to restore blood flow around a blockage.
3. Endovascular surgery offers reduced recovery time, lower immediate risk, and shorter hospital stay.
4. Suitability depends on the lesion's specific anatomy, which is not always technically appropriate for an endovascular approach.
5. Perioperative care spans preoperative optimisation, intraoperative monitoring, and postoperative recovery with complication surveillance.

References and Attributions [Series 3]

1. Sabiston, D. C., & Townsend, C. M. (2021). Sabiston Textbook of Surgery (21st ed.). Elsevier.
2. Yuh, D. D., Vricella, L. A., Yang, S. C., & Doty, J. R. (2014). Johns Hopkins Textbook of Cardiothoracic Surgery (2nd ed.). McGraw-Hill.
3. Shields, T. W. (2019). General Thoracic Surgery (8th ed.). Wolters Kluwer.
4. Rutherford, R. B. (2019). Rutherford's Vascular Surgery and Endovascular Therapy (9th ed.). Elsevier.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: A surgical team performing a median sternotomy at the start of cardiac surgery. AI-generated using the prompt: "Create a realistic clinical illustration titled Median Sternotomy Incision, showing a surgical team in theatre gowns and masks around a draped patient with a vertical sternal incision being made, operating theatre setting with instruments visible. Clean clinical illustration style, no text."
2. Table 3.1: Comparing mechanical and biological heart valves. AI-generated using the prompt: "Create a clean reference table titled Comparing Mechanical and Biological Heart Valves, listing feature, mechanical valve, and biological valve. Simple clinical reference table style with outside border."
3. Figure 3.2: A surgeon performing video-assisted thoracoscopic surgery guided by a screen. AI-generated using the prompt: "Create a realistic clinical illustration titled Video-Assisted Thoracoscopic Surgery, showing a surgeon in theatre attire manipulating thoracoscopic instruments through small chest incisions while viewing a monitor displaying the operative field, operating theatre setting. Clean clinical illustration style, no text."
4. Table 3.2: Comparing open and endovascular vascular surgery. AI-generated using the prompt: "Create a clean reference table titled Comparing Open and Endovascular Vascular Surgery, listing feature, open surgery, and endovascular surgery. Simple clinical reference table style with outside border."

Course code: SUG 603

Course title: Cardiothoracic including Vascular Surgery

Course credit load: 2 Units

Series 4: Investigation, Treatment, and Management of Complications in Cardiothoracic Surgery

- **Part 4.1: Investigation of Cardiac and Thoracic Lesions**
  - Sub Part 4.1.1: Electrocardiography and echocardiography
  - Sub Part 4.1.2: Cardiac catheterisation and coronary angiography
  - Sub Part 4.1.3: Chest imaging: radiography, CT, and biopsy
- **Part 4.2: Investigation of Vascular Lesions**
  - Sub Part 4.2.1: Duplex ultrasound in vascular disease
  - Sub Part 4.2.2: CT and MR angiography
  - Sub Part 4.2.3: Ankle-brachial pressure index and other vascular tests
- **Part 4.3: Treatment Decision-Making Across Cardiothoracic Surgery**
  - Sub Part 4.3.1: Medical versus surgical treatment decision-making
  - Sub Part 4.3.2: Multidisciplinary team decision-making
  - Sub Part 4.3.3: Postoperative recovery and rehabilitation
- **Part 4.4: Complications in Cardiothoracic and Vascular Surgery**
  - Sub Part 4.4.1: Bleeding and cardiac complications after surgery
  - Sub Part 4.4.2: Respiratory and infective complications after surgery
  - Sub Part 4.4.3: Graft and prosthesis-related complications

Introduction

Deciding what is wrong, confirming it with the right test, choosing the right treatment, and managing whatever goes wrong afterwards, this is the complete clinical cycle that closes out the

practical skills built across this course. This Series turns to **investigation, treatment, and the management of complications** in cardiothoracic and vascular surgery, drawing together the assessment skills from Series 1 and the surgical principles from Series 3 into a single, coherent clinical pathway.

The aim of this Series is to equip you with an understanding of the investigations used to confirm cardiac, thoracic, and vascular diagnoses, the factors guiding treatment decision-making including the role of the multidisciplinary team, and the recognition and management of the complications that can follow cardiothoracic and vascular surgery. Complications are an inevitable, if hopefully infrequent, part of any surgical specialty, and managing them well is just as important a skill as performing the original operation successfully.

This Series opens with **investigation of cardiac and thoracic lesions**, moves through **investigation of vascular lesions** and **treatment decision-making**, and closes with **complications in cardiothoracic and vascular surgery**.

Series Learning Outcomes

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

- **SLO 4.1:** describe the investigations used to assess cardiac and thoracic lesions
- **SLO 4.2:** discuss the role of cardiac catheterisation and coronary angiography
- **SLO 4.3:** describe the investigations used to assess vascular lesions
- **SLO 4.4:** discuss the role of duplex ultrasound and angiography in vascular disease
- **SLO 4.5:** discuss the factors guiding medical versus surgical treatment decisions
- **SLO 4.6:** describe the role of the multidisciplinary team in treatment planning
- **SLO 4.7:** list the complications of cardiothoracic and vascular surgery
- **SLO 4.8:** describe the management of postoperative complications

4.1 Investigation of Cardiac and Thoracic Lesions

4.1.1 electrocardiography and echocardiography

First-line, widely available cardiac investigations

The **electrocardiogram** remains the first-line investigation for suspected cardiac pathology, providing rapid information about rhythm, evidence of ischaemia or infarction, and chamber

enlargement, and its widespread availability and speed make it an essential initial step in almost any cardiac assessment, even though it cannot directly visualise structural cardiac anatomy.

Echocardiography, using ultrasound to directly visualise cardiac structure and function, assesses valve function, chamber size, wall motion, and overall pump function, and is generally the key investigation for confirming and quantifying suspected valvular heart disease, since it directly visualises the abnormality suspected from the murmur and symptoms already discussed in earlier Series of this course, converting a clinical suspicion into an objective, measurable diagnosis.

Fill in the blank: Echocardiography uses _____ to directly visualise cardiac structure and function.

4.1.2 cardiac catheterisation and coronary angiography

Directly visualising the coronary arteries

Coronary angiography, performed via cardiac catheterisation, involves injecting contrast directly into the coronary arteries under fluoroscopic guidance to directly visualise any stenosis or occlusion, and remains the definitive investigation for confirming and precisely characterising the extent and distribution of coronary artery disease before a decision is made between medical management, percutaneous intervention, or surgical revascularisation.

Cardiac catheterisation can also directly measure intracardiac pressures and oxygen saturations in specific chambers, providing additional physiological information particularly valuable in the assessment of certain congenital cardiac conditions, and the invasive nature of the procedure, though generally very safe, carries small but genuine specific procedural risks that must be weighed against the diagnostic and therapeutic benefit it offers over non-invasive alternatives.

Fill in the blank: Coronary angiography involves injecting contrast directly into the coronary arteries under fluoroscopic _____.

4.1.3 chest imaging: radiography, ct, and biopsy

From a simple film to definitive tissue diagnosis

Chest radiography remains a useful, widely available initial investigation for a range of thoracic pathology, including lung masses, pleural effusion, and pneumothorax, though its limited sensitivity for small or subtle lesions means a normal chest radiograph does not fully exclude significant underlying thoracic pathology in a patient with a suggestive clinical history.

Computed tomography provides considerably more detailed anatomical information than plain radiography, and is essential for accurately characterising a lung or mediastinal mass, planning surgical resection, and staging suspected malignant disease, while **image-guided biopsy**, typically performed under CT guidance, provides the definitive tissue diagnosis required before committing a patient to major surgery or oncological treatment for a suspicious thoracic lesion.

Fill in the blank: A normal chest radiograph does not fully exclude significant underlying thoracic _____ in a suggestive clinical history.

Figure 4.1: A sonographer performing transthoracic echocardiography.

Pilot questions 4.1

- Describe the role of the electrocardiogram as a first-line cardiac investigation. (Linked to SLO 4.1)
- Explain why echocardiography is the key investigation for valvular heart disease. (Linked to SLO 4.1)
- Describe the purpose of coronary angiography. (Linked to SLO 4.2)
- Explain the additional physiological information cardiac catheterisation can provide. (Linked to SLO 4.2)
- Explain why image-guided biopsy is required before major treatment of a suspicious thoracic lesion. (Linked to SLO 4.1)

4.2 Investigation of Vascular Lesions

4.2.1 duplex ultrasound in vascular disease

A non-invasive first-line vascular investigation

Duplex ultrasound, combining conventional ultrasound imaging with Doppler assessment of blood flow, is a non-invasive, widely available first-line investigation for both arterial and venous disease, capable of identifying arterial stenosis or occlusion, characterising an aneurysm, and confirming or excluding deep vein thrombosis, all without the radiation exposure or contrast-related risks associated with other imaging modalities.

Because duplex ultrasound is operator-dependent and its accuracy in certain anatomical locations, such as deep within the pelvis, is more limited than in more accessible peripheral vessels, it is frequently used as an effective first-line screening or surveillance test, with further cross-sectional imaging reserved for cases requiring more detailed anatomical information or where duplex findings are equivocal.

Fill in the blank: Duplex ultrasound combines conventional imaging with _____ assessment of blood flow.

4.2.2 ct and mr angiography

Detailed cross-sectional vascular imaging

CT angiography, using intravenous contrast and computed tomography to produce detailed images of the vasculature, provides considerably more comprehensive anatomical detail than duplex ultrasound, particularly valuable for surgical or endovascular planning, staging the extent of aneurysmal disease, or characterising complex arterial anatomy not fully accessible to ultrasound assessment alone.

MR angiography offers broadly comparable anatomical detail to CT angiography without ionising radiation, making it a valuable alternative in patients where radiation exposure is a particular concern, though it is generally less widely available, takes longer to perform, and is unsuitable for patients with certain implanted devices, considerations that influence the choice between these two broadly complementary cross-sectional imaging modalities.

Fill in the blank: MR angiography offers comparable detail to CT angiography without ionising _____.

4.2.3 ankle-brachial pressure index and other vascular tests

Simple bedside tests with genuine diagnostic value

The **ankle-brachial pressure index**, already introduced earlier in this course in the context of ulcer assessment, remains equally relevant here as a simple, quick bedside test for peripheral arterial disease, comparing systolic pressure at the ankle and arm to provide an objective measure of arterial supply to the lower limb without requiring specialist imaging equipment.

Exercise testing, measuring the ankle-brachial pressure index before and after a standardised period of walking, can unmask arterial disease that is not apparent at rest, since some patients with genuine claudication have a normal resting index but a significant drop after exercise, making this dynamic assessment a valuable addition to the vascular investigation pathway for patients presenting with symptoms suggestive of claudication despite unremarkable resting findings.

Fill in the blank: Exercise testing can unmask arterial disease not apparent at _____ by measuring the pressure index change.

Table 4.1: Comparing vascular investigations

Investigation	Invasiveness	Key use
Duplex ultrasound	Non-invasive	First-line screening and surveillance
CT angiography	Requires intravenous contrast	Detailed surgical or endovascular planning
MR angiography	Requires intravenous contrast, no radiation	Alternative where radiation is a concern

Pilot questions 4.2

1. Describe duplex ultrasound and its main advantages. (Linked to SLO 4.3)
2. Explain a limitation of duplex ultrasound. (Linked to SLO 4.3)
3. Distinguish CT angiography from MR angiography. (Linked to SLO 4.4)
4. Describe the ankle-brachial pressure index. (Linked to SLO 4.3)
5. Explain the value of exercise testing in suspected claudication. (Linked to SLO 4.3)

4.3 Treatment Decision-Making Across Cardiothoracic Surgery

4.3.1 medical versus surgical treatment decision-making

Weighing options against the individual patient

The decision between **medical** and **surgical treatment** for many cardiothoracic and vascular conditions depends on the severity and progression of the underlying disease, the patient's overall physiological reserve and comorbidities, the anticipated benefit of intervention weighed against its risks, and, genuinely importantly, the patient's own values and preferences once fully and honestly informed of the realistic options available.

Some conditions have a clear evidence-based threshold favouring surgical intervention, such as severe symptomatic valvular disease, while others involve a genuinely more nuanced discussion balancing modest incremental benefit against procedural risk, particularly in older or frailer patients where the calculus between intervention and conservative management is considerably less straightforward than textbook criteria alone might suggest.

Fill in the blank: Treatment decisions genuinely depend on the patient's own values and _____ once fully informed.

4.3.2 multidisciplinary team decision-making

No single specialist has the whole picture alone

Multidisciplinary team meetings, bringing together surgeons, cardiologists or physicians, radiologists, oncologists where relevant, and specialist nurses, have become the standard mechanism for complex treatment decision-making across cardiothoracic and vascular surgery, ensuring that a treatment recommendation reflects genuinely collective expert input rather than the judgement of a single clinician working in isolation.

This collaborative approach is particularly valuable for genuinely borderline cases, where the correct treatment is not immediately obvious from a single specialist's perspective, and structured multidisciplinary team discussion has been shown to improve both the consistency and quality of treatment decisions across a wide range of complex cardiothoracic and vascular conditions compared with individual clinician decision-making alone.

Fill in the blank: Multidisciplinary team discussion ensures a treatment recommendation reflects genuinely collective expert _____.

4.3.3 postoperative recovery and rehabilitation

Treatment does not end when the operation does

Postoperative recovery following major cardiothoracic or vascular surgery follows a structured pathway of early mobilisation, respiratory physiotherapy, gradual return to normal activity, and close monitoring for the early signs of complications, with the specific pace and content of this pathway tailored to the individual procedure performed and the patient's overall physiological reserve.

Cardiac rehabilitation, a structured programme of supervised exercise, education, and psychological support following cardiac surgery or a significant cardiac event, meaningfully improves long-term functional outcome and reduces future cardiovascular risk, and referral to such a programme should be considered a routine, expected part of the postoperative pathway rather than an optional extra offered only to particularly motivated patients.

Fill in the blank: Cardiac rehabilitation meaningfully improves long-term functional outcome and reduces future cardiovascular _____.

Figure 4.2: A multidisciplinary team reviewing patient imaging during a treatment planning meeting.

Pilot questions 4.3

1. List the factors guiding the decision between medical and surgical treatment. (Linked to SLO 4.5)
2. Explain why patient values and preferences matter in treatment decision-making. (Linked to SLO 4.5)
3. Describe the composition and purpose of a multidisciplinary team meeting. (Linked to SLO 4.6)
4. Explain why multidisciplinary discussion is particularly valuable for borderline cases. (Linked to SLO 4.6)
5. Describe the components of cardiac rehabilitation and its benefit. (Linked to SLO 4.8)

4.4 Complications in Cardiothoracic and Vascular Surgery

4.4.1 bleeding and cardiac complications after surgery

Early complications requiring prompt recognition

Postoperative bleeding, whether from a surgical site or related to the anticoagulation required during cardiopulmonary bypass, presents with excessive chest drain output, hypotension, or signs of tamponade if bleeding accumulates within the pericardial space, and prompt recognition, with return to theatre for exploration where indicated, meaningfully reduces the risk of a poor outcome from ongoing, unrecognised haemorrhage.

Arrhythmia, particularly atrial fibrillation, is a genuinely common complication following cardiac surgery, related to the surgical manipulation and inflammation of cardiac tissue, and, while often self-limiting or straightforward to manage with medication, requires active monitoring and prompt treatment given the associated risk of haemodynamic compromise or thromboembolism if left unaddressed.

Fill in the blank: Postoperative bleeding into the pericardial space can present with signs of _____ if it accumulates.

4.4.2 respiratory and infective complications after surgery

The chest's own vulnerability after major surgery

Respiratory complications, including atelectasis, pneumonia, and, less commonly, acute respiratory distress syndrome, are particularly common after thoracic and cardiac surgery given the direct effect of surgery on the chest wall and lungs, alongside the effects of prolonged anaesthesia and, frequently, inadequate postoperative pain control limiting effective deep breathing and coughing.

Surgical site infection, including the particularly serious complication of deep sternal wound infection or mediastinitis following median sternotomy, requires prompt recognition through active surveillance for wound erythema, discharge, or instability, and management ranging from antibiotic therapy for superficial infection to surgical debridement and, in severe cases, flap reconstruction for deep sternal infection, reflecting the genuinely serious nature of this specific complication.

Fill in the blank: Deep sternal wound infection following median sternotomy is also known as _____.

4.4.3 graft and prosthesis-related complications

Long-term problems specific to implanted material

Graft-related complications, including graft occlusion, infection, or, for vascular grafts specifically, pseudoaneurysm formation at an anastomotic site, can occur at any point after surgery, from the immediate postoperative period through to many years later, and structured long-term surveillance, particularly following vascular bypass or endovascular repair, allows early identification and treatment before a complication progresses to a more serious, potentially limb- or life-threatening stage.

Prosthetic valve complications, including thrombosis, infective endocarditis affecting the prosthesis, and structural valve deterioration over time, particularly relevant for biological valves given their more limited durability already discussed earlier in this Series, require ongoing surveillance and a low threshold for further investigation in any patient with a prosthetic valve presenting with new or worsening cardiac symptoms, given the potentially serious consequences of a missed prosthesis-related complication.

Fill in the blank: A pseudoaneurysm can form at an anastomotic site as a specific _____-related complication.

Table 4.2: Timing and management of key postoperative complications

Complication	Typical timing	Management focus
Postoperative bleeding	Early, within hours	Monitoring, return to theatre if indicated
Surgical site infection	Days to weeks	Antibiotics or debridement depending on depth
Graft or prosthesis complication	Months to years	Long-term surveillance and early intervention

Pilot questions 4.4

1. Describe the presentation of postoperative bleeding after cardiac surgery. (Linked to SLO 4.7)
2. Explain why atrial fibrillation after cardiac surgery requires active management. (Linked to SLO 4.7)
3. List the respiratory complications common after thoracic and cardiac surgery. (Linked to SLO 4.7)
4. Describe the management of deep sternal wound infection. (Linked to SLO 4.8)
5. Explain why long-term surveillance is important after vascular bypass or endovascular repair. (Linked to SLO 4.8)

Series Summary

This Series completed the clinical cycle begun earlier in this course, from investigation through to treatment decision-making and the management of complications. Part 4.1 covered the investigation of cardiac and thoracic lesions, electrocardiography, echocardiography, catheterisation, and chest imaging, while Part 4.2 turned to the investigation of vascular lesions, duplex ultrasound, angiography, and the ankle-brachial pressure index. Part 4.3 covered treatment decision-making, medical versus surgical choice, the multidisciplinary team, and postoperative recovery, and Part 4.4 closed with the complications of cardiothoracic and vascular surgery.

You should now be able to describe the relevant investigations, discuss treatment decision-making, and recognise and manage the complications covered across all four Parts, meeting the

outcomes set for this Series. Series 5 turns next to congenital malformations and their management.

Glossary of Terms

1. **Ankle-brachial pressure index:** a bedside test comparing ankle and arm blood pressure to assess arterial disease.
2. **Atrial fibrillation:** a common cardiac arrhythmia frequently occurring after cardiac surgery.
3. **Cardiac rehabilitation:** a structured programme of exercise, education, and support following cardiac surgery.
4. **Coronary angiography:** direct imaging of the coronary arteries using contrast and fluoroscopy.
5. **Duplex ultrasound:** ultrasound imaging combined with Doppler assessment of blood flow.
6. **Echocardiography:** ultrasound imaging used to assess cardiac structure and function.
7. **Electrocardiogram:** a recording of the heart's electrical activity, the first-line cardiac investigation.
8. **Mediastinitis:** infection of the mediastinum, a serious complication of sternal wound infection.
9. **Multidisciplinary team meeting:** a collaborative forum for complex treatment decision-making.
10. **Prosthetic valve complication:** a problem such as thrombosis or infection affecting an implanted heart valve.
11. **Pseudoaneurysm:** a contained vascular leak at an anastomotic or puncture site.
12. **Surgical site infection:** infection at or near a surgical incision, ranging from superficial to deep.

Concept Check Questions [Series 4]

Objective questions

- Echocardiography uses _____ to directly visualise cardiac structure and function. (Linked to SLO 4.1)
- Duplex ultrasound combines conventional imaging with _____ assessment of blood flow. (Linked to SLO 4.3)

- Treatment decisions genuinely depend on the patient's own values and _____ once fully informed. (Linked to SLO 4.5)
- Postoperative bleeding into the pericardial space can present with signs of _____ if it accumulates. (Linked to SLO 4.7)
- Deep sternal wound infection following median sternotomy is also known as _____. (Linked to SLO 4.7)

Short-answer questions

1. Describe the purpose of coronary angiography. (Linked to SLO 4.2)
2. Distinguish CT angiography from MR angiography. (Linked to SLO 4.4)
3. Describe the composition and purpose of a multidisciplinary team meeting. (Linked to SLO 4.6)
4. Describe the components of cardiac rehabilitation and its benefit. (Linked to SLO 4.8)
5. List the respiratory complications common after thoracic and cardiac surgery. (Linked to SLO 4.7)

Long-answer questions

6. Discuss the investigations used to assess cardiac and thoracic lesions, including the role of coronary angiography. (Linked to SLO 4.1, 4.2)
7. Describe the investigations used to assess vascular lesions, including duplex ultrasound and angiography. (Linked to SLO 4.3, 4.4)
8. Discuss the factors guiding medical versus surgical treatment decisions and the role of the multidisciplinary team. (Linked to SLO 4.5, 4.6)
9. Describe postoperative recovery and rehabilitation following cardiothoracic surgery. (Linked to SLO 4.8)
10. Discuss the complications of cardiothoracic and vascular surgery and their management. (Linked to SLO 4.7, 4.8)

Answers to Concept Check Questions [Series 4]

Objective questions

11. Ultrasound.
12. Doppler.
13. Preferences.
14. Tamponade.
15. Mediastinitis.

Short-answer questions

16. Coronary angiography directly visualises coronary artery stenosis or occlusion to guide treatment choice.
17. CT angiography uses ionising radiation and contrast, while MR angiography offers comparable detail without radiation but is less widely available.
18. A multidisciplinary team meeting brings together surgeons, physicians, radiologists, and specialist nurses to collectively decide complex treatment plans.
19. Cardiac rehabilitation combines supervised exercise, education, and psychological support, improving long-term functional outcome and reducing cardiovascular risk.
20. Common respiratory complications include atelectasis, pneumonia, and, less commonly, acute respiratory distress syndrome.

Long-answer questions

21. **Basic response:** The electrocardiogram is first-line; echocardiography confirms structural and functional cardiac disease; coronary angiography directly visualises coronary artery disease; chest radiography and CT assess thoracic pathology, with biopsy providing tissue diagnosis.

    Value-added response: A value-added response notes that cardiac catheterisation can also measure intracardiac pressures, providing additional physiological information in selected cases.

22. **Basic response:** Duplex ultrasound is a non-invasive first-line test; CT and MR angiography provide detailed cross-sectional imaging for planning; the ankle-brachial pressure index and exercise testing offer simple, valuable bedside assessment.

    Value-added response: A value-added response notes that exercise testing can unmask claudication not apparent on resting ankle-brachial pressure index measurement.

23. **Basic response:** Decisions depend on disease severity, patient reserve, risk-benefit balance, and patient preference; multidisciplinary team meetings ensure collective expert input, particularly valuable for borderline cases.

    Value-added response: A value-added response notes that structured multidisciplinary discussion has been shown to improve consistency and quality of treatment decisions.

24. **Basic response:** Recovery follows a structured pathway of early mobilisation, physiotherapy, and complication monitoring; cardiac rehabilitation combines exercise, education, and support to improve long-term outcome.

Value-added response: A value-added response notes that referral to cardiac rehabilitation should be a routine, expected part of the postoperative pathway rather than optional.

25. **Basic response:** Complications include bleeding, arrhythmia, respiratory complications, surgical site infection, and graft or prosthesis-related problems, each managed according to its specific timing and severity.

    Value-added response: A value-added response notes that structured long-term surveillance allows early identification of graft and prosthesis complications before they progress to a more serious stage.

Answers to Pilot Questions [Series 4]

Part 4.1

1. The electrocardiogram provides rapid information about rhythm, ischaemia, and chamber enlargement as a first-line test.
2. Echocardiography directly visualises the valve abnormality suspected from the murmur, confirming and quantifying the diagnosis.
3. Coronary angiography directly visualises coronary artery stenosis or occlusion to guide treatment choice.
4. Cardiac catheterisation can measure intracardiac pressures and oxygen saturations, valuable in congenital cardiac assessment.
5. Image-guided biopsy provides the definitive tissue diagnosis required before committing to major surgery or oncological treatment.

Part 4.2

6. Duplex ultrasound combines imaging with Doppler flow assessment, offering a non-invasive, widely available first-line test.
7. Duplex ultrasound is operator-dependent and less accurate in certain anatomical locations, such as deep within the pelvis.
8. CT angiography uses ionising radiation, while MR angiography avoids radiation but is less widely available and slower.
9. The ankle-brachial pressure index compares ankle and arm systolic pressure to assess arterial supply to the limb.

10. Exercise testing can reveal a significant pressure drop after walking even when the resting index is normal.

Part 4.3

11. Factors include disease severity, patient reserve and comorbidities, risk-benefit balance, and patient preference.
12. Patient values ensure the decision reflects what genuinely matters to the individual once fully informed of realistic options.
13. A multidisciplinary team brings together surgeons, physicians, radiologists, and nurses to collectively plan complex treatment.
14. Borderline cases benefit from combined expert perspectives where the correct treatment is not obvious from a single viewpoint.
15. Cardiac rehabilitation combines supervised exercise, education, and psychological support, improving long-term outcome and reducing risk.

Part 4.4

1. Postoperative bleeding presents with excessive drain output, hypotension, or signs of tamponade.
2. Atrial fibrillation carries risk of haemodynamic compromise or thromboembolism if left unaddressed.
3. Respiratory complications include atelectasis, pneumonia, and acute respiratory distress syndrome.
4. Management ranges from antibiotics for superficial infection to debridement and flap reconstruction for deep sternal infection.
5. Long-term surveillance allows early identification of graft or prosthesis complications before they progress to a more serious stage.

References and Attributions [Series 4]

1. Sabiston, D. C., & Townsend, C. M. (2021). Sabiston Textbook of Surgery (21st ed.). Elsevier.
2. Douglas, G., Nicol, F., & Robertson, C. (2013). Macleod's Clinical Examination (13th ed.). Churchill Livingstone.
3. Rutherford, R. B. (2019). Rutherford's Vascular Surgery and Endovascular Therapy (9th ed.). Elsevier.

4. Yuh, D. D., Vricella, L. A., Yang, S. C., & Doty, J. R. (2014). Johns Hopkins Textbook of Cardiothoracic Surgery (2nd ed.). McGraw-Hill.

Figures, Plates, Tables, and Boxes

1. Figure 4.1: A sonographer performing transthoracic echocardiography. AI-generated using the prompt: "Create a realistic clinical illustration titled Transthoracic Echocardiography, showing a sonographer holding an ultrasound probe against a patient's chest wall while viewing the cardiac image displayed on a nearby screen, examination room setting. Clean clinical illustration style, no text."
2. Table 4.1: Comparing vascular investigations. AI-generated using the prompt: "Create a clean reference table titled Comparing Vascular Investigations, listing investigation, invasiveness, and key use. Simple clinical reference table style with outside border."
3. Figure 4.2: A multidisciplinary team reviewing patient imaging during a treatment planning meeting. AI-generated using the prompt: "Create a realistic clinical illustration titled Multidisciplinary Team Meeting, showing a group of clinicians from different specialties seated around a table reviewing scan images displayed on a large screen, meeting room setting. Clean clinical illustration style, no text."
4. Table 4.2: Timing and management of key postoperative complications. AI-generated using the prompt: "Create a clean reference table titled Timing and Management of Key Postoperative Complications, listing complication, typical timing, and management focus. Simple clinical reference table style with outside border."

Course code: SUG 603

Course title: Cardiothoracic including Vascular Surgery

Course credit load: 2 Units

Series 5: Congenital Malformations and Their Management

- **Part 5.1: Acyanotic Congenital Heart Disease**
  - Sub Part 5.1.1: Atrial septal defect
  - Sub Part 5.1.2: Ventricular septal defect
  - Sub Part 5.1.3: Patent ductus arteriosus
- **Part 5.2: Cyanotic Congenital Heart Disease and Coarctation**
  - Sub Part 5.2.1: Tetralogy of Fallot
  - Sub Part 5.2.2: Transposition of the great arteries
  - Sub Part 5.2.3: Coarctation of the aorta
- **Part 5.3: Congenital Lung and Chest Wall Malformations**
  - Sub Part 5.3.1: Congenital pulmonary airway malformation
  - Sub Part 5.3.2: Pulmonary sequestration
  - Sub Part 5.3.3: Pectus excavatum and pectus carinatum
- **Part 5.4: Congenital Vascular Malformations and General Management Principles**
  - Sub Part 5.4.1: Vascular rings
  - Sub Part 5.4.2: Congenital vascular malformations of the limbs
  - Sub Part 5.4.3: Principles of timing and management of congenital malformations

Introduction

This closing Series turns to a population very different from most of the patients discussed elsewhere in this course, infants and children born with a structural abnormality of the heart, lungs, chest wall, or blood vessels, present from birth rather than acquired through disease or injury later in life. **Congenital malformations** within cardiothoracic and vascular surgery span a genuinely wide spectrum, from lesions that resolve spontaneously without any intervention to complex defects requiring staged surgical correction over the first years of life.

The aim of this Series is to equip you with the ability to list and describe common congenital heart defects, both acyanotic and cyanotic, congenital lung and chest wall malformations, congenital vascular malformations, and the general principles guiding the timing and management of congenital malformations across this specialty. Recognising these conditions promptly, and understanding when intervention is needed and when watchful waiting is entirely appropriate, are equally important skills for anyone caring for this patient population.

This Series opens with **acyanotic congenital heart disease**, moves through **cyanotic congenital heart disease and coarctation** and **congenital lung and chest wall malformations**, and closes with **congenital vascular malformations and general management principles**.

Series Learning Outcomes

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

- **SLO 5.1:** list the common acyanotic congenital heart defects and describe their presentation
- **SLO 5.2:** describe the management of atrial septal defect, ventricular septal defect, and patent ductus arteriosus
- **SLO 5.3:** describe the presentation of cyanotic congenital heart disease
- **SLO 5.4:** discuss the management of tetralogy of Fallot, transposition of the great arteries, and coarctation of the aorta
- **SLO 5.5:** describe common congenital lung malformations
- **SLO 5.6:** discuss congenital chest wall deformities and their management
- **SLO 5.7:** describe congenital vascular malformations
- **SLO 5.8:** discuss the principles guiding timing and management of congenital malformations

5.1 Acyanotic Congenital Heart Disease

5.1.1 atrial septal defect

A gap between the upper chambers of the heart

An **atrial septal defect** is a persistent opening between the left and right atria, allowing oxygenated blood to shunt from the left to the right side of the heart given the normally higher pressure on the left, and many small atrial septal defects are entirely asymptomatic in childhood, sometimes only identified incidentally later in life or during investigation of an unrelated concern.

Larger defects can present with exertional breathlessness, recurrent respiratory infections, or failure to thrive in infancy, and, over many years of untreated left-to-right shunting, can lead to right heart enlargement and, eventually, pulmonary hypertension, making timely diagnosis and, where indicated, closure genuinely important to prevent this progressive long-term complication.

Fill in the blank: An atrial septal defect allows oxygenated blood to shunt from the left to the _____ side of the heart.

5.1.2 ventricular septal defect

The most common congenital heart defect

A **ventricular septal defect**, a persistent opening between the left and right ventricles, is the most common congenital heart defect, and, like an atrial septal defect, typically produces a left-to-right shunt given the higher pressure in the left ventricle, with the size of the defect largely determining both the symptoms produced and the likelihood of spontaneous closure over time.

Small ventricular septal defects are frequently asymptomatic and many close spontaneously during early childhood without any intervention required, while larger defects can present in infancy with breathlessness, poor feeding, and failure to thrive, and produce a characteristic pansystolic murmur on examination, findings that together should prompt echocardiographic assessment to confirm the diagnosis and characterise the defect precisely.

Fill in the blank: A ventricular septal defect produces a characteristic _____ murmur on examination.

5.1.3 patent ductus arteriosus

A fetal connection that fails to close after birth

The **ductus arteriosus**, a normal fetal connection between the pulmonary artery and the aorta that diverts blood away from the fetal lungs before birth, should functionally close within the first day or two of life and structurally close within the following weeks, and a **patent ductus arteriosus** describes persistence of this connection beyond the expected closure period.

A small patent ductus arteriosus may be entirely asymptomatic, while a larger one produces a continuous, machinery-like murmur and can lead to the same pattern of left-to-right shunting and, if untreated, pulmonary hypertension already described for atrial and ventricular septal defects, and closure, whether by catheter-delivered device or, less commonly today, surgical ligation, is generally recommended for a haemodynamically significant defect.

Fill in the blank: A significant patent ductus arteriosus produces a continuous, _____-like murmur.

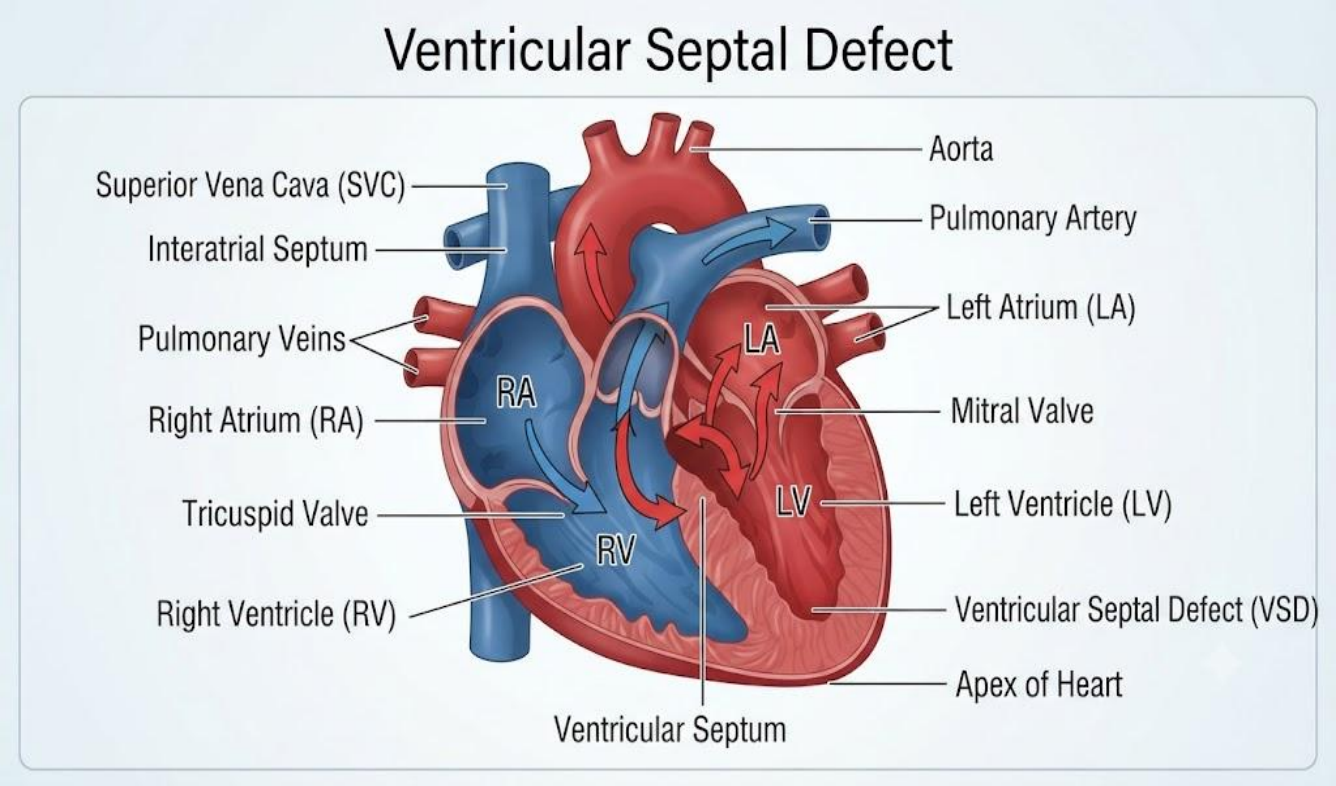

Figure 5.1: An anatomical cross-section of the heart showing a ventricular septal defect.

Pilot questions 5.1

- Define atrial septal defect. (Linked to SLO 5.1)
- Describe the long-term complication of an untreated, significant left-to-right shunt. (Linked to SLO 5.1)
- Explain why the size of a ventricular septal defect matters clinically. (Linked to SLO 5.1)
- Describe the murmur associated with a ventricular septal defect. (Linked to SLO 5.1)
- Define patent ductus arteriosus. (Linked to SLO 5.2)

5.2 Cyanotic Congenital Heart Disease and Coarctation

5.2.1 tetralogy of fallot

The most common cyanotic congenital heart defect

Tetralogy of Fallot, the most common cyanotic congenital heart defect, comprises four characteristic features: a ventricular septal defect, pulmonary stenosis, an overriding aorta positioned above the ventricular septal defect, and right ventricular hypertrophy, a combination that together produces a right-to-left shunt across the ventricular septal defect and resulting cyanosis.

Affected infants can present with cyanosis from birth or develop it progressively over the following months, and characteristically experience **hypercyanotic spells**, sudden episodes of worsening cyanosis, irritability, and breathlessness, often triggered by crying or feeding, that require prompt recognition and specific management, including positioning the infant with knees drawn to the chest, a manoeuvre that increases systemic vascular resistance and temporarily improves pulmonary blood flow.

Fill in the blank: Tetralogy of Fallot comprises a ventricular septal defect, pulmonary stenosis, an overriding aorta, and right ventricular _____.

5.2.2 transposition of the great arteries

The great vessels connected to the wrong ventricle

Transposition of the great arteries describes a condition in which the aorta arises from the right ventricle and the pulmonary artery arises from the left ventricle, the reverse of the normal arrangement, creating two parallel, rather than the normal sequential, circulations that are

incompatible with life unless there is some form of mixing between them, such as a coexisting septal defect or patent ductus arteriosus.

Affected infants typically present with profound cyanosis within the first hours or days of life, and initial management involves maintaining ductal patency with a **prostaglandin infusion** to preserve mixing between the two circulations until definitive surgical correction, typically an **arterial switch operation**, can be performed, usually within the first two weeks of life given the urgency this condition demands.

Fill in the blank: Initial management of transposition of the great arteries involves maintaining ductal patency with a _____ infusion.

5.2.3 coarctation of the aorta

A narrowing that can present at any age

Coarctation of the aorta, a narrowing of the aorta typically located near the site of the ductus arteriosus, can present acutely in infancy with heart failure and poor perfusion of the lower body as the ductus closes and the collateral circulation has not yet had time to develop, or present later in childhood or even adulthood with hypertension, discovered incidentally, or with the classical finding of radio-femoral delay on examination.

Radio-femoral delay, a perceptible delay between the radial and femoral pulses on simultaneous palpation, is a specific and important sign of coarctation that should be actively sought in any child or young adult presenting with hypertension, since this simple bedside examination finding can prompt the correct diagnosis well before more sophisticated imaging is required to confirm it.

Fill in the blank: Radio-femoral delay is a perceptible delay between the radial and femoral _____ on simultaneous palpation.

Table 5.1: Comparing acyanotic and cyanotic congenital heart disease presentation

Feature	Acyanotic disease	Cyanotic disease
Shunt direction	Left to right	Right to left
Cyanosis	Typically absent	Present
Example	Ventricular septal defect	Tetralogy of Fallot

Pilot questions 5.2

1. List the four features of tetralogy of Fallot. (Linked to SLO 5.3)
2. Describe a hypercyanotic spell and its immediate management. (Linked to SLO 5.4)
3. Explain why transposition of the great arteries is incompatible with life without mixing. (Linked to SLO 5.3)
4. Describe the initial and definitive management of transposition of the great arteries. (Linked to SLO 5.4)
5. Describe radio-femoral delay and its significance. (Linked to SLO 5.4)

5.3 Congenital Lung and Chest Wall Malformations

5.3.1 congenital pulmonary airway malformation

Abnormal lung tissue development before birth

Congenital pulmonary airway malformation, an abnormal area of developing lung tissue with disorganised airway and cystic structure, is increasingly identified on routine antenatal ultrasound before birth, and many lesions remain asymptomatic throughout infancy, though some can cause respiratory distress in the newborn period if the affected area is large enough to compress adjacent normal lung tissue.

Management of an asymptomatic congenital pulmonary airway malformation identified antenatally or in infancy remains an area of ongoing discussion, with some centres favouring elective surgical resection in early childhood given the small but genuine risk of infection or, rarely, malignant transformation within the abnormal tissue, while others favour continued observation, a decision that should be made collaboratively with the family after thorough discussion of the relevant risks and benefits.

Fill in the blank: Congenital pulmonary airway malformation is increasingly identified on routine _____ ultrasound before birth.

5.3.2 pulmonary sequestration

Lung tissue with its own separate blood supply

Pulmonary sequestration describes an area of abnormal, non-functioning lung tissue that lacks a normal connection to the tracheobronchial tree and instead receives its blood supply directly from a systemic artery, most commonly arising from the aorta, rather than from the pulmonary

circulation, an anatomical distinction that carries direct surgical relevance since this anomalous systemic vessel must be carefully identified and controlled during resection to avoid catastrophic intraoperative bleeding.

Sequestrations are classified as intralobar, located within the normal visceral pleura of a lung lobe, or extralobar, possessing its own separate pleural covering, a distinction with genuine clinical relevance since extralobar sequestrations are more frequently associated with other congenital anomalies and are more often identified antenatally or in early infancy, while intralobar sequestrations more commonly present later with recurrent infection.

Fill in the blank: Pulmonary sequestration receives its blood supply directly from a _____ artery rather than the pulmonary circulation.

5.3.3 pectus excavatum and pectus carinatum

Two mirror-image chest wall deformities

Pectus excavatum, a depression of the sternum and adjacent costal cartilages producing a sunken chest appearance, is the more common of the two major chest wall deformities, and, while often primarily a cosmetic concern, can occasionally cause cardiopulmonary symptoms in severe cases through direct compression of the heart and lungs within a significantly reduced thoracic volume.

Pectus carinatum, the mirror-image deformity in which the sternum protrudes outward rather than inward, is generally associated with fewer functional symptoms than pectus excavatum but carries its own significant cosmetic and psychological impact, particularly during adolescence, and management for both conditions ranges from bracing in appropriately selected, growing patients to surgical correction for more severe or symptomatic deformities.

Fill in the blank: Pectus carinatum is the mirror-image deformity in which the sternum protrudes _____ rather than inward.

Figure 5.2: A child's chest showing visible pectus excavatum deformity.

Pilot questions 5.3

1. Describe congenital pulmonary airway malformation. (Linked to SLO 5.5)
2. Explain the ongoing discussion around managing an asymptomatic congenital pulmonary airway malformation. (Linked to SLO 5.5)
3. Describe the anatomical distinction underlying pulmonary sequestration. (Linked to SLO 5.5)
4. Distinguish intralobar from extralobar pulmonary sequestration. (Linked to SLO 5.5)
5. Distinguish pectus excavatum from pectus carinatum. (Linked to SLO 5.6)

5.4 Congenital Vascular Malformations and General Management Principles

5.4.1 vascular rings

Vessels encircling structures they should not touch

A **vascular ring** describes an abnormal arrangement of the great vessels that completely or partially encircles the trachea and oesophagus, potentially causing compression of one or both structures, and infants and children with a significant vascular ring can present with stridor,

recurrent respiratory infections, or feeding difficulty, symptoms directly attributable to the compressive effect of the abnormal vessel arrangement.

Diagnosis is confirmed with cross-sectional imaging, typically CT or MR angiography, precisely delineating the abnormal vascular anatomy before surgical division of the ring, and surgical correction, dividing the least essential component of the ring while preserving adequate blood flow through the remaining vessels, is generally recommended for a symptomatic vascular ring to relieve the compression and its associated symptoms.

Fill in the blank: A vascular ring can potentially compress the trachea and _____.

5.4.2 congenital vascular malformations of the limbs

Abnormal vessels present from birth, in the arms or legs

Congenital vascular malformations of the limbs encompass a spectrum of abnormalities involving capillaries, veins, arteries, or lymphatics, either in isolation or in combination, and, unlike infantile haemangiomas which typically proliferate and then involute over the first years of life, true vascular malformations are present from birth and generally persist and grow proportionally with the child rather than resolving spontaneously.

Management depends heavily on the specific type of malformation, its location, and the symptoms it produces, ranging from simple observation for an asymptomatic, cosmetically acceptable lesion, through compression garments and sclerotherapy for symptomatic venous or lymphatic malformations, to surgical excision or embolisation for more complex or high-flow arteriovenous malformations, reflecting the genuinely wide spectrum of severity this category of condition encompasses.

Fill in the blank: Unlike infantile haemangiomas, true vascular malformations generally persist and grow proportionally with the _____.

5.4.3 principles of timing and management of congenital malformations

Balancing urgency, growth, and developmental windows

The **timing** of intervention for a congenital malformation depends on the severity of symptoms, the natural history of the specific condition, whether spontaneous resolution is genuinely likely, and the physiological ability of the infant or child to safely tolerate anaesthesia and surgery at a given age, a balance that varies enormously between conditions, from the immediate, life-saving urgency of transposition of the great arteries to the entirely appropriate years of watchful waiting for a small, asymptomatic atrial septal defect.

Management of congenital malformations throughout childhood genuinely benefits from a **multidisciplinary approach**, drawing on paediatric surgeons, cardiologists, geneticists, and specialist nurses, alongside close, honest, and ongoing communication with the family, since many congenital conditions require monitoring and staged management across several years of the child's development rather than a single decisive intervention at one point in time.

Fill in the blank: Timing of intervention balances symptom severity, natural history, and the child's physiological ability to tolerate _____.

Table 5.2: Comparing congenital vascular malformation types

Type	Vessel involved	Typical management
Venous malformation	Veins	Compression garments, sclerotherapy
Lymphatic malformation	Lymphatic vessels	Sclerotherapy, surgical excision if symptomatic
Arteriovenous malformation	Arteries and veins	Embolisation, surgical excision for complex lesions

Pilot questions 5.4

1. Define vascular ring and its typical presentation. (Linked to SLO 5.7)
2. Describe how a vascular ring is diagnosed and managed. (Linked to SLO 5.7)
3. Distinguish a true vascular malformation from an infantile haemangioma. (Linked to SLO 5.7)
4. List the factors guiding the timing of intervention for a congenital malformation. (Linked to SLO 5.8)
5. Explain the value of a multidisciplinary approach in managing congenital malformations. (Linked to SLO 5.8)

Series Summary

This final Series turned to congenital malformations within cardiothoracic and vascular surgery. Part 5.1 covered acyanotic congenital heart disease, atrial and ventricular septal defects and patent ductus arteriosus, while Part 5.2 turned to cyanotic congenital heart disease, tetralogy of Fallot, transposition of the great arteries, and coarctation of the aorta. Part 5.3 covered congenital

lung and chest wall malformations, and Part 5.4 closed with congenital vascular malformations and the general principles guiding timing and management across this whole category of condition.

You should now be able to list and describe common congenital heart defects, lung and chest wall malformations, and vascular malformations, and discuss the principles guiding their management, meeting the outcomes set for this Series. Across the full course, Series 1 covered the symptoms and signs of common cardiothoracic and vascular lesions, Series 2 covered chest trauma and chest wall tumours, Series 3 covered the principles of surgical management, Series 4 covered investigation, treatment, and complications, and this Series has closed the course with congenital malformations and their management, together forming a comprehensive foundation in cardiothoracic including vascular surgery.

Glossary of Terms

1. **Atrial septal defect:** a persistent opening between the left and right atria.
2. **Coarctation of the aorta:** a narrowing of the aorta typically near the site of the ductus arteriosus.
3. **Congenital pulmonary airway malformation:** an abnormal area of developing lung tissue with disorganised structure.
4. **Hypercyanotic spell:** a sudden episode of worsening cyanosis and distress seen in tetralogy of Fallot.
5. **Patent ductus arteriosus:** persistence of the fetal connection between the pulmonary artery and aorta.
6. **Pectus excavatum:** a depression of the sternum producing a sunken chest appearance.
7. **Pulmonary sequestration:** abnormal lung tissue with a systemic rather than pulmonary blood supply.
8. **Radio-femoral delay:** a perceptible delay between radial and femoral pulses, suggesting coarctation.
9. **Tetralogy of Fallot:** the most common cyanotic congenital heart defect, comprising four characteristic features.
10. **Transposition of the great arteries:** a condition in which the aorta and pulmonary artery arise from the wrong ventricles.
11. **Vascular malformation:** an abnormal vessel structure present from birth that persists and grows with the child.
12. **Vascular ring:** an abnormal arrangement of great vessels encircling the trachea and oesophagus.

Concept Check Questions [Series 5]

Objective questions

- An atrial septal defect allows oxygenated blood to shunt from the left to the _____ side of the heart. (Linked to SLO 5.1)
- Tetralogy of Fallot comprises a ventricular septal defect, pulmonary stenosis, an overriding aorta, and right ventricular _____. (Linked to SLO 5.3)
- Initial management of transposition of the great arteries involves maintaining ductal patency with a _____ infusion. (Linked to SLO 5.4)
- Pulmonary sequestration receives its blood supply directly from a _____ artery rather than the pulmonary circulation. (Linked to SLO 5.5)
- A vascular ring can potentially compress the trachea and _____. (Linked to SLO 5.7)

Short-answer questions

1. Describe the long-term complication of an untreated, significant left-to-right shunt. (Linked to SLO 5.2)
2. Describe a hypercyanotic spell and its immediate management. (Linked to SLO 5.4)
3. Describe radio-femoral delay and its significance. (Linked to SLO 5.4)
4. Distinguish intralobar from extralobar pulmonary sequestration. (Linked to SLO 5.5)
5. List the factors guiding the timing of intervention for a congenital malformation. (Linked to SLO 5.8)

Long-answer questions

6. Discuss the common acyanotic congenital heart defects and their management. (Linked to SLO 5.1, 5.2)
7. Describe the presentation and management of tetralogy of Fallot, transposition of the great arteries, and coarctation of the aorta. (Linked to SLO 5.3, 5.4)
8. Discuss congenital lung malformations and chest wall deformities and their management. (Linked to SLO 5.5, 5.6)
9. Describe congenital vascular malformations, including vascular rings and limb malformations. (Linked to SLO 5.7)
10. Discuss the general principles guiding timing and management of congenital malformations. (Linked to SLO 5.8)

Answers to Concept Check Questions [Series 5]

Objective questions

11. Right.
12. Hypertrophy.
13. Prostaglandin.
14. Systemic.
15. Oesophagus.

Short-answer questions

16. Untreated significant left-to-right shunting can lead to right heart enlargement and, eventually, pulmonary hypertension.
17. A hypercyanotic spell is sudden worsening cyanosis and distress, managed by positioning the infant with knees drawn to the chest.
18. Radio-femoral delay is a perceptible pulse timing difference suggesting coarctation of the aorta.
19. Intralobar sequestration lies within normal visceral pleura, while extralobar sequestration has its own separate pleural covering.
20. Factors include symptom severity, natural history, likelihood of spontaneous resolution, and the child's physiological ability to tolerate surgery.

Long-answer questions

21. **Basic response:** Atrial and ventricular septal defects and patent ductus arteriosus all produce left-to-right shunting; small defects are often observed, while larger defects require closure to prevent pulmonary hypertension.

    Value-added response: A value-added response notes that many ventricular septal defects close spontaneously in early childhood without intervention.

22. **Basic response:** Tetralogy of Fallot presents with cyanosis and hypercyanotic spells; transposition presents with profound cyanosis requiring prostaglandin infusion and arterial switch surgery; coarctation presents in infancy or later with hypertension and radio-femoral delay.

    Value-added response: A value-added response notes that transposition requires surgical correction within the first two weeks of life given its urgency.

23. **Basic response:** Congenital pulmonary airway malformation and pulmonary sequestration are increasingly identified antenatally, with management varying by

symptoms; pectus excavatum and carinatum are managed with bracing or surgical correction depending on severity.

Value-added response: A value-added response notes that pulmonary sequestration's systemic blood supply carries direct surgical relevance for safe resection.

24. **Basic response:** Vascular rings can compress the trachea and oesophagus, requiring surgical division if symptomatic; limb vascular malformations involve capillaries, veins, arteries, or lymphatics and are managed according to type and severity.

    Value-added response: A value-added response notes that true vascular malformations, unlike infantile haemangiomas, persist and grow proportionally with the child rather than involuting.

25. **Basic response:** Timing balances symptom severity, natural history, and the child's physiological ability to tolerate surgery, ranging from immediate intervention to years of watchful waiting.

    Value-added response: A value-added response notes that a multidisciplinary approach with ongoing family communication is genuinely valuable given the staged nature of management for many congenital conditions.

Answers to Pilot Questions [Series 5]

Part 5.1

1. An atrial septal defect is a persistent opening between the left and right atria.
2. Untreated significant shunting can lead to right heart enlargement and pulmonary hypertension.
3. The size of a ventricular septal defect determines the symptoms produced and the likelihood of spontaneous closure.
4. A ventricular septal defect produces a characteristic pansystolic murmur.
5. Patent ductus arteriosus is persistence of the fetal connection between the pulmonary artery and aorta beyond the expected closure period.

Part 5.2

6. The four features are ventricular septal defect, pulmonary stenosis, overriding aorta, and right ventricular hypertrophy.
7. A hypercyanotic spell is sudden worsening cyanosis, managed by positioning the infant with knees drawn to the chest.
8. Without mixing, the two circulations remain parallel rather than sequential, which is incompatible with survival.
9. Initial management uses a prostaglandin infusion, with definitive treatment being an arterial switch operation.
10. Radio-femoral delay is a perceptible pulse timing difference that suggests coarctation of the aorta.

Part 5.3

11. Congenital pulmonary airway malformation is an abnormal area of lung tissue with disorganised airway and cystic structure.
12. Some centres favour early elective resection given infection or malignant transformation risk, while others favour observation.
13. Pulmonary sequestration receives its blood supply from a systemic artery rather than the pulmonary circulation.
14. Intralobar sequestration lies within normal visceral pleura, while extralobar sequestration has its own separate pleural covering.
15. Pectus excavatum is a sunken chest depression, while pectus carinatum is the mirror-image outward protrusion.

Part 5.4

1. A vascular ring is an abnormal vessel arrangement encircling the trachea and oesophagus, presenting with stridor or feeding difficulty.
2. Diagnosis uses CT or MR angiography, with surgical division of the ring recommended if symptomatic.
3. True vascular malformations are present from birth and persist and grow with the child, unlike haemangiomas which involute.
4. Factors include symptom severity, natural history, likelihood of resolution, and the child's ability to tolerate surgery.
5. A multidisciplinary approach ensures coordinated, staged management across the several years many congenital conditions require.

References and Attributions [Series 5]

1. Sabiston, D. C., & Townsend, C. M. (2021). Sabiston Textbook of Surgery (21st ed.). Elsevier.
2. Yuh, D. D., Vricella, L. A., Yang, S. C., & Doty, J. R. (2014). Johns Hopkins Textbook of Cardiothoracic Surgery (2nd ed.). McGraw-Hill.
3. Coran, A. G. (2012). Pediatric Surgery (7th ed.). Elsevier.
4. Shields, T. W. (2019). General Thoracic Surgery (8th ed.). Wolters Kluwer.

Figures, Plates, Tables, and Boxes

1. Figure 5.1: An anatomical cross-section of the heart showing a ventricular septal defect. AI-generated using the prompt: "Create a clean, accurate anatomical cross-section illustration titled Ventricular Septal Defect, showing the four chambers of the heart with a labelled opening in the ventricular septum and arrows indicating the direction of blood shunting. Educational anatomical diagram style, no photographic content."
2. Table 5.1: Comparing acyanotic and cyanotic congenital heart disease presentation. AI-generated using the prompt: "Create a clean reference table titled Comparing Acyanotic and Cyanotic Congenital Heart Disease Presentation, listing feature, acyanotic disease, and cyanotic disease. Simple clinical reference table style with outside border."
3. Figure 5.2: A child's chest showing visible pectus excavatum deformity. AI-generated using the prompt: "Create a realistic clinical illustration titled Pectus Excavatum, showing the bare chest of a child with a visible sunken depression of the central chest wall, clinical examination setting, respectful and clinical in tone. Clean clinical illustration style, no text."
4. Table 5.2: Comparing congenital vascular malformation types. AI-generated using the prompt: "Create a clean reference table titled Comparing Congenital Vascular Malformation Types, listing type, vessel involved, and typical management. Simple clinical reference table style with outside border."