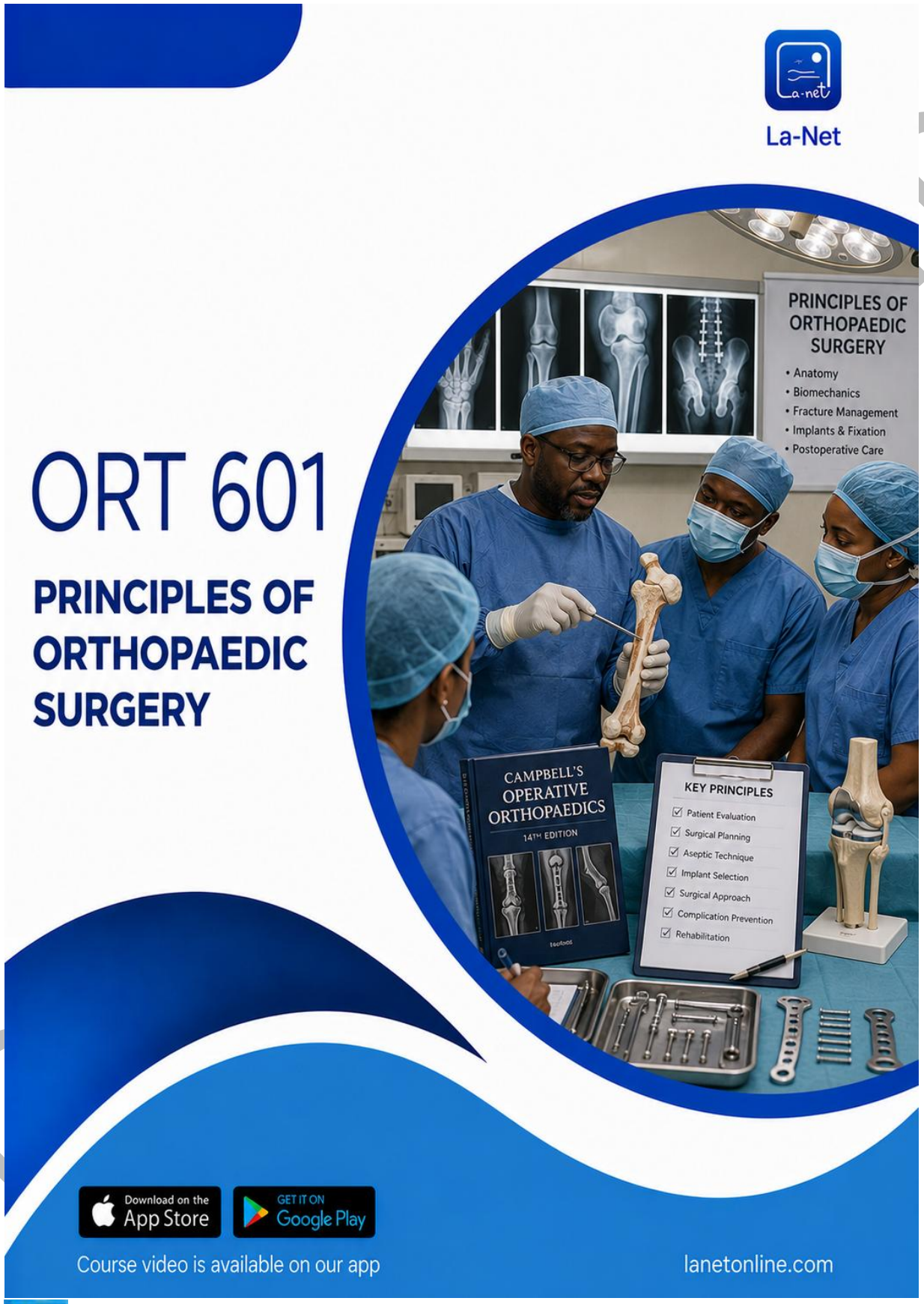
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# Series 1: Clinical Approach and Management of the Injured Patient

- **Part 1.1: Clerking and Examination in Orthopaedics**
  - Sub Part 1.1.1: Orthopaedic history taking
  - Sub Part 1.1.2: Apley's principles: look
  - Sub Part 1.1.3: Apley's principles: feel and move
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- **Part 1.3: ATLS Primary Survey**
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  - Sub Part 1.5.3: Outlining injuries to plan definitive management
- **Part 1.6: Multidisciplinary Management of the Multiply Injured Patient**
  - Sub Part 1.6.1: The multidisciplinary team in trauma care
  - Sub Part 1.6.2: Planning definitive management
  - Sub Part 1.6.3: Communication and handover in multidisciplinary trauma care

# Introduction

Welcome to **ORT 601: Principles of Orthopaedic Surgery**. Confident orthopaedic and trauma practice begins with disciplined clinical **clerking and examination**, and, for the injured patient, a systematic, protocol-driven approach spanning field management through ATLS resuscitation, secondary survey, and coordinated **multidisciplinary** definitive care. This opening Series establishes both of these essential foundations, forming the basis for every subsequent orthopaedic topic examined throughout this course.

The aim of this Series is to equip you with a thorough understanding of orthopaedic clerking and examination, the general approach to the injured patient, ATLS primary survey and resuscitation principles, the secondary survey, and the multidisciplinary management of the multiply injured patient.

This Series begins with **clerking and examination in orthopaedics**, before turning to the **general approach to the injured patient**. We then examine the **ATLS primary survey**, followed by **ATLS resuscitation principles**, then the **secondary survey**, concluding with the **multidisciplinary management of the multiply injured patient**.

# Series Learning Outcomes

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

- **SLO 1.1:** take a systematic orthopaedic history
- **SLO 1.2:** apply Apley's principles of look, feel, and move in orthopaedic examination
- **SLO 1.3:** enumerate the general approach to an injured patient
- **SLO 1.4:** describe field and hospital management of the injured patient
- **SLO 1.5:** perform the ATLS primary survey, assessing airway, breathing, circulation, disability, and exposure
- **SLO 1.6:** describe the sequence and rationale of the ATLS primary survey
- **SLO 1.7:** describe the principles of resuscitation in the multiply injured patient, including fluid resuscitation and haemorrhage control
- **SLO 1.8:** describe the importance of continuous reassessment during resuscitation
- **SLO 1.9:** describe the principles, timing, and conduct of the secondary survey
- **SLO 1.10:** outline injuries identified on secondary survey to plan definitive management

- **SLO 1.11:** describe the role of the multidisciplinary team in trauma care, and
- **SLO 1.12:** describe the planning of definitive management and effective communication and handover in multidisciplinary trauma care.

# 1.1 Clerking and Examination in Orthopaedics

## 1.1.1 orthopaedic history taking

### Establishing the presenting complaint and its functional impact

**Orthopaedic clerking** should establish the specific nature, onset, and progression of the presenting complaint, generally pain, deformity, swelling, or loss of function, together with relevant mechanism of **injury** where trauma is involved, discussed further later in this Series.

Further essential history includes the functional **impact** of the presenting problem on the patient's daily activities and occupation, relevant past medical and surgical history, particularly prior orthopaedic intervention, and social history relevant to rehabilitation planning and eventual return to normal **function**.

**Fill in the blank:** Orthopaedic clerking should establish the specific nature, onset, and progression of the presenting complaint, together with relevant mechanism of _____ where trauma is involved.

## 1.1.2 apley's principles: look

**Apley's principles** of orthopaedic examination begin with **look**, systematic visual inspection of the affected region, assessing skin colour and integrity, swelling, deformity, muscle wasting, and scars from previous surgery, generally performed with the patient adequately exposed and compared directly against the contralateral, unaffected **side**.

Inspection additionally includes assessment of the patient's overall **posture** and gait where relevant, discussed further in relation to specific conditions throughout this course, since these broader observations frequently provide valuable diagnostic clues before any direct palpation or movement assessment has even **begun**.

**Fill in the blank:** Apley's principles of orthopaedic examination begin with look, generally performed with the patient adequately exposed and compared directly against the contralateral, unaffected _____.

## 1.1.3 apley's principles: feel and move

**Feel**, the second component of Apley's principles, involves systematic palpation to assess **temperature**, tenderness, swelling character, and specific anatomical landmarks, generally performed gently and progressively, moving from areas away from the presenting complaint toward the specific area of maximal concern.

**Move**, the final component, assesses both **active** movement, performed independently by the patient, and **passive** movement, performed by the examiner, comparing range of motion against the contralateral side, discussed earlier in this Part, and noting any pain, crepitus, or restriction encountered during **assessment**.

**Fill in the blank:** Apley's principles conclude with move, assessing both active movement, performed independently by the patient, and passive movement, performed by the _____.

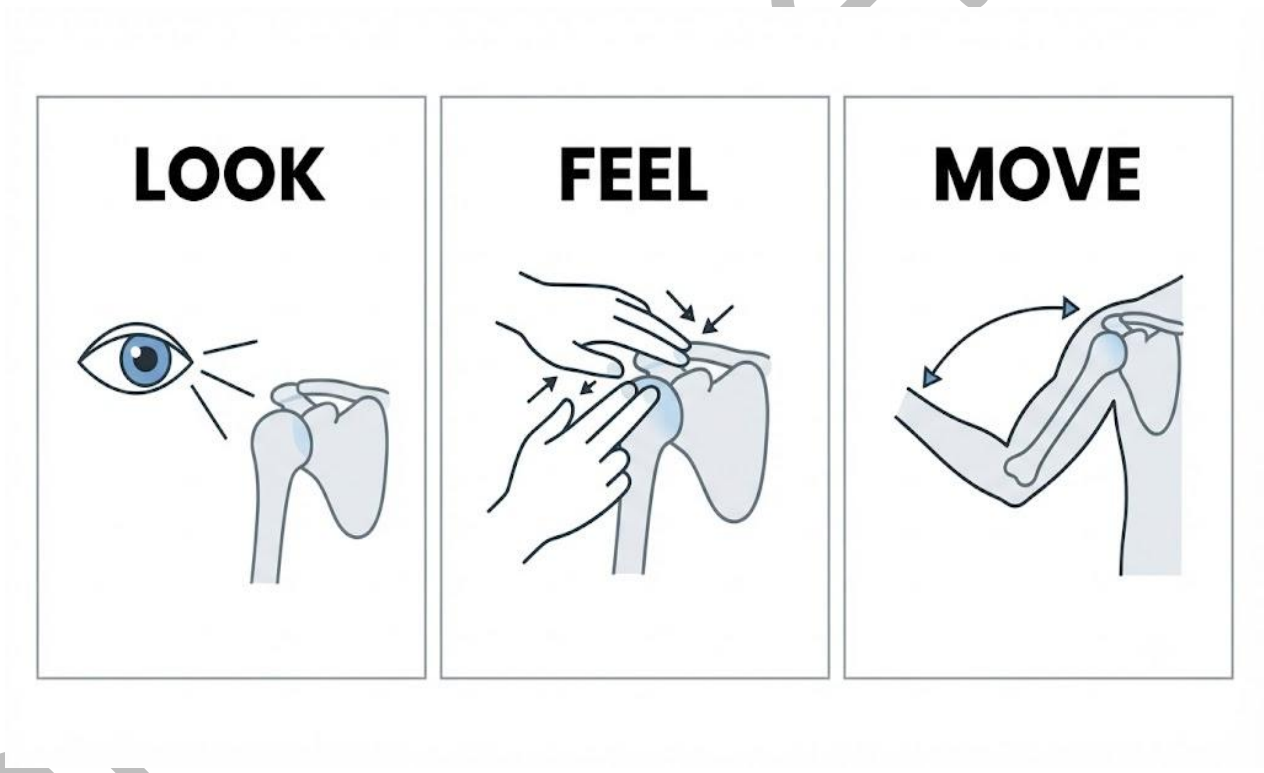


Figure 1.1: Diagram illustrating Apley's three-stage orthopaedic examination sequence of look, feel, and move.

**Pilot questions 1.1**

1. List the essential components of a systematic orthopaedic history. (Linked to SLO 1.1)
2. State Apley's three principles of orthopaedic examination. (Linked to SLO 1.2)
3. Describe what is assessed during the look component of orthopaedic examination. (Linked to SLO 1.2)
4. Describe what is assessed during the feel component of orthopaedic examination. (Linked to SLO 1.2)
5. Distinguish active from passive movement assessment. (Linked to SLO 1.2)

# 1.2 General Approach to the Injured Patient

## 1.2.1 initial assessment principles

### A structured, protocol-driven approach to the injured patient

The general approach to an injured patient follows a structured, sequential process, generally beginning with rapid assessment of immediately life-threatening problems, discussed further in relation to the primary survey later in this Series, before proceeding to more detailed assessment of the specific injuries **sustained**.

This structured approach reflects the principle of addressing the greatest immediate threat to life first, rather than the most visually striking or painful **injury**, meaning disciplined adherence to a consistent, protocol-driven sequence, discussed throughout this Series, represents an essential safeguard against missed, potentially fatal injuries.

**Fill in the blank:** The general approach to an injured patient reflects the principle of addressing the greatest immediate threat to life first, rather than the most visually striking or painful _____.

## 1.2.2 field management of the injured patient

**Field management** of the injured patient generally prioritises basic airway maintenance, control of obvious external **haemorrhage**, discussed further later in this Series, and appropriate immobilisation of suspected fractures or spinal injury before **transport** to definitive hospital care.

Effective field management additionally requires accurate, concise communication of the mechanism of injury and initial clinical findings to the receiving hospital team, discussed further

later in this Series, supporting appropriate advance preparation and ensuring genuine continuity of care across the entire **prehospital** to hospital transition.

**Fill in the blank:** Field management generally prioritises basic airway maintenance, control of obvious external haemorrhage, and appropriate immobilisation before _____ to definitive hospital care.

### 1.2.3 hospital management on arrival

On hospital arrival, the injured patient should undergo an immediate, structured handover from prehospital providers, discussed earlier in this Part, before proceeding directly to the **primary survey**, discussed further in the next Part of this Series, without unnecessary delay for administrative processes that could postpone recognition of immediately life-threatening injury.

Hospital management additionally requires immediate availability of appropriate **resuscitation** equipment and personnel, discussed further later in this Series, together with rapid access to supportive investigations, discussed in relation to imaging in an earlier related course, each essential to the efficient, coordinated trauma **response** every injured patient deserves.

**Fill in the blank:** On hospital arrival, the injured patient should proceed directly to the primary survey without unnecessary delay for administrative processes that could postpone recognition of immediately life-threatening _____.

Table 1.2: Comparing field and hospital management priorities for the injured patient.

| Setting | Immediate priority | Key supporting action |
|---|---|---|
| Field (prehospital) | Airway maintenance and haemorrhage control | Immobilisation and rapid transport |
| Hospital | Primary survey without delay | Immediate resuscitation resource availability |

**Pilot questions 1.2**

1. Describe the guiding principle of the general approach to an injured patient. (Linked to SLO 1.3)
2. List the immediate priorities of field management of the injured patient. (Linked to SLO 1.4)
3. Explain why accurate prehospital communication to the receiving hospital team is important. (Linked to SLO 1.4)
4. Describe what should happen immediately on hospital arrival of an injured patient. (Linked to SLO 1.4)

5. Explain why administrative processes should not delay the primary survey. (Linked to SLO 1.4)

## 1.3 ATLS Primary Survey

### 1.3.1 airway and breathing assessment

Securing the airway with cervical spine protection, then assessing breathing

The **ATLS primary survey** begins with **airway** assessment with cervical spine protection, discussed in relation to spinal injury later in this Series, identifying and immediately addressing any airway obstruction, since airway compromise represents the most rapidly fatal threat among all primary survey **components**.

**Breathing** assessment follows, evaluating respiratory rate, chest wall movement, and oxygenation, identifying immediately life-threatening thoracic conditions such as tension pneumothorax, discussed in relation to chest imaging in an earlier related course, requiring immediate **intervention** before proceeding to the next primary survey component.

**Fill in the blank:** The ATLS primary survey begins with airway assessment with cervical spine protection, since airway compromise represents the most rapidly fatal threat among all primary survey _____.

### 1.3.2 circulation and disability assessment

**Circulation** assessment identifies and controls significant haemorrhage, discussed further later in this Series, assessing pulse rate and character, blood pressure, and skin perfusion as indicators of overall circulatory **status**, with external bleeding controlled by direct pressure as an immediate priority.

**Disability** assessment provides a rapid neurological evaluation, generally using the **Glasgow Coma Scale**, discussed in relation to neurological assessment in an earlier related course, together with pupillary examination, providing essential baseline information and an early indication of possible traumatic brain **injury**.

**Fill in the blank:** Disability assessment provides a rapid neurological evaluation, generally using the Glasgow Coma Scale, together with pupillary _____.

## 1.3.3 exposure and environmental control

**Exposure** requires fully undressing the patient to allow complete examination for injuries that might otherwise remain concealed, discussed in relation to systematic examination earlier in this Series, an essential step despite its potential to seem, superficially, less urgent than the preceding primary survey **components**.

**Environmental control** requires prompt attention to preventing **hypothermia** following full exposure, using warmed fluids and blankets where appropriate, since hypothermia can significantly worsen coagulopathy and overall patient outcome, meaning this final primary survey component carries genuine clinical **importance**.

**Fill in the blank:** Environmental control requires prompt attention to preventing hypothermia, since hypothermia can significantly worsen coagulopathy and overall patient _____.

**Table 1.3: The ATLS primary survey sequence.**

| Component | Focus | Key immediate action |
|---|---|---|
| Airway | Airway patency with cervical spine protection | Clear obstruction, protect the cervical spine |
| Breathing | Respiratory rate, chest movement, oxygenation | Treat immediately life-threatening chest conditions |
| Circulation, Disability, Exposure | Haemorrhage control, neurological status, full examination | Control bleeding, assess GCS, prevent hypothermia |

**Pilot questions 1.3**

1. Describe the airway component of the ATLS primary survey. (Linked to SLO 1.5)
2. Describe the breathing component of the ATLS primary survey. (Linked to SLO 1.5)
3. Describe the circulation component of the ATLS primary survey. (Linked to SLO 1.5)
4. Describe the disability component of the ATLS primary survey. (Linked to SLO 1.6)
5. Explain why environmental control matters despite occurring last in the primary survey sequence. (Linked to SLO 1.6)

# 1.4 ATLS Resuscitation Principles

## 1.4.1 principles of resuscitation in the multiply injured patient

### Simultaneous assessment and treatment of life-threatening problems

Resuscitation of the multiply injured patient proceeds **simultaneously** with the primary survey, discussed earlier in this Series, rather than as a separate, subsequent step, meaning life-threatening problems identified during assessment are addressed **immediately** as they are found rather than deferred until the entire survey is complete.

This simultaneous approach requires adequate **personnel** and equipment to allow concurrent assessment and intervention, reflecting the genuinely multidisciplinary nature of trauma resuscitation, discussed further later in this Series, since a single clinician cannot realistically perform every necessary assessment and intervention **alone**.

**Fill in the blank:** Resuscitation of the multiply injured patient proceeds simultaneously with the primary survey, meaning life-threatening problems are addressed _____ as they are found.

## 1.4.2 fluid resuscitation and haemorrhage control

**Haemorrhage control**, discussed earlier in this Series in relation to circulation assessment, represents the immediate priority in the hypotensive trauma patient, achieved through direct pressure, appropriate splinting of fractures, discussed further in the next Series of this course, and, where indicated, surgical or interventional **control** of ongoing internal bleeding.

**Fluid resuscitation**, generally using warmed intravenous crystalloid solution initially, discussed in relation to hypothermia prevention earlier in this Series, together with blood product transfusion where significant haemorrhage is confirmed or strongly suspected, aims to restore adequate tissue **perfusion** while haemorrhage control measures are simultaneously pursued.

**Fill in the blank:** Fluid resuscitation aims to restore adequate tissue perfusion while haemorrhage control measures are simultaneously _____.

## 1.4.3 reassessment during resuscitation

Continuous **reassessment** throughout resuscitation represents an essential safeguard, since a patient's clinical status can change rapidly, meaning the primary survey sequence, discussed earlier in this Series, is generally repeated at regular intervals or whenever the patient's condition unexpectedly **deteriorates**.

Reassessment additionally allows the trauma team to monitor **response** to interventions already performed, discussed earlier in this Part, confirming that a given treatment has achieved its intended effect, and promptly identifying any new or previously unrecognised problem requiring further **attention**.

**Fill in the blank:** Continuous reassessment throughout resuscitation allows the trauma team to monitor response to interventions already performed, confirming that a given treatment has achieved its intended _____.

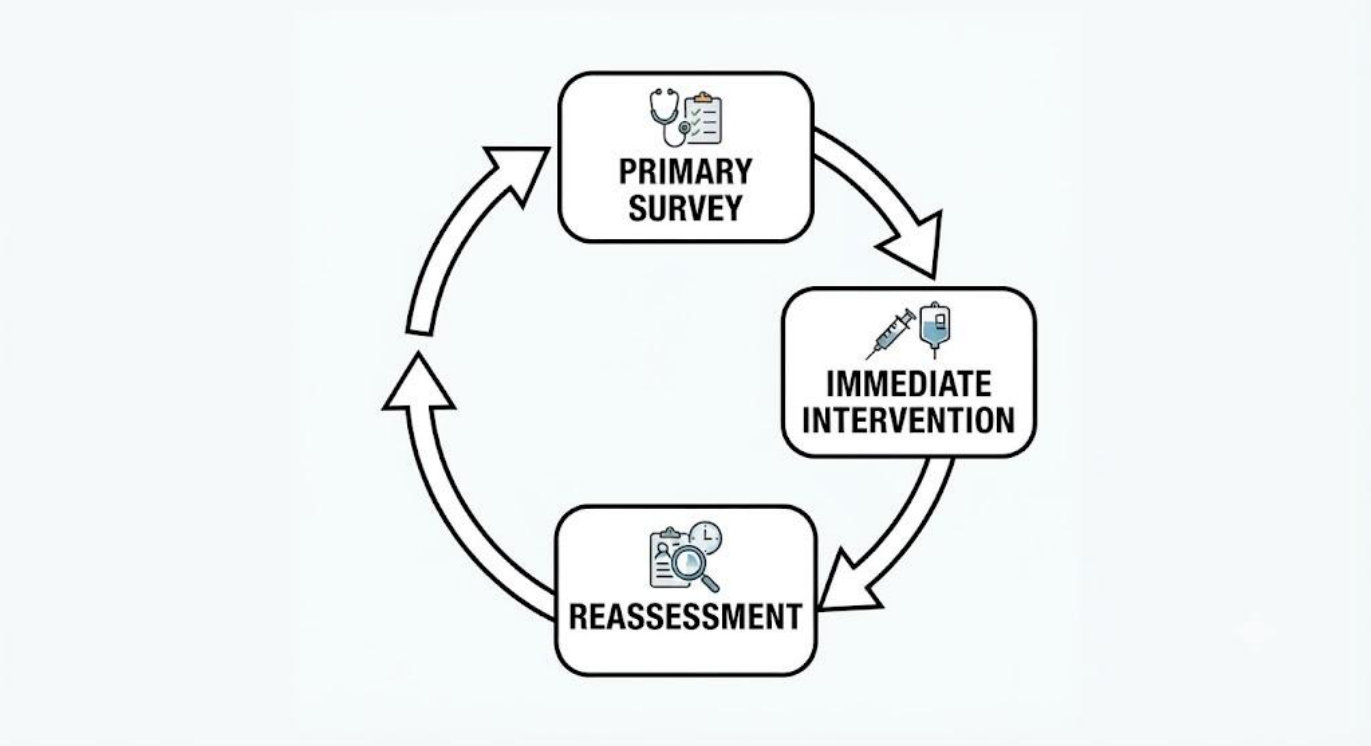


Figure 1.4: Diagram illustrating the cyclical relationship between primary survey, intervention, and continuous reassessment during trauma resuscitation.

**Pilot questions 1.4**

1. Explain why resuscitation proceeds simultaneously with the primary survey rather than afterward. (Linked to SLO 1.7)
2. Describe the immediate priorities of haemorrhage control in the hypotensive trauma patient. (Linked to SLO 1.7)
3. Describe the general approach to fluid resuscitation in the trauma patient. (Linked to SLO 1.7)

4. Explain why continuous reassessment is essential during resuscitation. (Linked to SLO 1.8)
5. Describe what reassessment allows the trauma team to confirm or identify. (Linked to SLO 1.8)

## 1.5 Secondary Survey

### 1.5.1 principles and timing of the secondary survey

A thorough evaluation once immediate threats to life are controlled

The **secondary survey** begins only once the primary survey, discussed earlier in this Series, is complete and any immediately life-threatening problems have been identified and appropriately **managed**, representing a genuinely thorough, comprehensive evaluation rather than the rapid, life-threat-focused assessment of the primary survey.

The secondary survey generally includes a comprehensive **AMPLE** history, covering Allergies, Medications, Past medical history, Last meal, and Events surrounding the injury, together with a complete **head-to-toe** physical examination, discussed further in the next sub-Part, ensuring no significant injury is inadvertently overlooked.

**Fill in the blank:** The secondary survey generally includes a comprehensive AMPLE history, covering allergies, medications, past medical history, last meal, and _____ surrounding the injury.

### 1.5.2 head-to-toe examination in the secondary survey

The head-to-toe examination proceeds **systematically**, discussed in relation to systematic orthopaedic examination earlier in this Series, from the scalp and skull, through the face, neck, chest, abdomen, and pelvis, to the extremities and, finally, a log-roll examination of the entire **spine** and posterior body surface.

This systematic sequence specifically applies the Apley principles of look, feel, and move, discussed earlier in this Series, to each anatomical region in turn, together with careful assessment of distal neurovascular **status** in any limb with suspected fracture or soft tissue injury, discussed further in the next Series of this course.

**Fill in the blank:** The head-to-toe examination applies the Apley principles of look, feel, and move to each anatomical region, together with careful assessment of distal _____ status in any limb with suspected injury.

## 1.5.3 outlining injuries to plan definitive management

Findings from the secondary survey should be systematically **documented**, generating a comprehensive outline of all identified injuries, discussed throughout this Series, providing the essential foundation for subsequent definitive management planning, discussed further later in this Series, across every affected body system and specific structure.

This comprehensive injury outline additionally supports appropriate **prioritisation** of definitive treatment, since not every identified injury requires immediate intervention, meaning careful clinical judgement, informed by the complete secondary survey findings, guides the sequencing of subsequent surgical or non-surgical **management**.

**Fill in the blank:** A comprehensive injury outline supports appropriate prioritisation of definitive treatment, since not every identified injury requires immediate _____.

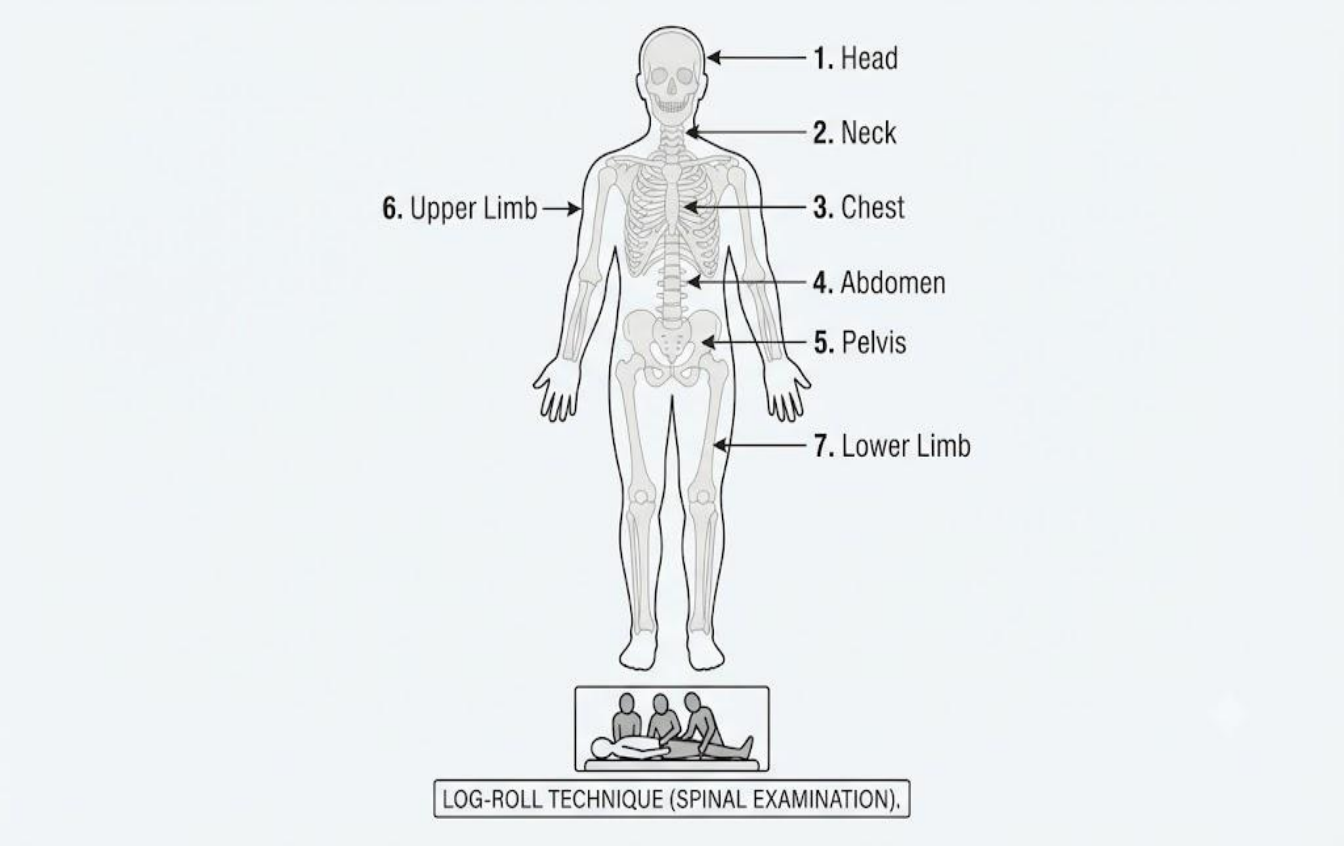


Figure 1.5: Diagram illustrating the head-to-toe examination sequence of the secondary survey, from scalp through to a log-roll spinal examination.

**Pilot questions 1.5**

- State when the secondary survey should begin. (Linked to SLO 1.9)
- State what the AMPLE mnemonic stands for. (Linked to SLO 1.9)
- Describe the systematic sequence of the head-to-toe examination. (Linked to SLO 1.10)
- Explain why distal neurovascular status should be assessed in any limb with suspected injury. (Linked to SLO 1.10)
- Explain why a comprehensive injury outline supports appropriate prioritisation of definitive treatment. (Linked to SLO 1.10)

# 1.6 Multidisciplinary Management of the Multiply Injured Patient

## 1.6.1 the multidisciplinary team in trauma care

### Coordinated expertise spanning multiple specialities

Management of the multiply injured patient is genuinely **multidisciplinary**, discussed throughout this Series, generally involving emergency medicine, orthopaedic surgery, general or trauma surgery, anaesthesia, and, where indicated, neurosurgery or other specialist input, each contributing essential expertise toward the patient's overall **management**.

Effective multidisciplinary trauma care additionally requires input from nursing, radiography, discussed in relation to imaging in an earlier related course, and rehabilitation services, discussed further in relation to specific orthopaedic conditions throughout this course, reflecting the genuinely comprehensive scope of care the multiply injured patient ultimately **requires**.

**Fill in the blank:** Management of the multiply injured patient generally involves emergency medicine, orthopaedic surgery, general or trauma surgery, anaesthesia, and, where indicated, _____ or other specialist input.

## 1.6.2 planning definitive management

Planning definitive management requires careful **prioritisation** across the multiple injuries identified during the secondary survey, discussed earlier in this Series, generally addressing immediately life-threatening problems first, discussed in relation to the primary survey earlier in

this Series, followed by limb- or function-threatening injuries, discussed further in the next Series of this course.

This prioritisation process requires genuine **collaboration** between the involved specialities, discussed earlier in this Part, since the optimal sequence and timing of multiple surgical interventions frequently depends on factors spanning several different specialities' areas of expertise **simultaneously**.

**Fill in the blank:** Planning definitive management requires genuine collaboration between the involved specialities, since the optimal sequence and timing of multiple surgical interventions frequently depends on several specialities' expertise _____.

## 1.6.3 communication and handover in multidisciplinary trauma care

Effective **communication** between team members, discussed throughout this Series, and structured **handover** at each stage of care, from field to hospital, discussed earlier in this Series, and between successive hospital teams, represents an essential safeguard against inadvertently overlooked injuries or **miscommunicated** clinical information.

Structured handover tools, such as standardised verbal or written **handover** formats, discussed in relation to systematic documentation earlier in this Series, help ensure consistent, complete transfer of essential clinical information regardless of which specific individuals are involved in a given patient's ongoing **care**.

**Fill in the blank:** Structured handover tools help ensure consistent, complete transfer of essential clinical information regardless of which specific individuals are involved in a given patient's ongoing _____.

**Table 1.6: Key specialities contributing to multidisciplinary trauma care.**

| Speciality | Primary contribution | Timing of involvement |
|---|---|---|
| Emergency medicine | Initial resuscitation and primary survey | Immediate, on arrival |
| Orthopaedic surgery | Fracture and limb injury management | Early, during secondary survey and beyond |
| Anaesthesia | Airway management and perioperative care | Throughout resuscitation and definitive surgery |

**Pilot questions 1.6**

1. List the specialities generally involved in multidisciplinary management of the multiply injured patient. (Linked to SLO 1.11)
2. Describe the general prioritisation approach when planning definitive management of multiple injuries. (Linked to SLO 1.12)
3. Explain why collaboration between specialities is essential when planning definitive management. (Linked to SLO 1.12)
4. Explain why effective communication and handover are essential safeguards in trauma care. (Linked to SLO 1.12)
5. Describe the value of structured handover tools in multidisciplinary trauma care. (Linked to SLO 1.12)

*Series Summary*

This opening Series established the clinical foundation of orthopaedic and trauma practice, beginning with **clerking and examination in orthopaedics**, systematic history taking and Apley's principles of look, feel, and move, before turning to the **general approach to the injured patient**, field and hospital management principles.

We then examined the **ATLS primary survey**, airway, breathing, circulation, disability, and exposure, followed by **ATLS resuscitation principles**, simultaneous assessment and treatment, fluid resuscitation, and continuous reassessment, then the **secondary survey**, its principles, head-to-toe examination, and injury outlining, concluding with the **multidisciplinary management of the multiply injured patient**, the trauma team, definitive management planning, and communication and handover. Having worked through this Series, you should now be equipped to understand fractures, missile, and blast injuries examined in the next Series of this course.

*Glossary of Terms*

- **Apley's principles:** the systematic orthopaedic examination sequence of look, feel, and move.
- **Primary survey:** the rapid ATLS assessment sequence identifying immediately life-threatening injuries.
- **Airway with cervical spine protection:** the first ATLS primary survey component, securing the airway while protecting the neck.

- **Glasgow Coma Scale:** a scoring system providing rapid neurological assessment during the disability component of the primary survey.
- **Environmental control:** the primary survey component preventing hypothermia after full patient exposure.
- **Fluid resuscitation:** the administration of intravenous fluids or blood products to restore tissue perfusion.
- **Reassessment:** repeated evaluation during resuscitation to monitor response and detect new problems.
- **Secondary survey:** a comprehensive head-to-toe evaluation performed once immediate threats to life are controlled.
- **AMPLE history:** a structured history mnemonic covering allergies, medications, past history, last meal, and events.
- **Log-roll examination:** a technique for examining the posterior body surface and spine while maintaining spinal precautions.
- **Multidisciplinary team:** the coordinated group of specialities involved in managing the multiply injured patient.
- **Handover:** the structured transfer of clinical information between care providers or teams.



*Concept Check Questions [Series 1]*

**Objective questions**

- Apley's principles begin with look, generally performed with the patient adequately exposed and compared against the contralateral, unaffected _____.
- The ATLS primary survey begins with airway assessment with cervical spine protection, since airway compromise represents the most rapidly fatal _____.
- Resuscitation of the multiply injured patient proceeds simultaneously with the primary survey, meaning life-threatening problems are addressed _____ as they are found.
- The secondary survey includes a comprehensive AMPLE history, covering allergies, medications, past medical history, last meal, and _____ surrounding the injury.
- Management of the multiply injured patient generally involves emergency medicine, orthopaedic surgery, general or trauma surgery, anaesthesia, and, where indicated, _____.

**Short-answer questions**

6. State Apley's three principles of orthopaedic examination.

7. Describe the airway and breathing components of the ATLS primary survey.
8. Describe the general approach to fluid resuscitation in the trauma patient.
9. State what the AMPLE mnemonic stands for.
10. Describe the general prioritisation approach when planning definitive management of multiple injuries.

**Long-answer questions**

11. Discuss orthopaedic history taking and Apley's principles of look, feel, and move. (Linked to SLO 1.1, SLO 1.2)
12. Discuss the general approach to the injured patient, including field and hospital management. (Linked to SLO 1.3, SLO 1.4)
13. Discuss the ATLS primary survey and the principles of resuscitation, fluid resuscitation, and reassessment. (Linked to SLO 1.5, SLO 1.6, SLO 1.7, SLO 1.8)
14. Discuss the principles, timing, and conduct of the secondary survey, and outlining injuries to plan definitive management. (Linked to SLO 1.9, SLO 1.10)
15. Discuss the multidisciplinary team in trauma care, planning definitive management, and communication and handover. (Linked to SLO 1.11, SLO 1.12)

*Answers to Concept Check Questions [Series 1]*

**Objective questions**

1. Side.
2. Threat.
3. Immediately.
4. Events.
5. Neurosurgery.

**Short-answer questions**

6. Look, feel, and move.
7. Airway assesses and secures airway patency with cervical spine protection; breathing evaluates respiratory rate, chest movement, and oxygenation, treating life-threatening chest conditions.
8. Warmed intravenous crystalloid initially, with blood product transfusion where significant haemorrhage is confirmed or strongly suspected, alongside haemorrhage control measures.

9. Allergies, Medications, Past medical history, Last meal, and Events surrounding the injury.
10. Addressing immediately life-threatening problems first, followed by limb- or function-threatening injuries, guided by collaborative specialist input.

**Long-answer questions**

11. **Basic response:** Orthopaedic history taking establishes the presenting complaint, its functional impact, and relevant background, complemented by Apley's systematic examination sequence of look, feel, and move.

**Value-added response:** Each stage builds on the previous, from visual inspection through palpation to active and passive movement assessment, always compared against the unaffected side.

12. **Basic response:** The general approach to the injured patient follows a structured, life-threat-prioritised sequence, from field management, prioritising airway, haemorrhage control, and immobilisation, through prompt hospital primary survey.

**Value-added response:** Administrative processes must never delay the primary survey, ensuring immediately life-threatening injuries are recognised and treated without avoidable delay.

13. **Basic response:** The ATLS primary survey proceeds through airway, breathing, circulation, disability, and exposure, with resuscitation occurring simultaneously rather than afterward.

**Value-added response:** Fluid resuscitation and haemorrhage control address circulatory compromise, while continuous reassessment ensures the team detects both treatment response and any new deterioration.

14. **Basic response:** The secondary survey begins once the primary survey is complete, incorporating an AMPLE history and a systematic head-to-toe examination applying the Apley principles throughout.

**Value-added response:** This comprehensive assessment generates a full injury outline, directly informing prioritised definitive management planning.

15. **Basic response:** Multidisciplinary trauma care draws on emergency medicine, orthopaedics, trauma surgery, anaesthesia, and other specialities as needed, requiring genuine collaborative planning of definitive management.

**Value-added response:** Effective communication and structured handover throughout every stage of care safeguard against overlooked injuries or lost clinical information.

*Answers to Pilot Questions [Series 1]*

**Part 1.1**

1. Nature, onset, and progression of the presenting complaint, functional impact, past medical/surgical history, and relevant social history.
2. Look, feel, and move.
3. Skin colour and integrity, swelling, deformity, muscle wasting, and scars, compared with the contralateral side.
4. Temperature, tenderness, swelling character, and specific anatomical landmarks.
5. Active movement is performed independently by the patient; passive movement is performed by the examiner.

**Part 1.2**

1. Addressing the greatest immediate threat to life first, rather than the most visually striking or painful injury.
2. Basic airway maintenance, control of external haemorrhage, and appropriate immobilisation.
3. It supports advance preparation and continuity of care across the prehospital to hospital transition.
4. Immediate, structured handover from prehospital providers, followed directly by the primary survey.
5. Because delay risks postponing recognition of immediately life-threatening injury.

**Part 1.3**

1. Assessing and securing airway patency with cervical spine protection, since airway compromise is the most rapidly fatal threat.
2. Evaluating respiratory rate, chest wall movement, and oxygenation, treating immediately life-threatening chest conditions.
3. Identifying and controlling significant haemorrhage, assessing pulse, blood pressure, and skin perfusion.
4. A rapid neurological evaluation using the Glasgow Coma Scale and pupillary examination.

5. Because hypothermia can significantly worsen coagulopathy and overall patient outcome.

**Part 1.4**

1. Because life-threatening problems must be treated immediately as found, rather than deferred until the full survey is complete.
2. Direct pressure, appropriate fracture splinting, and surgical or interventional control of ongoing internal bleeding where indicated.
3. Warmed intravenous crystalloid initially, with blood product transfusion where significant haemorrhage is confirmed or suspected.
4. Because the patient's clinical status can change rapidly, requiring repeated evaluation.
5. It confirms treatment response and identifies any new or previously unrecognised problem requiring attention.

**Part 1.5**

- Once the primary survey is complete and immediately life-threatening problems are managed.
- Allergies, Medications, Past medical history, Last meal, and Events surrounding the injury.
- Scalp and skull, face, neck, chest, abdomen, pelvis, extremities, and finally a log-roll examination of the spine and posterior surface.
- Because it identifies vascular or nerve compromise that may require urgent intervention.
- Because it allows careful clinical judgement to sequence treatment appropriately rather than treating every injury with equal urgency.

**Part 1.6**

- Emergency medicine, orthopaedic surgery, general or trauma surgery, anaesthesia, and, where indicated, neurosurgery or other specialities.
- Addressing immediately life-threatening problems first, then limb- or function-threatening injuries.
- Because the optimal sequence and timing of interventions often depends on several specialities' expertise simultaneously.
- Because they safeguard against inadvertently overlooked injuries or miscommunicated clinical information.
- They ensure consistent, complete transfer of essential clinical information regardless of the specific individuals involved.

*References and Attributions [Series 1]*


- American College of Surgeons Committee on Trauma (2018). Advanced Trauma Life Support (ATLS) Student Course Manual (10th ed.).
- Solomon, L., Warwick, D., & Nayagam, S. (2018). Apley and Solomon's System of Orthopaedics and Trauma (10th ed.). CRC Press.
- McRae, R., & Esser, M. (2008). Practical Fracture Treatment (5th ed.). Churchill Livingstone.
- Skinner, H. B., & McMahon, P. J. (Eds.). (2013). Current Diagnosis and Treatment in Orthopedics (5th ed.). McGraw-Hill.


**Figures, Plates, Tables, and Boxes**

- Figure 1.1: Diagram illustrating Apley's three-stage orthopaedic examination sequence of look, feel, and move. AI-generated using the prompt: "A single clean, accurate three-panel schematic educational diagram, each panel labelled Look, Feel, and Move respectively, using simple icons representing visual inspection, palpating hands, and a joint range of motion arc, textbook clinical skills diagram style, neutral background, no photographic realism, no other panels."
- Table 1.2: Comparing field and hospital management priorities for the injured patient. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Field and Hospital Management Priorities, listing setting, immediate priority, and key supporting action. Trauma reference table style with outside border, no photographic elements."
- Table 1.3: The ATLS primary survey sequence. AI-generated using the prompt: "Create a clean clinical reference table titled The ATLS Primary Survey Sequence, listing component, focus, and key immediate action. Trauma reference table style with outside border, no photographic elements."
- Figure 1.4: Diagram illustrating the cyclical relationship between primary survey, intervention, and continuous reassessment during trauma resuscitation. AI-generated using the prompt: "A single clean, accurate circular flow diagram with three labelled stages, Primary Survey, Immediate Intervention, and Reassessment, connected by curved arrows forming a continuous loop, textbook clinical process diagram style, neutral background, no photographic realism, no other panels."
- Figure 1.5: Diagram illustrating the head-to-toe examination sequence of the secondary survey, from scalp through to a log-roll spinal examination. AI-generated using the prompt: "A single clean, accurate schematic diagram of a simplified human body outline

with numbered labels proceeding from the head down through neck, chest, abdomen, pelvis, and limbs, with a final labelled log-roll icon for spinal examination, textbook clinical skills diagram style, neutral background, no photographic realism, no other panels."

- Table 1.6: Key specialities contributing to multidisciplinary trauma care. AI-generated using the prompt: "Create a clean clinical reference table titled Key Specialities Contributing to Multidisciplinary Trauma Care, listing speciality, primary contribution, and timing of involvement. Trauma reference table style with outside border, no photographic elements."

**Course code: ORT 601**

**Course title: Principles of Orthopaedic Surgery**

**Course credit load: 4 Units**

# Series 2: Fractures, Missile, and Blast Injuries

- **Part 2.1: Definition, Causes, and Classification of Fractures**
  - Sub Part 2.1.1: Definition and causes of fracture
  - Sub Part 2.1.2: Classification of fractures by pattern and mechanism
  - Sub Part 2.1.3: Classification of fractures by soft tissue involvement
- **Part 2.2: Fracture Healing**
  - Sub Part 2.2.1: Stages of fracture healing
  - Sub Part 2.2.2: Factors affecting fracture healing
  - Sub Part 2.2.3: Complications of fracture healing
- **Part 2.3: Principles of Fracture Management**
  - Sub Part 2.3.1: Principles of reduction
  - Sub Part 2.3.2: Principles of immobilisation
  - Sub Part 2.3.3: Principles of rehabilitation
- **Part 2.4: Missile Injuries**
  - Sub Part 2.4.1: Wound ballistics and mechanism of missile injury
  - Sub Part 2.4.2: Classification of missile injuries by body system
  - Sub Part 2.4.3: Initial management of missile injuries
- **Part 2.5: Blast Injuries**
  - Sub Part 2.5.1: Mechanism and classification of blast injury
  - Sub Part 2.5.2: Blast injuries by body system
  - Sub Part 2.5.3: Initial management of blast injuries
- **Part 2.6: Mass Casualty Triage and ATLS in Combined Injury**
  - Sub Part 2.6.1: Principles of triage in mass casualty situations
  - Sub Part 2.6.2: Triage categories and systems
  - Sub Part 2.6.3: Applying the ATLS protocol to missile and blast casualties

# Introduction

In the last Series, we established the clinical approach and multidisciplinary management of the injured patient. We now turn to **fractures**, their definition, causes, classification, healing, and management principles, together with **missile and blast injuries**, the specific mechanisms and systemic patterns of injury they produce, and the essential skill of **mass casualty triage** applied alongside ATLS resuscitation, discussed in the previous Series of this course.

The aim of this Series is to equip you with a thorough understanding of fractures, their definition, causes, classification, and principles of management, missile and blast injuries, the injuries they cause, and the approach to patient management, and mass casualty triage.

This Series begins with the **definition, causes, and classification of fractures**, before examining **fracture healing**. We then turn to the **principles of fracture management**, followed by **missile injuries**, then **blast injuries**, concluding with **mass casualty triage and ATLS in combined injury**.

# Series Learning Outcomes

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

- **SLO 2.1:** define fracture, describe its causes, and classify fractures by pattern, mechanism, and soft tissue involvement
- **SLO 2.2:** describe the stages of fracture healing
- **SLO 2.3:** describe the factors affecting fracture healing and the complications of impaired healing
- **SLO 2.4:** describe the principles of fracture reduction and immobilisation
- **SLO 2.5:** describe the principles of rehabilitation following fracture management
- **SLO 2.6:** describe the mechanism of missile injury and classify missile injuries by body system
- **SLO 2.7:** describe the initial management of missile injuries
- **SLO 2.8:** describe the mechanism and classification of blast injury and blast injuries by body system
- **SLO 2.9:** describe the initial management of blast injuries
- **SLO 2.10:** describe the principles of triage in mass casualty situations
- **SLO 2.11:** describe triage categories and systems, and
- **SLO 2.12:** explain how the ATLS protocol is applied to missile and blast casualties.

## 2.1 Definition, Causes, and Classification of Fractures

### 2.1.1 definition and causes of fracture

***A structural break in bone continuity***

A **fracture** is defined as a break in the structural continuity of bone, resulting from an applied force exceeding the bone's inherent **strength**, whether through a single, substantial traumatic impact or through repetitive, cumulative loading over time.

Recognised causes include **traumatic** fractures, resulting from a single significant applied force, **stress** fractures, resulting from repetitive submaximal loading, discussed further in relation to overuse in an earlier related course, and **pathological** fractures, occurring through bone already weakened by an underlying disease process, such as a bone tumour, discussed in a later Series of this course, requiring substantially less force than would otherwise be **necessary**.

**Fill in the blank:** A pathological fracture occurs through bone already weakened by an underlying disease process, requiring substantially less force than would otherwise be _____.

### 2.1.2 classification of fractures by pattern and mechanism

Fractures are classified by their specific **pattern**, including **transverse**, a fracture line running perpendicular to the bone's long axis, **oblique**, running at an angle, **spiral**, resulting from a rotational force, and **comminuted**, comprising more than two fracture fragments.

Fracture pattern generally reflects the underlying **mechanism** of injury, with transverse fractures typically resulting from direct bending forces, spiral fractures from rotational forces discussed earlier in this Part, and comminuted fractures generally reflecting high-energy trauma, meaning careful attention to fracture pattern can provide valuable clues regarding the likely mechanism and associated soft tissue **injury**.

**Fill in the blank:** Fracture pattern generally reflects the underlying mechanism of injury, with comminuted fractures generally reflecting _____ trauma.

### 2.1.3 classification of fractures by soft tissue involvement

A **closed fracture** occurs without any overlying skin breach communicating with the fracture site, while an **open fracture**, discussed in relation to the Gustilo-Anderson classification in an

earlier related course, involves a wound communicating directly with the fracture, carrying substantially increased risk of infection, discussed further in a later Series of this course.

Open fractures are further classified according to **wound size** and degree of soft tissue damage, contamination, and vascular injury, with more severe grades carrying correspondingly greater infection risk and requiring more urgent, aggressive surgical **debridement** and wound management.

**Fill in the blank:** Open fractures carry substantially increased risk of infection and are further classified according to wound size and degree of soft tissue damage, contamination, and vascular _____.

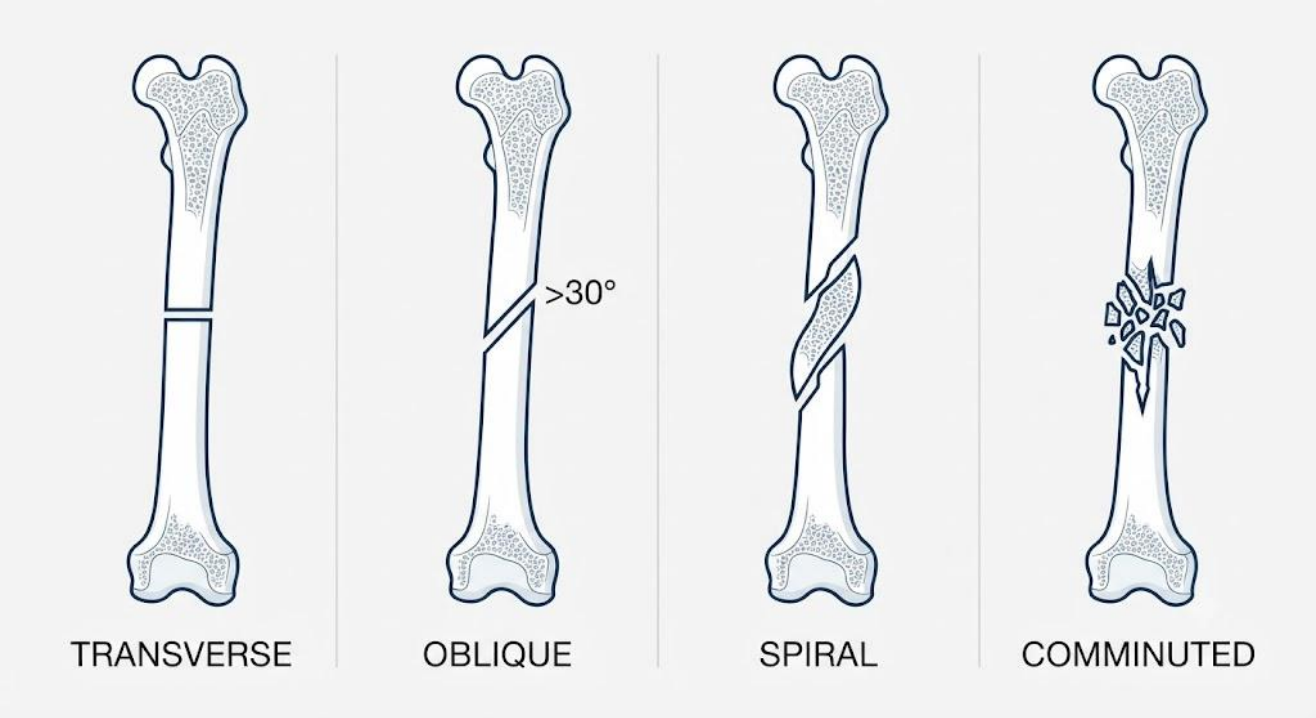


Figure 2.1: Diagram illustrating transverse, oblique, spiral, and comminuted fracture patterns.

**Pilot questions 2.1**

1. Define fracture. (Linked to SLO 2.1)
2. Distinguish traumatic, stress, and pathological fractures by cause. (Linked to SLO 2.1)
3. Describe the transverse, oblique, spiral, and comminuted fracture patterns. (Linked to SLO 2.1)
4. Explain how fracture pattern relates to the mechanism of injury. (Linked to SLO 2.1)
5. Distinguish an open fracture from a closed fracture. (Linked to SLO 2.1)

## 2.2 Fracture Healing

### 2.2.1 stages of fracture healing

***A sequential biological repair process***

Fracture healing proceeds through a sequential process, beginning with **haematoma formation** at the fracture site, followed by **inflammation**, with recruitment of inflammatory cells initiating the repair cascade, generally occurring within the first few days following injury.

Subsequent stages include **soft callus** formation, as fibrocartilaginous tissue bridges the fracture gap, **hard callus** formation, as this soft callus progressively ossifies into woven bone, and finally **remodelling**, a prolonged process during which woven bone is gradually replaced by mature lamellar bone restored to its original **structural** configuration.

**Fill in the blank:** Fracture healing includes soft callus formation, hard callus formation, and finally remodelling, during which woven bone is gradually replaced by mature lamellar _____.

### 2.2.2 factors affecting fracture healing

Factors affecting fracture healing include **local** factors, such as the degree of fracture displacement, adequacy of blood supply, discussed in relation to specific fracture sites in an earlier related course, and presence of infection, discussed earlier in this Series, each directly influencing the biological environment available for **repair**.

Further important **systemic** factors include patient age, nutritional status, smoking, and underlying medical conditions such as diabetes mellitus, discussed in an earlier related course, each capable of meaningfully impairing the normal fracture healing process regardless of otherwise optimal local fracture **management**.

**Fill in the blank:** Systemic factors affecting fracture healing include patient age, nutritional status, smoking, and underlying medical conditions such as diabetes _____.

### 2.2.3 complications of fracture healing

**Delayed union** describes fracture healing proceeding more slowly than expected for the specific fracture and patient, while **non-union** describes complete cessation of the healing process

without bony union ever being achieved, discussed in relation to healing factors earlier in this Part, generally requiring further surgical intervention to achieve union.

**Mal-union** describes healing occurring with unacceptable residual deformity, angulation, or shortening, discussed in relation to fracture reduction principles in the next Part of this Series, each of these complications carrying potential functional consequences requiring careful clinical recognition and appropriate further **management**.

**Fill in the blank:** Mal-union describes fracture healing occurring with unacceptable residual deformity, angulation, or _____.

**Table 2.2: Comparing complications of fracture healing.**

| Complication | Definition | General management approach |
|---|---|---|
| Delayed union | Healing proceeding more slowly than expected | Continued monitoring, addressing modifiable factors |
| Non-union | Complete cessation of healing without bony union | Further surgical intervention |
| Mal-union | Healing with unacceptable residual deformity | Corrective surgery if functionally significant |

**Pilot questions 2.2**

1. Describe the sequential stages of fracture healing. (Linked to SLO 2.2)
2. Define remodelling as a stage of fracture healing. (Linked to SLO 2.2)
3. List two local and two systemic factors affecting fracture healing. (Linked to SLO 2.3)
4. Distinguish delayed union from non-union. (Linked to SLO 2.3)
5. Define mal-union. (Linked to SLO 2.3)

## 2.3 Principles of Fracture Management

### 2.3.1 principles of reduction

***Restoring acceptable bony alignment***

**Reduction** aims to restore acceptable anatomical alignment of a displaced fracture, generally achieved through **closed reduction**, manipulation performed without a surgical incision, or **open**

**reduction**, requiring direct surgical exposure of the fracture, discussed further in an earlier related course, with the specific approach chosen depending on fracture pattern and displacement.

The acceptability of a given reduction is judged against defined criteria for angulation, rotation, and shortening, discussed in relation to mal-union earlier in this Series, since not every fracture requires perfect anatomical reduction, particularly where functional outcome is unlikely to be meaningfully affected by modest residual **displacement**.

**Fill in the blank:** Reduction is generally achieved through closed reduction, manipulation performed without a surgical incision, or open reduction, requiring direct surgical exposure of the _____.

## 2.3.2 principles of immobilisation

**Immobilisation** maintains the reduced fracture position while healing proceeds, discussed earlier in this Series, achieved through **external** methods, such as plaster cast application, or **internal** fixation, using plates, screws, or intramedullary devices, discussed further in an earlier related course, surgically applied directly to the bone.

**External fixation**, using pins inserted into bone connected by an external frame, represents a further recognised option, particularly valuable for severely comminuted or contaminated open fractures, discussed earlier in this Series, where internal fixation might carry unacceptable infection **risk**.

**Fill in the blank:** External fixation, using pins inserted into bone connected by an external frame, is particularly valuable for severely comminuted or contaminated open fractures where internal fixation might carry unacceptable infection _____.

## 2.3.3 principles of rehabilitation

**Rehabilitation** following fracture management aims to restore function, generally involving progressive, structured **physiotherapy** addressing joint range of motion, muscle strength, and overall functional mobility, commenced as early as the specific fracture stability and healing **status** permit.

Effective rehabilitation additionally requires close monitoring for potential complications, discussed earlier in this Series, and appropriate progression of weight-bearing status guided by radiographic and clinical evidence of adequate healing, reflecting the genuinely coordinated relationship between fracture management and successful functional **recovery**.

**Fill in the blank:** Effective rehabilitation requires appropriate progression of weight-bearing status guided by radiographic and clinical evidence of adequate _____.

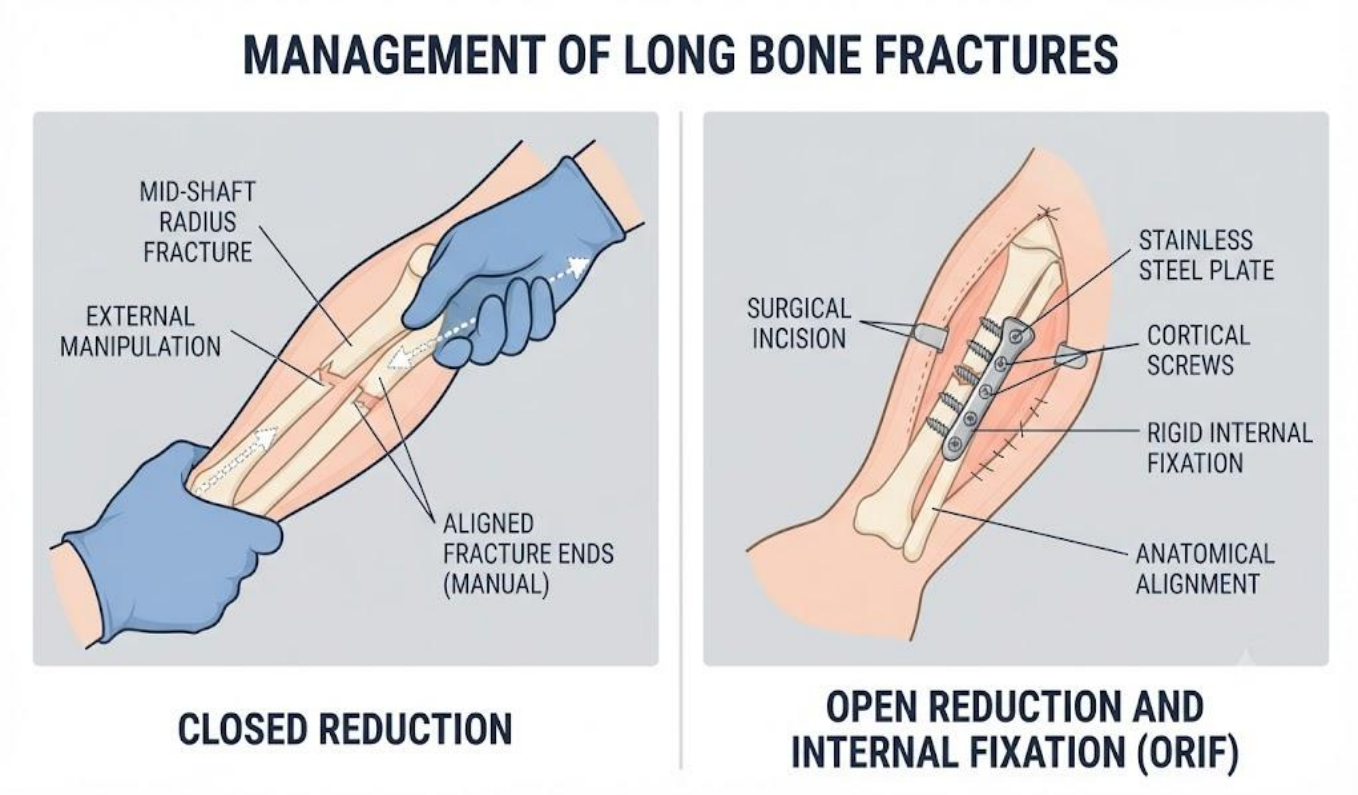


Figure 2.3: Diagram comparing closed reduction with manipulation to open reduction with internal fixation using a plate and screws.

**Pilot questions 2.3**

1. Distinguish closed reduction from open reduction. (Linked to SLO 2.4)
2. Explain why not every fracture requires perfect anatomical reduction. (Linked to SLO 2.4)
3. Distinguish external immobilisation from internal fixation. (Linked to SLO 2.4)
4. Describe the particular value of external fixation for certain fracture types. (Linked to SLO 2.4)
5. Describe the principles of rehabilitation following fracture management. (Linked to SLO 2.5)

## 2.4 Missile Injuries

### 2.4.1 wound ballistics and mechanism of missile injury

***Tissue damage from a rapidly moving projectile***

**Missile injury**, discussed in relation to trauma mechanisms throughout this Series, results from tissue damage caused by a rapidly moving **projectile**, generally a bullet or fragment, with the degree of tissue destruction directly related to the projectile's kinetic **energy** at the point of impact.

Wound ballistics additionally involves the concept of **temporary cavitation**, a transient radial expansion of tissue around the projectile's path caused by energy transfer, which, particularly with high-velocity projectiles, can produce tissue damage considerably beyond the projectile's immediate, visible **track**.

**Fill in the blank:** Wound ballistics involves the concept of temporary cavitation, a transient radial expansion of tissue around the projectile's path, which can produce tissue damage considerably beyond the projectile's immediate, visible _____.

### 2.4.2 classification of missile injuries by body system

Missile injuries are usefully classified according to the specific body system involved, including **musculoskeletal** injury, discussed throughout this Series, producing comminuted fracture and soft tissue damage, and **vascular** injury, discussed in relation to circulation assessment in an earlier Series of this course, requiring urgent recognition given the risk of significant haemorrhage.

Further important system-specific injuries include **thoracic** and **abdominal** missile injury, discussed in relation to chest and abdominal imaging in earlier related courses, each carrying distinct management priorities, and **neurological** injury, where the missile track involves the central or peripheral nervous **system**, each requiring specific specialist assessment.

**Fill in the blank:** Missile injuries are classified by body system, including musculoskeletal, vascular, thoracic, abdominal, and _____ injury.

### 2.4.3 initial management of missile injuries

Initial management of missile injuries follows the ATLS primary survey principles, discussed in the previous Series of this course, with particular attention to identifying and controlling significant haemorrhage, discussed earlier in this Series, and assessing distal neurovascular status

in any affected limb, discussed in relation to secondary survey principles in the previous Series of this course.

Wound management generally requires thorough surgical **debridement** of devitalised tissue, discussed in relation to open fracture management earlier in this Series, appropriate antibiotic prophylaxis, and, where indicated, delayed primary or secondary wound closure, reflecting the genuinely contaminated nature of most missile **wounds**.

**Fill in the blank:** Wound management of missile injuries generally requires thorough surgical debridement of devitalised tissue, reflecting the genuinely contaminated nature of most missile _____.

**Table 2.4: Classification of missile injuries by body system.**

| System | Typical injury pattern | Key management priority |
|---|---|---|
| Musculoskeletal | Comminuted fracture and soft tissue damage | Debridement and appropriate fixation |
| Vascular | Significant haemorrhage or vessel disruption | Urgent recognition and haemorrhage control |
| Thoracic/abdominal | Organ injury and internal haemorrhage | Urgent surgical assessment |

**Pilot questions 2.4**

1. Describe the relationship between projectile kinetic energy and tissue destruction. (Linked to SLO 2.6)
2. Define temporary cavitation. (Linked to SLO 2.6)
3. List three body systems used to classify missile injuries. (Linked to SLO 2.6)
4. Describe the initial management priorities for missile injuries. (Linked to SLO 2.7)
5. Explain why thorough surgical debridement is essential in missile wound management. (Linked to SLO 2.7)

## 2.5 Blast Injuries

### 2.5.1 mechanism and classification of blast injury

*A distinct injury pattern from explosive detonation*

**Blast injury**, resulting from explosive **detonation**, discussed in relation to trauma mechanisms throughout this Series, is classified into distinct categories reflecting the different physical mechanisms of tissue injury involved, discussed further in the next sub-Part, rather than a single uniform injury pattern.

**Primary blast injury** results directly from the blast pressure wave itself, particularly affecting gas-containing organs such as the lungs and bowel, while **secondary blast injury** results from penetrating injury caused by fragments propelled by the explosion, discussed in relation to missile injury earlier in this Series.

**Fill in the blank:** Primary blast injury results directly from the blast pressure wave itself, particularly affecting gas-containing organs such as the lungs and _____.

## 2.5.2 blast injuries by body system

**Tertiary blast injury** results from the patient's body being physically displaced by the blast wind, producing blunt trauma on impact with a surrounding structure, while **quaternary blast injury** encompasses all other blast-related injuries, including burns, discussed in an earlier related course, and inhalation injury from the explosion itself.

Blast lung injury, a specific form of primary blast injury, discussed earlier in this Part, produces pulmonary contusion and haemorrhage, discussed in relation to chest trauma imaging in an earlier related course, together with a recognised risk of arterial **air embolism**, reflecting the unique physical mechanism of primary blast injury to gas-containing structures.

**Fill in the blank:** Blast lung injury produces pulmonary contusion and haemorrhage together with a recognised risk of arterial air _____.

## 2.5.3 initial management of blast injuries

Initial management of blast injuries similarly follows ATLS primary survey principles, discussed in the previous Series of this course, with particular attention to respiratory assessment given the specific risk of primary blast lung injury, discussed earlier in this Series, and systematic assessment for penetrating fragment injury, discussed in relation to secondary blast injury earlier in this Part.

Management additionally requires a high index of suspicion for **combined** injury patterns, given the multiple simultaneous mechanisms characteristic of blast trauma, discussed throughout this

Part, meaning a single identified injury should never be assumed to represent the entirety of the patient's overall injury **burden**.

**Fill in the blank:** Management of blast injuries requires a high index of suspicion for combined injury patterns, meaning a single identified injury should never be assumed to represent the entirety of the patient's overall injury _____.

Table 2.5: Classification of blast injury by mechanism.

| Category | Mechanism | Typical injury |
|---|---|---|
| Primary | Blast pressure wave | Lung and bowel injury |
| Secondary | Penetrating fragments propelled by the explosion | Penetrating wounds, similar to missile injury |
| Tertiary | Body displacement by blast wind | Blunt trauma on impact |

**Pilot questions 2.5**

- Distinguish primary from secondary blast injury. (Linked to SLO 2.8)
- Distinguish tertiary from quaternary blast injury. (Linked to SLO 2.8)
- Describe blast lung injury and its specific recognised risk. (Linked to SLO 2.8)
- Describe the initial management priorities for blast injury. (Linked to SLO 2.9)
- Explain why a high index of suspicion for combined injury patterns is essential in blast trauma. (Linked to SLO 2.9)

## 2.6 Mass Casualty Triage and ATLS in Combined Injury

### 2.6.1 principles of triage in mass casualty situations

***Allocating limited resources to maximise overall survival***

**Triage** in mass casualty situations, discussed in relation to multiple casualties throughout this Series, involves rapidly sorting patients according to injury severity and likely benefit from treatment, aiming to allocate genuinely limited available resources to achieve the greatest overall **benefit** across the entire casualty group.

This approach represents a fundamental departure from standard individual patient care, discussed throughout this course, since triage decisions are explicitly made based on the needs of

the entire casualty **population** rather than focusing exclusively on any single patient regardless of the overall situation.

**Fill in the blank:** Triage in mass casualty situations aims to allocate genuinely limited available resources to achieve the greatest overall benefit across the entire casualty _____.

## 2.6.2 triage categories and systems

Triage systems generally sort casualties into defined categories, commonly including **immediate**, patients requiring urgent, life-saving intervention with a realistic chance of survival, **delayed**, patients with serious injuries who can safely wait for treatment, and **minimal**, patients with relatively minor injuries requiring only limited treatment.

A further recognised category, **expectant**, describes patients whose injuries are so severe that survival is considered highly unlikely even with maximal available resources, discussed in relation to resource allocation earlier in this Part, meaning treatment priority is directed instead toward casualties more likely to benefit from immediate **intervention**.

**Fill in the blank:** Triage systems generally sort casualties into categories, commonly including immediate, delayed, minimal, and _____, describing patients whose survival is considered highly unlikely even with maximal available resources.

## 2.6.3 applying the atls protocol to missile and blast casualties

Once individual casualties from a missile or blast incident, discussed throughout this Series, have been triaged and receive treatment priority, discussed earlier in this Part, standard ATLS primary survey and resuscitation principles, discussed in the previous Series of this course, apply in essentially the same sequence as for any other injured patient.

Specific attention should additionally be directed toward the recognised injury patterns characteristic of missile and blast trauma, discussed throughout this Series, including combined penetrating and blast lung injury, meaning the ATLS protocol's systematic, life-threat-prioritised approach remains equally valid and essential even within the specific context of mass casualty **management**.

**Fill in the blank:** Specific attention should be directed toward recognised injury patterns characteristic of missile and blast trauma, meaning the ATLS protocol's systematic, life-threat-prioritised approach remains equally valid within mass casualty _____.


Figure 2.6: Diagram illustrating a mass casualty triage colour-coding system with immediate, delayed, minimal, and expectant categories.

**Pilot questions 2.6**

1. Define triage in the context of mass casualty situations. (Linked to SLO 2.10)
2. Explain how triage represents a departure from standard individual patient care. (Linked to SLO 2.10)
3. List the four common triage categories. (Linked to SLO 2.11)
4. Define the expectant triage category. (Linked to SLO 2.11)
5. Explain how the ATLS protocol is applied to missile and blast casualties following triage. (Linked to SLO 2.12)

**Series Summary**

This Series examined **fractures, missile, and blast injuries**, beginning with the **definition, causes, and classification of fractures**, before turning to **fracture healing**, its stages, affecting factors, and complications, and the **principles of fracture management**, reduction, immobilisation, and rehabilitation.

We then examined **missile injuries**, wound ballistics, systemic classification, and initial management, followed by **blast injuries**, mechanism, classification, and initial management, concluding with **mass casualty triage and ATLS in combined injury**, triage principles, categories, and applying the ATLS protocol to missile and blast casualties. Having worked through this Series, you should now be equipped to understand amputation and compartment syndrome examined in the next Series of this course.

## Glossary of Terms

- **Fracture:** a break in the structural continuity of bone.
- **Pathological fracture:** a fracture occurring through bone weakened by an underlying disease process.
- **Comminuted fracture:** a fracture comprising more than two fragments.
- **Non-union:** complete cessation of fracture healing without bony union ever being achieved.
- **Mal-union:** fracture healing with unacceptable residual deformity, angulation, or shortening.
- **Closed reduction:** fracture manipulation performed without a surgical incision.
- **External fixation:** fracture stabilisation using pins connected by an external frame.
- **Temporary cavitation:** transient radial tissue expansion around a projectile's path from energy transfer.
- **Primary blast injury:** injury resulting directly from the blast pressure wave, particularly affecting gas-containing organs.
- **Secondary blast injury:** penetrating injury caused by fragments propelled by an explosion.
- **Triage:** the process of sorting casualties by severity and likely benefit to allocate limited resources.
- **Expectant (triage category):** a triage category for patients whose survival is considered highly unlikely even with maximal resources.

## Concept Check Questions [Series 2]

### Objective questions

6. A pathological fracture occurs through bone already weakened by an underlying disease process, requiring substantially less force than would otherwise be _____.

7. Fracture healing includes soft callus, hard callus, and remodelling, during which woven bone is gradually replaced by mature lamellar _____.
8. Wound ballistics involves temporary cavitation, which can produce tissue damage considerably beyond the projectile's immediate, visible _____.
9. Primary blast injury results directly from the blast pressure wave, particularly affecting gas-containing organs such as the lungs and _____.
10. Triage systems sort casualties into categories including immediate, delayed, minimal, and _____.

**Short-answer questions**

11. Distinguish traumatic, stress, and pathological fractures by cause.
12. Distinguish delayed union from non-union.
13. Distinguish closed reduction from open reduction.
14. Distinguish primary from secondary blast injury.
15. Define the expectant triage category.

**Long-answer questions**

1. Discuss the definition, causes, and classification of fractures. (Linked to SLO 2.1)
2. Discuss the stages of fracture healing, factors affecting healing, and complications of impaired healing. (Linked to SLO 2.2, SLO 2.3)
3. Discuss the principles of fracture reduction, immobilisation, and rehabilitation. (Linked to SLO 2.4, SLO 2.5)
4. Discuss missile and blast injuries, the injuries they cause, and their initial management. (Linked to SLO 2.6, SLO 2.7, SLO 2.8, SLO 2.9)
5. Discuss mass casualty triage and applying the ATLS protocol to missile and blast casualties. (Linked to SLO 2.10, SLO 2.11, SLO 2.12)

**Answers to Concept Check Questions [Series 2]**

**Objective questions**

6. Necessary.
7. Bone.
8. Track.
9. Bowel.
10. Expectant.

**Short-answer questions**

11. Traumatic fractures result from a single significant force; stress fractures from repetitive submaximal loading; pathological fractures from bone weakened by disease.
12. Delayed union proceeds more slowly than expected; non-union is complete cessation of healing without bony union ever being achieved.
13. Closed reduction manipulates the fracture without a surgical incision; open reduction requires direct surgical exposure of the fracture.
14. Primary blast injury results directly from the pressure wave; secondary blast injury results from penetrating fragments propelled by the explosion.
15. A category for patients whose survival is considered highly unlikely even with maximal available resources, directing priority elsewhere.

**Long-answer questions**

16. **Basic response:** A fracture is a break in bone continuity, caused by traumatic, stress, or pathological processes, and classified by pattern, mechanism, and soft tissue involvement.

**Value-added response:** Open fractures carry substantially increased infection risk compared with closed fractures, requiring careful classification and management.

17. **Basic response:** Fracture healing proceeds through haematoma formation, inflammation, soft and hard callus formation, and remodelling, influenced by local and systemic factors.

**Value-added response:** Impaired healing can result in delayed union, non-union, or mal-union, each requiring specific recognition and, where indicated, further intervention.

18. **Basic response:** Reduction restores acceptable alignment through closed or open methods, while immobilisation, external or internal, maintains this position during healing.

**Value-added response:** Rehabilitation restores function through structured physiotherapy and progressive weight-bearing, guided by evidence of adequate healing.

19. **Basic response:** Missile injury results from projectile kinetic energy and cavitation, classified by body system, while blast injury involves primary, secondary, tertiary, and quaternary mechanisms.

**Value-added response:** Both require ATLS-based initial management with thorough debridement, respiratory assessment, and a high index of suspicion for combined injury patterns.

20. **Basic response:** Mass casualty triage sorts patients by severity and likely benefit into immediate, delayed, minimal, and expectant categories to maximise overall survival.

**Value-added response:** Once triaged, standard ATLS protocol applies to missile and blast casualties, with specific attention to the characteristic injury patterns of these mechanisms.

**Answers to Pilot Questions [Series 2]**

**Part 2.1**

11. A break in the structural continuity of bone.
12. Traumatic fractures result from a single significant force; stress fractures from repetitive loading; pathological fractures from bone weakened by disease.
13. Transverse runs perpendicular to the bone axis; oblique at an angle; spiral from rotational force; comminuted has more than two fragments.
14. Transverse fractures typically result from direct bending, spiral from rotation, and comminuted from high-energy trauma.
15. A closed fracture has no overlying skin breach communicating with the fracture site; an open fracture does.

**Part 2.2**

1. Haematoma formation, inflammation, soft callus formation, hard callus formation, and remodelling.
2. The prolonged process during which woven bone is gradually replaced by mature lamellar bone.
3. Local: fracture displacement and blood supply; Systemic: patient age and smoking.
4. Delayed union proceeds more slowly than expected; non-union is complete cessation of healing without bony union.
5. Fracture healing with unacceptable residual deformity, angulation, or shortening.

**Part 2.3**

1. Closed reduction is manipulation without an incision; open reduction requires direct surgical exposure.
2. Because functional outcome is unlikely to be meaningfully affected by modest residual displacement in some fractures.

3. External immobilisation uses casts; internal fixation surgically applies plates, screws, or intramedullary devices.
4. It is valuable for severely comminuted or contaminated open fractures where internal fixation might carry unacceptable infection risk.
5. Progressive, structured physiotherapy addressing range of motion, strength, and mobility, guided by healing status.

**Part 2.4**

1. Greater kinetic energy at impact produces greater tissue destruction.
2. A transient radial expansion of tissue around a projectile's path caused by energy transfer.
3. Musculoskeletal, vascular, and thoracic/abdominal, among others such as neurological.
4. Following ATLS primary survey principles, with attention to haemorrhage control and distal neurovascular assessment.
5. Because missile wounds are generally contaminated, requiring removal of devitalised tissue to reduce infection risk.

**Part 2.5**

1. Primary blast injury results from the pressure wave itself; secondary blast injury results from penetrating fragments.
2. Tertiary results from body displacement causing blunt trauma; quaternary encompasses other injuries such as burns and inhalation injury.
3. Pulmonary contusion and haemorrhage, with a recognised risk of arterial air embolism.
4. ATLS primary survey principles, with attention to respiratory assessment and systematic assessment for fragment injury.
5. Because blast trauma involves multiple simultaneous mechanisms, so a single identified injury may not represent the full injury burden.

**Part 2.6**

- Rapidly sorting patients by injury severity and likely benefit from treatment to allocate limited resources.
- It focuses on the needs of the entire casualty population rather than a single patient in isolation.
- Immediate, delayed, minimal, and expectant.
- A category for patients whose survival is considered highly unlikely even with maximal available resources.
- Standard ATLS primary survey and resuscitation principles apply once casualties are triaged, with attention to characteristic missile and blast injury patterns.

**References and Attributions [Series 2]**


6. McRae, R., & Esser, M. (2008). Practical Fracture Treatment (5th ed.). Churchill Livingstone.
7. Solomon, L., Warwick, D., & Nayagam, S. (2018). Apley and Solomon's System of Orthopaedics and Trauma (10th ed.). CRC Press.
8. American College of Surgeons Committee on Trauma (2018). Advanced Trauma Life Support (ATLS) Student Course Manual (10th ed.).
9. International Committee of the Red Cross (2013). War Surgery: Working with Limited Resources in Armed Conflict and Other Situations of Violence.


**Figures, Plates, Tables, and Boxes**

- Figure 2.1: Diagram illustrating transverse, oblique, spiral, and comminuted fracture patterns. AI-generated using the prompt: "A single clean, accurate four-panel schematic diagram of a long bone shaft, each panel showing a different fracture line pattern labelled transverse, oblique, spiral, and comminuted respectively, textbook orthopaedic teaching diagram style, neutral background, no photographic realism, no other panels."
- Table 2.2: Comparing complications of fracture healing. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Complications of Fracture Healing, listing complication, definition, and general management approach. Orthopaedic reference table style with outside border, no photographic elements."
- Figure 2.3: Diagram comparing closed reduction with manipulation to open reduction with internal fixation using a plate and screws. AI-generated using the prompt: "A single clean, accurate two-panel schematic diagram of a long bone fracture, one panel labelled closed reduction showing hands manipulating the bone ends into alignment, the other panel labelled open reduction and internal fixation showing a metal plate and screws securing the aligned fracture, orthopaedic teaching diagram style, neutral background, no photographic realism."
- Table 2.4: Classification of missile injuries by body system. AI-generated using the prompt: "Create a clean clinical reference table titled Classification of Missile Injuries by Body System, listing system, typical injury pattern, and key management priority. Trauma reference table style with outside border, no photographic elements."
- Table 2.5: Classification of blast injury by mechanism. AI-generated using the prompt: "Create a clean clinical reference table titled Classification of Blast Injury by Mechanism,

listing category, mechanism, and typical injury. Trauma reference table style with outside border, no photographic elements."

- Figure 2.6: Diagram illustrating a mass casualty triage colour-coding system with immediate, delayed, minimal, and expectant categories. AI-generated using the prompt: "A single clean, accurate schematic diagram showing four labelled coloured tags, red labelled immediate, yellow labelled delayed, green labelled minimal, and black labelled expectant, arranged in a simple row, textbook mass casualty triage diagram style, neutral background, no photographic realism, no other panels."

**Course code: ORT 601**

**Course title: Principles of Orthopaedic Surgery**

**Course credit load: 4 Units**

# Series 3: Amputation, the Spinal Injured Patient, and Compartment Syndrome

1. **Part 3.1: Principles and Indications for Amputation**
    1. Sub Part 3.1.1: Definition and principles of amputation
    2. Sub Part 3.1.2: Indications for amputation
    3. Sub Part 3.1.3: Levels of amputation and factors influencing choice
2. **Part 3.2: Preparing the Patient for Amputation Surgery**
    1. Sub Part 3.2.1: Diagnosis, resuscitation, and preoperative assessment
    2. Sub Part 3.2.2: Consent taking for amputation
    3. Sub Part 3.2.3: Other pre-operative preparation
3. **Part 3.3: Intra-Operative and Post-Operative Amputation Management**
    1. Sub Part 3.3.1: Intra-operative principles of amputation surgery
    2. Sub Part 3.3.2: Post-operative management
    3. Sub Part 3.3.3: Complications of amputation and their prevention
4. **Part 3.4: Preventive Measures and Rehabilitation After Amputation**
    1. Sub Part 3.4.1: Preventive measures reducing the need for amputation
    2. Sub Part 3.4.2: Prosthetic rehabilitation
    3. Sub Part 3.4.3: Psychological and functional adaptation after amputation
5. **Part 3.5: The Spinal Injured Patient**
    1. Sub Part 3.5.1: Assessment of the spinal injured patient
    2. Sub Part 3.5.2: Classification of spinal cord injury
    3. Sub Part 3.5.3: Initial management of the spinal injured patient
6. **Part 3.6: Compartment Syndrome**
    1. Sub Part 3.6.1: Pathophysiology and causes of compartment syndrome
    2. Sub Part 3.6.2: Danger signs of compartment syndrome

3. Sub Part 3.6.3: Prevention and management of compartment syndrome

## Introduction

In the last Series, we established fractures, missile, and blast injuries. We now turn to **amputation**, its indications and the careful preparation, execution, and rehabilitation surrounding this significant surgical decision, the specific assessment and management of the **spinal injured patient**, and **compartment syndrome**, a genuine limb-threatening emergency demanding urgent recognition of its danger signs.

The aim of this Series is to equip you with a thorough understanding of amputation, its indications and the preparation of a patient for surgery, the assessment and management of the spinal injured patient, and compartment syndrome, particularly its danger signs and prevention.

This Series begins with the **principles and indications for amputation**, before turning to **preparing the patient for amputation surgery**. We then examine **intra-operative and post-operative amputation management**, followed by **preventive measures and rehabilitation after amputation**, then **the spinal injured patient**, concluding with **compartment syndrome**.

## Series Learning Outcomes

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

7. **SLO 3.1:** define amputation and describe its indications
8. **SLO 3.2:** describe levels of amputation and the factors influencing level selection
9. **SLO 3.3:** describe diagnosis, resuscitation, and preoperative assessment before amputation, with emphasis on consent taking
10. **SLO 3.4:** describe other essential pre-operative preparation before amputation surgery
11. **SLO 3.5:** describe the intra-operative and post-operative principles of amputation management
12. **SLO 3.6:** describe complications of amputation and how to prevent or manage them
13. **SLO 3.7:** describe preventive measures reducing the need for amputation, and prosthetic and psychological rehabilitation
14. **SLO 3.8:** describe the assessment of the spinal injured patient
15. **SLO 3.9:** describe the classification of spinal cord injury
16. **SLO 3.10:** describe the initial management of the spinal injured patient

17. **SLO 3.11:** describe the pathophysiology, causes, and danger signs of compartment syndrome, and
18. **SLO 3.12:** describe the prevention and management of compartment syndrome.

## 3.1 Principles and Indications for Amputation

### 3.1.1 definition and principles of amputation

***The deliberate surgical removal of a limb or part of a limb***

**Amputation** refers to the surgical removal of a limb, or portion of a limb, generally undertaken when the affected part is no longer viable, poses a threat to the patient's overall **survival**, or cannot provide sufficient function to justify continued attempts at preservation.

The fundamental principle guiding amputation surgery is preservation of the maximum functional **limb length** consistent with achieving a healthy, well-vascularised residual limb, discussed further later in this Series, since a longer, functional residual limb generally supports better eventual prosthetic fitting and overall rehabilitation **outcome**.

**Fill in the blank:** The fundamental principle guiding amputation surgery is preservation of the maximum functional limb length consistent with achieving a healthy, well-vascularised residual _____.

### 3.1.2 indications for amputation

Recognised indications for amputation include severe, irreparable **trauma**, discussed in relation to missile and blast injuries in the previous Series of this course, with vascular injury or tissue loss precluding limb salvage, and severe, uncontrolled **infection**, discussed further in a later Series of this course, threatening the patient's life.

Further important indications include peripheral vascular disease with critical limb ischaemia, discussed in relation to vascular assessment in an earlier related course, and certain malignant **bone tumours**, discussed in a later Series of this course, where amputation offers the most reliable means of achieving adequate oncological clearance.

**Fill in the blank:** Further important indications for amputation include peripheral vascular disease with critical limb ischaemia and certain malignant bone _____.

## 3.1.3 levels of amputation and factors influencing choice

The specific **level** of amputation is chosen based on the extent of non-viable tissue, discussed earlier in this Part, the adequacy of blood supply to potential residual limb tissue, and the functional requirements of prosthetic fitting, discussed further later in this Series, balancing maximum length preservation against the need for reliable, complete wound **healing**.

Further factors influencing level choice include the patient's overall **functional status** and activity level, discussed in relation to rehabilitation planning later in this Series, and specific biomechanical considerations relevant to particular amputation levels, since certain levels offer more favourable prosthetic fitting and gait characteristics than **others**.

**Fill in the blank:** Factors influencing amputation level choice include the patient's overall functional status and activity level, and specific biomechanical considerations relevant to particular amputation _____.

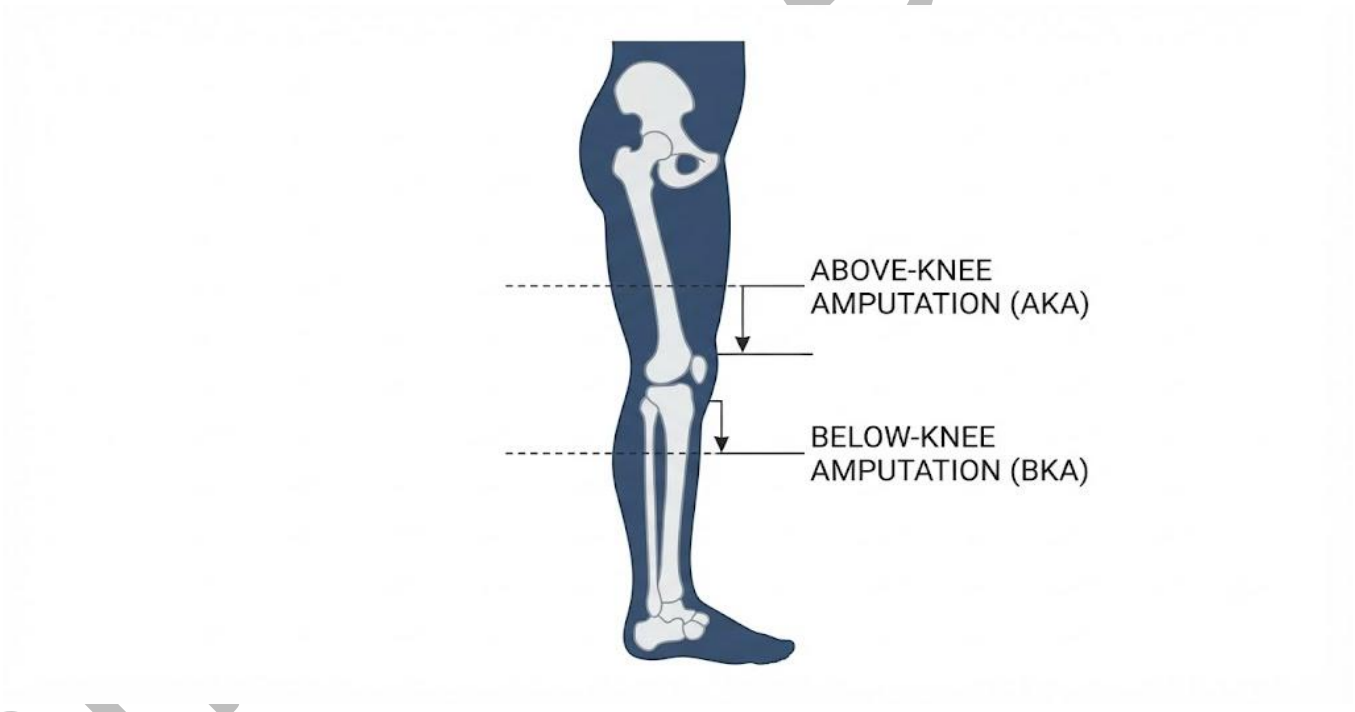


Figure 3.1: Diagram illustrating common lower limb amputation levels, including below-knee and above-knee amputation.

**Pilot questions 3.1**

1. Define amputation. (Linked to SLO 3.1)
2. State the fundamental principle guiding amputation surgery. (Linked to SLO 3.1)

3. List three indications for amputation. (Linked to SLO 3.1)
4. Describe the factors that influence the choice of amputation level. (Linked to SLO 3.2)
5. Explain why a longer residual limb is generally preferred where achievable. (Linked to SLO 3.2)

## 3.2 Preparing the Patient for Amputation Surgery

### 3.2.1 diagnosis, resuscitation, and preoperative assessment

***Confirming the diagnosis and optimising the patient before surgery***

Preparation for amputation begins with accurate confirmation of the underlying **diagnosis**, discussed earlier in this Series, and appropriate resuscitation of the patient where relevant, discussed in relation to ATLS resuscitation principles in an earlier Series of this course, particularly for patients presenting with severe trauma or sepsis.

Preoperative assessment additionally requires careful evaluation of the patient's overall **medical fitness** for surgery and anaesthesia, discussed in relation to comorbidity assessment in an earlier related course, together with assessment of the specific vascular status and extent of tissue involvement guiding the eventual amputation **level**, discussed earlier in this Series.

**Fill in the blank:** Preoperative assessment requires careful evaluation of the patient's overall medical fitness for surgery and anaesthesia, together with assessment of the specific vascular status and extent of tissue _____.

### 3.2.2 consent taking for amputation

**Consent taking** for amputation carries particular emphasis given the profound, irreversible nature of the intervention, requiring clear, honest discussion of the specific indication, alternative treatment options where genuinely available, and the expected functional consequences of the proposed **procedure**.

Effective consent additionally requires realistic discussion of anticipated rehabilitation, discussed further later in this Series, and recognised risks and complications, discussed further in the next Part of this Series, ensuring the patient, or an appropriate surrogate decision maker, genuinely understands the decision being **made**.

**Fill in the blank:** Effective consent for amputation requires realistic discussion of anticipated rehabilitation and recognised risks and complications, ensuring the patient genuinely understands the decision being _____.

### 3.2.3 other pre-operative preparation

Further pre-operative preparation includes appropriate **antibiotic prophylaxis**, discussed in relation to infection prevention in an earlier related course, careful marking of the intended amputation level, and psychological preparation of the patient, discussed further later in this Series, given the substantial emotional impact amputation frequently carries.

Multidisciplinary preoperative involvement, discussed in relation to trauma team coordination in an earlier Series of this course, including early input from physiotherapy and, where available, prosthetic services, discussed further later in this Series, supports optimal planning and realistic patient **expectation** ahead of the procedure itself.

**Fill in the blank:** Multidisciplinary preoperative involvement, including early input from physiotherapy and prosthetic services, supports optimal planning and realistic patient _____ ahead of the procedure.

Table 3.2: Key components of amputation surgical preparation.

| Component | Purpose | Timing |
|---|---|---|
| Diagnosis and resuscitation | Confirm indication and stabilise the patient | Before surgical decision finalised |
| Consent taking | Ensure informed, understood decision | Before surgery, with adequate discussion time |
| Multidisciplinary involvement | Optimise planning and rehabilitation expectation | Preoperative, ideally early |

**Pilot questions 3.2**

1. Describe the essential elements of preoperative assessment before amputation. (Linked to SLO 3.3)
2. Explain why consent taking for amputation carries particular emphasis. (Linked to SLO 3.3)
3. List the essential elements of effective consent discussion for amputation. (Linked to SLO 3.3)

4. Describe other essential pre-operative preparation before amputation surgery. (Linked to SLO 3.4)
5. Explain the value of early multidisciplinary involvement before amputation surgery. (Linked to SLO 3.4)

## 3.3 Intra-Operative and Post-Operative Amputation Management

### 3.3.1 intra-operative principles of amputation surgery

***Careful technique supporting a healthy, functional residual limb***

Intra-operative amputation technique emphasises careful, atraumatic soft tissue handling, appropriate **bone** transection at the planned level, discussed earlier in this Series, and meticulous haemostasis, discussed in relation to haemorrhage control principles in an earlier Series of this course, minimising subsequent wound complication risk.

Further important intra-operative principles include appropriate shaping of the residual bone end and careful, tension-free soft tissue **closure**, generally with a well padded, mobile myocutaneous flap covering the bone end, supporting both wound healing and eventual comfortable prosthetic **fitting**.

**Fill in the blank:** Further important intra-operative principles include appropriate shaping of the residual bone end and careful, tension-free soft tissue _____.

### 3.3.2 post-operative management

Post-operative management includes careful **wound monitoring** for signs of infection or inadequate healing, discussed in relation to wound complications later in this Series, appropriate analgesia, and early attention to residual limb **positioning** to prevent contracture development at adjacent joints.

Early post-operative **physiotherapy**, discussed in relation to rehabilitation principles in an earlier Series of this course, supports maintenance of joint range of motion and general conditioning, with progressive residual limb shaping and desensitisation preparing the limb for eventual prosthetic **fitting**, discussed further later in this Series.

**Fill in the blank:** Early post-operative physiotherapy supports maintenance of joint range of motion and general conditioning, with progressive residual limb shaping and _____ preparing the limb for eventual prosthetic fitting.

### 3.3.3 complications of amputation and their prevention

Recognised complications of amputation include **wound infection** and dehiscence, discussed earlier in this Part, **phantom limb pain**, a persistent sensation of pain apparently arising from the amputated portion of the limb, and joint **contracture**, discussed earlier in this Part, resulting from inadequate early positioning and mobilisation.

Prevention of these complications relies on the careful surgical technique and post-operative management principles discussed throughout this Series, together with early, structured rehabilitation input, with prompt recognition and appropriate management of any complication that does occur essential to optimal eventual functional **outcome**.

**Fill in the blank:** Prevention of amputation complications relies on careful surgical technique and post-operative management, together with early, structured rehabilitation _____.

**Table 3.3: Comparing common complications of amputation.**

| Complication | Description | Prevention strategy |
|---|---|---|
| Wound infection/dehiscence | Impaired healing of the surgical wound | Meticulous technique and wound monitoring |
| Phantom limb pain | Persistent pain sensation from the amputated part | Early recognition and multimodal pain management |
| Joint contracture | Fixed joint shortening from inadequate positioning | Early positioning and physiotherapy |

**Pilot questions 3.3**

1. Describe the intra-operative principles of amputation surgery. (Linked to SLO 3.5)
2. Describe the essential elements of post-operative amputation management. (Linked to SLO 3.5)
3. Define phantom limb pain. (Linked to SLO 3.6)
4. Explain how joint contracture develops after amputation and how it can be prevented. (Linked to SLO 3.6)
5. List three recognised complications of amputation. (Linked to SLO 3.6)

## 3.4 Preventive Measures and Rehabilitation After Amputation

### 3.4.1 preventive measures reducing the need for amputation

***Addressing modifiable risk factors before limb loss becomes necessary***

Preventive measures reducing the need for amputation include appropriate **management of diabetes mellitus**, discussed in an earlier related course, and peripheral vascular disease, discussed earlier in this Series, since these conditions represent major recognised contributors to eventual limb loss where inadequately controlled.

Further important preventive measures include prompt, appropriate management of open fractures and severe soft tissue injury, discussed in relation to open fracture classification in the previous Series of this course, and timely treatment of severe infection, discussed further in a later Series of this course, before limb-threatening progression **occurs**.

**Fill in the blank:** Preventive measures reducing the need for amputation include appropriate management of diabetes mellitus and peripheral vascular disease, major recognised contributors to eventual limb _____.

### 3.4.2 prosthetic rehabilitation

**Prosthetic rehabilitation** aims to restore functional mobility and independence following amputation, generally beginning with residual limb shaping and desensitisation, discussed earlier in this Series, before progressing to fitting of a temporary, and eventually definitive, **prosthesis** matched to the patient's specific functional needs and activity level.

Effective prosthetic rehabilitation additionally requires ongoing physiotherapy input, discussed earlier in this Series, supporting gait training and progressive functional adaptation, with regular prosthetic review and adjustment essential given the residual limb's tendency to change shape and volume over **time**.

**Fill in the blank:** Regular prosthetic review and adjustment is essential given the residual limb's tendency to change shape and volume over _____.

### 3.4.3 psychological and functional adaptation after amputation

Amputation frequently carries substantial **psychological** impact, given the profound change to body image and function involved, meaning appropriate psychological support and counselling,

discussed in relation to consent discussion earlier in this Series, represents an essential component of comprehensive amputation rehabilitation.

Successful functional adaptation additionally depends on realistic goal setting, discussed earlier in this Series, and ongoing support from the multidisciplinary rehabilitation team, discussed throughout this Series, with peer support from other amputees frequently providing further valuable practical and emotional **benefit**.

**Fill in the blank:** Successful functional adaptation after amputation additionally depends on realistic goal setting and ongoing support from the multidisciplinary rehabilitation _____.

Figure 3.4: A physiotherapist guiding a patient through gait training with a lower limb prosthesis using parallel bars.

**Pilot questions 3.4**

- List two preventive measures that reduce the need for amputation. (Linked to SLO 3.7)
- Describe the general progression of prosthetic rehabilitation. (Linked to SLO 3.7)
- Explain why regular prosthetic review and adjustment is necessary. (Linked to SLO 3.7)
- Explain why amputation frequently carries substantial psychological impact. (Linked to SLO 3.7)

- Describe the role of peer support in functional adaptation after amputation. (Linked to SLO 3.7)

## 3.5 The Spinal Injured Patient

### 3.5.1 assessment of the spinal injured patient

***Careful, protected examination preserving spinal alignment***

Assessment of the spinal injured patient begins within the ATLS primary and secondary survey framework, discussed in an earlier Series of this course, with particular attention to maintaining spinal **precautions**, including appropriate immobilisation, until significant spinal injury has been confidently excluded.

Careful **neurological examination**, discussed in relation to disability assessment in an earlier Series of this course, including assessment of motor power, sensation, and reflexes at each spinal level, together with the log-roll examination of the entire spine, discussed in relation to the secondary survey in an earlier Series of this course, forms the essential basis for accurate spinal injury **assessment**.

**Fill in the blank:** Assessment of the spinal injured patient requires particular attention to maintaining spinal precautions until significant spinal injury has been confidently _____.

### 3.5.2 classification of spinal cord injury

Spinal cord injury is classified as **complete**, with total absence of motor and sensory function below the level of injury, or **incomplete**, with some preservation of function below the injury level, this distinction carrying direct prognostic significance for eventual functional **recovery**.

Recognised incomplete spinal cord injury syndromes include **central cord syndrome**, generally affecting the upper limbs more severely than the lower limbs, and **Brown-Séquard syndrome**, resulting from hemisection of the cord and producing a characteristic pattern of ipsilateral motor loss with contralateral loss of pain and temperature **sensation**.

**Fill in the blank:** Brown-Séquard syndrome results from hemisection of the cord, producing ipsilateral motor loss with contralateral loss of pain and temperature _____.

### 3.5.3 initial management of the spinal injured patient

Initial management of the spinal injured patient requires ongoing spinal **immobilisation**, discussed earlier in this Part, until definitive imaging, discussed in relation to CT and MRI principles in an earlier related course, has appropriately characterised the injury and guided further specialist management planning.

Further essential early management includes careful attention to **neurogenic shock**, hypotension resulting from loss of sympathetic vascular tone below the level of a significant spinal cord injury, and vigilant prevention of pressure injury, discussed in relation to skin care in an earlier related course, given the patient's reduced or absent sensation and **mobility**.

**Fill in the blank:** Further essential early management includes careful attention to neurogenic shock, hypotension resulting from loss of sympathetic vascular tone below the level of a significant spinal cord _____.

**Table 3.5: Comparing complete and incomplete spinal cord injury.**

| Feature | Complete spinal cord injury | Incomplete spinal cord injury |
|---|---|---|
| Function below injury level | Total absence of motor and sensory function | Some preservation of function |
| Prognosis | Generally more limited recovery potential | Generally more favourable recovery potential |
| Example syndromes | Not applicable (complete loss) | Central cord syndrome, Brown-Séquard syndrome |

**Pilot questions 3.5**

1. Describe the essential principles of assessing the spinal injured patient. (Linked to SLO 3.8)
2. Distinguish complete from incomplete spinal cord injury. (Linked to SLO 3.9)
3. Describe central cord syndrome and Brown-Séquard syndrome. (Linked to SLO 3.9)
4. Describe the initial management principles for the spinal injured patient. (Linked to SLO 3.10)
5. Define neurogenic shock and explain its relevance to spinal cord injury. (Linked to SLO 3.10)

## 3.6 Compartment Syndrome

### 3.6.1 pathophysiology and causes of compartment syndrome

***Rising pressure within a confined fascial space compromising perfusion***

**Compartment syndrome** results from progressively rising pressure within a confined **fascial compartment**, ultimately compromising local tissue perfusion and, if untreated, producing irreversible muscle and nerve **ischaemia**, meaning early recognition represents a genuine limb-saving priority.

Recognised causes include closed fractures, discussed in relation to fracture classification earlier in this Series, producing internal bleeding and swelling within the affected compartment, open fractures, despite the apparent decompressive effect of the overlying wound, and external causes such as an overly tight **splint** or cast constricting the limb.

**Fill in the blank:** Compartment syndrome results from progressively rising pressure within a confined fascial compartment, ultimately compromising local tissue perfusion and, if untreated, producing irreversible muscle and nerve _____.

### 3.6.2 danger signs of compartment syndrome

The classical danger signs of compartment syndrome are often summarised using the mnemonic **"the six Ps"**, pain disproportionate to the apparent injury and, critically, pain **exacerbated by passive stretching** of the affected muscles, together with paraesthesia, pallor, pulselessness, paralysis, and poikilothermia, or coldness.

Of these signs, disproportionate **pain** and pain on passive stretch represent the earliest and most clinically reliable indicators, since pulselessness and paralysis, discussed earlier in this Part, generally represent genuinely late findings, meaning waiting for these later signs before acting risks irreversible tissue **damage**.

**Fill in the blank:** Disproportionate pain and pain on passive stretch represent the earliest and most clinically reliable indicators of compartment syndrome, since pulselessness and paralysis generally represent genuinely _____ findings.

### 3.6.3 prevention and management of compartment syndrome

Prevention of compartment syndrome requires avoiding overly tight splints or casts, discussed earlier in this Part, and maintaining a high index of clinical **suspicion** in any patient with a closed

fracture or significant soft tissue injury, particularly during the initial hours following injury when swelling is most likely to progress.

Confirmed or strongly suspected compartment syndrome requires urgent **fasciotomy**, surgical release of the affected fascial compartments, discussed earlier in this Part, since delayed treatment risks permanent muscle and nerve damage, or, in severe cases, eventual limb loss, discussed earlier in this Series, meaning genuine surgical urgency applies whenever this diagnosis is confidently **suspected**.

**Fill in the blank:** Confirmed or strongly suspected compartment syndrome requires urgent fasciotomy, since delayed treatment risks permanent muscle and nerve damage or, in severe cases, eventual limb _____.

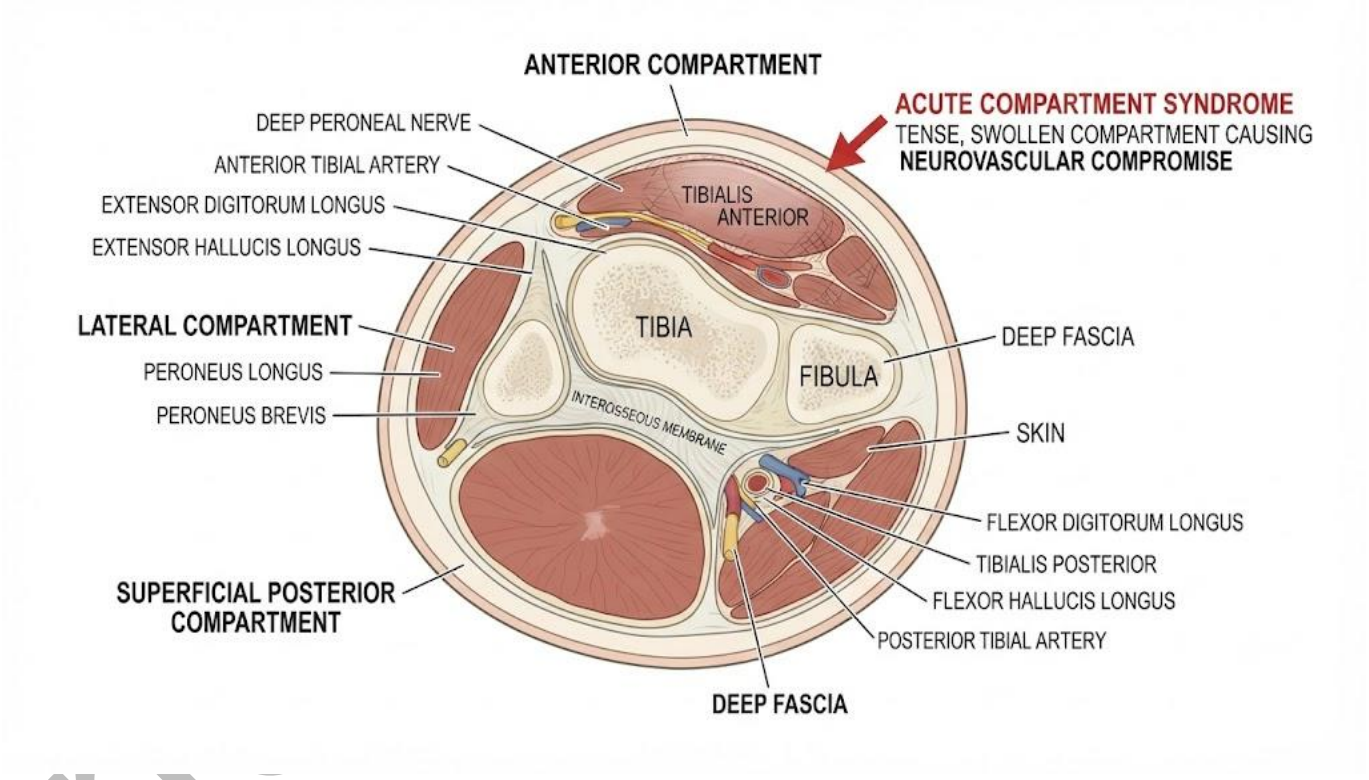


Figure 3.6: Diagram illustrating rising pressure within a confined lower leg fascial compartment compressing muscle, nerve, and vessels.

**Pilot questions 3.6**

6. Describe the pathophysiology of compartment syndrome. (Linked to SLO 3.11)
7. List three causes of compartment syndrome. (Linked to SLO 3.11)
8. State the six Ps of compartment syndrome. (Linked to SLO 3.11)

9. Explain why disproportionate pain and pain on passive stretch are the most clinically reliable danger signs. (Linked to SLO 3.11)
10. Describe the prevention and definitive management of compartment syndrome. (Linked to SLO 3.12)

**Series Summary**

This Series examined **amputation, the spinal injured patient, and compartment syndrome**, beginning with the **principles and indications for amputation**, before turning to **preparing the patient for amputation surgery**, with particular emphasis on consent taking, and **intra-operative and post-operative amputation management**, including recognised complications.

We then examined **preventive measures and rehabilitation after amputation**, prosthetic and psychological adaptation, followed by **the spinal injured patient**, assessment, classification, and initial management, concluding with **compartment syndrome**, its pathophysiology, danger signs, and prevention. Having worked through this Series, you should now be equipped to understand bone and joint infections and metabolic bone disease examined in the next Series of this course.

**Glossary of Terms**

6. **Amputation:** the surgical removal of a limb or part of a limb.
7. **Residual limb:** the remaining portion of a limb following amputation.
8. **Phantom limb pain:** a persistent pain sensation apparently arising from the amputated part of a limb.
9. **Prosthetic rehabilitation:** the process of fitting and training a patient to use an artificial limb.
10. **Neurogenic shock:** hypotension from loss of sympathetic vascular tone below a significant spinal cord injury.
11. **Complete spinal cord injury:** total absence of motor and sensory function below the level of injury.
12. **Incomplete spinal cord injury:** some preservation of motor or sensory function below the level of injury.

13. **Central cord syndrome:** an incomplete spinal cord injury pattern affecting the upper limbs more than the lower limbs.
14. **Brown-Séquard syndrome:** spinal cord hemisection producing ipsilateral motor and contralateral pain/temperature loss.
15. **Compartment syndrome:** raised pressure within a confined fascial space compromising tissue perfusion.
16. **The six Ps:** the classical danger signs of compartment syndrome: pain, paraesthesia, pallor, pulselessness, paralysis, poikilothermia.
17. **Fasciotomy:** surgical release of a fascial compartment to relieve compartment syndrome.

## Concept Check Questions [Series 3]

### Objective questions

11. The fundamental principle guiding amputation surgery is preservation of the maximum functional limb length consistent with achieving a healthy, well-vascularised residual _____.
12. Effective consent for amputation requires realistic discussion of anticipated rehabilitation, ensuring the patient genuinely understands the decision being _____.
13. Brown-Séquard syndrome results from hemisection of the cord, producing ipsilateral motor loss with contralateral loss of pain and temperature _____.
14. Disproportionate pain and pain on passive stretch represent the earliest and most reliable indicators of compartment syndrome, since pulselessness and paralysis generally represent _____ findings.
15. Confirmed or strongly suspected compartment syndrome requires urgent fasciotomy, since delayed treatment risks eventual limb _____.

### Short-answer questions

1. List three indications for amputation.
2. Define phantom limb pain.
3. Distinguish complete from incomplete spinal cord injury.
4. Describe central cord syndrome and Brown-Séquard syndrome.
5. State the six Ps of compartment syndrome.

### Long-answer questions

6. Discuss the principles, indications, and level selection for amputation. (Linked to SLO 3.1, SLO 3.2)

7. Discuss preparation of the patient for amputation surgery, including consent taking, and intra-operative and post-operative management. (Linked to SLO 3.3, SLO 3.4, SLO 3.5, SLO 3.6)
8. Discuss preventive measures and rehabilitation after amputation. (Linked to SLO 3.7)
9. Discuss the assessment, classification, and initial management of the spinal injured patient. (Linked to SLO 3.8, SLO 3.9, SLO 3.10)
10. Discuss the pathophysiology, danger signs, prevention, and management of compartment syndrome. (Linked to SLO 3.11, SLO 3.12)

**Answers to Concept Check Questions [Series 3]**

**Objective questions**

11. Limb.
12. Made.
13. Sensation.
14. Late.
15. Loss.

**Short-answer questions**

16. Severe irreparable trauma, uncontrolled infection, and peripheral vascular disease with critical limb ischaemia, among others such as malignant bone tumours.
17. A persistent pain sensation apparently arising from the amputated portion of the limb.
18. Complete injury shows total absence of function below the injury level; incomplete injury shows some preservation of function.
19. Central cord syndrome affects the upper limbs more than the lower limbs; Brown-Séquard syndrome shows ipsilateral motor loss with contralateral loss of pain and temperature sensation.
20. Pain, paraesthesia, pallor, pulselessness, paralysis, and poikilothermia.

**Long-answer questions**

21. **Basic response:** Amputation aims to preserve maximum functional residual limb length, indicated by severe trauma, uncontrolled infection, vascular disease, or malignant tumour.

**Value-added response:** Level selection balances tissue viability, blood supply, and functional prosthetic requirements to achieve the best rehabilitation outcome.

22. **Basic response:** Amputation preparation requires diagnosis confirmation, resuscitation, and careful consent discussion given the procedure's irreversible nature.

**Value-added response:** Intra-operative technique emphasises atraumatic handling and tension-free closure, while post-operative management addresses wound care, positioning, and early physiotherapy to prevent complications.

23. **Basic response:** Preventive measures address modifiable risk factors such as diabetes and vascular disease, while rehabilitation progresses from residual limb shaping through prosthetic fitting and gait training.

**Value-added response:** Psychological support and peer engagement are essential given the profound functional and body image changes amputation involves.

24. **Basic response:** Assessment of the spinal injured patient requires spinal precautions and careful neurological examination, classifying injury as complete or incomplete.

**Value-added response:** Initial management requires ongoing immobilisation, attention to neurogenic shock, and vigilant pressure injury prevention pending definitive imaging and specialist care.

25. **Basic response:** Compartment syndrome results from rising pressure within a confined fascial space, recognised by disproportionate pain and pain on passive stretch as the earliest reliable signs.

**Value-added response:** Prevention requires avoiding overly tight splints and maintaining vigilance, with confirmed cases requiring urgent fasciotomy to prevent permanent damage or limb loss.

**Answers to Pilot Questions [Series 3]**

**Part 3.1**

1. The surgical removal of a limb or part of a limb.
2. Preservation of the maximum functional limb length consistent with a healthy, well-vascularised residual limb.

3. Severe irreparable trauma, uncontrolled infection, and critical limb ischaemia from vascular disease.
4. Extent of non-viable tissue, adequacy of blood supply, functional prosthetic requirements, and patient activity level.
5. Because it generally supports better prosthetic fitting and overall rehabilitation outcome.

**Part 3.2**

1. Confirmation of diagnosis, resuscitation where relevant, and assessment of medical fitness and vascular status.
2. Because amputation is a profound, irreversible intervention with substantial functional consequences.
3. Discussion of the indication, alternatives, expected functional consequences, and anticipated rehabilitation and risks.
4. Antibiotic prophylaxis, marking of the amputation level, and psychological preparation.
5. It supports optimal surgical and rehabilitation planning and realistic patient expectations.

**Part 3.3**

1. Careful soft tissue handling, appropriate bone transection, meticulous haemostasis, and tension-free closure.
2. Wound monitoring, appropriate analgesia, limb positioning to prevent contracture, and early physiotherapy.
3. A persistent pain sensation apparently arising from the amputated portion of the limb.
4. It develops from inadequate early positioning and mobilisation; prevented through early positioning and physiotherapy.
5. Wound infection or dehiscence, phantom limb pain, and joint contracture.

**Part 3.4**

1. Appropriate diabetes management, and control of peripheral vascular disease.
2. Residual limb shaping and desensitisation, followed by temporary and then definitive prosthetic fitting with gait training.
3. Because the residual limb tends to change shape and volume over time.
4. Because it involves a profound change to body image and function.
5. It provides valuable practical and emotional benefit from others with shared experience.

**Part 3.5**

- Maintaining spinal precautions, careful neurological examination, and log-roll examination of the spine.

- Complete injury shows total absence of function below the level of injury; incomplete injury shows some preservation.
- Central cord syndrome affects upper limbs more than lower limbs; Brown-Séquard syndrome shows ipsilateral motor loss with contralateral sensory loss.
- Ongoing immobilisation until definitive imaging, attention to neurogenic shock, and pressure injury prevention.
- Hypotension from loss of sympathetic vascular tone below the injury level; it requires careful haemodynamic management.

**Part 3.6**

- Rising pressure within a confined fascial compartment compromising perfusion and causing tissue ischaemia if untreated.
- Closed fractures, open fractures, and an overly tight splint or cast.
- Pain, paraesthesia, pallor, pulselessness, paralysis, and poikilothermia.
- Because pulselessness and paralysis are late findings, so waiting for them risks irreversible tissue damage.
- Prevention involves avoiding tight splints and maintaining vigilance; definitive management requires urgent fasciotomy.

**References and Attributions [Series 3]**


- Solomon, L., Warwick, D., & Nayagam, S. (2018). Apley and Solomon's System of Orthopaedics and Trauma (10th ed.). CRC Press.
- McRae, R., & Esser, M. (2008). Practical Fracture Treatment (5th ed.). Churchill Livingstone.
- American Spinal Injury Association (2019). International Standards for Neurological Classification of Spinal Cord Injury.
- American College of Surgeons Committee on Trauma (2018). Advanced Trauma Life Support (ATLS) Student Course Manual (10th ed.).


**Figures, Plates, Tables, and Boxes**

- Figure 3.1: Diagram illustrating common lower limb amputation levels, including below-knee and above-knee amputation. AI-generated using the prompt: "A single clean,

accurate schematic diagram of a lower limb silhouette with horizontal labelled lines marking below-knee and above-knee amputation levels, textbook orthopaedic teaching diagram style, neutral background, no photographic realism, no other panels."

- Table 3.2: Key components of amputation surgical preparation. AI-generated using the prompt: "Create a clean clinical reference table titled Key Components of Amputation Surgical Preparation, listing component, purpose, and timing. Orthopaedic reference table style with outside border, no photographic elements."
- Table 3.3: Comparing common complications of amputation. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Common Complications of Amputation, listing complication, description, and prevention strategy. Orthopaedic reference table style with outside border, no photographic elements."
- Figure 3.4: A physiotherapist guiding a patient through gait training with a lower limb prosthesis using parallel bars. AI-generated using the prompt: "A single clean, realistic clinical illustration of a physiotherapist supporting a patient walking between parallel bars while wearing a lower limb prosthesis, calm rehabilitation gym setting, natural lighting, no text overlays, no other panels, respectful depiction, no identifying facial features."
- Table 3.5: Comparing complete and incomplete spinal cord injury. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Complete and Incomplete Spinal Cord Injury, listing feature, complete spinal cord injury, and incomplete spinal cord injury. Orthopaedic reference table style with outside border, no photographic elements."
- Figure 3.6: Diagram illustrating rising pressure within a confined lower leg fascial compartment compressing muscle, nerve, and vessels. AI-generated using the prompt: "A single clean, accurate cross-sectional schematic diagram of the lower leg showing labelled fascial compartments, with one compartment shown swollen and tense compressing muscle, nerve, and vessel structures within it, textbook orthopaedic teaching diagram style, neutral background, no photographic realism, no other panels."

**Course code: ORT 601**

**Course title: Principles of Orthopaedic Surgery**

**Course credit load: 4 Units**

# Series 4: Bone and Joint Infections and Metabolic Bone Disease

1. **Part 4.1: Acute Osteomyelitis**
    1. Sub Part 4.1.1: Pathogenesis and causative organisms
    2. Sub Part 4.1.2: Clinical features and diagnosis
    3. Sub Part 4.1.3: Management of acute osteomyelitis
2. **Part 4.2: Chronic Osteomyelitis**
    1. Sub Part 4.2.1: Pathogenesis and features of chronic osteomyelitis
    2. Sub Part 4.2.2: Sequestrum and involucrum
    3. Sub Part 4.2.3: Management of chronic osteomyelitis
3. **Part 4.3: Bone Metabolism I: Vitamin D and Parathyroid Hormone**
    1. Sub Part 4.3.1: Vitamin D synthesis and function in bone metabolism
    2. Sub Part 4.3.2: Parathyroid hormone and calcium homeostasis
    3. Sub Part 4.3.3: Interaction between vitamin D and parathyroid hormone
4. **Part 4.4: Bone Metabolism II: Calcitonin and Related Regulators**
    1. Sub Part 4.4.1: Calcitonin and its role in bone metabolism
    2. Sub Part 4.4.2: Other regulators of bone metabolism
    3. Sub Part 4.4.3: Integrated regulation of bone remodelling
5. **Part 4.5: Rickets and Osteomalacia**
    1. Sub Part 4.5.1: Pathophysiology and causes of rickets
    2. Sub Part 4.5.2: Clinical and radiological features of rickets
    3. Sub Part 4.5.3: Osteomalacia: the adult counterpart of rickets
6. **Part 4.6: Tuberculous Arthritis and Pott's Disease**
    1. Sub Part 4.6.1: Pathogenesis of tuberculous arthritis

2. Sub Part 4.6.2: Clinical and radiological features of tuberculous arthritis
3. Sub Part 4.6.3: Pott's disease: spinal tuberculosis

## Introduction

In the last Series, we established amputation, the spinal injured patient, and compartment syndrome. We now turn to **bone and joint infections**, acute and chronic osteomyelitis and tuberculous arthritis, together with **bone metabolism** and the specific hormonal regulators, vitamin D, parathyroid hormone, and calcitonin, governing calcium homeostasis, and the **metabolic bone diseases**, rickets and osteomalacia, arising when these regulatory processes are disrupted.

The aim of this Series is to equip you with a thorough understanding of acute and chronic osteomyelitis, bone metabolism and the roles of vitamin D, parathyroid hormone, and calcitonin, the diseases affecting these processes including rickets and osteomalacia, and tuberculous arthritis and Pott's disease.

This Series begins with **acute osteomyelitis**, before turning to **chronic osteomyelitis**. We then examine **bone metabolism**, covering vitamin D and parathyroid hormone, followed by **calcitonin and related regulators**, then **rickets and osteomalacia**, concluding with **tuberculous arthritis and Pott's disease**.

## Series Learning Outcomes

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

7. **SLO 4.1:** describe the pathogenesis, causative organisms, and clinical features of acute osteomyelitis
8. **SLO 4.2:** describe the diagnosis and management of acute osteomyelitis
9. **SLO 4.3:** describe the pathogenesis and features of chronic osteomyelitis, including sequestrum and involucrum
10. **SLO 4.4:** describe the management of chronic osteomyelitis
11. **SLO 4.5:** describe the synthesis and function of vitamin D in bone metabolism
12. **SLO 4.6:** describe the role of parathyroid hormone in calcium homeostasis and its interaction with vitamin D

13. **SLO 4.7:** describe the role of calcitonin and other regulators of bone metabolism
14. **SLO 4.8:** describe the integrated regulation of bone remodelling
15. **SLO 4.9:** describe the pathophysiology, causes, and features of rickets
16. **SLO 4.10:** describe osteomalacia as the adult counterpart of rickets
17. **SLO 4.11:** describe the pathogenesis and features of tuberculous arthritis, and
18. **SLO 4.12:** describe Pott's disease.

## 4.1 Acute Osteomyelitis

### 4.1.1 pathogenesis and causative organisms

***Haematogenous seeding of the richly vascular metaphysis***

**Acute osteomyelitis** most commonly results from **haematogenous** spread of bacteria to bone, particularly affecting the richly vascular **metaphysis** of long bones in children, where sluggish blood flow within the metaphyseal vascular loops favours bacterial **seeding** and subsequent infection establishment.

**Staphylococcus aureus** represents the most common causative organism across all age groups, with **Haemophilus influenzae** historically important in young children prior to widespread vaccination, and **Salmonella species** carrying particular relevance in patients with underlying sickle cell disease, discussed in relation to haemoglobinopathy in an earlier related course.

**Fill in the blank:** Acute osteomyelitis most commonly results from haematogenous spread of bacteria to bone, particularly affecting the richly vascular metaphysis, where sluggish blood flow favours bacterial _____.

### 4.1.2 clinical features and diagnosis

Acute osteomyelitis typically presents with localised bone pain, swelling, warmth, and **tenderness**, generally accompanied by fever and systemic malaise, particularly in children, where reluctance to move or bear weight on the affected limb frequently represents an important early clinical clue.

Diagnosis is supported by elevated inflammatory markers, discussed in relation to full blood count and ESR in an earlier related course, blood culture, which may identify the causative organism, and imaging, with **MRI**, discussed in an earlier related course, offering the greatest

early sensitivity for detecting acute osteomyelitis before plain radiographic changes become **apparent**.

**Fill in the blank:** Diagnosis of acute osteomyelitis is supported by MRI, offering the greatest early sensitivity for detecting infection before plain radiographic changes become _____.

### 4.1.3 management of acute osteomyelitis

Management of acute osteomyelitis requires prompt **intravenous antibiotic** therapy, generally guided initially by the most likely causative organism, discussed earlier in this Part, and subsequently refined according to culture and sensitivity results where available, with early treatment offering the best opportunity to prevent progression to chronic disease.

Surgical **drainage** is generally indicated where a subperiosteal or intraosseous abscess is identified, discussed in relation to imaging findings earlier in this Part, or where the patient fails to respond adequately to antibiotic therapy alone, meaning close clinical monitoring throughout treatment remains essential to timely recognition of this **need**.

**Fill in the blank:** Surgical drainage is generally indicated where a subperiosteal or intraosseous abscess is identified, or where the patient fails to respond adequately to antibiotic therapy _____.

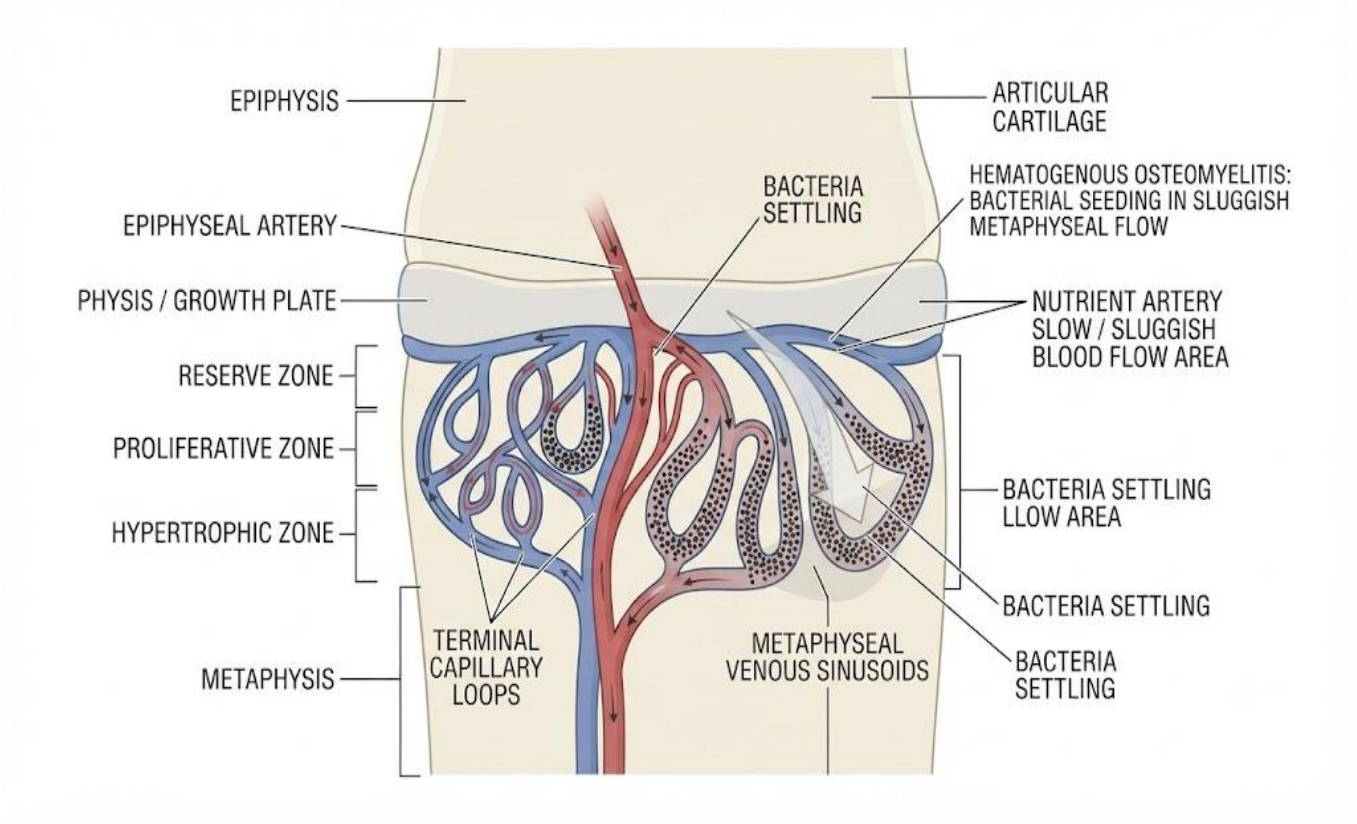


Figure 4.1: Diagram illustrating haematogenous bacterial seeding within the metaphyseal vascular loops of a growing long bone.

**Pilot questions 4.1**

1. Describe the pathogenesis of acute osteomyelitis. (Linked to SLO 4.1)
2. Name the most common causative organism of acute osteomyelitis. (Linked to SLO 4.1)
3. Explain the particular relevance of Salmonella species in certain patients. (Linked to SLO 4.1)
4. Describe the typical clinical presentation of acute osteomyelitis. (Linked to SLO 4.1)
5. Describe the management of acute osteomyelitis. (Linked to SLO 4.2)

## 4.2 Chronic Osteomyelitis

### 4.2.1 pathogenesis and features of chronic osteomyelitis

***Persistent infection following inadequately treated acute disease***

**Chronic osteomyelitis** generally results from inadequately treated acute osteomyelitis, discussed earlier in this Series, or from direct inoculation following open fracture or surgical intervention, discussed in relation to open fracture classification in an earlier Series of this course, characterised by persistent, low-grade infection and **inflammation**.

Clinical features include persistent or intermittent **discharge**, discussed in relation to sinus tract formation in the next sub-Part, chronic pain, and, over time, progressive bone **deformity** and functional impairment, reflecting the genuinely prolonged, relapsing-remitting natural history characteristic of this condition.

**Fill in the blank:** Chronic osteomyelitis is characterised by persistent, low-grade infection and inflammation, with clinical features including persistent or intermittent _____.

## 4.2.2 sequestrum and involucrum

A **sequestrum** refers to a fragment of necrotic bone that has become separated from viable surrounding bone, discussed earlier in this Series, generally acting as a persistent nidus for ongoing infection given its lack of blood supply and consequent inaccessibility to systemic **antibiotic** therapy.

An **involucrum** describes a layer of new, viable bone formed by the periosteum around the sequestrum, discussed earlier in this Part, in an attempt to contain the infection, with **cloacae**, small openings within the involucrum, allowing chronic discharge to track from the underlying infected sequestrum to the skin **surface**.

**Fill in the blank:** An involucrum describes a layer of new, viable bone formed by the periosteum around the sequestrum, with cloacae allowing chronic discharge to track to the skin _____.

## 4.2.3 management of chronic osteomyelitis

Management of chronic osteomyelitis generally requires surgical **debridement**, discussed in relation to open fracture and missile wound management in an earlier Series of this course, specifically removing the necrotic sequestrum discussed earlier in this Series, since antibiotic therapy alone cannot eradicate infection persisting within avascular, necrotic bone.

Further management considerations include prolonged **antibiotic** therapy following surgical debridement, appropriate management of any resulting bone defect, discussed in relation to bone healing principles in an earlier Series of this course, and, in severe, refractory cases,

consideration of amputation, discussed earlier in this Series, where limb salvage proves genuinely **unachievable**.

**Fill in the blank:** Management of chronic osteomyelitis requires surgical debridement to remove the necrotic sequestrum, since antibiotic therapy alone cannot eradicate infection persisting within avascular, necrotic _____.

**Table 4.2: Comparing acute and chronic osteomyelitis.**

| Feature | Acute osteomyelitis | Chronic osteomyelitis |
|---|---|---|
| Onset | Rapid, often days | Prolonged, following inadequately treated acute disease or direct inoculation |
| Key pathological feature | Metaphyseal bacterial seeding and inflammation | Sequestrum, involucrum, and cloacae |
| Primary treatment | Intravenous antibiotics, drainage if abscess present | Surgical debridement plus prolonged antibiotics |

**Pilot questions 4.2**

1. Describe the pathogenesis of chronic osteomyelitis. (Linked to SLO 4.3)
2. Define sequestrum. (Linked to SLO 4.3)
3. Define involucrum and cloacae. (Linked to SLO 4.3)
4. Explain why a sequestrum acts as a persistent nidus for infection. (Linked to SLO 4.3)
5. Describe the management of chronic osteomyelitis. (Linked to SLO 4.4)

## 4.3 Bone Metabolism I: Vitamin D and Parathyroid Hormone

### 4.3.1 vitamin d synthesis and function in bone metabolism

***A hormone synthesised through skin, liver, and kidney***

**Vitamin D** synthesis begins with ultraviolet-induced photoconversion of a precursor within the **skin**, discussed in relation to skin structure in an earlier related course, followed by sequential hepatic and renal **hydroxylation** steps ultimately producing the biologically active hormone, **calcitriol**.

Calcitriol's principal function is promoting **intestinal calcium absorption**, together with calcium reabsorption within the kidney and, at higher concentrations, mobilisation of calcium from bone, meaning adequate vitamin D status represents an essential precondition for normal bone **mineralisation**, discussed further later in this Series.

**Fill in the blank:** Vitamin D synthesis begins with ultraviolet-induced photoconversion of a precursor within the skin, followed by sequential hepatic and renal _____ steps producing the active hormone calcitriol.

## 4.3.2 parathyroid hormone and calcium homeostasis

**Parathyroid hormone**, or **PTH**, is released by the parathyroid glands in response to falling serum **calcium** concentration, acting to raise serum calcium through increased bone **resorption**, increased renal calcium reabsorption, and stimulation of renal calcitriol production, discussed earlier in this Part.

Sustained PTH elevation, termed **secondary hyperparathyroidism** when occurring in response to an underlying calcium or vitamin D deficiency, discussed further later in this Series, produces progressive bone resorption if the underlying deficiency remains uncorrected, illustrating the genuinely interconnected relationship between vitamin D and PTH regulation of calcium **homeostasis**.

**Fill in the blank:** Parathyroid hormone is released in response to falling serum calcium concentration, acting to raise serum calcium through increased bone _____.

## 4.3.3 interaction between vitamin d and parathyroid hormone

Vitamin D and parathyroid hormone operate as a genuinely **interdependent** regulatory system, discussed throughout this Part, with PTH stimulating renal calcitriol production, and calcitriol, in turn, providing negative feedback suppression of further PTH **secretion** once adequate serum calcium levels are restored.

Disruption of this interdependent system, whether through primary vitamin D deficiency or primary parathyroid gland dysfunction, discussed further later in this Series, produces predictable **metabolic bone disease**, meaning understanding this regulatory relationship is essential to interpreting the specific conditions discussed further later in this Series.

**Fill in the blank:** Disruption of the interdependent vitamin D and parathyroid hormone system, whether through primary vitamin D deficiency or primary parathyroid gland dysfunction, produces predictable metabolic bone _____.

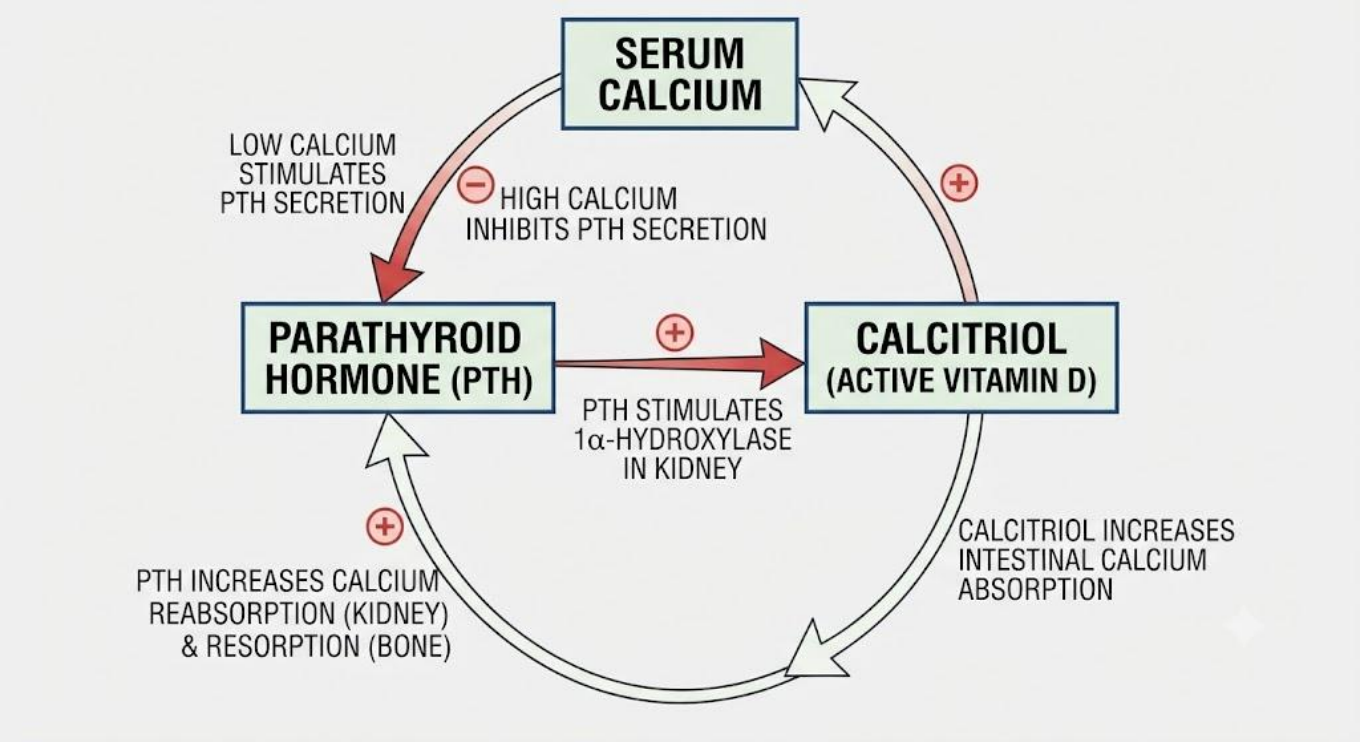


Figure 4.3: Diagram illustrating the negative feedback loop between parathyroid hormone, vitamin D (calcitriol), and serum calcium.

**Pilot questions 4.3**

- Describe the synthesis pathway of vitamin D from skin to active calcitriol. (Linked to SLO 4.5)
- Describe the principal function of calcitriol. (Linked to SLO 4.5)
- Describe the actions of parathyroid hormone that raise serum calcium. (Linked to SLO 4.6)
- Define secondary hyperparathyroidism. (Linked to SLO 4.6)
- Describe the feedback relationship between vitamin D and parathyroid hormone. (Linked to SLO 4.6)

## 4.4 Bone Metabolism II: Calcitonin and Related Regulators

### 4.4.1 calcitonin and its role in bone metabolism

*A counter-regulatory hormone opposing PTH action*

**Calcitonin**, secreted by the parafollicular, or C, cells of the thyroid gland, discussed in relation to thyroid gland anatomy in an earlier related course, is released in response to rising serum **calcium** concentration, acting to lower serum calcium primarily through inhibition of **osteoclast** activity and reduced bone resorption.

Calcitonin's physiological role in humans is generally considered more **modest** than that of parathyroid hormone and vitamin D, discussed earlier in this Series, though it retains recognised therapeutic application in conditions of pathologically excessive bone resorption, discussed further in a later Series of this course, such as certain bone tumours or Paget's disease.

**Fill in the blank:** Calcitonin is released in response to rising serum calcium concentration, acting to lower serum calcium primarily through inhibition of _____ activity.

## 4.4.2 other regulators of bone metabolism

Further important regulators of bone metabolism include **oestrogen**, exerting a broadly protective effect against excessive bone resorption, with declining oestrogen levels following menopause contributing to accelerated bone loss, and **growth hormone**, promoting bone formation and longitudinal growth during childhood and adolescence.

Additional regulatory factors include local cytokines and growth factors governing the balance between **osteoblast** bone formation and **osteoclast** bone resorption, discussed earlier in this Part, together with mechanical loading, which itself represents an important physiological stimulus for maintaining normal bone **density**.

**Fill in the blank:** Other regulators of bone metabolism include oestrogen and growth hormone, together with local cytokines and growth factors governing the balance between osteoblast bone formation and osteoclast bone _____.

## 4.4.3 integrated regulation of bone remodelling

**Bone remodelling**, the continuous, coordinated cycle of bone resorption by osteoclasts followed by new bone formation by osteoblasts, discussed earlier in this Part, is regulated by the integrated action of the hormonal and local factors discussed throughout this Series, maintaining overall skeletal integrity and appropriate serum calcium **homeostasis**.

Disruption of this integrated regulatory balance, whether through hormonal imbalance, discussed throughout this Series, nutritional deficiency, discussed further in the next Part of this Series, or other pathological process, can produce a wide range of recognised metabolic bone diseases,

each reflecting a specific underlying disturbance of this normally tightly coordinated remodelling **process**.

**Fill in the blank:** Disruption of the integrated regulatory balance of bone remodelling can produce a wide range of recognised metabolic bone _____.

Table 4.4: Comparing key hormonal regulators of bone metabolism.

| Hormone | Stimulus for release | Overall effect on serum calcium |
|---|---|---|
| Parathyroid hormone | Falling serum calcium | Raises serum calcium |
| Calcitriol (vitamin D) | Low serum calcium (via PTH stimulation) | Raises serum calcium via intestinal absorption |
| Calcitonin | Rising serum calcium | Lowers serum calcium |

**Pilot questions 4.4**

1. Describe the source and stimulus for release of calcitonin. (Linked to SLO 4.7)
2. Describe the main action of calcitonin on bone. (Linked to SLO 4.7)
3. Describe the role of oestrogen in bone metabolism. (Linked to SLO 4.7)
4. Describe the role of mechanical loading in bone metabolism. (Linked to SLO 4.7)
5. Explain what bone remodelling is and how it is regulated. (Linked to SLO 4.8)

## 4.5 Rickets and Osteomalacia

### 4.5.1 pathophysiology and causes of rickets

***Impaired mineralisation of growing bone***

**Rickets** results from impaired **mineralisation** of newly formed bone and growth plate cartilage in growing children, discussed in relation to bone metabolism regulation earlier in this Series, most commonly resulting from **vitamin D deficiency**, though calcium or phosphate deficiency can produce a similar clinical picture.

Recognised causes of vitamin D deficiency rickets include inadequate sunlight exposure, discussed in relation to vitamin D synthesis earlier in this Series, dietary deficiency, and, less commonly, specific genetic disorders affecting vitamin D metabolism or renal phosphate

handling, meaning careful clinical evaluation is required to identify the specific underlying **cause**.

**Fill in the blank:** Rickets results from impaired mineralisation of newly formed bone and growth plate cartilage, most commonly resulting from vitamin D _____.

## 4.5.2 clinical and radiological features of rickets

Clinical features of rickets include **bowing deformity** of the weight-bearing long bones, widening of the wrists and costochondral junctions, producing the characteristic **rachitic rosary**, and delayed closure of the fontanelles, discussed in relation to skeletal growth in an earlier related course, reflecting widespread impaired bone mineralisation.

Radiological features include **widening and cupping** of the growth plate metaphysis, discussed in relation to metaphyseal anatomy earlier in this Series, and generalised **osteopenia**, reduced bone density, with these characteristic radiographic changes generally most pronounced at rapidly growing sites such as the wrist and knee **regions**.

**Fill in the blank:** Radiological features of rickets include widening and cupping of the growth plate metaphysis and generalised _____, reduced bone density.

## 4.5.3 osteomalacia: the adult counterpart of rickets

**Osteomalacia** represents the adult counterpart of rickets, discussed earlier in this Part, occurring after epiphyseal growth plate closure, discussed in relation to skeletal maturity in an earlier related course, and consequently producing impaired mineralisation of mature bone rather than the growth plate abnormalities characteristic of childhood rickets.

Clinical features of osteomalacia include diffuse bone **pain** and tenderness, proximal muscle weakness, and increased fracture risk, discussed in relation to fracture causes in an earlier Series of this course, with radiological features including generalised osteopenia and characteristic **Looser's zones**, pseudofractures representing localised areas of unmineralised osteoid.

**Fill in the blank:** Radiological features of osteomalacia include generalised osteopenia and characteristic Looser's zones, pseudofractures representing localised areas of unmineralised _____.

**Table 4.5: Comparing rickets and osteomalacia.**

| Feature | Rickets | Osteomalacia |
|---|---|---|

| | | |
|---|---|---|
| Patient population | Growing children (open growth plates) | Adults (closed growth plates) |
| Characteristic deformity | Bowing of weight-bearing bones, rachitic rosary | Bone pain and proximal muscle weakness |
| Characteristic radiological finding | Widened, cupped metaphysis | Looser's zones (pseudofractures) |

**Pilot questions 4.5**

6. Describe the pathophysiology of rickets. (Linked to SLO 4.9)
7. List two causes of vitamin D deficiency rickets. (Linked to SLO 4.9)
8. Describe the clinical features of rickets, including the rachitic rosary. (Linked to SLO 4.9)
9. Define osteomalacia and explain how it differs from rickets. (Linked to SLO 4.10)
10. Describe Looser's zones. (Linked to SLO 4.10)

## 4.6 Tuberculous Arthritis and Pott's Disease

### 4.6.1 pathogenesis of tuberculous arthritis

***Haematogenous spread of tuberculous infection to a joint***

**Tuberculous arthritis**, caused by **Mycobacterium tuberculosis**, discussed in relation to pulmonary tuberculosis in an earlier related course, generally results from haematogenous spread of infection to a joint, discussed in relation to haematogenous osteomyelitis earlier in this Series, most commonly affecting large, weight-bearing **joints** such as the hip and knee.

The infection typically produces a slowly progressive, granulomatous synovitis with progressive **joint destruction**, discussed further in the next sub-Part, reflecting the genuinely indolent, chronic natural history characteristic of tuberculous infection, in contrast to the more acute presentation typical of pyogenic **septic arthritis**.

**Fill in the blank:** Tuberculous arthritis typically produces a slowly progressive, granulomatous synovitis with progressive joint destruction, in contrast to the more acute presentation typical of pyogenic septic _____.

## 4.6.2 clinical and radiological features of tuberculous arthritis

Clinical features of tuberculous arthritis include chronic joint pain and swelling, discussed earlier in this Part, progressive loss of joint movement, and constitutional symptoms including **weight loss**, night sweats, and low-grade fever, reflecting the systemic nature of the underlying tuberculous infection.

Radiological features include periarticular **osteopenia**, discussed in relation to bone density changes earlier in this Series, joint space narrowing, and, characteristically, relatively **preserved joint space** in earlier disease compared with the more rapid joint space loss typical of pyogenic septic arthritis, together with peripherally located bone erosions.

**Fill in the blank:** Radiological features of tuberculous arthritis include periarticular osteopenia, joint space narrowing, and relatively preserved joint space in earlier disease compared with pyogenic septic _____.

## 4.6.3 pott's disease: spinal tuberculosis

**Pott's disease** refers specifically to tuberculous infection of the **spine**, discussed in relation to spinal anatomy in an earlier Series of this course, typically affecting the anterior vertebral body and intervertebral disc, and generally producing progressive vertebral body **collapse** and resulting kyphotic spinal deformity if inadequately treated.

Pott's disease may additionally produce a **paravertebral abscess**, sometimes tracking a considerable distance from the original site of spinal infection along fascial planes, and, in more severe cases, spinal cord compression producing neurological deficit, discussed in relation to spinal cord injury classification earlier in this Series, meaning prompt recognition and treatment carries genuine neurological **importance**.

**Fill in the blank:** Pott's disease may produce a paravertebral abscess, sometimes tracking a considerable distance from the original site of spinal infection along fascial _____.

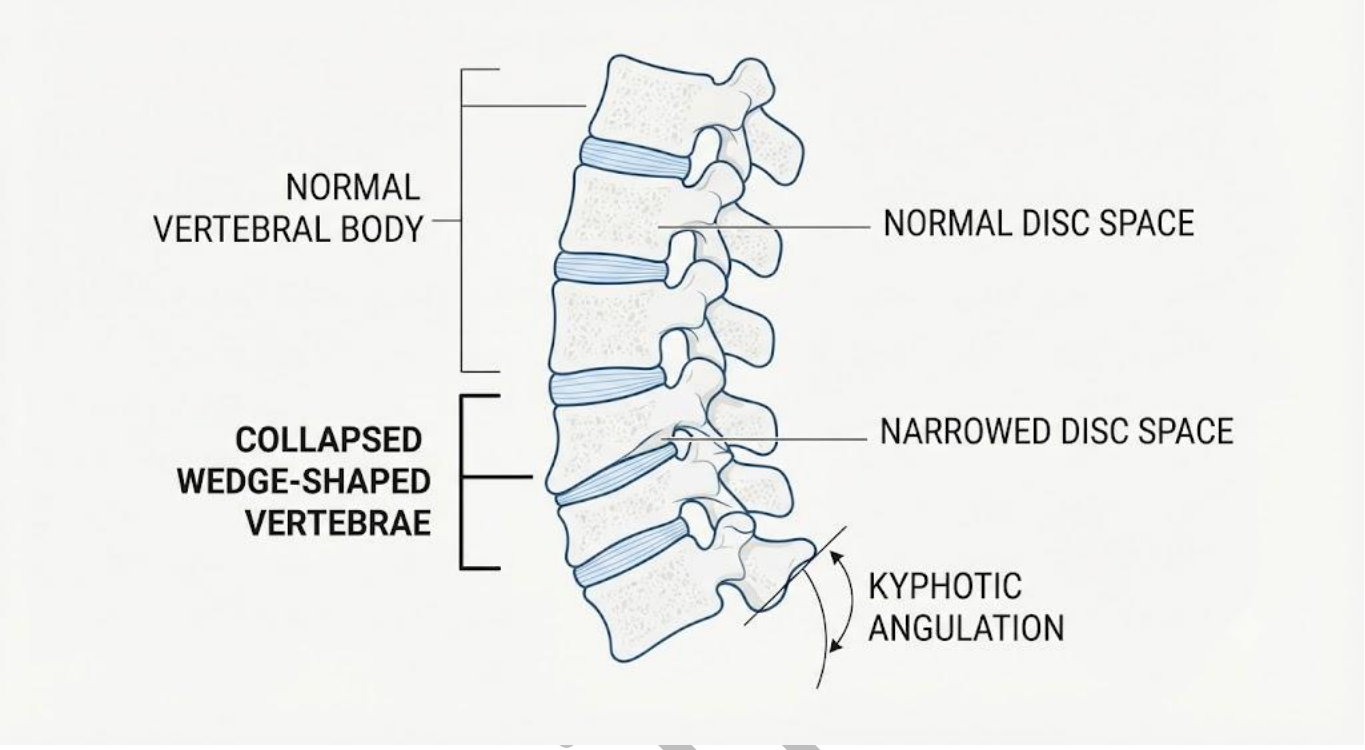


Figure 4.6: Diagram illustrating anterior vertebral body collapse and kyphotic deformity characteristic of Pott's disease.

**Pilot questions 4.6**

11. Describe the pathogenesis of tuberculous arthritis. (Linked to SLO 4.11)
12. List the joints most commonly affected by tuberculous arthritis. (Linked to SLO 4.11)
13. Describe the clinical features of tuberculous arthritis, including constitutional symptoms. (Linked to SLO 4.11)
14. Define Pott's disease. (Linked to SLO 4.12)
15. Describe the potential complications of Pott's disease. (Linked to SLO 4.12)

**Series Summary**

This Series examined **bone and joint infections and metabolic bone disease**, beginning with **acute osteomyelitis**, its pathogenesis, clinical features, and management, before turning to **chronic osteomyelitis**, sequestrum, involucrum, and definitive management.

We then examined **bone metabolism**, the roles of vitamin D and parathyroid hormone, followed by **calcitonin and related regulators** and the integrated regulation of bone remodelling, then

**rickets and osteomalacia**, the childhood and adult presentations of impaired bone mineralisation, concluding with **tuberculous arthritis and Pott's disease**. Having worked through this Series, you should now be equipped to understand hand surgery, congenital deformities, and bone tumours examined in the final Series of this course.

## Glossary of Terms

11. **Acute osteomyelitis:** acute bacterial bone infection, most commonly haematogenous, affecting the metaphysis.
12. **Sequestrum:** a fragment of necrotic bone separated from viable surrounding bone in chronic osteomyelitis.
13. **Involucrum:** new, viable bone formed by the periosteum surrounding a sequestrum.
14. **Cloaca:** an opening within the involucrum allowing chronic discharge to reach the skin surface.
15. **Calcitriol:** the biologically active form of vitamin D, promoting intestinal calcium absorption.
16. **Parathyroid hormone (PTH):** a hormone released in response to low serum calcium, raising calcium via bone resorption and renal effects.
17. **Secondary hyperparathyroidism:** sustained PTH elevation occurring in response to underlying calcium or vitamin D deficiency.
18. **Calcitonin:** a hormone lowering serum calcium primarily by inhibiting osteoclast activity.
19. **Rickets:** impaired mineralisation of growing bone and growth plate cartilage, generally from vitamin D deficiency.
20. **Rachitic rosary:** widening of the costochondral junctions seen in rickets.
21. **Osteomalacia:** impaired mineralisation of mature bone, the adult counterpart of rickets.
22. **Pott's disease:** tuberculous infection of the spine, typically producing vertebral collapse and kyphosis.

## Concept Check Questions [Series 4]

### Objective questions

1. Acute osteomyelitis most commonly results from haematogenous spread of bacteria to bone, particularly affecting the richly vascular metaphysis, where sluggish blood flow favours bacterial _____.

2. A sequestrum acts as a persistent nidus for infection given its lack of blood supply and consequent inaccessibility to systemic _____ therapy.
3. Parathyroid hormone is released in response to falling serum calcium concentration, acting to raise serum calcium through increased bone _____.
4. Rickets results from impaired mineralisation of newly formed bone, most commonly resulting from vitamin D _____.
5. Pott's disease may produce a paravertebral abscess, sometimes tracking a considerable distance from the original site of spinal infection along fascial _____.

**Short-answer questions**

6. Name the most common causative organism of acute osteomyelitis.
7. Define involucrum and cloacae.
8. Describe the actions of parathyroid hormone that raise serum calcium.
9. Distinguish rickets from osteomalacia in terms of patient population.
10. Describe the radiological features of tuberculous arthritis compared with pyogenic septic arthritis.

**Long-answer questions**

11. Discuss the pathogenesis, clinical features, diagnosis, and management of acute osteomyelitis. (Linked to SLO 4.1, SLO 4.2)
12. Discuss the pathogenesis, features, and management of chronic osteomyelitis, including sequestrum and involucrum. (Linked to SLO 4.3, SLO 4.4)
13. Discuss the roles of vitamin D, parathyroid hormone, and calcitonin in bone metabolism, and the integrated regulation of bone remodelling. (Linked to SLO 4.5, SLO 4.6, SLO 4.7, SLO 4.8)
14. Discuss the pathophysiology, features, and distinction between rickets and osteomalacia. (Linked to SLO 4.9, SLO 4.10)
15. Discuss the pathogenesis and features of tuberculous arthritis and Pott's disease. (Linked to SLO 4.11, SLO 4.12)

**Answers to Concept Check Questions [Series 4]**

**Objective questions**

1. Seeding.
2. Antibiotic.

3. Resorption.
4. Deficiency.
5. Planes.

**Short-answer questions**

6. Staphylococcus aureus.
7. Involucrum is new bone formed by the periosteum around a sequestrum; cloacae are openings within it allowing chronic discharge to reach the skin.
8. Increased bone resorption, increased renal calcium reabsorption, and stimulation of renal calcitriol production.
9. Rickets affects growing children with open growth plates; osteomalacia affects adults with closed growth plates.
10. Tuberculous arthritis shows periarticular osteopenia and relatively preserved joint space early on, unlike the more rapid joint space loss of pyogenic septic arthritis.

**Long-answer questions**

11. **Basic response:** Acute osteomyelitis results from haematogenous bacterial seeding of the metaphysis, most commonly Staphylococcus aureus, presenting with pain, swelling, and fever.

**Value-added response:** Diagnosis is supported by MRI and blood culture, with management requiring prompt intravenous antibiotics and surgical drainage where an abscess is present.

12. **Basic response:** Chronic osteomyelitis follows inadequately treated acute infection or direct inoculation, producing a sequestrum of necrotic bone surrounded by an involucrum with cloacae.

**Value-added response:** Management requires surgical debridement to remove necrotic bone, since antibiotics alone cannot reach avascular tissue, combined with prolonged antibiotic therapy.

13. **Basic response:** Vitamin D promotes calcium absorption, parathyroid hormone raises serum calcium via bone resorption and renal effects, and calcitonin lowers serum calcium by inhibiting osteoclasts.

**Value-added response:** These hormones, together with oestrogen, growth hormone, and local factors, integrate to regulate the continuous cycle of bone remodelling.

14. **Basic response:** Rickets and osteomalacia both reflect impaired bone mineralisation, most commonly from vitamin D deficiency, differing according to whether growth plates remain open.

**Value-added response:** Rickets produces characteristic growth plate widening and bowing deformity in children, while osteomalacia produces bone pain, weakness, and Looser's zones in adults.

15. **Basic response:** Tuberculous arthritis results from haematogenous spread to a joint, producing chronic, indolent joint destruction with relatively preserved early joint space.

**Value-added response:** Pott's disease, spinal tuberculosis, produces vertebral collapse, kyphosis, and potential paravertebral abscess or spinal cord compression requiring prompt recognition.

**Answers to Pilot Questions [Series 4]**

**Part 4.1**

1. Haematogenous spread of bacteria to the richly vascular metaphysis, where sluggish flow favours seeding.
2. Staphylococcus aureus.
3. Salmonella species carry particular relevance in patients with underlying sickle cell disease.
4. Localised bone pain, swelling, warmth, tenderness, fever, and reluctance to move or bear weight, especially in children.
5. Prompt intravenous antibiotics guided by likely organism, with surgical drainage if an abscess is identified or response is inadequate.

**Part 4.2**

1. Follows inadequately treated acute osteomyelitis or direct inoculation, characterised by persistent, low-grade infection.
2. A fragment of necrotic bone that has become separated from viable surrounding bone.
3. Involucrum is new periosteal bone surrounding the sequestrum; cloacae are openings allowing discharge to the skin.
4. Because it lacks blood supply, making it inaccessible to systemic antibiotic therapy.

5. Surgical debridement to remove necrotic bone, combined with prolonged antibiotic therapy.

**Part 4.3**

1. UV photoconversion in the skin, followed by hepatic and renal hydroxylation to form calcitriol.
2. Promoting intestinal calcium absorption, together with renal calcium reabsorption and bone mobilisation.
3. Increased bone resorption, increased renal calcium reabsorption, and stimulation of renal calcitriol production.
4. Sustained PTH elevation occurring in response to underlying calcium or vitamin D deficiency.
5. PTH stimulates calcitriol production; calcitriol provides negative feedback suppressing further PTH release once calcium is restored.

**Part 4.4**

- Secreted by parafollicular (C) cells of the thyroid, released in response to rising serum calcium.
- Inhibiting osteoclast activity, reducing bone resorption.
- It exerts a protective effect against excessive bone resorption; declining levels after menopause accelerate bone loss.
- It acts as a physiological stimulus supporting maintenance of normal bone density.
- The continuous, coordinated cycle of osteoclast resorption and osteoblast formation, regulated by integrated hormonal and local factors.

**Part 4.5**

- Impaired mineralisation of growing bone and growth plate cartilage, most commonly from vitamin D deficiency.
- Inadequate sunlight exposure and dietary deficiency.
- Bowing deformity, widened wrists, and the rachitic rosary at costochondral junctions.
- Impaired mineralisation of mature bone after growth plate closure, the adult counterpart of rickets.
- Pseudofractures representing localised areas of unmineralised osteoid seen in osteomalacia.

**Part 4.6**

- Haematogenous spread of Mycobacterium tuberculosis to a joint, producing slowly progressive granulomatous synovitis.
- Large, weight-bearing joints such as the hip and knee.
- Chronic joint pain and swelling, progressive movement loss, weight loss, night sweats, and low-grade fever.
- Tuberculous infection of the spine, typically affecting the anterior vertebral body and disc.
- Vertebral collapse and kyphosis, paravertebral abscess, and spinal cord compression with neurological deficit.

**References and Attributions [Series 4]**


- Solomon, L., Warwick, D., & Nayagam, S. (2018). Apley and Solomon's System of Orthopaedics and Trauma (10th ed.). CRC Press.
- Skinner, H. B., & McMahon, P. J. (Eds.). (2013). Current Diagnosis and Treatment in Orthopedics (5th ed.). McGraw-Hill.
- World Health Organization (2022). Global Tuberculosis Report.
- Longmore, M., et al. (2020). Oxford Handbook of Clinical Medicine (10th ed.). Oxford University Press.


**Figures, Plates, Tables, and Boxes**

- Figure 4.1: Diagram illustrating haematogenous bacterial seeding within the metaphyseal vascular loops of a growing long bone. AI-generated using the prompt: "A single clean, accurate schematic diagram of a long bone growth plate region showing labelled looping metaphyseal vessels with small dots representing bacteria settling within the sluggish flow area, textbook pathology teaching diagram style, neutral background, no photographic realism, no other panels."
- Table 4.2: Comparing acute and chronic osteomyelitis. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Acute and Chronic Osteomyelitis, listing feature, acute osteomyelitis, and chronic osteomyelitis. Orthopaedic reference table style with outside border, no photographic elements."

- Figure 4.3: Diagram illustrating the negative feedback loop between parathyroid hormone, vitamin D (calcitriol), and serum calcium. AI-generated using the prompt: "A single clean, accurate schematic feedback loop diagram with labelled boxes for serum calcium, parathyroid hormone, and calcitriol connected by directional arrows showing the stimulatory and inhibitory relationships, textbook physiology diagram style, neutral background, no photographic realism, no other panels."
- Table 4.4: Comparing key hormonal regulators of bone metabolism. AI-generated using the prompt: "Create a clean physiology reference table titled Comparing Key Hormonal Regulators of Bone Metabolism, listing hormone, stimulus for release, and overall effect on serum calcium. Physiology reference table style with outside border, no photographic elements."
- Table 4.5: Comparing rickets and osteomalacia. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Rickets and Osteomalacia, listing feature, rickets, and osteomalacia. Orthopaedic reference table style with outside border, no photographic elements."
- Figure 4.6: Diagram illustrating anterior vertebral body collapse and kyphotic deformity characteristic of Pott's disease. AI-generated using the prompt: "A single clean, accurate schematic lateral spine diagram showing several normal vertebral bodies alongside one or two collapsed, wedge-shaped vertebral bodies with narrowed disc space producing a forward kyphotic angulation, textbook orthopaedic teaching diagram style, neutral background, no photographic realism, no other panels."

**Course code: ORT 601**

**Course title: Principles of Orthopaedic Surgery**

**Course credit load: 4 Units**

# Series 5: Hand Surgery, Congenital Deformities, and Bone Tumours

1. **Part 5.1: Anatomy and Function of the Hand**
    1. Sub Part 5.1.1: Osteology and joints of the hand
    2. Sub Part 5.1.2: Tendons and muscles of the hand
    3. Sub Part 5.1.3: Nerve supply and functional zones of the hand
2. **Part 5.2: Hand Injuries**
    1. Sub Part 5.2.1: Principles of assessment of hand injuries
    2. Sub Part 5.2.2: Tendon and nerve injuries of the hand
    3. Sub Part 5.2.3: Principles of management of hand injuries
3. **Part 5.3: Hand Infections**
    1. Sub Part 5.3.1: Principles and common types of hand infections
    2. Sub Part 5.3.2: Flexor tendon sheath infection
    3. Sub Part 5.3.3: Management of hand infections
4. **Part 5.4: Congenital Talipes Equinovarus**
    1. Sub Part 5.4.1: Basis of congenital talipes equinovarus: idiopathic versus syndromic
    2. Sub Part 5.4.2: Clinical assessment of congenital talipes equinovarus
    3. Sub Part 5.4.3: Management: serial manipulation and casting
5. **Part 5.5: Congenital Hand Abnormalities**
    1. Sub Part 5.5.1: Classification of congenital hand abnormalities
    2. Sub Part 5.5.2: Common congenital hand abnormalities
    3. Sub Part 5.5.3: Principles of management of congenital hand abnormalities
6. **Part 5.6: Bone Tumours**
    1. Sub Part 5.6.1: Classification of bone tumours: benign versus malignant

2. Sub Part 5.6.2: Common benign bone tumours
3. Sub Part 5.6.3: Common malignant bone tumours

## Introduction

In the last Series, we established bone and joint infections and metabolic bone disease. We now conclude this course with **hand surgery**, the anatomy, injuries, and infections of this functionally vital structure, **congenital deformities**, congenital talipes equinovarus and congenital hand abnormalities, and **bone tumours**, completing the comprehensive foundation of orthopaedic surgical practice established throughout this course.

The aim of this Series is to equip you with a thorough understanding of the anatomy and functions of the hand, the principles of management of hand injuries and hand infections, the basis and management of congenital talipes equinovarus, congenital hand abnormalities, and bone tumours.

This Series begins with the **anatomy and function of the hand**, before turning to **hand injuries**. We then examine **hand infections**, followed by **congenital talipes equinovarus**, then **congenital hand abnormalities**, concluding with **bone tumours**.

## Series Learning Outcomes

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

7. **SLO 5.1:** describe the osteology, joints, tendons, and muscles of the hand
8. **SLO 5.2:** describe the nerve supply and functional zones of the hand
9. **SLO 5.3:** describe the principles of assessment of hand injuries, including tendon and nerve injury
10. **SLO 5.4:** describe the principles of management of hand injuries
11. **SLO 5.5:** describe the principles and common types of hand infections, including flexor tendon sheath infection
12. **SLO 5.6:** describe the management of hand infections
13. **SLO 5.7:** explain the basis of congenital talipes equinovarus, distinguishing idiopathic from syndromic forms
14. **SLO 5.8:** describe the clinical assessment and management of congenital talipes equinovarus, including serial manipulation and casting
15. **SLO 5.9:** describe the classification and common types of congenital hand abnormalities

16. **SLO 5.10:** describe the principles of management of congenital hand abnormalities
17. **SLO 5.11:** describe the classification of bone tumours and common benign bone tumours, and
18. **SLO 5.12:** describe common malignant bone tumours.

## 5.1 Anatomy and Function of the Hand

### 5.1.1 osteology and joints of the hand

***A complex, mobile skeleton supporting fine dexterity***

The hand skeleton comprises the **carpal bones**, arranged in proximal and distal rows, the **metacarpals**, and the **phalanges**, with the thumb possessing only two phalanges compared with three in each of the remaining digits, reflecting its distinct functional **role**.

Key joints include the **metacarpophalangeal** joints, permitting flexion, extension, and some abduction-adduction, and the **interphalangeal** joints, permitting flexion and extension only, with the specific mobility of the **carpometacarpal** joint of the thumb enabling its characteristic **opposition** movement essential to grip and pinch function.

**Fill in the blank:** The metacarpophalangeal joints permit flexion, extension, and some abduction-adduction, while the interphalangeal joints permit flexion and _____ only.

### 5.1.2 tendons and muscles of the hand

Hand movement is produced by both **extrinsic muscles**, originating in the forearm with long tendons crossing the wrist, discussed in relation to tendon injury later in this Series, and **intrinsic muscles**, arising entirely within the hand itself, including the thenar, hypothenar, and interosseous muscle groups.

**Flexor tendons** pass through a series of fibro-osseous **pulleys**, discussed further in relation to tendon sheath infection later in this Series, maintaining close tendon-to-bone apposition during flexion, while **extensor tendons** form a more complex, interconnected **extensor hood** mechanism over the dorsum of each digit.

**Fill in the blank:** Flexor tendons pass through a series of fibro-osseous pulleys, maintaining close tendon-to-bone apposition during _____.

## 5.1.3 nerve supply and functional zones of the hand

The hand receives its sensory and motor innervation from the **median**, **ulnar**, and **radial** nerves, each supplying a distinct, clinically relevant cutaneous and motor distribution, meaning careful nerve examination can localise a suspected nerve **injury** to a specific nerve based on the pattern of deficit identified.

Flexor tendon injuries, discussed further later in this Series, are classified according to anatomical **zones**, with **zone II**, spanning the region where flexor digitorum superficialis and profundus tendons run together within the flexor sheath, carrying particular clinical significance given its historically challenging surgical repair **outcomes**.

**Fill in the blank:** Flexor tendon injuries are classified according to anatomical zones, with zone II carrying particular clinical significance given its historically challenging surgical repair _____.

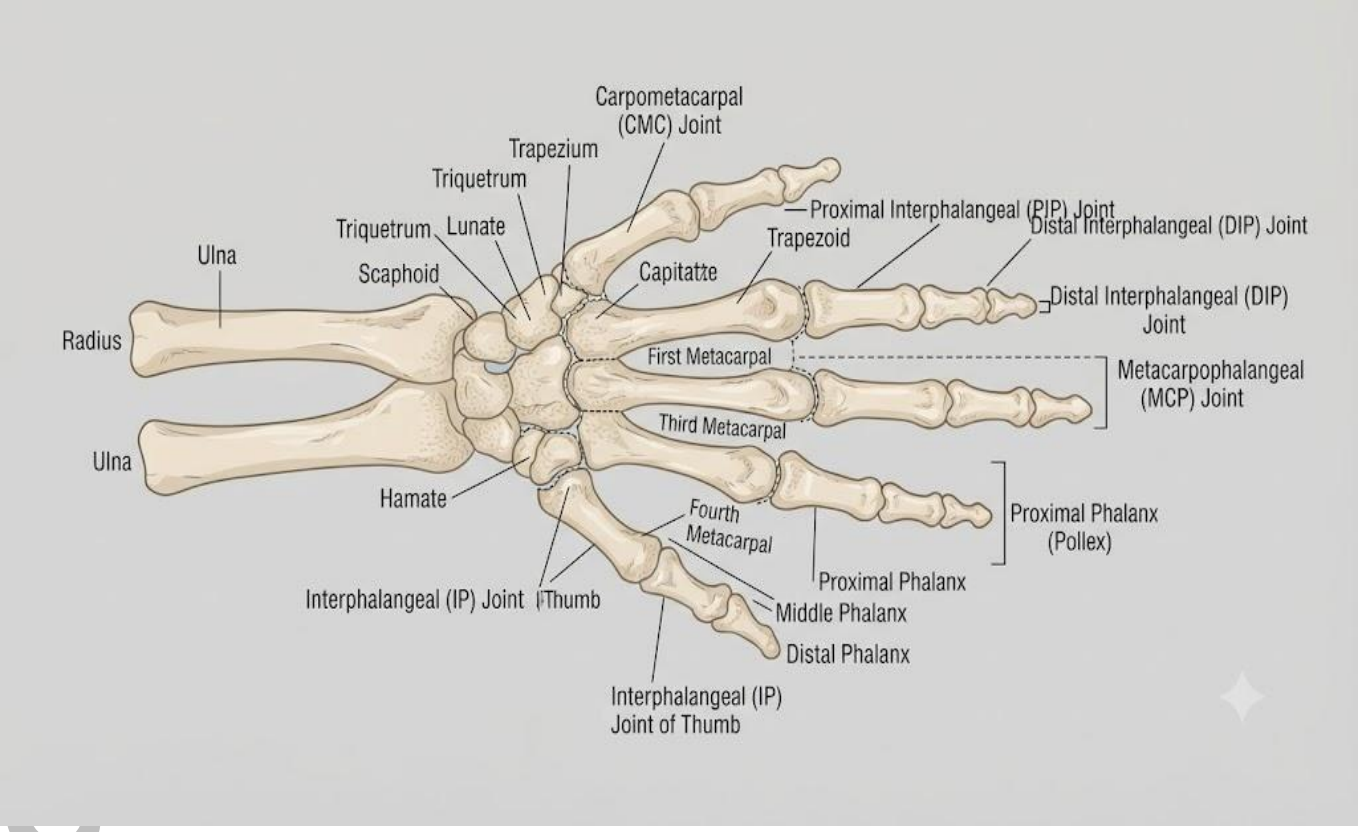


Figure 5.1: Diagram illustrating the bones and joints of the hand, including carpals, metacarpals, and phalanges.

**Pilot questions 5.1**

1. List the bones of the hand. (Linked to SLO 5.1)
2. Distinguish the movements permitted at the metacarpophalangeal and interphalangeal joints. (Linked to SLO 5.1)
3. Distinguish extrinsic from intrinsic hand muscles. (Linked to SLO 5.1)
4. Name the three nerves supplying the hand. (Linked to SLO 5.2)
5. Explain the particular clinical significance of zone II flexor tendon injury. (Linked to SLO 5.2)

## 5.2 Hand Injuries

### 5.2.1 principles of assessment of hand injuries

***Systematic evaluation preserving future hand function***

Assessment of hand injuries applies the general principles of orthopaedic examination discussed in an earlier Series of this course, look, feel, and move, with particular attention to specific **tendon** function testing, individual **nerve** distribution sensory testing, and vascular status of each affected digit.

A careful, accurate **history** of the mechanism of injury, discussed in relation to wound contamination and tissue damage in an earlier Series of this course, together with the specific hand position at the time of injury, provides essential information supporting accurate prediction of the likely underlying structures at **risk**.

**Fill in the blank:** A careful, accurate history of the mechanism of injury, together with the specific hand position at the time of injury, provides essential information supporting accurate prediction of the likely underlying structures at _____.

### 5.2.2 tendon and nerve injuries of the hand

**Flexor tendon injury** typically presents with loss of active flexion at the affected joint, discussed in relation to tendon anatomy earlier in this Series, while **extensor tendon injury** presents with loss of active extension, with the specific pattern of deficit assisting localisation of the injured **tendon**.

**Nerve injury**, discussed in relation to nerve distribution earlier in this Series, presents with sensory loss in the affected nerve's specific cutaneous distribution, together with motor weakness

of muscles supplied by that nerve, meaning careful, systematic examination can reliably identify which specific nerve has been **injured**.

**Fill in the blank:** Nerve injury presents with sensory loss in the affected nerve's specific cutaneous distribution, together with motor weakness of muscles supplied by that _____.

## 5.2.3 principles of management of hand injuries

Management of hand injuries generally requires thorough wound **exploration** and cleaning, discussed in relation to wound debridement principles in an earlier Series of this course, accurate identification of all injured structures, and, where tendon or nerve injury is confirmed, appropriate surgical **repair**, generally most successful when performed **promptly** after injury.

Post-repair management requires appropriate **splinting** to protect the repair during early healing, followed by carefully structured, progressive rehabilitation, discussed in relation to physiotherapy principles in an earlier Series of this course, since inadequate rehabilitation risks significant residual functional **impairment** despite technically successful repair.

**Fill in the blank:** Post-repair management requires appropriate splinting to protect the repair during early healing, followed by carefully structured, progressive _____.

**Table 5.2: Comparing flexor tendon, extensor tendon, and nerve injury of the hand.**

| Injury type | Key clinical sign | Management priority |
|---|---|---|
| Flexor tendon injury | Loss of active flexion at the affected joint | Prompt surgical repair |
| Extensor tendon injury | Loss of active extension at the affected joint | Prompt surgical repair and splinting |
| Nerve injury | Sensory loss and motor weakness in the nerve's distribution | Surgical exploration and repair where indicated |

**Pilot questions 5.2**

- Describe the general approach to assessing a hand injury. (Linked to SLO 5.3)
- Distinguish the clinical presentation of flexor tendon injury from extensor tendon injury. (Linked to SLO 5.3)
- Describe how nerve injury of the hand typically presents. (Linked to SLO 5.3)
- Describe the general principles of managing tendon and nerve injuries of the hand. (Linked to SLO 5.4)
- Explain why post-repair rehabilitation is essential to a successful outcome. (Linked to SLO 5.4)

## 5.3 Hand Infections

### 5.3.1 principles and common types of hand infections

***Infections spreading rapidly along enclosed fascial and tendon spaces***

Hand infections carry particular clinical importance given the hand's complex, enclosed fascial and tendon sheath **spaces**, discussed in relation to hand anatomy earlier in this Series, allowing infection to spread rapidly and, if inadequately treated, produce lasting functional **impairment**.

Common hand infections include **paronychia**, infection of the tissue surrounding the nail fold, **felon**, infection of the fingertip pulp space, and **cellulitis**, discussed in an earlier related course, each requiring prompt recognition given the hand's genuinely limited capacity to accommodate swelling without functional **consequence**.

**Fill in the blank:** Common hand infections include paronychia, felon, and cellulitis, each requiring prompt recognition given the hand's genuinely limited capacity to accommodate swelling without functional _____.

### 5.3.2 flexor tendon sheath infection

**Flexor tendon sheath infection**, or suppurative tenosynovitis, discussed in relation to the flexor tendon sheath earlier in this Series, represents a genuine surgical emergency given the flexor sheath's potential to allow infection to spread proximally, threatening both digit and hand **function**.

The condition is classically recognised by **Kanavel's cardinal signs**, fusiform swelling of the affected digit, held in slight flexion, tenderness along the flexor tendon sheath, and pain on passive **extension** of the digit, together representing a highly reliable diagnostic pattern.

**Fill in the blank:** Flexor tendon sheath infection is classically recognised by Kanavel's cardinal signs, including fusiform swelling, tenderness along the sheath, and pain on passive _____ of the digit.

### 5.3.3 management of hand infections

Management of hand infections generally requires appropriate **antibiotic** therapy, discussed in relation to infection management principles throughout this course, with surgical incision and

**drainage** indicated where a discrete abscess has formed, discussed in relation to felon and paronychia earlier in this Part.

**Flexor tendon sheath infection**, discussed earlier in this Part, generally requires urgent surgical **decompression** and irrigation of the sheath given the risk of rapid, potentially irreversible tendon and hand functional damage if treatment is delayed, meaning genuine surgical urgency applies whenever Kanavel's signs are confidently identified.

**Fill in the blank:** Flexor tendon sheath infection generally requires urgent surgical decompression and irrigation of the sheath given the risk of rapid, potentially irreversible tendon and hand functional _____ if treatment is delayed.

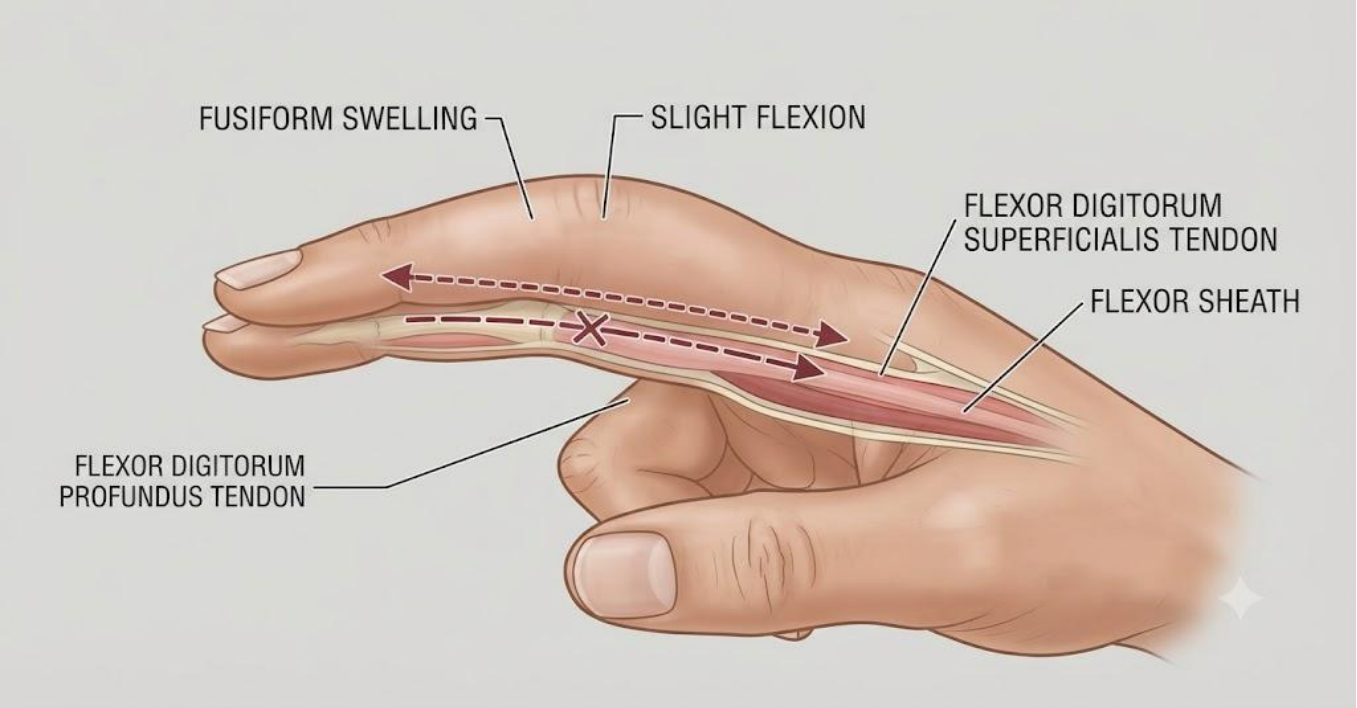


Figure 5.3: Diagram illustrating Kanavel's cardinal signs of flexor tendon sheath infection: fusiform swelling, flexed posture, and sheath tenderness.

**Pilot questions 5.3**

1. Explain why hand infections carry particular clinical importance. (Linked to SLO 5.5)
2. Define paronychia and felon. (Linked to SLO 5.5)
3. State Kanavel's cardinal signs of flexor tendon sheath infection. (Linked to SLO 5.5)
4. Describe the general management of hand infections such as paronychia and felon. (Linked to SLO 5.6)

5. Explain why flexor tendon sheath infection requires urgent surgical decompression. (Linked to SLO 5.6)

## 5.4 Congenital Talipes Equinovarus

### 5.4.1 basis of congenital talipes equinovarus: idiopathic versus syndromic

***A complex foot deformity present from birth***

**Congenital talipes equinovarus**, or clubfoot, is a complex congenital foot deformity, combining **hindfoot equinus**, plantarflexion at the ankle, **hindfoot varus**, and **forefoot adduction**, with **cavus**, an abnormally high arch, generally also present.

The condition is classified as **idiopathic**, occurring in an otherwise healthy infant without an identifiable underlying cause, or **syndromic**, occurring in association with a broader underlying congenital condition, such as arthrogryposis or spina bifida, discussed in relation to spinal development in an earlier related course, with syndromic cases generally carrying a more guarded prognosis for straightforward correction.

**Fill in the blank:** Congenital talipes equinovarus is classified as idiopathic, occurring without an identifiable underlying cause, or syndromic, occurring in association with a broader underlying congenital _____.

### 5.4.2 clinical assessment of congenital talipes equinovarus

Clinical assessment of congenital talipes equinovarus should be performed at, or very soon after, **birth**, discussed further in the next sub-Part, systematically documenting the severity of each specific deformity component discussed earlier in this Part using a recognised **scoring system**, such as the Pirani score.

Assessment should additionally include careful examination for associated syndromic features, discussed earlier in this Part, given the distinction between idiopathic and syndromic disease carries direct relevance to overall prognosis and the likely **complexity** of the treatment course ahead.

**Fill in the blank:** Clinical assessment of congenital talipes equinovarus should systematically document the severity of each specific deformity component using a recognised scoring _____.

### 5.4.3 management: serial manipulation and casting

**Serial manipulation and casting**, generally following the **Ponseti method**, represents the mainstay of treatment for congenital talipes equinovarus, discussed earlier in this Series, beginning at, or very soon after, **birth** and progressively correcting each deformity component through a defined weekly sequence of gentle manipulation and cast application.

Most patients additionally require a minor surgical **tenotomy** of the Achilles tendon to fully correct residual equinus deformity, discussed earlier in this Series, following the casting phase, with subsequent maintenance of correction requiring a prolonged period of night-time **bracing**, essential to preventing deformity recurrence.

**Fill in the blank:** Most patients additionally require a minor surgical tenotomy of the Achilles tendon to fully correct residual equinus deformity, with subsequent correction maintained through a prolonged period of night-time _____.

**Table 5.4: Components of the Ponseti method for congenital talipes equinovarus.**

| Stage | Description | Key purpose |
|---|---|---|
| Serial manipulation and casting | Weekly gentle manipulation and cast application, beginning soon after birth | Progressive correction of each deformity component |
| Achilles tenotomy | Minor surgical release, generally after casting | Correct residual equinus deformity |
| Night-time bracing | Prolonged bracing following correction | Maintain correction and prevent recurrence |

**Pilot questions 5.4**

6. Describe the components of congenital talipes equinovarus deformity. (Linked to SLO 5.7)
7. Distinguish idiopathic from syndromic congenital talipes equinovarus. (Linked to SLO 5.7)
8. Describe the timing and general approach to clinical assessment of congenital talipes equinovarus. (Linked to SLO 5.8)
9. Describe the Ponseti method of serial manipulation and casting. (Linked to SLO 5.8)
10. Explain the role of Achilles tenotomy and night-time bracing in Ponseti treatment. (Linked to SLO 5.8)

## 5.5 Congenital Hand Abnormalities

### 5.5.1 classification of congenital hand abnormalities

***Diverse developmental disruptions of hand formation***

**Congenital hand abnormalities** are broadly classified according to the specific **developmental** disruption involved, including **failure of formation**, resulting in absent or incomplete structures, and **failure of differentiation**, resulting in structures that have formed but failed to properly separate from one another.

Further recognised categories include **duplication**, the presence of additional digit structures, **overgrowth**, and **undergrowth**, each reflecting a distinct underlying disturbance of the normally tightly regulated process of embryological hand **development**.

**Fill in the blank:** Congenital hand abnormalities are broadly classified according to the specific developmental disruption involved, including failure of formation and failure of _____.

### 5.5.2 common congenital hand abnormalities

**Syndactyly**, a failure of differentiation, discussed earlier in this Part, describes webbing or fusion between adjacent digits, ranging from simple skin fusion to more complex fusion involving underlying bone, while **polydactyly**, a duplication abnormality, describes the presence of one or more supernumerary digits.

**Radial club hand**, a failure of formation affecting the radial, or thumb, side of the forearm and hand, produces radial deviation of the wrist together with thumb hypoplasia or absence, representing a further recognised, functionally significant congenital hand **abnormality**.

**Fill in the blank:** Syndactyly, a failure of differentiation, describes webbing or fusion between adjacent _____.

### 5.5.3 principles of management of congenital hand abnormalities

Management of congenital hand abnormalities requires careful assessment of the specific **functional** impact of the deformity, discussed earlier in this Part, rather than purely cosmetic considerations, since surgical intervention timing and technique are generally guided primarily by the potential for improving hand **function**.

Surgical correction, where indicated, is generally planned for a specific developmental **timing** balancing surgical feasibility against the benefits of earlier intervention for optimal functional

adaptation, with ongoing multidisciplinary involvement, discussed in relation to coordinated care throughout this course, supporting comprehensive long-term **management**.

**Fill in the blank:** Surgical correction of congenital hand abnormalities is generally planned for a specific developmental timing balancing surgical feasibility against the benefits of earlier intervention for optimal functional _____.

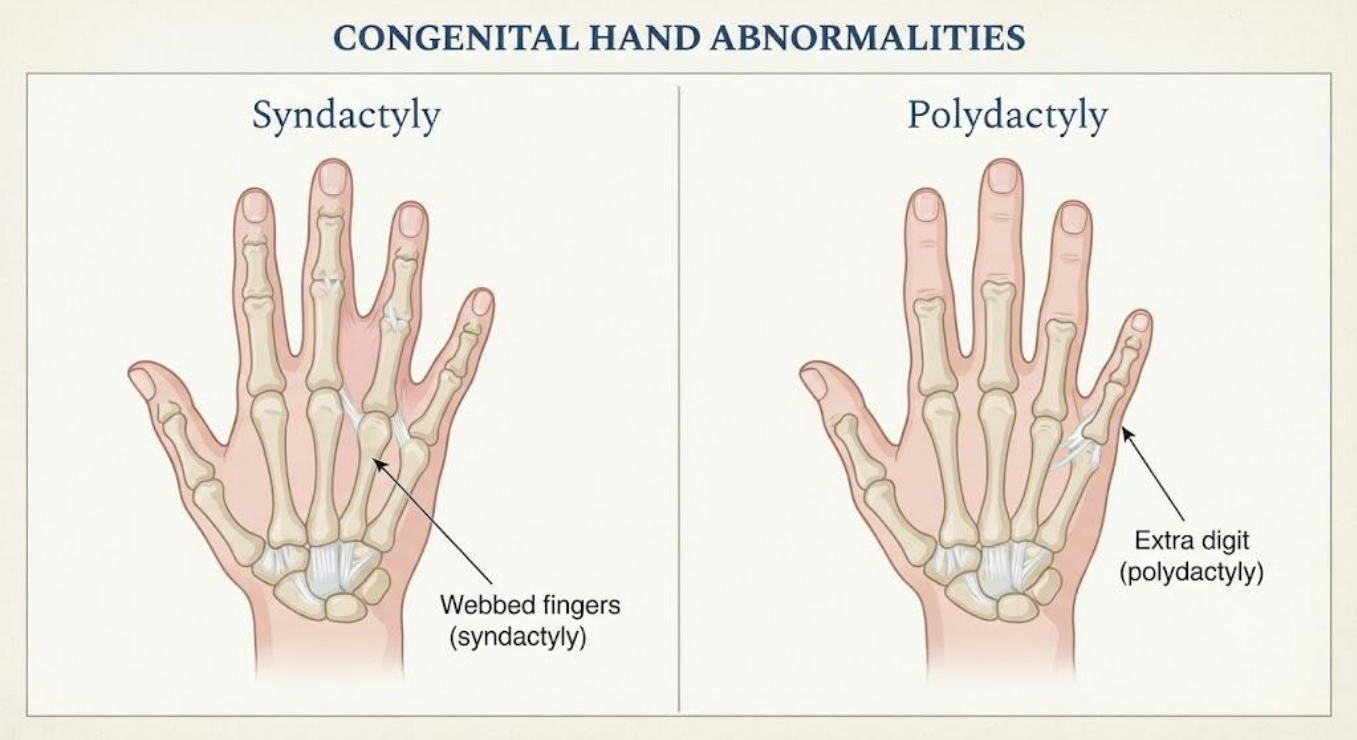


Figure 5.5: Diagram illustrating syndactyly (webbed digits) and polydactyly (supernumerary digit) as examples of congenital hand abnormalities.

**Pilot questions 5.5**

11. List the broad categories used to classify congenital hand abnormalities. (Linked to SLO 5.9)
12. Define syndactyly. (Linked to SLO 5.9)
13. Define polydactyly. (Linked to SLO 5.9)
14. Describe radial club hand. (Linked to SLO 5.9)
15. Describe the principles guiding management of congenital hand abnormalities. (Linked to SLO 5.10)

## 5.6 Bone Tumours

### 5.6.1 classification of bone tumours: benign versus malignant

***Distinguishing indolent from aggressive skeletal neoplasms***

Bone tumours are broadly classified as **benign**, generally well defined, slow-growing, and non-metastasising, or **malignant**, either arising primarily within bone or, more commonly, representing **metastatic** deposits from a distant primary tumour, discussed in relation to haematogenous spread in an earlier related course.

Radiological features assisting this distinction include the tumour's **margin**, generally well defined and sclerotic in benign lesions compared with poorly defined, permeative margins in malignant lesions, and the presence or absence of an associated soft tissue mass or **periosteal reaction**, each providing important diagnostic information.

**Fill in the blank:** Radiological features assisting the distinction between benign and malignant bone tumours include the tumour's margin, and the presence or absence of an associated soft tissue mass or periosteal _____.

### 5.6.2 common benign bone tumours

**Osteochondroma**, the most common benign bone tumour, presents as a cartilage-capped bony projection arising from the metaphysis, discussed in relation to metaphyseal anatomy in an earlier Series of this course, generally identified incidentally or due to local mechanical symptoms.

Further common benign bone tumours include **simple bone cyst**, a fluid-filled cavity typically presenting following a pathological fracture, discussed in relation to fracture causes in an earlier Series of this course, and **giant cell tumour**, a locally aggressive, though generally non-metastasising, lesion typically arising at the **epiphysis** of a long bone in young adults.

**Fill in the blank:** Giant cell tumour is a locally aggressive, though generally non-metastasising, lesion typically arising at the epiphysis of a long bone in young _____.

### 5.6.3 common malignant bone tumours

**Osteosarcoma**, the most common primary malignant bone tumour, typically affects the metaphysis of long bones in adolescents and young adults, producing characteristic aggressive radiological features including a **sunburst** periosteal reaction and **Codman's triangle**, elevated periosteum at the tumour margin.

**Ewing's sarcoma**, generally affecting a slightly younger age group, typically produces a characteristic **onion-skin** periosteal reaction, while **chondrosarcoma**, generally affecting an older adult population, arises from cartilage-forming cells and demonstrates characteristic **rings and arcs** calcification on imaging, reflecting its distinct cartilaginous **origin**.

**Fill in the blank:** Ewing's sarcoma, generally affecting a slightly younger age group, typically produces a characteristic onion-skin periosteal _____.

**Table 5.6: Comparing common malignant bone tumours.**

| Tumour | Typical age group | Characteristic imaging feature |
|---|---|---|
| Osteosarcoma | Adolescents and young adults | Sunburst periosteal reaction and Codman's triangle |
| Ewing's sarcoma | Children and young adolescents | Onion-skin periosteal reaction |
| Chondrosarcoma | Older adults | Rings and arcs calcification |

**Pilot questions 5.6**

1. Distinguish benign from malignant bone tumours in terms of general radiological appearance. (Linked to SLO 5.11)
2. Describe osteochondroma. (Linked to SLO 5.11)
3. Describe simple bone cyst and giant cell tumour. (Linked to SLO 5.11)
4. Describe the characteristic imaging features of osteosarcoma. (Linked to SLO 5.12)
5. Distinguish Ewing's sarcoma from chondrosarcoma in terms of typical age group and characteristic imaging feature. (Linked to SLO 5.12)

**Series Summary**

This final Series examined **hand surgery, congenital deformities, and bone tumours**, beginning with the **anatomy and function of the hand**, before turning to **hand injuries** and **hand infections**, including flexor tendon sheath infection and Kanavel's cardinal signs.

We then examined **congenital talipes equinovarus**, its idiopathic and syndromic basis and the Ponseti method of serial manipulation and casting, followed by **congenital hand abnormalities**, syndactyly, polydactyly, and radial club hand, concluding with **bone tumours**, the distinction

between benign and malignant lesions and common examples of each. Having worked through this Series, and indeed this entire course, you should now possess a comprehensive, clinically grounded foundation in the principles of orthopaedic surgery, from the clinical approach to the injured patient through fractures, missile and blast injuries, amputation, compartment syndrome, bone and joint infections, metabolic bone disease, and, finally, hand surgery, congenital deformities, and bone tumours addressed throughout ORT 601.

## Glossary of Terms

16. **Zone II (flexor tendon):** the region of the flexor sheath where superficialis and profundus tendons run together, historically challenging to repair.
17. **Kanavel's cardinal signs:** the classic clinical signs of flexor tendon sheath infection.
18. **Paronychia:** infection of the tissue surrounding the nail fold.
19. **Felon:** infection of the fingertip pulp space.
20. **Congenital talipes equinovarus:** a congenital foot deformity combining equinus, varus, adduction, and cavus.
21. **Ponseti method:** the mainstay treatment for clubfoot using serial manipulation, casting, tenotomy, and bracing.
22. **Syndactyly:** webbing or fusion between adjacent digits, a failure of differentiation.
23. **Polydactyly:** the presence of one or more supernumerary digits, a duplication abnormality.
24. **Osteochondroma:** the most common benign bone tumour, a cartilage-capped metaphyseal projection.
25. **Osteosarcoma:** the most common primary malignant bone tumour, producing a sunburst periosteal reaction.
26. **Codman's triangle:** elevated periosteum at the margin of an aggressive bone tumour.
27. **Chondrosarcoma:** a malignant cartilage-forming bone tumour showing rings and arcs calcification.

## Concept Check Questions [Series 5]

### Objective questions

6. The metacarpophalangeal joints permit flexion, extension, and some abduction-adduction, while the interphalangeal joints permit flexion and _____ only.
7. Flexor tendon sheath infection is classically recognised by Kanavel's cardinal signs, including fusiform swelling and pain on passive _____ of the digit.

8. Congenital talipes equinovarus is classified as idiopathic or _____, occurring in association with a broader underlying congenital condition.
9. Syndactyly, a failure of differentiation, describes webbing or fusion between adjacent _____.
10. Ewing's sarcoma typically produces a characteristic onion-skin periosteal _____.

**Short-answer questions**

11. Name the three nerves supplying the hand.
12. Distinguish the clinical presentation of flexor tendon injury from extensor tendon injury.
13. State Kanavel's cardinal signs of flexor tendon sheath infection.
14. Describe the Ponseti method of serial manipulation and casting.
15. Distinguish Ewing's sarcoma from chondrosarcoma in terms of typical age group and characteristic imaging feature.

**Long-answer questions**

1. Discuss the anatomy and function of the hand. (Linked to SLO 5.1, SLO 5.2)
2. Discuss the principles of assessment and management of hand injuries, including tendon and nerve injury. (Linked to SLO 5.3, SLO 5.4)
3. Discuss the principles, common types, and management of hand infections, including flexor tendon sheath infection. (Linked to SLO 5.5, SLO 5.6)
4. Discuss the basis, assessment, and management of congenital talipes equinovarus. (Linked to SLO 5.7, SLO 5.8)
5. Discuss the classification, common types, and management of congenital hand abnormalities, and the classification and common examples of bone tumours. (Linked to SLO 5.9, SLO 5.10, SLO 5.11, SLO 5.12)

**Answers to Concept Check Questions [Series 5]**

**Objective questions**

1. Extension.
2. Extension.
3. Syndromic.
4. Digits.
5. Reaction.

**Short-answer questions**

6. Median, ulnar, and radial nerves.
7. Flexor tendon injury causes loss of active flexion; extensor tendon injury causes loss of active extension at the affected joint.
8. Fusiform swelling, digit held in slight flexion, tenderness along the flexor sheath, and pain on passive extension.
9. Weekly gentle manipulation and cast application beginning soon after birth, generally followed by Achilles tenotomy and then night-time bracing.
10. Ewing's sarcoma affects children/young adolescents with an onion-skin reaction; chondrosarcoma affects older adults with rings and arcs calcification.

**Long-answer questions**

11. **Basic response:** The hand comprises carpal bones, metacarpals, and phalanges, with extrinsic and intrinsic muscles acting through flexor and extensor tendon systems.

**Value-added response:** Sensory and motor innervation from the median, ulnar, and radial nerves, together with flexor tendon zone classification, underpins accurate clinical assessment.

12. **Basic response:** Hand injury assessment applies look, feel, and move with specific tendon and nerve testing, identifying characteristic patterns of flexion, extension, or sensory/motor loss.

**Value-added response:** Management requires thorough wound exploration, prompt surgical repair where indicated, and structured splinting and rehabilitation for optimal functional outcome.

13. **Basic response:** Hand infections, including paronychia and felon, require prompt recognition given limited capacity for swelling, with flexor tendon sheath infection representing a surgical emergency identified by Kanavel's signs.

**Value-added response:** Management ranges from antibiotics and incision and drainage for localised infection to urgent surgical decompression for flexor tendon sheath infection.

14. **Basic response:** Congenital talipes equinovarus combines equinus, varus, adduction, and cavus, classified as idiopathic or syndromic, assessed soon after birth using scoring systems.

**Value-added response:** The Ponseti method of serial manipulation and casting, generally followed by tenotomy and bracing, represents the mainstay treatment approach.

15. **Basic response:** Congenital hand abnormalities are classified by developmental disruption, including syndactyly, polydactyly, and radial club hand, managed according to functional impact.

**Value-added response:** Bone tumours are classified as benign or malignant based on radiological features, with common examples including osteochondroma, osteosarcoma, Ewing's sarcoma, and chondrosarcoma.

**Answers to Pilot Questions [Series 5]**

**Part 5.1**

1. Carpal bones, metacarpals, and phalanges.
2. MCP joints permit flexion, extension, and some abduction-adduction; IP joints permit flexion and extension only.
3. Extrinsic muscles originate in the forearm; intrinsic muscles arise entirely within the hand.
4. Median, ulnar, and radial nerves.
5. Because superficialis and profundus tendons run together there, making surgical repair historically challenging.

**Part 5.2**

1. Applying look, feel, and move with specific tendon function, nerve sensory, and vascular testing.
2. Flexor tendon injury causes loss of active flexion; extensor tendon injury causes loss of active extension.
3. Sensory loss in the nerve's cutaneous distribution and motor weakness of muscles it supplies.
4. Thorough wound exploration, identification of injured structures, and prompt surgical repair.
5. Because inadequate rehabilitation risks significant residual functional impairment despite successful repair.

**Part 5.3**

- Because the hand's complex, enclosed fascial and tendon spaces allow rapid infection spread and limited capacity for swelling.

- Paronychia is infection of the tissue around the nail fold; felon is infection of the fingertip pulp space.
- Fusiform swelling, digit held in slight flexion, tenderness along the flexor sheath, and pain on passive extension.
- Antibiotic therapy, with surgical incision and drainage where a discrete abscess has formed.
- Because delayed treatment risks rapid, potentially irreversible tendon and hand functional damage.

**Part 5.4**

- Hindfoot equinus, hindfoot varus, forefoot adduction, and cavus.
- Idiopathic occurs without an identifiable cause; syndromic occurs alongside a broader congenital condition.
- Performed at or soon after birth, systematically documenting deformity severity using a scoring system such as Pirani.
- Weekly gentle manipulation and cast application beginning soon after birth, progressively correcting each deformity component.
- Tenotomy corrects residual equinus after casting; bracing maintains correction and prevents recurrence.

**Part 5.5**

- Failure of formation, failure of differentiation, duplication, overgrowth, and undergrowth.
- Webbing or fusion between adjacent digits.
- The presence of one or more supernumerary digits.
- A failure of formation affecting the radial side of the forearm and hand, producing wrist radial deviation and thumb hypoplasia or absence.
- Careful assessment of functional impact, guiding surgical timing and technique, supported by multidisciplinary involvement.

**Part 5.6**

- Benign tumours are well defined and sclerotic; malignant tumours have poorly defined, permeative margins.
- The most common benign bone tumour, a cartilage-capped bony projection arising from the metaphysis.
- Simple bone cyst is a fluid-filled cavity often presenting with pathological fracture; giant cell tumour is a locally aggressive epiphyseal lesion in young adults.
- A sunburst periosteal reaction and Codman's triangle.

- Ewing's sarcoma affects a younger age group with an onion-skin reaction; chondrosarcoma affects older adults with rings and arcs calcification.

**References and Attributions [Series 5]**


- Solomon, L., Warwick, D., & Nayagam, S. (2018). Apley and Solomon's System of Orthopaedics and Trauma (10th ed.). CRC Press.
- Green, D. P., Wolfe, S. W., et al. (Eds.). (2021). Green's Operative Hand Surgery (8th ed.). Elsevier.
- Ponseti, I. V. (1996). Congenital Clubfoot: Fundamentals of Treatment. Oxford University Press.
- Skinner, H. B., & McMahon, P. J. (Eds.). (2013). Current Diagnosis and Treatment in Orthopedics (5th ed.). McGraw-Hill.


**Figures, Plates, Tables, and Boxes**

- Figure 5.1: Diagram illustrating the bones and joints of the hand, including carpals, metacarpals, and phalanges. AI-generated using the prompt: "A single clean, accurate anatomical diagram of the dorsal hand skeleton with labelled carpal bones, metacarpals, and phalanges, and labelled joint lines at the metacarpophalangeal and interphalangeal levels, textbook anatomical diagram style, neutral background, no photographic realism, no other panels."
- Table 5.2: Comparing flexor tendon, extensor tendon, and nerve injury of the hand. AI-generated using the prompt: "Create a clean clinical reference table titled Comparing Flexor Tendon, Extensor Tendon, and Nerve Injury of the Hand, listing injury type, key clinical sign, and management priority. Orthopaedic reference table style with outside border, no photographic elements."
- Figure 5.3: Diagram illustrating Kanavel's cardinal signs of flexor tendon sheath infection: fusiform swelling, flexed posture, and sheath tenderness. AI-generated using the prompt: "A single clean, clinically accurate illustration of a single finger held in slight flexion with labelled fusiform swelling along its length and a labelled line indicating tenderness along the flexor tendon sheath, medical textbook illustration style, neutral background, no photographic realism, no other panels."
- Table 5.4: Components of the Ponseti method for congenital talipes equinovarus. AI-generated using the prompt: "Create a clean clinical reference table titled Components of

the Ponseti Method for Congenital Talipes Equinovarus, listing stage, description, and key purpose. Orthopaedic reference table style with outside border, no photographic elements."

- Figure 5.5: Diagram illustrating syndactyly (webbed digits) and polydactyly (supernumerary digit) as examples of congenital hand abnormalities. AI-generated using the prompt: "A single clean, accurate two-panel schematic hand diagram, one panel labelled syndactyly showing two adjacent fingers joined together, the other panel labelled polydactyly showing an extra small digit beside the normal fingers, medical textbook illustration style, neutral background, no photographic realism, no other panels."
- Table 5.6: Comparing common malignant bone tumours. AI-generated using the prompt: "Create a clean radiology reference table titled Comparing Common Malignant Bone Tumours, listing tumour, typical age group, and characteristic imaging feature. Orthopaedic reference table style with outside border, no photographic elements."