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SUG 605

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Course code: SUG 605

Course title: Neurosurgery

Course credit load: 2 Units

Series 1: Head Injury and Spinal Trauma

- **Part 1.1: Assessment of Head Injury**
    - Sub Part 1.1.1: Initial assessment and the Glasgow Coma Scale
    - Sub Part 1.1.2: Classification of head injury severity
    - Sub Part 1.1.3: Recognising signs of raised intracranial pressure
- **Part 1.2: Types of Traumatic Brain Injury**
    - Sub Part 1.2.1: Skull fractures
    - Sub Part 1.2.2: Extradural and subdural haematoma
    - Sub Part 1.2.3: Diffuse axonal injury and cerebral contusion
- **Part 1.3: Management of Head Injury**
    - Sub Part 1.3.1: Emergency management of severe head injury
    - Sub Part 1.3.2: Indications for neurosurgical intervention in head injury
    - Sub Part 1.3.3: Complications of head injury
- **Part 1.4: Spinal Trauma**
    - Sub Part 1.4.1: Assessment of spinal trauma
    - Sub Part 1.4.2: Spinal cord injury syndromes
    - Sub Part 1.4.3: Management of spinal trauma

Introduction

A fall from a ladder, a road traffic collision, a blow to the head during sport, these everyday mechanisms of injury can produce anything from a trivial bump to a genuinely life-threatening neurosurgical emergency, and correctly distinguishing between the two within the first minutes of assessment is the essential skill this opening Series sets out to build. **Head injury and spinal trauma** together account for a substantial proportion of neurosurgical emergency practice, and

both demand rapid, structured assessment given how quickly a seemingly stable patient can deteriorate.

The aim of this Series is to equip you with the ability to assess a patient with head injury using the Glasgow Coma Scale, classify head injury severity, recognise raised intracranial pressure, describe the types of traumatic brain injury and their management, and assess and manage spinal trauma. Building this assessment and recognition skill early gives you the foundation needed for everything that follows in this course.

This Series opens with the **assessment of head injury**, moves through **types of traumatic brain injury** and **management of head injury**, and closes with **spinal trauma**.

Series Learning Outcomes

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

- **SLO 1.1:** describe the initial assessment of a patient with head injury, including the Glasgow Coma Scale
- **SLO 1.2:** classify head injury severity and recognise signs of raised intracranial pressure
- **SLO 1.3:** describe the types of traumatic brain injury, including skull fractures and intracranial haematomas
- **SLO 1.4:** distinguish diffuse axonal injury from cerebral contusion
- **SLO 1.5:** describe the emergency management of severe head injury
- **SLO 1.6:** discuss the indications for neurosurgical intervention and the complications of head injury
- **SLO 1.7:** describe the assessment and classification of spinal cord injury
- **SLO 1.8:** discuss the management of spinal trauma

1.1 Assessment of Head Injury

1.1.1 initial assessment and the glasgow coma scale

A standardised way of describing conscious level

Initial assessment of head injury follows standard trauma principles, an **airway, breathing, circulation** approach, before turning to focused neurological assessment using the **Glasgow Coma Scale**, a standardised, reproducible tool scoring eye opening, verbal response, and motor

response, with the three component scores summed to give a total ranging from three, indicating the deepest unresponsiveness, to fifteen, indicating full consciousness.

Using the Glasgow Coma Scale consistently, and repeating it at regular intervals rather than performing a single assessment, allows genuine deterioration to be recognised promptly, since a falling score over time is often more clinically significant than the absolute value at any single point, and any drop of two or more points warrants urgent reassessment and escalation regardless of the starting score.

Fill in the blank: The Glasgow Coma Scale scores eye opening, verbal response, and _____ response.

1.1.2 classification of head injury severity

Sorting patients by initial Glasgow Coma Scale score

Head injury is broadly classified by the initial Glasgow Coma Scale score into **mild**, a score of thirteen to fifteen, **moderate**, a score of nine to twelve, and **severe**, a score of eight or below, a classification that, while imperfect and requiring clinical judgement alongside it, provides a useful, widely understood shorthand for communicating injury severity and guiding initial management decisions.

A Glasgow Coma Scale score of eight or below is specifically significant since it is generally taken as the threshold below which a patient's airway reflexes can no longer be relied upon to protect against aspiration, making airway protection, typically through intubation, a genuine priority in any patient scoring at or below this level regardless of the specific underlying cause of the reduced conscious level.

Fill in the blank: A Glasgow Coma Scale score of eight or below is the threshold below which airway _____ can no longer be relied upon.

1.1.3 recognising signs of raised intracranial pressure

Warning signs that the brain is running out of room

Raised intracranial pressure presents with headache, vomiting, reduced conscious level, and, in more advanced or rapidly progressive cases, the **Cushing's triad** of hypertension, bradycardia, and irregular breathing, a late and ominous physiological response reflecting the brain's attempt to maintain adequate perfusion pressure against a dangerously elevated intracranial pressure.

Pupillary changes, particularly a unilaterally dilated, poorly reactive pupil, are a critically important sign of raised intracranial pressure causing compression of the third cranial nerve as the brain begins to herniate, and this specific finding, particularly when it develops or worsens during observation, constitutes a genuine neurosurgical emergency requiring immediate escalation rather than continued watchful waiting.

Fill in the blank: A unilaterally dilated, poorly reactive pupil suggests compression of the third cranial _____.

Figure 1.1: A clinician assessing pupillary response with a penlight during neurological examination.

Pilot questions 1.1

1. Describe the three components of the Glasgow Coma Scale. (Linked to SLO 1.1)
2. Explain why repeated Glasgow Coma Scale assessment matters more than a single reading. (Linked to SLO 1.1)
3. List the Glasgow Coma Scale ranges for mild, moderate, and severe head injury. (Linked to SLO 1.2)
4. Explain the significance of a Glasgow Coma Scale score of eight or below. (Linked to SLO 1.2)
5. Describe Cushing's triad. (Linked to SLO 1.2)

1.2 Types of Traumatic Brain Injury

1.2.1 skull fractures

A fractured skull, and what it can signal beneath

Skull fractures are classified as linear, depressed, or basal, with a **linear fracture** often clinically insignificant in isolation but important as a marker of the force involved in the injury, and a **depressed fracture**, where a fragment of bone is displaced inward, carrying a higher risk of underlying brain injury and, if open, infection, sometimes requiring surgical elevation depending on the degree of depression and associated findings.

Basal skull fractures carry particular clinical significance and are suggested by specific signs including **Battle's sign**, bruising over the mastoid process, **panda eyes**, bruising around both orbits, cerebrospinal fluid leakage from the nose or ear, and haemotympanum, blood behind the eardrum, findings that should prompt specific caution, including avoiding nasogastric tube insertion through the nose given the theoretical risk of intracranial passage through an associated skull base defect.

Fill in the blank: Bruising over the mastoid process, known as Battle's sign, suggests a _____ skull fracture.

1.2.2 extradural and subdural haematoma

Two collections of blood, two very different courses

An **extradural haematoma**, blood collecting between the skull and the dura, classically results from arterial bleeding, often from the middle meningeal artery following a temporal bone fracture, and presents with a characteristic, though not universal, **lucid interval**, brief initial recovery of consciousness followed by rapid deterioration as the haematoma expands, a pattern reflecting the arterial source and correspondingly rapid rate of bleeding.

A **subdural haematoma**, blood collecting between the dura and the underlying brain, typically results from venous bleeding, often from torn bridging veins, and can present acutely following significant trauma or, particularly in older adults on anticoagulation or with age-related brain atrophy, chronically over weeks following a comparatively minor or even forgotten injury, a genuinely important distinction given how differently these two presentations, acute and chronic, are managed.

Fill in the blank: An extradural haematoma classically presents with a lucid interval reflecting its _____ source of bleeding.

1.2.3 diffuse axonal injury and cerebral contusion

Injury spread through, or bruising within, the brain tissue itself

Diffuse axonal injury results from rotational or shearing forces disrupting axons diffusely throughout the brain, typically following high-energy deceleration injury such as a high-speed road traffic collision, and presents with a conscious level often disproportionately reduced relative to the sometimes relatively unremarkable initial appearance of the brain on standard imaging, since the diffuse microscopic injury is not always well visualised on conventional computed tomography.

Cerebral contusion, bruising of the brain tissue itself, most commonly occurs at the site of direct impact or at the opposite pole of the brain through a **contrecoup** mechanism, and, while often visible on imaging as areas of mixed density reflecting blood and swelling, contusions can evolve and expand over the days following injury, making repeat imaging genuinely important in a patient whose clinical condition changes during the acute observation period.

Fill in the blank: Cerebral contusion at the site opposite the direct impact occurs through a _____ mechanism.

Table 1.1: Comparing extradural and subdural haematoma

Feature	Extradural haematoma	Subdural haematoma
Bleeding source	Arterial, often middle meningeal artery	Venous, often bridging veins
Classic presentation	Lucid interval then rapid deterioration	Acute or chronic, gradual onset possible
Typical location	Between skull and dura	Between dura and brain

Pilot questions 1.2

1. Distinguish a linear from a depressed skull fracture. (Linked to SLO 1.3)
2. List the signs suggesting a basal skull fracture. (Linked to SLO 1.3)
3. Describe the classic presentation of an extradural haematoma. (Linked to SLO 1.3)
4. Distinguish acute from chronic subdural haematoma. (Linked to SLO 1.3)
5. Explain why the conscious level in diffuse axonal injury can seem disproportionate to initial imaging. (Linked to SLO 1.4)

1.3 Management of Head Injury

1.3.1 emergency management of severe head injury

Protecting the brain while the primary problem is addressed

Emergency management of severe head injury follows the airway, breathing, circulation sequence, with particular attention to avoiding **secondary brain injury**, additional damage arising from hypoxia, hypotension, or hypercapnia following the original insult, since these secondary insults are frequently more preventable than the original primary injury itself and meaningfully worsen eventual outcome if not actively avoided.

Specific measures to reduce intracranial pressure in the acute setting include head-up positioning, ensuring adequate sedation and analgesia to prevent straining or agitation that transiently raises intracranial pressure, and, in selected cases, osmotic therapy with mannitol or hypertonic saline to temporarily reduce brain swelling while definitive investigation and, where indicated, neurosurgical intervention are arranged.

Fill in the blank: Secondary brain injury arises from hypoxia, hypotension, or _____ following the original insult.

1.3.2 indications for neurosurgical intervention in head injury

Deciding who needs the operating theatre, and when

Indications for neurosurgical intervention in head injury include a significant extradural or acute subdural haematoma causing mass effect or midline shift, a depressed skull fracture with significant depression or an open injury, and progressive neurological deterioration despite maximal medical management, decisions generally made in close consultation with a specialist neurosurgical team based on imaging findings alongside the trajectory of the patient's clinical examination.

Craniotomy, surgically opening the skull to evacuate a haematoma or address another intracranial lesion, and **decompressive craniectomy**, removing a section of skull without immediate replacement to allow the swollen brain room to expand without dangerously raising intracranial pressure, are the two principal surgical techniques employed, chosen according to the specific pathology and clinical scenario the patient presents with.

Fill in the blank: Decompressive craniectomy removes a section of skull to allow the swollen brain room to _____.

1.3.3 complications of head injury

Problems that can follow even successfully treated injury

Post-traumatic seizures, occurring either immediately, early within the first week, or late beyond the first week following injury, are a recognised complication of head injury, with late seizures in particular carrying implications for long-term epilepsy risk and requiring careful discussion with the patient about driving restrictions and ongoing anticonvulsant treatment where indicated.

Post-concussion syndrome, a constellation of headache, dizziness, cognitive difficulty, and mood disturbance persisting beyond the expected recovery period following even a mild head injury, and **cerebrospinal fluid leak** following a basal skull fracture, carrying a genuine risk of ascending meningitis if not identified and appropriately managed, are two further recognised complications requiring active clinical awareness well beyond the initial acute presentation.

Fill in the blank: Cerebrospinal fluid leak following a basal skull fracture carries a genuine risk of ascending _____.

Figure 1.2: A surgical team performing a burr hole procedure to evacuate an extradural haematoma.

- **Sample AI prompt:** Create a realistic clinical illustration titled Burr Hole Evacuation of Extradural Haematoma, showing a surgical team in theatre attire performing a burr hole procedure on a draped patient's head, operating theatre setting with instruments visible. Clean clinical illustration style, no text.

- **Suggested OER search string:** OER Commons burr hole evacuation surgical illustration

Pilot questions 1.3

1. Explain the concept of secondary brain injury and how it is minimised. (Linked to SLO 1.5)
2. List specific measures used to reduce intracranial pressure in the acute setting. (Linked to SLO 1.5)
3. List the indications for neurosurgical intervention in head injury. (Linked to SLO 1.6)
4. Distinguish craniotomy from decompressive craniectomy. (Linked to SLO 1.6)
5. Describe post-concussion syndrome. (Linked to SLO 1.6)

1.4 Spinal Trauma

1.4.1 assessment of spinal trauma

Protecting the spine until injury is confidently excluded

Assessment of spinal trauma begins with **spinal immobilisation**, maintained from the point of first contact until injury has been confidently excluded, alongside a focused history covering the mechanism of injury and any reported neurological symptoms such as limb weakness, numbness, or bladder and bowel dysfunction, symptoms that carry particular diagnostic weight given their potential to indicate genuine spinal cord involvement.

Examination assesses motor power, sensation, and reflexes systematically in each limb, alongside specific assessment of perianal sensation and anal tone, since preservation or loss of function in this specific region carries genuine prognostic significance in distinguishing a complete from an incomplete spinal cord injury, a distinction with direct implications for expected recovery and long-term management planning.

Fill in the blank: Spinal immobilisation is maintained from first contact until injury has been confidently _____.

1.4.2 spinal cord injury syndromes

Recognisable patterns of incomplete cord injury

Central cord syndrome, the most common incomplete spinal cord injury syndrome, typically follows hyperextension injury in an older patient with pre-existing cervical spondylosis, and characteristically produces weakness disproportionately affecting the upper limbs compared with the lower limbs, reflecting the specific anatomical arrangement of the corticospinal tract fibres within the affected central portion of the cord.

Anterior cord syndrome, resulting from injury to the anterior two-thirds of the cord, typically from a flexion or vascular mechanism, produces loss of motor function and pain and temperature sensation below the level of injury with relative preservation of proprioception and vibration sense, while **Brown-Sequard syndrome**, resulting from hemisection of the cord, produces the distinctive pattern of ipsilateral motor loss with contralateral loss of pain and temperature sensation, a pattern directly reflecting the specific anatomical tracts affected on each side of the injured cord.

Fill in the blank: Central cord syndrome characteristically produces weakness disproportionately affecting the upper _____.

1.4.3 management of spinal trauma

Stabilising the spine, protecting the cord, and planning recovery

Management of spinal trauma begins with continued immobilisation and careful attention to avoiding secondary injury during transfer and investigation, alongside supportive measures addressing the specific physiological consequences of significant spinal cord injury, including **neurogenic shock**, hypotension and bradycardia resulting from disrupted sympathetic outflow, which must be distinguished from haemorrhagic shock given the very different management each requires.

Surgical management, typically involving decompression of the spinal cord and stabilisation of the spinal column with instrumentation, is indicated for a significant unstable fracture, ongoing cord compression, or progressive neurological deterioration, with the specific timing and technique guided by the pattern of injury identified on imaging and the patient's overall clinical trajectory, and rehabilitation, beginning as early as safely possible, forms an equally essential and genuinely long-term component of the overall management plan for any patient with significant spinal cord injury.

Fill in the blank: Neurogenic shock results from disrupted sympathetic _____ following significant spinal cord injury.

Table 1.2: Comparing spinal cord injury syndromes

Syndrome	Mechanism	Key clinical pattern
Central cord syndrome	Hyperextension in cervical spondylosis	Upper limb weakness greater than lower limb
Anterior cord syndrome	Flexion or vascular injury	Motor and pain and temperature loss, proprioception preserved
Brown-Sequard syndrome	Hemisection of the cord	Ipsilateral motor loss, contralateral pain and temperature loss

Pilot questions 1.4

1. Explain why perianal sensation and anal tone are specifically assessed in spinal trauma. (Linked to SLO 1.7)
2. Describe central cord syndrome and its typical mechanism. (Linked to SLO 1.7)
3. Distinguish anterior cord syndrome from Brown-Sequard syndrome. (Linked to SLO 1.7)
4. Describe neurogenic shock and how it differs from haemorrhagic shock. (Linked to SLO 1.8)
5. List the indications for surgical management of spinal trauma. (Linked to SLO 1.8)

Series Summary

This opening Series built the foundation of assessing and managing head injury and spinal trauma, the two most common neurosurgical emergencies. Part 1.1 covered the assessment of head injury, the Glasgow Coma Scale, severity classification, and signs of raised intracranial pressure, while Part 1.2 turned to the types of traumatic brain injury, skull fractures, haematomas, and diffuse axonal injury. Part 1.3 covered the management of head injury, emergency care, neurosurgical intervention, and complications, and Part 1.4 closed with spinal trauma, its assessment, injury syndromes, and management.

You should now be able to assess and classify head injury, describe its types and management, and assess and manage spinal trauma, meeting the outcomes set for this Series. Series 2 turns next to common surgical intracranial lesions.

Glossary of Terms

- **Brown-Sequard syndrome:** an incomplete spinal cord injury from hemisection, producing ipsilateral motor and contralateral sensory loss.
- **Central cord syndrome:** the most common incomplete spinal cord injury, with weakness greater in the upper limbs.
- **Cushing's triad:** hypertension, bradycardia, and irregular breathing, a late sign of raised intracranial pressure.
- **Decompressive craniectomy:** removal of a section of skull to allow a swollen brain room to expand.
- **Diffuse axonal injury:** widespread axonal disruption from rotational or shearing forces.
- **Extradural haematoma:** blood collecting between the skull and the dura, typically arterial in origin.
- **Glasgow Coma Scale:** a standardised scale scoring eye opening, verbal response, and motor response.
- **Lucid interval:** a brief recovery of consciousness followed by deterioration, classic of extradural haematoma.
- **Neurogenic shock:** hypotension and bradycardia from disrupted sympathetic outflow after spinal cord injury.
- **Raised intracranial pressure:** elevated pressure within the skull, presenting with headache, vomiting, and reduced conscious level.
- **Secondary brain injury:** additional brain damage from hypoxia, hypotension, or hypercapnia after the original injury.
- **Subdural haematoma:** blood collecting between the dura and brain, typically venous in origin.

Concept Check Questions [Series 1]

Objective questions

1. The Glasgow Coma Scale scores eye opening, verbal response, and _____ response. (Linked to SLO 1.1)
2. Bruising over the mastoid process, known as Battle's sign, suggests a _____ skull fracture. (Linked to SLO 1.3)
3. An extradural haematoma classically presents with a lucid interval reflecting its _____ source of bleeding. (Linked to SLO 1.3)
4. Decompressive craniectomy removes a section of skull to allow the swollen brain room to _____. (Linked to SLO 1.6)

5. Central cord syndrome characteristically produces weakness disproportionately affecting the upper _____. (Linked to SLO 1.7)

Short-answer questions

6. List the Glasgow Coma Scale ranges for mild, moderate, and severe head injury. (Linked to SLO 1.2)
7. Describe Cushing's triad. (Linked to SLO 1.2)
8. Distinguish acute from chronic subdural haematoma. (Linked to SLO 1.3)
9. List the indications for neurosurgical intervention in head injury. (Linked to SLO 1.6)
10. Distinguish anterior cord syndrome from Brown-Sequard syndrome. (Linked to SLO 1.7)

Long-answer questions

11. Discuss the initial assessment of head injury, including the Glasgow Coma Scale and signs of raised intracranial pressure. (Linked to SLO 1.1, 1.2)
12. Compare extradural haematoma, subdural haematoma, and diffuse axonal injury. (Linked to SLO 1.3, 1.4)
13. Discuss the emergency management of severe head injury and the indications for neurosurgical intervention. (Linked to SLO 1.5, 1.6)
14. Describe the complications of head injury. (Linked to SLO 1.6)
15. Discuss the assessment, classification, and management of spinal trauma. (Linked to SLO 1.7, 1.8)

Answers to Concept Check Questions [Series 1]

Objective questions

1. Motor.
2. Basal.
3. Arterial.
4. Expand.
5. Limbs.

Short-answer questions

6. Mild is thirteen to fifteen, moderate is nine to twelve, and severe is eight or below.
7. Cushing's triad is hypertension, bradycardia, and irregular breathing, a late sign of raised intracranial pressure.

8. Acute subdural haematoma presents rapidly after significant trauma, while chronic subdural haematoma develops gradually over weeks after minor injury.
9. Indications include significant haematoma with mass effect, significantly depressed or open skull fracture, and progressive deterioration despite medical management.
10. Anterior cord syndrome causes bilateral motor and pain and temperature loss with preserved proprioception, while Brown-Sequard causes ipsilateral motor loss with contralateral sensory loss.

Long-answer questions

11. **Basic response:** Assessment follows airway, breathing, circulation, then the Glasgow Coma Scale scoring eye, verbal, and motor response; raised intracranial pressure presents with headache, vomiting, reduced conscious level, and, late, Cushing's triad.

    Value-added response: A value-added response notes that repeated Glasgow Coma Scale assessment detects deterioration more reliably than a single reading.

12. **Basic response:** Extradural haematoma is arterial with a classic lucid interval; subdural haematoma is venous and can be acute or chronic; diffuse axonal injury results from shearing forces with conscious level often disproportionate to initial imaging.

    Value-added response: A value-added response notes that cerebral contusions can evolve over days, making repeat imaging important if clinical condition changes.

13. **Basic response:** Management prioritises avoiding secondary brain injury from hypoxia or hypotension, alongside measures to reduce intracranial pressure; neurosurgical intervention is indicated for significant haematoma, depressed fracture, or progressive deterioration.

    Value-added response: A value-added response notes that craniotomy and decompressive craniectomy are chosen according to the specific pathology and clinical scenario.

14. **Basic response:** Complications include post-traumatic seizures, post-concussion syndrome, and cerebrospinal fluid leak with risk of ascending meningitis.

    Value-added response: A value-added response notes that late seizures carry implications for long-term epilepsy risk and driving restrictions.

15. **Basic response:** Assessment includes immobilisation, neurological examination, and perianal assessment; injury syndromes include central cord, anterior cord, and Brown-

Sequard syndrome; management includes immobilisation, addressing neurogenic shock, and surgical stabilisation where indicated.

Value-added response: A value-added response notes that early rehabilitation forms an essential, genuinely long-term component of overall management.

Answers to Pilot Questions [Series 1]

Part 1.1

1. The three components are eye opening, verbal response, and motor response.
2. A falling score over time is often more significant than the absolute value at a single point.
3. Mild is thirteen to fifteen, moderate is nine to twelve, and severe is eight or below.
4. A score of eight or below indicates airway reflexes can no longer be relied upon, requiring airway protection.
5. Cushing's triad is hypertension, bradycardia, and irregular breathing.

Part 1.2

1. A linear fracture is often clinically insignificant, while a depressed fracture carries higher risk of underlying brain injury.
2. Signs include Battle's sign, panda eyes, cerebrospinal fluid leak, and haemotympanum.
3. An extradural haematoma classically presents with a lucid interval followed by rapid deterioration.
4. Acute subdural haematoma presents rapidly after significant trauma, while chronic subdural haematoma develops gradually over weeks.
5. The diffuse microscopic axonal injury is not always well visualised on conventional imaging despite significant clinical impairment.

Part 1.3

1. Secondary brain injury is additional damage from hypoxia or hypotension, minimised by avoiding these insults actively.

2. Measures include head-up positioning, adequate sedation, and osmotic therapy with mannitol or hypertonic saline.
3. Indications include significant haematoma with mass effect, significantly depressed or open fracture, and progressive deterioration.
4. Craniotomy evacuates a lesion and replaces the bone, while decompressive craniectomy removes bone without immediate replacement.
5. Post-concussion syndrome is persistent headache, dizziness, cognitive difficulty, and mood disturbance after mild head injury.

Part 1.4

1. Perianal sensation and anal tone help distinguish complete from incomplete spinal cord injury, affecting prognosis.
2. Central cord syndrome follows hyperextension in cervical spondylosis, with upper limb weakness greater than lower limb.
3. Anterior cord syndrome causes bilateral motor and pain and temperature loss, while Brown-Sequard causes ipsilateral motor and contralateral sensory loss.
4. Neurogenic shock causes hypotension with bradycardia from sympathetic disruption, unlike haemorrhagic shock which causes tachycardia.
5. Surgical management is indicated for unstable fracture, ongoing cord compression, or progressive neurological deterioration.

References and Attributions [Series 1]

- Greenberg, M. S. (2020). Handbook of Neurosurgery (9th ed.). Thieme.
- American College of Surgeons (2018). Advanced Trauma Life Support Student Course Manual (10th ed.). American College of Surgeons.
- Ellis, H., & Mahadevan, V. (2019). Clinical Anatomy (14th ed.). Wiley-Blackwell.
- Williams, N. S., Bulstrode, C. J. K., & O'Connell, P. R. (2018). Bailey and Love's Short Practice of Surgery (27th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

- Figure 1.1: A clinician assessing pupillary response with a penlight during neurological examination. AI-generated using the prompt: "Create a realistic clinical illustration titled Pupillary Examination in Head Injury, showing a clinician shining a penlight into a

patient's eye to assess pupillary response, emergency department setting. Clean clinical illustration style, no text."

- Table 1.1: Comparing extradural and subdural haematoma. AI-generated using the prompt: "Create a clean reference table titled Comparing Extradural and Subdural Haematoma, listing feature, extradural haematoma, and subdural haematoma. Simple clinical reference table style with outside border."
- Figure 1.2: A surgical team performing a burr hole procedure to evacuate an extradural haematoma. AI-generated using the prompt: "Create a realistic clinical illustration titled Burr Hole Evacuation of Extradural Haematoma, showing a surgical team in theatre attire performing a burr hole procedure on a draped patient's head, operating theatre setting with instruments visible. Clean clinical illustration style, no text."
- Table 1.2: Comparing spinal cord injury syndromes. AI-generated using the prompt: "Create a clean reference table titled Comparing Spinal Cord Injury Syndromes, listing syndrome, mechanism, and key clinical pattern. Simple clinical reference table style with outside border."

Course code: SUG 605

Course title: Neurosurgery

Course credit load: 2 Units

Series 2: Common Surgical Intracranial Lesions

- **Part 2.1: Intracranial Tumours I: Gliomas and Meningiomas**
  - Sub Part 2.1.1: Classification of intracranial tumours
  - Sub Part 2.1.2: Gliomas
  - Sub Part 2.1.3: Meningiomas
- **Part 2.2: Intracranial Tumours II: Pituitary and Other Lesions**
  - Sub Part 2.2.1: Pituitary adenomas
  - Sub Part 2.2.2: Acoustic neuroma
  - Sub Part 2.2.3: Metastatic brain tumours
- **Part 2.3: Hydrocephalus**
  - Sub Part 2.3.1: Pathophysiology and classification of hydrocephalus
  - Sub Part 2.3.2: Clinical presentation of hydrocephalus
  - Sub Part 2.3.3: Management of hydrocephalus
- **Part 2.4: Intracranial Infections and Abscess**
  - Sub Part 2.4.1: Brain abscess
  - Sub Part 2.4.2: Subdural empyema
  - Sub Part 2.4.3: Principles of management of intracranial infection

Introduction

Having built a foundation in trauma across Series 1, this Series turns to a very different category of neurosurgical problem, lesions that develop within the skull over weeks, months, or years rather than in an instant. **Common surgical intracranial lesions** include tumours arising from brain tissue itself, the meninges, or nearby structures such as the pituitary gland, alongside

hydrocephalus and intracranial infection, each producing its own recognisable pattern of presentation and demanding its own specific management approach.

The aim of this Series is to equip you with the ability to classify intracranial tumours and describe the presentation and management of gliomas, meningiomas, pituitary adenomas, acoustic neuroma, and metastatic brain tumours, alongside the pathophysiology, presentation, and management of hydrocephalus, and the presentation and management of intracranial infection including brain abscess and subdural empyema.

This Series opens with **intracranial tumours: gliomas and meningiomas**, moves through **intracranial tumours: pituitary and other lesions** and **hydrocephalus**, and closes with **intracranial infections and abscess**.

Series Learning Outcomes

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

- **SLO 2.1:** classify intracranial tumours
- **SLO 2.2:** describe the presentation and management of gliomas and meningiomas
- **SLO 2.3:** describe the presentation of pituitary adenomas
- **SLO 2.4:** describe the presentation of acoustic neuroma and metastatic brain tumours
- **SLO 2.5:** describe the pathophysiology and classification of hydrocephalus
- **SLO 2.6:** describe the clinical presentation and management of hydrocephalus
- **SLO 2.7:** describe the presentation of brain abscess and subdural empyema
- **SLO 2.8:** discuss the principles of managing intracranial infection

2.1 Intracranial Tumours I: Gliomas and Meningiomas

2.1.1 classification of intracranial tumours

Sorting tumours by origin and behaviour

Intracranial tumours are broadly classified as **primary**, arising from brain tissue, the meninges, cranial nerves, or the pituitary gland, or **secondary**, representing metastatic spread from a distant primary tumour elsewhere in the body, a distinction that carries direct relevance to prognosis and treatment planning, since primary and secondary tumours are generally managed quite differently.

Primary tumours are further classified as **intra-axial**, arising from within the brain parenchyma itself, such as a glioma, or **extra-axial**, arising from structures adjacent to but outside the brain parenchyma, such as a meningioma arising from the meninges, a distinction that carries direct surgical relevance, since extra-axial tumours are frequently more amenable to complete surgical resection given their typically better-defined plane of separation from surrounding normal brain tissue.

Fill in the blank: Intra-axial tumours arise from within the brain _____ itself, unlike extra-axial tumours.

2.1.2 gliomas

The most common primary brain tumours

Gliomas, tumours arising from glial supporting cells within the brain, are the most common primary brain tumour and are graded from one to four according to their histological features, with grade one tumours generally slow-growing and potentially curable with surgery alone, and **glioblastoma**, a grade four tumour, being the most common and most aggressive glioma in adults, characteristically infiltrating diffusely into surrounding brain tissue rather than growing as a discrete, well-defined mass.

Presentation depends heavily on tumour location and growth rate, ranging from headache and seizures to focal neurological deficit reflecting the specific area of brain affected, and management typically combines maximal safe surgical resection, aiming to remove as much tumour as possible while preserving neurological function, with adjuvant radiotherapy and chemotherapy for higher-grade tumours, since complete surgical cure is rarely achievable given the characteristically infiltrative growth pattern of higher-grade gliomas.

Fill in the blank: Glioblastoma characteristically infiltrates diffusely rather than growing as a discrete, well-defined _____.

2.1.3 meningiomas

Usually benign tumours of the meninges

Meningiomas, arising from the meninges rather than the brain tissue itself, are generally slow-growing and, in the great majority of cases, histologically benign, presenting either incidentally on imaging performed for another reason or with symptoms reflecting local compression of adjacent brain tissue, cranial nerves, or venous sinuses depending on the specific location of the tumour.

Management of an asymptomatic, incidentally discovered meningioma frequently favours observation with serial imaging given the typically slow growth rate, while symptomatic or growing meningiomas are generally managed with surgical resection, with the completeness of resection achievable depending heavily on the tumour's location and its relationship to critical adjacent structures such as major venous sinuses or cranial nerves.

Fill in the blank: Management of an asymptomatic, incidentally discovered meningioma frequently favours _____ with serial imaging.

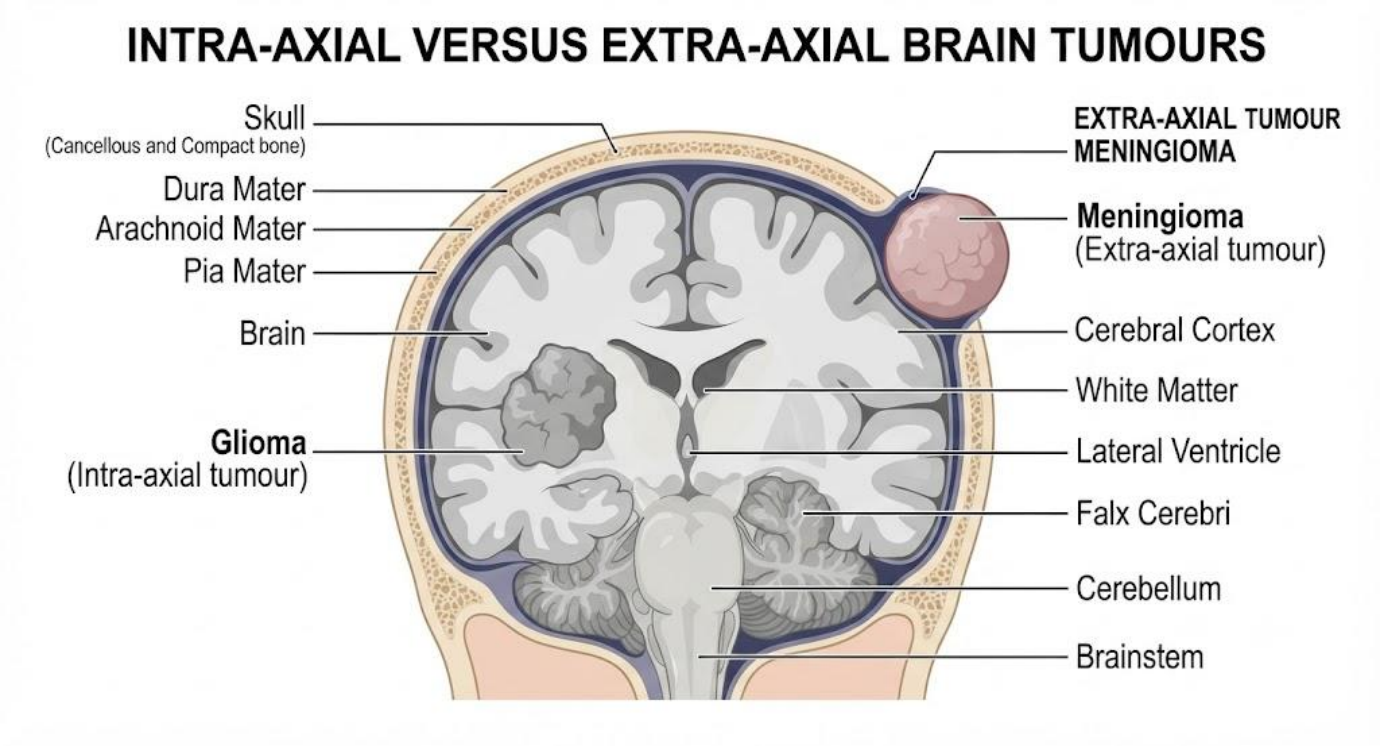

Figure 2.1: A labelled anatomical cross-section distinguishing an intra-axial glioma from an extra-axial meningioma.

Pilot questions 2.1

- Distinguish primary from secondary intracranial tumours. (Linked to SLO 2.1)
- Distinguish intra-axial from extra-axial tumours. (Linked to SLO 2.1)
- Describe glioblastoma and its characteristic growth pattern. (Linked to SLO 2.2)
- Describe the management approach for a high-grade glioma. (Linked to SLO 2.2)
- Explain when observation is favoured over surgery for a meningioma. (Linked to SLO 2.2)

2.2 Intracranial Tumours II: Pituitary and Other Lesions

2.2.1 pituitary adenomas

Tumours that can speak through hormones as well as mass effect

Pituitary adenomas are classified as functioning, secreting excess hormone and producing a specific clinical syndrome depending on which hormone is involved, or non-functioning, presenting instead with symptoms of local mass effect, most characteristically **bitemporal hemianopia**, loss of the outer visual field on both sides, from compression of the optic chiasm sitting directly above the pituitary gland.

Functioning adenomas produce recognisable syndromes depending on the hormone secreted, including acromegaly from excess growth hormone, Cushing's disease from excess adrenocorticotropic hormone, and galactorrhoea and menstrual disturbance from excess prolactin, with management depending on the specific tumour type, ranging from medical therapy, particularly effective for prolactin-secreting tumours, to **transsphenoidal surgery**, accessing the pituitary gland through the nose and sphenoid sinus, avoiding the need for a formal craniotomy in most cases.

Fill in the blank: Bitemporal hemianopia results from compression of the optic chiasm sitting directly above the pituitary _____.

2.2.2 acoustic neuroma

A tumour of the vestibular nerve, not actually hearing tissue

Acoustic neuroma, more accurately termed vestibular schwannoma given its true origin from the vestibular rather than auditory component of the eighth cranial nerve, typically presents with progressive unilateral hearing loss, tinnitus, and, as the tumour enlarges, balance disturbance and, in larger tumours, symptoms from compression of adjacent cranial nerves or the brainstem.

Management options range from observation with serial imaging for small, slow-growing, asymptomatic tumours, particularly in older patients, through stereotactic radiosurgery for appropriately selected tumours, to surgical resection for larger or growing tumours, with the specific choice guided by tumour size, growth rate, patient age, and hearing status, since preserving hearing where possible is a genuinely important consideration in treatment planning for this specific tumour.

Fill in the blank: Acoustic neuroma more accurately arises from the vestibular rather than auditory component of the eighth cranial _____.

2.2.3 metastatic brain tumours

The most common intracranial tumour overall

Metastatic brain tumours, secondary deposits from a distant primary cancer, most commonly lung, breast, and melanoma, are actually the most common intracranial tumour overall in adults, frequently presenting with multiple lesions rather than a single mass, and often producing relatively rapid symptom onset given their characteristically faster growth compared with many primary brain tumours.

Management depends on the number and location of metastases, the specific primary tumour type and its systemic treatment options, and the patient's overall prognosis and performance status, ranging from surgical resection or stereotactic radiosurgery for a single, accessible metastasis in a patient with otherwise controlled systemic disease, to whole-brain radiotherapy or systemic treatment alone for more widespread intracranial disease, a genuinely individualised decision requiring close collaboration between the neurosurgical and oncology teams.

Fill in the blank: Metastatic brain tumours frequently present with _____ lesions rather than a single mass.

Table 2.1: Comparing pituitary adenoma, acoustic neuroma, and metastatic brain tumour

Lesion	Typical presentation	Key management option
Pituitary adenoma	Hormonal syndrome or bitemporal hemianopia	Transsphenoidal surgery or medical therapy
Acoustic neuroma	Progressive unilateral hearing loss and tinnitus	Observation, radiosurgery, or resection
Metastatic brain tumour	Often multiple lesions, rapid onset	Depends on number, location, and systemic disease

Pilot questions 2.2

1. Distinguish functioning from non-functioning pituitary adenomas. (Linked to SLO 2.3)
2. Describe bitemporal hemianopia and its cause. (Linked to SLO 2.3)
3. Describe the typical presentation of acoustic neuroma. (Linked to SLO 2.4)
4. List the factors guiding management choice in acoustic neuroma. (Linked to SLO 2.4)

5. Explain why metastatic brain tumours often present with multiple lesions. (Linked to SLO 2.4)

2.3 Hydrocephalus

2.3.1 pathophysiology and classification of hydrocephalus

Too much fluid, too little drainage

Hydrocephalus describes an abnormal accumulation of cerebrospinal fluid within the ventricular system, resulting from an imbalance between production and drainage, and is classified as **obstructive**, resulting from a physical blockage somewhere along the normal pathway of cerebrospinal fluid flow, or **communicating**, resulting from impaired absorption of cerebrospinal fluid despite an unobstructed pathway between the ventricles themselves.

Common causes of obstructive hydrocephalus include a tumour or congenital narrowing obstructing the cerebral aqueduct, while communicating hydrocephalus commonly follows subarachnoid haemorrhage or meningitis, where inflammation impairs the normal reabsorption of cerebrospinal fluid at the arachnoid granulations, and correctly distinguishing between these two categories directly informs the most appropriate treatment approach for a given patient.

Fill in the blank: Communicating hydrocephalus results from impaired _____ of cerebrospinal fluid despite an unobstructed pathway.

2.3.2 clinical presentation of hydrocephalus

How raised ventricular pressure announces itself

In infants, before the cranial sutures have fused, hydrocephalus presents with progressive **macrocephaly**, an abnormally enlarging head circumference, a bulging anterior fontanelle, and, in more advanced cases, the characteristic **sunsetting sign**, downward deviation of the eyes, while in older children and adults with fused sutures, hydrocephalus presents instead with the symptoms and signs of raised intracranial pressure already discussed in Series 1.

Normal pressure hydrocephalus, a distinct entity typically affecting older adults, presents with a characteristic clinical triad of gait disturbance, cognitive decline, and urinary incontinence, occurring despite cerebrospinal fluid pressure measurements that are, somewhat counterintuitively given the name of the condition, generally within the statistically normal

range, making this a genuinely distinct diagnostic and management challenge compared with other forms of hydrocephalus.

Fill in the blank: Normal pressure hydrocephalus presents with a triad of gait disturbance, cognitive decline, and urinary _____.

2.3.3 management of hydrocephalus

Diverting fluid, or removing the obstruction directly

Ventriculoperitoneal shunting, inserting a catheter to divert cerebrospinal fluid from the ventricular system to the peritoneal cavity for reabsorption, remains the most commonly used definitive treatment for hydrocephalus, effectively bypassing the underlying obstruction or absorption defect regardless of its specific cause, though the shunt system itself carries its own recognised risks of mechanical failure and infection requiring ongoing surveillance.

Endoscopic third ventriculostomy, creating a new communication within the ventricular system to bypass a specific obstruction, offers an alternative to shunting in appropriately selected cases of obstructive hydrocephalus, avoiding the long-term presence of an implanted foreign device and its associated risks, though it is only suitable for specific anatomical patterns of obstruction rather than universally applicable across every cause of hydrocephalus.

Fill in the blank: Endoscopic third ventriculostomy avoids the long-term presence of an implanted foreign _____.

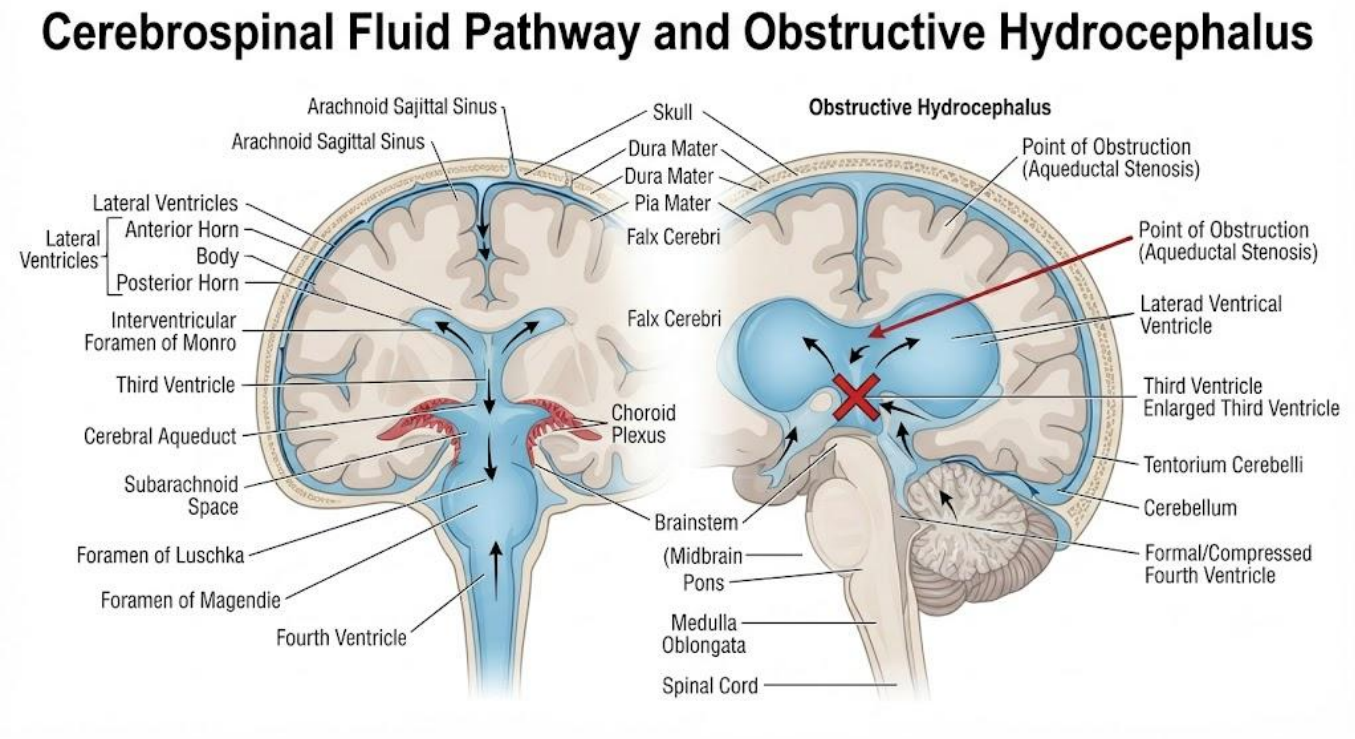

Figure 2.2: A labelled diagram of the cerebrospinal fluid pathway showing a site of obstruction in hydrocephalus.

Pilot questions 2.3

1. Distinguish obstructive from communicating hydrocephalus. (Linked to SLO 2.5)
2. List common causes of obstructive and communicating hydrocephalus. (Linked to SLO 2.5)
3. Describe the presentation of hydrocephalus in an infant. (Linked to SLO 2.6)
4. Describe normal pressure hydrocephalus and its clinical triad. (Linked to SLO 2.6)
5. Distinguish ventriculoperitoneal shunting from endoscopic third ventriculostomy. (Linked to SLO 2.6)

2.4 Intracranial Infections and Abscess

2.4.1 brain abscess

A localised collection of infection within brain tissue

A **brain abscess**, a localised collection of pus within the brain parenchyma, can arise from direct spread from an adjacent infected structure such as the sinuses, middle ear, or teeth, from

haematogenous spread from a distant infection elsewhere in the body, or following penetrating head trauma or neurosurgical procedures, with the source of infection often influencing both the likely causative organism and the specific location of the resulting abscess.

Presentation typically includes headache, fever, and focal neurological deficit reflecting the specific location of the abscess, though the classical triad of headache, fever, and focal deficit is present together in only a minority of cases, meaning a normal temperature or absence of focal signs should never be used alone to exclude the diagnosis in a patient with a genuinely suggestive clinical picture and risk factors.

Fill in the blank: A brain abscess can arise from direct spread, haematogenous spread, or following penetrating trauma or neurosurgical _____.

2.4.2 subdural empyema

Infection spreading across the surface of the brain

Subdural empyema, a collection of pus within the subdural space, most commonly arises as a complication of sinusitis, particularly frontal sinusitis, and, unlike a localised brain abscess, can spread relatively rapidly across the surface of the brain given the potential space it occupies, making it a genuinely more rapidly progressive and dangerous condition than a comparably sized brain abscess in many cases.

Presentation includes headache, fever, and rapidly progressive neurological deterioration, including seizures and focal deficit, and, given the potential for rapid clinical decline, subdural empyema is generally considered a genuine neurosurgical emergency requiring urgent imaging, prompt surgical drainage, and immediate broad-spectrum antibiotic therapy rather than a period of watchful waiting or trial of antibiotics alone.

Fill in the blank: Subdural empyema most commonly arises as a complication of _____, particularly frontal sinusitis.

2.4.3 principles of management of intracranial infection

Combining source control with targeted antimicrobial therapy

Management of intracranial infection combines **surgical drainage** of any significant collection, whether by burr hole aspiration or formal craniotomy depending on the size, location, and accessibility of the collection, with prolonged, targeted **antimicrobial therapy**, typically continued for several weeks given the relatively poor penetration of many antibiotics into

infected brain tissue and the correspondingly greater difficulty in achieving adequate treatment compared with infection elsewhere in the body.

Identifying the causative organism, wherever possible through culture of aspirated pus, guides the specific choice and duration of antimicrobial therapy, and close monitoring for clinical deterioration or failure to respond to treatment, including repeat imaging where indicated, allows prompt escalation, such as further surgical drainage or a change in antimicrobial regimen, before a treatable intracranial infection progresses to an irreversible or fatal outcome.

Fill in the blank: Antimicrobial therapy for intracranial infection is typically continued for several _____ given poor antibiotic penetration into infected tissue.

Table 2.2: Comparing brain abscess and subdural empyema

Feature	Brain abscess	Subdural empyema
Location	Within brain parenchyma	Within the subdural space
Common source	Sinuses, ear, teeth, bloodstream	Sinusitis, particularly frontal
Rate of progression	Variable, often more indolent	Often rapidly progressive

Pilot questions 2.4

1. List the routes by which a brain abscess can develop. (Linked to SLO 2.7)
2. Explain why the classical triad of brain abscess should not be relied upon exclusively. (Linked to SLO 2.7)
3. Describe subdural empyema and its most common source. (Linked to SLO 2.7)
4. Explain why subdural empyema is considered a neurosurgical emergency. (Linked to SLO 2.7)
5. Describe the combined management approach to intracranial infection. (Linked to SLO 2.8)

Series Summary

This Series covered the common surgical intracranial lesions encountered beyond trauma. Part 2.1 covered the classification of intracranial tumours, gliomas, and meningiomas, while Part 2.2 turned to pituitary adenomas, acoustic neuroma, and metastatic brain tumours. Part 2.3 covered the pathophysiology, presentation, and management of hydrocephalus, and Part 2.4 closed with intracranial infections, brain abscess, subdural empyema, and their management.

You should now be able to classify and describe intracranial tumours, hydrocephalus, and intracranial infection across all four Parts of this Series, meeting the outcomes set for this Series. Series 3 turns next to spinal cord lesions.

Glossary of Terms

1. **Acoustic neuroma:** a tumour of the vestibular component of the eighth cranial nerve, more accurately termed vestibular schwannoma.
2. **Bitemporal hemianopia:** loss of the outer visual field on both sides from optic chiasm compression.
3. **Brain abscess:** a localised collection of pus within the brain parenchyma.
4. **Communicating hydrocephalus:** hydrocephalus from impaired cerebrospinal fluid absorption despite an unobstructed pathway.
5. **Endoscopic third ventriculostomy:** a procedure creating a new pathway to bypass an obstruction in hydrocephalus.
6. **Glioma:** a tumour arising from glial supporting cells within the brain.
7. **Macrocephaly:** an abnormally enlarging head circumference, seen in infant hydrocephalus.
8. **Meningioma:** a usually benign tumour arising from the meninges.
9. **Normal pressure hydrocephalus:** hydrocephalus with a triad of gait disturbance, cognitive decline, and incontinence.
10. **Obstructive hydrocephalus:** hydrocephalus from a physical blockage in the cerebrospinal fluid pathway.
11. **Subdural empyema:** a collection of pus within the subdural space, often from sinusitis.
12. **Ventriculoperitoneal shunt:** a device diverting cerebrospinal fluid from the ventricles to the peritoneal cavity.

Concept Check Questions [Series 2]

Objective questions

- Intra-axial tumours arise from within the brain _____ itself, unlike extra-axial tumours. (Linked to SLO 2.1)
- Bitemporal hemianopia results from compression of the optic chiasm sitting directly above the pituitary _____. (Linked to SLO 2.3)
- Communicating hydrocephalus results from impaired _____ of cerebrospinal fluid despite an unobstructed pathway. (Linked to SLO 2.5)
- Subdural empyema most commonly arises as a complication of _____, particularly frontal sinusitis. (Linked to SLO 2.7)
- Antimicrobial therapy for intracranial infection is typically continued for several _____ given poor antibiotic penetration. (Linked to SLO 2.8)

Short-answer questions

1. Describe glioblastoma and its characteristic growth pattern. (Linked to SLO 2.2)
2. Describe the typical presentation of acoustic neuroma. (Linked to SLO 2.4)
3. Describe normal pressure hydrocephalus and its clinical triad. (Linked to SLO 2.6)
4. Explain why the classical triad of brain abscess should not be relied upon exclusively. (Linked to SLO 2.7)
5. Describe the combined management approach to intracranial infection. (Linked to SLO 2.8)

Long-answer questions

6. Discuss the classification of intracranial tumours and the presentation and management of gliomas and meningiomas. (Linked to SLO 2.1, 2.2)
7. Describe the presentation of pituitary adenomas, acoustic neuroma, and metastatic brain tumours. (Linked to SLO 2.3, 2.4)
8. Discuss the pathophysiology, presentation, and management of hydrocephalus. (Linked to SLO 2.5, 2.6)
9. Describe the presentation of brain abscess and subdural empyema. (Linked to SLO 2.7)
10. Discuss the principles of managing intracranial infection. (Linked to SLO 2.8)

Answers to Concept Check Questions [Series 2]

Objective questions

11. Parenchyma.
12. Gland.
13. Absorption.
14. Sinusitis.
15. Weeks.

Short-answer questions

16. Glioblastoma is the most aggressive glioma, characteristically infiltrating diffusely rather than forming a discrete mass.
17. Acoustic neuroma presents with progressive unilateral hearing loss, tinnitus, and later balance disturbance.
18. Normal pressure hydrocephalus presents with gait disturbance, cognitive decline, and urinary incontinence despite normal pressure readings.
19. The classical triad is present together in only a minority of cases, so its absence should not exclude the diagnosis.
20. Management combines surgical drainage of any collection with prolonged, targeted antimicrobial therapy.

Long-answer questions

21. **Basic response:** Tumours are classified as primary or secondary, and intra-axial or extra-axial; gliomas are graded one to four and managed with resection plus adjuvant therapy for high grade; meningiomas are usually benign and often observed if asymptomatic.

    Value-added response: A value-added response notes that extra-axial tumours like meningiomas are often more amenable to complete resection given a clearer surgical plane.

22. **Basic response:** Pituitary adenomas present with hormonal syndromes or bitemporal hemianopia; acoustic neuroma presents with progressive hearing loss and tinnitus; metastatic tumours often present with multiple lesions and rapid onset.

    Value-added response: A value-added response notes that preserving hearing is a genuinely important consideration in acoustic neuroma treatment planning.

23. **Basic response:** Hydrocephalus is classified as obstructive or communicating; infants present with macrocephaly, while older patients present with raised intracranial pressure

or normal pressure hydrocephalus; management uses shunting or endoscopic third ventriculostomy.

Value-added response: A value-added response notes that endoscopic third ventriculostomy avoids a permanently implanted device but is only suitable for specific obstruction patterns.

24. **Basic response:** Brain abscess presents with headache, fever, and focal deficit, though the full triad is uncommon; subdural empyema presents similarly but progresses more rapidly, most commonly following frontal sinusitis.

    Value-added response: A value-added response notes that subdural empyema is generally considered a genuine neurosurgical emergency given its potential for rapid spread.

25. **Basic response:** Management combines surgical drainage of any significant collection with prolonged, targeted antimicrobial therapy, guided by culture results where possible.

    Value-added response: A value-added response notes that close monitoring for deterioration allows prompt escalation before a treatable infection becomes irreversible.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Primary tumours arise from brain or nearby structures, while secondary tumours are metastases from a distant cancer.
2. Intra-axial tumours arise within the brain parenchyma, while extra-axial tumours arise from adjacent structures such as the meninges.
3. Glioblastoma is the most aggressive glioma, infiltrating diffusely rather than forming a discrete mass.
4. High-grade gliomas are managed with maximal safe resection plus adjuvant radiotherapy and chemotherapy.
5. Observation is favoured for asymptomatic, incidentally discovered meningiomas given their typically slow growth.

Part 2.2

6. Functioning adenomas secrete excess hormone, while non-functioning adenomas present with mass effect symptoms.
7. Bitemporal hemianopia is loss of the outer visual field on both sides, from optic chiasm compression.
8. Acoustic neuroma presents with progressive unilateral hearing loss, tinnitus, and later balance disturbance.
9. Factors include tumour size, growth rate, patient age, and hearing status.
10. Metastatic tumours frequently spread haematogenously to multiple sites within the brain simultaneously.

Part 2.3

11. Obstructive hydrocephalus results from physical blockage, while communicating hydrocephalus results from impaired absorption.
12. Obstructive causes include aqueduct obstruction; communicating causes include subarachnoid haemorrhage and meningitis.
13. Infants present with macrocephaly, a bulging fontanelle, and, in advanced cases, the sunsetting sign.
14. Normal pressure hydrocephalus presents with gait disturbance, cognitive decline, and urinary incontinence.
15. Shunting diverts fluid to another body cavity, while ventriculostomy creates a new internal pathway bypassing the obstruction.

Part 2.4

1. Routes include direct spread, haematogenous spread, and penetrating trauma or neurosurgical procedures.
2. The full triad is present together in only a minority of cases, so its absence should not exclude the diagnosis.
3. Subdural empyema is a collection of pus within the subdural space, most commonly from frontal sinusitis.
4. It can spread rapidly across the brain surface given the potential space it occupies, causing rapid deterioration.
5. Management combines surgical drainage with prolonged, targeted antimicrobial therapy.

References and Attributions [Series 2]

1. Greenberg, M. S. (2020). Handbook of Neurosurgery (9th ed.). Thieme.
2. Ellis, H., & Mahadevan, V. (2019). Clinical Anatomy (14th ed.). Wiley-Blackwell.
3. Winn, H. R. (2016). Youmans and Winn Neurological Surgery (7th ed.). Elsevier.
4. Williams, N. S., Bulstrode, C. J. K., & O'Connell, P. R. (2018). Bailey and Love's Short Practice of Surgery (27th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

1. Figure 2.1: A labelled anatomical cross-section distinguishing an intra-axial glioma from an extra-axial meningioma. AI-generated using the prompt: "Create a clean, accurate labelled anatomical cross-section diagram titled Intra-Axial versus Extra-Axial Brain Tumours, showing a coronal section of the skull and brain with a labelled glioma within the brain parenchyma and a labelled meningioma arising from the meninges at the brain surface. Educational anatomical diagram style, no photographic content."
2. Table 2.1: Comparing pituitary adenoma, acoustic neuroma, and metastatic brain tumour. AI-generated using the prompt: "Create a clean reference table titled Comparing Pituitary Adenoma, Acoustic Neuroma, and Metastatic Brain Tumour, listing lesion, typical presentation, and key management option. Simple clinical reference table style with outside border."
3. Figure 2.2: A labelled diagram of the cerebrospinal fluid pathway showing a site of obstruction in hydrocephalus. AI-generated using the prompt: "Create a clean, accurate labelled anatomical diagram titled Cerebrospinal Fluid Pathway and Obstructive Hydrocephalus, showing the lateral, third, and fourth ventricles connected by the cerebral aqueduct, with a labelled point of obstruction at the aqueduct and enlarged ventricles proximal to it. Educational anatomical diagram style, no photographic content."
4. Table 2.2: Comparing brain abscess and subdural empyema. AI-generated using the prompt: "Create a clean reference table titled Comparing Brain Abscess and Subdural Empyema, listing feature, brain abscess, and subdural empyema. Simple clinical reference table style with outside border."

Course code: SUG 605

Course title: Neurosurgery

Course credit load: 2 Units

Series 3: Spinal Cord Lesions

- **Part 3.1: Degenerative Spine Disease**
    - Sub Part 3.1.1: Cervical spondylosis and myelopathy
    - Sub Part 3.1.2: Lumbar disc prolapse and sciatica
    - Sub Part 3.1.3: Spinal stenosis
- **Part 3.2: Spinal Tumours**
    - Sub Part 3.2.1: Classification of spinal tumours
    - Sub Part 3.2.2: Extradural spinal tumours
    - Sub Part 3.2.3: Intradural spinal tumours
- **Part 3.3: Spinal Infections**
    - Sub Part 3.3.1: Discitis and vertebral osteomyelitis
    - Sub Part 3.3.2: Spinal epidural abscess
    - Sub Part 3.3.3: Principles of management of spinal infection
- **Part 3.4: Cauda Equina Syndrome and Surgical Principles**
    - Sub Part 3.4.1: Cauda equina syndrome
    - Sub Part 3.4.2: Indications for spinal surgery
    - Sub Part 3.4.3: Principles of spinal surgical approaches

Introduction

This Series moves from the skull to the spine, working through the range of non-traumatic conditions that can compress or damage the spinal cord and nerve roots, from the everyday wear and tear of degenerative spine disease through to spinal tumours, infections, and the genuine surgical emergency of cauda equina syndrome. **Spinal cord lesions** share a common underlying

theme with the intracranial lesions covered in Series 2, a space-occupying or destructive process compromising delicate neural tissue, but the spine's specific anatomy and the nerve roots it houses give this topic its own distinct clinical patterns.

The aim of this Series is to equip you with the ability to describe degenerative spine disease, classify and describe spinal tumours, describe the presentation and management of spinal infections, and recognise and manage cauda equina syndrome, alongside understanding the general indications and principles of spinal surgery. Recognising cauda equina syndrome in particular, given its time-critical nature, is a genuinely essential skill this Series aims to consolidate.

This Series opens with **degenerative spine disease**, moves through **spinal tumours** and **spinal infections**, and closes with **cauda equina syndrome and surgical principles**.

Series Learning Outcomes

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

- **SLO 3.1:** describe the presentation of cervical spondylosis and cervical myelopathy
- **SLO 3.2:** describe lumbar disc prolapse, sciatica, and spinal stenosis
- **SLO 3.3:** classify spinal tumours
- **SLO 3.4:** describe extradural and intradural spinal tumours
- **SLO 3.5:** describe the presentation of spinal infections
- **SLO 3.6:** discuss the management of spinal infections
- **SLO 3.7:** describe cauda equina syndrome and its management
- **SLO 3.8:** discuss the indications and principles of spinal surgery

3.1 Degenerative Spine Disease

3.1.1 cervical spondylosis and myelopathy

Wear and tear that can compress the cord itself

Cervical spondylosis, age-related degenerative change affecting the cervical intervertebral discs and facet joints, is extremely common and often entirely asymptomatic, though it can produce neck pain and stiffness, and, when degenerative change narrows the spinal canal sufficiently to compress the spinal cord itself, results in **cervical myelopathy**, a genuinely more serious condition with distinct clinical features requiring specific recognition.

Cervical myelopathy presents with a characteristic combination of upper limb clumsiness and loss of fine motor control, gait disturbance often described by patients as unsteadiness, and, on examination, upper motor neuron signs such as hyperreflexia and spasticity below the level of compression, a symptom pattern that develops gradually and progressively, distinguishing it clinically from the more acute presentation of radiculopathy from a single compressed nerve root.

Fill in the blank: Cervical myelopathy presents with upper motor neuron signs such as hyperreflexia and _____ below the level of compression.

3.1.2 lumbar disc prolapse and sciatica

A herniated disc pressing on a single nerve root

Lumbar disc prolapse, herniation of intervertebral disc material compressing an adjacent nerve root, classically presents with **sciatica**, pain radiating from the lower back down the leg following the distribution of the affected nerve root, often accompanied by numbness or weakness in the corresponding dermatome and myotome, a pattern that allows the specific level of disc prolapse to be predicted clinically before any imaging is performed.

The majority of lumbar disc prolapses improve with conservative management, including analgesia, physiotherapy, and activity modification, over a period of weeks to a few months, with surgical discectomy generally reserved for patients with significant, persistent symptoms despite an adequate trial of conservative treatment, progressive neurological deficit, or, as discussed later in this Series, the specific emergency presentation of cauda equina syndrome.

Fill in the blank: Sciatica is pain radiating from the lower back down the leg following the _____ of the affected nerve root.

3.1.3 spinal stenosis

A generally narrowed canal, rather than a single compressive lesion

Spinal stenosis, narrowing of the spinal canal from a combination of degenerative changes including disc bulging, facet joint hypertrophy, and ligamentous thickening, most commonly affects the lumbar spine and classically presents with **neurogenic claudication**, leg pain, numbness, or weakness brought on by walking or standing and relieved by sitting or forward flexion, a pattern distinguishable from vascular claudication by its characteristic relief with forward flexion, or leaning forward, rather than simply stopping and resting.

Distinguishing neurogenic from vascular claudication, already discussed in relation to peripheral arterial disease in an earlier course, relies on this specific positional pattern alongside examination for peripheral pulses, and management follows a similar conservative-first approach to lumbar disc prolapse, with surgical decompression reserved for patients with significant, persistent symptoms limiting quality of life despite adequate conservative management.

Fill in the blank: Neurogenic claudication is characteristically relieved by sitting or forward _____.

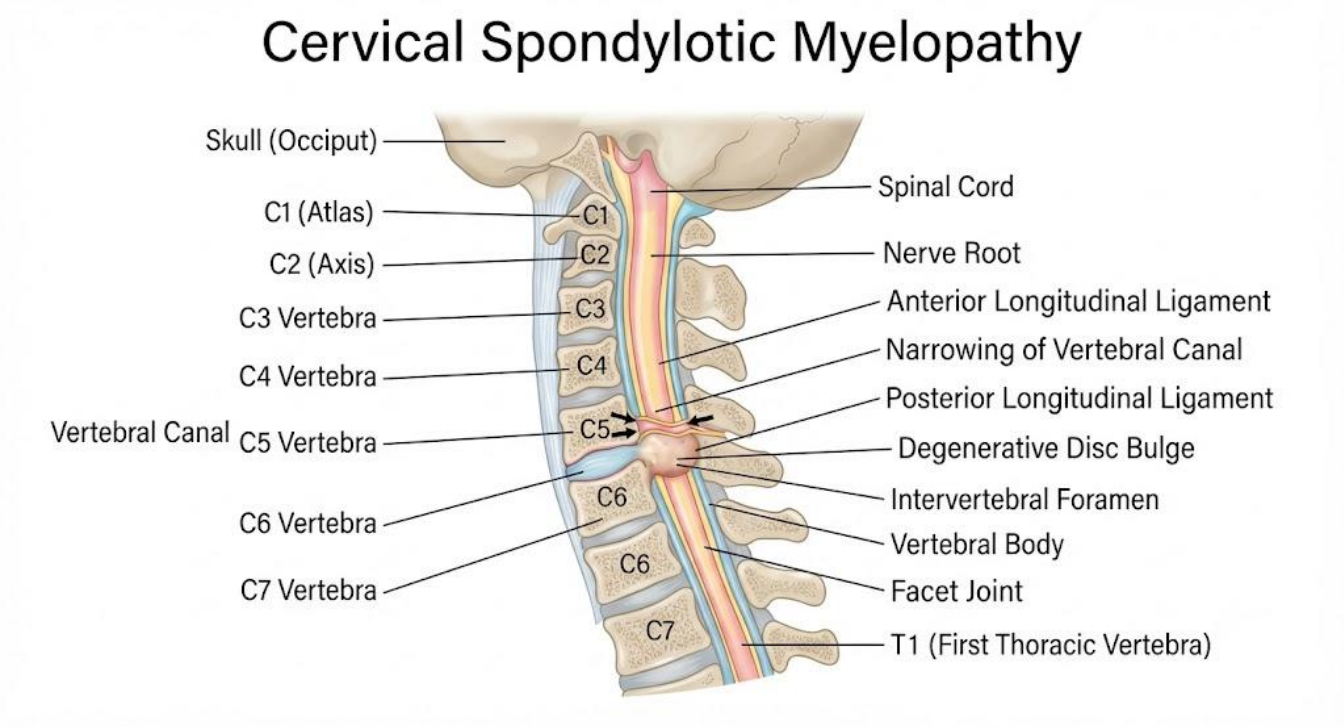

Figure 3.1: A labelled sagittal diagram of the cervical spine showing spondylotic cord compression.

Pilot questions 3.1

- Distinguish cervical spondylosis from cervical myelopathy. (Linked to SLO 3.1)
- Describe the clinical presentation of cervical myelopathy. (Linked to SLO 3.1)
- Describe sciatica and its typical cause. (Linked to SLO 3.2)
- Describe the general management approach to lumbar disc prolapse. (Linked to SLO 3.2)
- Distinguish neurogenic from vascular claudication. (Linked to SLO 3.2)

3.2 Spinal Tumours

3.2.1 classification of spinal tumours

Location relative to the dura and cord guides everything

Spinal tumours are classified by their anatomical relationship to the dura and spinal cord into three categories: **extradural**, lying outside the dura, **intradural-extramedullary**, lying within the dura but outside the spinal cord itself, and **intramedullary**, arising from within the spinal cord tissue itself, a classification carrying direct relevance to both the likely tumour type and the surgical approach required.

Extradural tumours are most commonly metastatic, reflecting the same principle already discussed for intracranial tumours in Series 2, while intradural-extramedullary tumours are frequently benign, such as meningioma or schwannoma, and intramedullary tumours, though less common overall, carry particular surgical challenge given their location within the functionally critical spinal cord tissue itself, requiring especially careful surgical technique to avoid worsening neurological function during resection.

Fill in the blank: Intradural-extramedullary tumours lie within the dura but outside the spinal _____ itself.

3.2.2 extradural spinal tumours

Most commonly, cancer that has spread to the spine

Extradural spinal tumours, most commonly metastatic deposits from breast, prostate, lung, or renal cancer, present with progressive back pain, often worse at night or with lying flat, alongside progressive neurological deficit as the tumour enlarges and compresses the spinal cord or nerve roots, a presentation that should always prompt urgent investigation given the genuine risk of rapid, potentially irreversible neurological deterioration if compression progresses unchecked.

Metastatic spinal cord compression is considered a genuine oncological and neurosurgical emergency, requiring urgent imaging, typically MRI of the whole spine given the possibility of multiple levels of involvement, and prompt treatment, which may include corticosteroids to reduce cord oedema, surgical decompression and stabilisation, and radiotherapy, chosen according to the specific tumour type, extent of disease, and the patient's overall prognosis and functional status.

Fill in the blank: Metastatic spinal cord compression requires urgent imaging, typically MRI of the _____ spine.

3.2.3 intradural spinal tumours

Tumours within the dura, benign and malignant alike

Intradural-extramedullary tumours, including meningioma and schwannoma, are generally benign and slow-growing, presenting with gradually progressive back or radicular pain and, as the tumour enlarges, spinal cord or nerve root compression, and are generally managed with surgical resection given their typically well-defined margin allowing complete removal with a good prognosis in the majority of cases.

Intramedullary tumours, including ependymoma and astrocytoma, arise from within the spinal cord tissue itself and present with progressive weakness, sensory disturbance, and pain that can be difficult to localise precisely to a single spinal level given the tumour's location within the cord parenchyma, and management requires especially careful, specialist microsurgical technique given the genuinely high stakes of operating directly within functioning spinal cord tissue.

Fill in the blank: Intramedullary tumours include ependymoma and _____.

Table 3.1: Comparing spinal tumour categories by location

Category	Location	Typical tumour type
Extradural	Outside the dura	Metastatic deposit
Intradural-extramedullary	Within dura, outside the cord	Meningioma or schwannoma
Intramedullary	Within the spinal cord	Ependymoma or astrocytoma

Pilot questions 3.2

1. List the three anatomical categories of spinal tumour. (Linked to SLO 3.3)
2. Explain why extradural tumours are most commonly metastatic. (Linked to SLO 3.4)
3. Describe metastatic spinal cord compression and why it is a genuine emergency. (Linked to SLO 3.4)
4. Describe the typical management of an intradural-extramedullary tumour. (Linked to SLO 3.4)

5. Explain why intramedullary tumour surgery requires especially careful technique. (Linked to SLO 3.4)

3.3 Spinal Infections

3.3.1 discitis and vertebral osteomyelitis

Infection of the disc and adjacent vertebral bone

Discitis, infection of the intervertebral disc, and **vertebral osteomyelitis**, infection of the adjacent vertebral bone, frequently occur together given their close anatomical relationship, presenting with progressive, often severe back pain, fever, and, in more advanced cases, neurological deficit if the infection extends to compress the spinal cord or nerve roots, a presentation with genuine potential to be initially mistaken for simple mechanical back pain if the possibility of infection is not actively considered.

Risk factors include intravenous drug use, diabetes, immunosuppression, and recent spinal surgery or intervention, and diagnosis relies on a combination of inflammatory markers, blood cultures, MRI imaging, and, where the diagnosis remains uncertain or the causative organism unidentified, image-guided biopsy to obtain tissue for culture and guide targeted antimicrobial therapy.

Fill in the blank: Discitis and vertebral osteomyelitis frequently occur together given their close anatomical _____.

3.3.2 spinal epidural abscess

A collection that can compress the cord directly

A **spinal epidural abscess**, a collection of pus within the epidural space, can arise as a complication of discitis and vertebral osteomyelitis, from haematogenous spread from a distant infection, or following spinal surgery or intervention, and presents with the classic, though not universally present, triad of back pain, fever, and neurological deficit, with the specific deficit reflecting the level and degree of cord or nerve root compression the abscess produces.

Given the genuine risk of rapid, potentially irreversible neurological deterioration if the abscess continues to compress the spinal cord, spinal epidural abscess is considered a neurosurgical emergency, requiring urgent MRI imaging, prompt initiation of broad-spectrum antibiotic

therapy, and, in cases with significant neurological deficit or a large collection causing significant cord compression, urgent surgical decompression and drainage.

Fill in the blank: Spinal epidural abscess presents with the classic triad of back pain, fever, and neurological _____.

3.3.3 principles of management of spinal infection

Balancing antimicrobial therapy against surgical need

Management of spinal infection, whether discitis, vertebral osteomyelitis, or epidural abscess, centres on prolonged, targeted antimicrobial therapy guided wherever possible by culture results, typically continued for several weeks to months given the relatively poor vascularity of infected bone and disc tissue and the correspondingly slower response to treatment compared with infection in better-vascularised tissue elsewhere.

Surgical intervention, whether for drainage of a significant abscess, decompression of neural structures, or stabilisation of the spine where infection has caused significant structural instability, is reserved for patients with significant neurological deficit, failure to respond to antimicrobial therapy alone, or genuine spinal instability, reflecting a generally conservative-first approach for spinal infection without significant neurological compromise, in contrast to the lower threshold for surgery in an intracranial infection already discussed in Series 2.

Fill in the blank: Antimicrobial therapy for spinal infection is typically continued for several weeks to _____.

Table 3.2: Comparing discitis, vertebral osteomyelitis, and spinal epidural abscess

Condition	Primary site	Key management focus
Discitis	Intervertebral disc	Prolonged targeted antimicrobial therapy
Vertebral osteomyelitis	Vertebral bone	Prolonged targeted antimicrobial therapy
Spinal epidural abscess	Epidural space	Urgent imaging, antibiotics, surgery if deficit

Pilot questions 3.3

1. List risk factors for discitis and vertebral osteomyelitis. (Linked to SLO 3.5)

2. Describe how the diagnosis of spinal infection is confirmed. (Linked to SLO 3.5)
3. Describe spinal epidural abscess and its classic triad. (Linked to SLO 3.5)
4. Explain why spinal epidural abscess is considered a neurosurgical emergency. (Linked to SLO 3.6)
5. Describe the indications for surgical intervention in spinal infection. (Linked to SLO 3.6)

3.4 Cauda Equina Syndrome and Surgical Principles

3.4.1 cauda equina syndrome

A genuine spinal surgical emergency

Cauda equina syndrome, compression of the bundle of nerve roots below the level of the spinal cord itself, most commonly from a large central lumbar disc prolapse, presents with bilateral leg pain and weakness, saddle anaesthesia, altered perianal sensation, and bladder or bowel dysfunction, typically urinary retention with overflow incontinence, a combination of symptoms that must be actively and specifically asked about in any patient presenting with significant back pain.

Recognising cauda equina syndrome promptly is genuinely critical, since delayed diagnosis and treatment carries a significant risk of permanent bladder, bowel, and sexual dysfunction, making this one of the few genuine spinal surgical emergencies requiring urgent MRI imaging and, where confirmed, emergency surgical decompression, typically within twenty-four to forty-eight hours of symptom onset, to maximise the chance of neurological recovery.

Fill in the blank: Cauda equina syndrome typically presents with urinary retention with overflow _____.

3.4.2 indications for spinal surgery

Deciding when the conservative approach has run its course

Beyond the genuine emergencies of cauda equina syndrome, metastatic spinal cord compression, and spinal epidural abscess with significant deficit already discussed, indications for elective spinal surgery include persistent, significant symptoms despite an adequate trial of conservative management, progressive neurological deficit, and genuine spinal instability, whether from trauma, tumour, infection, or severe degenerative disease, threatening neural structures or producing unacceptable pain and functional limitation.

The decision to proceed with elective spinal surgery genuinely requires careful weighing of the specific symptoms, imaging findings, and the patient's overall functional impact and expectations, since surgery for degenerative spine disease in particular carries a less guaranteed outcome than surgery for a clear structural emergency, making honest, thorough preoperative counselling about realistic expected benefit a genuinely essential part of the decision-making process.

Fill in the blank: Elective spinal surgery is generally indicated after persistent symptoms despite adequate _____ management.

3.4.3 principles of spinal surgical approaches

Reaching the spine from the front, back, or side

Spinal surgery can be approached **posteriorly**, the most common approach for many procedures including discectomy and decompression, **anteriorly**, particularly used for cervical disc disease and certain reconstructive procedures, or **laterally**, an approach increasingly used for specific lumbar procedures, with the choice guided by the specific pathology, the spinal level involved, and the surgeon's assessment of which approach provides the safest and most direct access to the target structure.

Instrumented fusion, using screws, rods, or cages to stabilise the spine following decompression, is added to the surgical plan where the underlying pathology or the extent of decompression required threatens spinal stability, and the decision to fuse, alongside the specific instrumentation technique chosen, depends on a careful individual assessment of the biomechanical consequences of the planned surgery for that specific patient and spinal level.

Fill in the blank: Instrumented fusion uses screws, rods, or cages to stabilise the spine following _____.

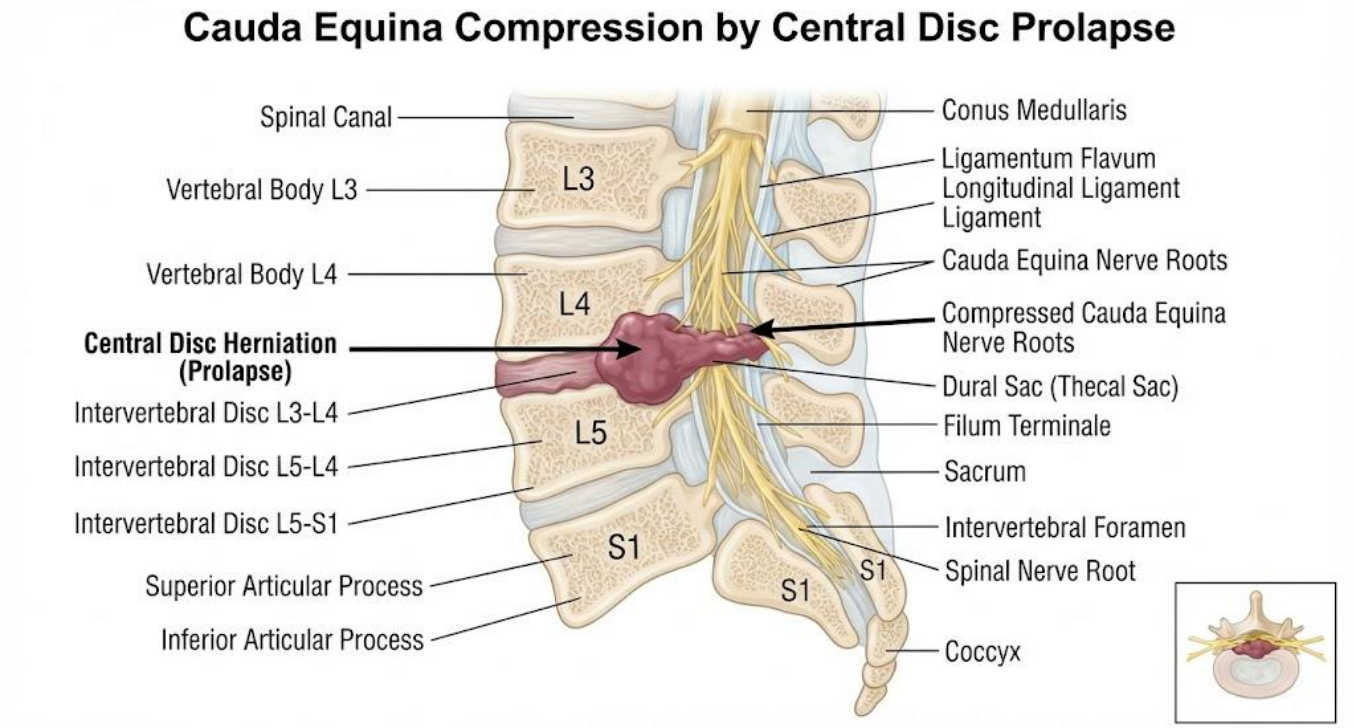

Figure 3.2: A labelled anatomical diagram of the cauda equina compressed by a central lumbar disc prolapse.

Pilot questions 3.4

1. List the key symptoms of cauda equina syndrome. (Linked to SLO 3.7)
2. Explain why prompt recognition of cauda equina syndrome is critical. (Linked to SLO 3.7)
3. List the indications for elective spinal surgery. (Linked to SLO 3.8)
4. Distinguish posterior, anterior, and lateral spinal surgical approaches. (Linked to SLO 3.8)
5. Explain when instrumented fusion is added to a spinal surgical plan. (Linked to SLO 3.8)

Series Summary

This Series worked through spinal cord lesions from degenerative disease through to the genuine surgical emergency of cauda equina syndrome. Part 3.1 covered degenerative spine disease, cervical myelopathy, disc prolapse, and spinal stenosis, while Part 3.2 turned to the classification and presentation of spinal tumours by anatomical location. Part 3.3 covered spinal infections,

discitis, vertebral osteomyelitis, and epidural abscess, and Part 3.4 closed with cauda equina syndrome and the general principles guiding spinal surgery.

You should now be able to describe degenerative spine disease, classify and describe spinal tumours, describe spinal infections, and recognise and manage cauda equina syndrome, meeting the outcomes set for this Series. Series 4 turns next to congenital malformations in neurosurgery and their management.

Glossary of Terms

1. **Cauda equina syndrome:** compression of the nerve root bundle below the spinal cord, a genuine surgical emergency.
2. **Cervical myelopathy:** spinal cord compression from cervical degenerative change, producing upper motor neuron signs.
3. **Discitis:** infection of the intervertebral disc.
4. **Extradural spinal tumour:** a spinal tumour lying outside the dura, most commonly metastatic.
5. **Instrumented fusion:** surgical stabilisation of the spine using screws, rods, or cages.
6. **Intradural-extramedullary tumour:** a spinal tumour within the dura but outside the spinal cord.
7. **Intramedullary tumour:** a spinal tumour arising from within the spinal cord tissue itself.
8. **Metastatic spinal cord compression:** cord compression from a metastatic tumour, a genuine oncological emergency.
9. **Neurogenic claudication:** leg symptoms from spinal stenosis, relieved by sitting or forward flexion.
10. **Sciatica:** pain radiating down the leg following the distribution of a compressed lumbar nerve root.
11. **Spinal epidural abscess:** a collection of pus within the spinal epidural space, a neurosurgical emergency.
12. **Vertebral osteomyelitis:** infection of the vertebral bone.

Concept Check Questions [Series 3]

Objective questions

- Cervical myelopathy presents with upper motor neuron signs such as hyperreflexia and _____ below the level of compression. (Linked to SLO 3.1)

- Intradural-extramedullary tumours lie within the dura but outside the spinal _____ itself. (Linked to SLO 3.3)
- Spinal epidural abscess presents with the classic triad of back pain, fever, and neurological _____. (Linked to SLO 3.5)
- Cauda equina syndrome typically presents with urinary retention with overflow _____. (Linked to SLO 3.7)
- Instrumented fusion uses screws, rods, or cages to stabilise the spine following _____. (Linked to SLO 3.8)

Short-answer questions

1. Describe sciatica and its typical cause. (Linked to SLO 3.2)
2. Explain why extradural tumours are most commonly metastatic. (Linked to SLO 3.4)
3. Describe spinal epidural abscess and its classic triad. (Linked to SLO 3.5)
4. List the key symptoms of cauda equina syndrome. (Linked to SLO 3.7)
5. List the indications for elective spinal surgery. (Linked to SLO 3.8)

Long-answer questions

6. Discuss degenerative spine disease, including cervical myelopathy, lumbar disc prolapse, and spinal stenosis. (Linked to SLO 3.1, 3.2)
7. Describe the classification and presentation of spinal tumours, including metastatic spinal cord compression. (Linked to SLO 3.3, 3.4)
8. Discuss the presentation and management of spinal infections. (Linked to SLO 3.5, 3.6)
9. Describe cauda equina syndrome and explain why prompt recognition is critical. (Linked to SLO 3.7)
10. Discuss the indications and principles of spinal surgery, including surgical approaches and instrumented fusion. (Linked to SLO 3.8)

Answers to Concept Check Questions [Series 3]

Objective questions

11. Spasticity.
12. Cord.
13. Deficit.
14. Incontinence.
15. Decompression.

Short-answer questions

16. Sciatica is pain radiating down the leg from a compressed lumbar nerve root, typically from disc prolapse.
17. Extradural tumours are metastatic because the vertebral bone is a common site for haematogenous spread from distant cancer.
18. A spinal epidural abscess presents with back pain, fever, and neurological deficit from compression.
19. Symptoms include bilateral leg pain and weakness, saddle anaesthesia, and bladder or bowel dysfunction.
20. Indications include persistent symptoms despite conservative management, progressive deficit, and spinal instability.

Long-answer questions

21. **Basic response:** Cervical myelopathy presents with upper limb clumsiness and gait disturbance from cord compression; lumbar disc prolapse causes sciatica; spinal stenosis causes neurogenic claudication relieved by forward flexion.

    Value-added response: A value-added response notes that most lumbar disc prolapses improve with conservative management over weeks to months.

22. **Basic response:** Spinal tumours are classified as extradural, intradural-extramedullary, or intramedullary; metastatic spinal cord compression presents with progressive back pain and deficit, a genuine oncological emergency.

    Value-added response: A value-added response notes that intramedullary tumours require especially careful microsurgical technique given their location within functioning cord tissue.

23. **Basic response:** Discitis and vertebral osteomyelitis present with severe back pain and fever; epidural abscess adds neurological deficit; management uses prolonged antimicrobial therapy with surgery reserved for deficit or instability.

    Value-added response: A value-added response notes that spinal infection management is generally more conservative than intracranial infection unless significant deficit is present.

24. **Basic response:** Cauda equina syndrome presents with bilateral leg symptoms, saddle anaesthesia, and bladder or bowel dysfunction; delayed treatment risks permanent dysfunction, making urgent decompression essential.

Value-added response: A value-added response notes that emergency decompression is typically undertaken within twenty-four to forty-eight hours to maximise recovery chances.

25. **Basic response:** Indications include emergencies, persistent symptoms, progressive deficit, and instability; approaches include posterior, anterior, and lateral; instrumented fusion stabilises the spine where decompression threatens stability.

    Value-added response: A value-added response notes that honest preoperative counselling about realistic benefit is essential given the less guaranteed outcome of degenerative spine surgery.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Cervical spondylosis is degenerative change, while cervical myelopathy is spinal cord compression from that change.
2. Cervical myelopathy presents with upper limb clumsiness, gait disturbance, and upper motor neuron signs.
3. Sciatica is pain radiating down the leg following a compressed nerve root's distribution, typically from disc prolapse.
4. Management is generally conservative first, with surgery reserved for persistent symptoms or progressive deficit.
5. Neurogenic claudication improves with forward flexion, while vascular claudication improves simply with rest.

Part 3.2

6. The three categories are extradural, intradural-extramedullary, and intramedullary.
7. Extradural tumours are metastatic because vertebral bone is a common site for haematogenous spread.
8. Metastatic spinal cord compression presents with progressive pain and deficit, a genuine oncological emergency given the risk of irreversible deterioration.
9. Intradural-extramedullary tumours are generally managed with surgical resection given their well-defined margins.
10. Intramedullary surgery requires careful technique given the high stakes of operating within functioning cord tissue.

Part 3.3

11. Risk factors include intravenous drug use, diabetes, immunosuppression, and recent spinal surgery.
12. Diagnosis relies on inflammatory markers, blood cultures, MRI, and biopsy where uncertain.
13. Spinal epidural abscess presents with back pain, fever, and neurological deficit from compression.
14. It is an emergency given the risk of rapid, irreversible neurological deterioration from ongoing compression.
15. Surgery is indicated for significant deficit, failure of antimicrobial therapy, or genuine spinal instability.

Part 3.4

1. Symptoms include bilateral leg pain and weakness, saddle anaesthesia, and bladder or bowel dysfunction.
2. Delayed treatment risks permanent bladder, bowel, and sexual dysfunction, making prompt recognition essential.
3. Indications include persistent symptoms despite conservative management, progressive deficit, and spinal instability.
4. Posterior is most common, anterior is used for cervical disc disease, and lateral is used for specific lumbar procedures.
5. Fusion is added when the pathology or extent of decompression threatens spinal stability.

References and Attributions [Series 3]

1. Greenberg, M. S. (2020). Handbook of Neurosurgery (9th ed.). Thieme.
2. Winn, H. R. (2016). Youmans and Winn Neurological Surgery (7th ed.). Elsevier.
3. Ellis, H., & Mahadevan, V. (2019). Clinical Anatomy (14th ed.). Wiley-Blackwell.
4. Williams, N. S., Bulstrode, C. J. K., & O'Connell, P. R. (2018). Bailey and Love's Short Practice of Surgery (27th ed.). CRC Press.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: A labelled sagittal diagram of the cervical spine showing spondylotic cord compression. AI-generated using the prompt: "Create a clean, accurate labelled sagittal anatomical diagram titled Cervical Spondylotic Myelopathy, showing a side view of the cervical vertebrae, intervertebral discs, and spinal cord, with a labelled area of degenerative disc bulging narrowing the canal and compressing the cord. Educational anatomical diagram style, no photographic content."
2. Table 3.1: Comparing spinal tumour categories by location. AI-generated using the prompt: "Create a clean reference table titled Comparing Spinal Tumour Categories by Location, listing category, location, and typical tumour type. Simple clinical reference table style with outside border."
3. Table 3.2: Comparing discitis, vertebral osteomyelitis, and spinal epidural abscess. AI-generated using the prompt: "Create a clean reference table titled Comparing Discitis, Vertebral Osteomyelitis, and Spinal Epidural Abscess, listing condition, primary site, and key management focus. Simple clinical reference table style with outside border."
4. Figure 3.2: A labelled anatomical diagram of the cauda equina compressed by a central lumbar disc prolapse. AI-generated using the prompt: "Create a clean, accurate labelled anatomical diagram titled Cauda Equina Compression by Central Disc Prolapse, showing a sagittal view of the lower lumbar spine with the cauda equina nerve roots and a labelled central disc herniation compressing the nerve bundle. Educational anatomical diagram style, no photographic content."

Course code: SUG 605

Course title: Neurosurgery

Course credit load: 2 Units

Series 4: Congenital Malformations in Neurosurgery and Their Management

- **Part 4.1: Neural Tube Defects**
  - Sub Part 4.1.1: Embryology of neural tube closure
  - Sub Part 4.1.2: Spina bifida occulta and spina bifida cystica
  - Sub Part 4.1.3: Myelomeningocele and its management
- **Part 4.2: Cranial Congenital Malformations**
  - Sub Part 4.2.1: Encephalocele
  - Sub Part 4.2.2: Craniosynostosis
  - Sub Part 4.2.3: Chiari malformation
- **Part 4.3: Spinal Congenital Malformations**
  - Sub Part 4.3.1: Tethered cord syndrome
  - Sub Part 4.3.2: Syringomyelia
  - Sub Part 4.3.3: Diastematomyelia
- **Part 4.4: General Principles of Management of Congenital Neurosurgical Malformations**
  - Sub Part 4.4.1: Antenatal diagnosis and counselling
  - Sub Part 4.4.2: Timing of surgical intervention
  - Sub Part 4.4.3: Long-term follow-up and multidisciplinary care

Introduction

This Series turns to a category of neurosurgical condition present from before birth, arising from errors during the earliest weeks of nervous system development, when the neural tube and skull are first taking shape. **Congenital malformations** in neurosurgery range from a completely asymptomatic incidental finding through to conditions requiring urgent surgical repair in the newborn period, and this Series works through the major categories affecting the spine, skull, and spinal cord in turn.

The aim of this Series is to equip you with an understanding of the embryological basis of neural tube defects, the classification and management of spina bifida and myelomeningocele, cranial congenital malformations including encephalocele, craniosynostosis, and Chiari malformation, spinal congenital malformations including tethered cord syndrome, syringomyelia, and diastematomyelia, and the general principles of antenatal diagnosis, timing of surgery, and long-term multidisciplinary care.

This Series opens with **neural tube defects**, moves through **cranial congenital malformations** and **spinal congenital malformations**, and closes with **general principles of management**.

Series Learning Outcomes

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

- **SLO 4.1:** describe the embryological basis of neural tube defects
- **SLO 4.2:** classify spina bifida and describe myelomeningocele and its management
- **SLO 4.3:** describe encephalocele and craniosynostosis
- **SLO 4.4:** discuss Chiari malformation
- **SLO 4.5:** describe tethered cord syndrome and syringomyelia
- **SLO 4.6:** describe diastematomyelia
- **SLO 4.7:** discuss antenatal diagnosis and the timing of surgical intervention for congenital neurosurgical malformations
- **SLO 4.8:** describe long-term follow-up and multidisciplinary care for congenital neurosurgical malformations

4.1 Neural Tube Defects

4.1.1 embryology of neural tube closure

A single closing zipper, and what happens if it fails

The **neural tube**, the embryological precursor to the brain and spinal cord, forms by folding and fusion of the neural plate during the third and fourth weeks of gestation, a process beginning in the middle of the developing embryo and progressing bidirectionally towards both the cranial and caudal ends, closing the cranial neuropore slightly before the caudal neuropore under normal circumstances.

Neural tube defects result from failure of this closure process at some point along its length, with the specific location and extent of failure determining the resulting malformation, ranging from a minor, asymptomatic bony defect to a severe, open defect exposing neural tissue, and adequate maternal **folic acid** intake before and during early pregnancy is well established to meaningfully reduce the risk of neural tube defects, underlining the genuine public health importance of preconception nutritional counselling.

Fill in the blank: Adequate maternal _____ intake before and during early pregnancy meaningfully reduces neural tube defect risk.

4.1.2 spina bifida occulta and spina bifida cystica

From a hidden bony gap to an open, visible defect

Spina bifida occulta, the mildest form, describes an isolated defect in the vertebral arch without herniation of underlying neural tissue, is frequently entirely asymptomatic, and is often identified incidentally on imaging performed for an unrelated reason, though it can occasionally be associated with cutaneous markers overlying the defect, such as a hairy patch, dimple, or lipoma, that should prompt further specific investigation.

Spina bifida cystica describes a more significant defect with herniation of the meninges, with or without neural tissue, through the vertebral defect, forming a visible sac, and is further subdivided into **meningocele**, herniation of meninges alone with the underlying neural tissue in a normal position, and **myelomeningocele**, herniation of both meninges and neural tissue, a genuinely more severe malformation carrying significant associated neurological deficit.

Fill in the blank: Spina bifida cystica forms a visible sac from herniation of the meninges through the vertebral _____.

4.1.3 myelomeningocele and its management

The most severe common neural tube defect

Myelomeningocele, the most severe common form of open spina bifida, presents at birth with a visible open or membrane-covered sac containing exposed or herniated neural tissue, typically in the lumbosacral region, and is associated with variable degrees of lower limb weakness, sensory loss, and bladder and bowel dysfunction depending on the specific level and extent of the underlying neural involvement.

Management involves early surgical closure of the defect, traditionally performed shortly after birth to reduce the risk of infection and further neural injury, though **fetal surgery**, repairing the defect before birth in appropriately selected cases, has emerged as an alternative in some specialist centres, offering the potential for improved neurological outcome at the cost of the additional maternal and fetal risks that any fetal surgical intervention inherently carries.

Fill in the blank: Fetal surgery for myelomeningocele repairs the defect _____ birth in appropriately selected cases.

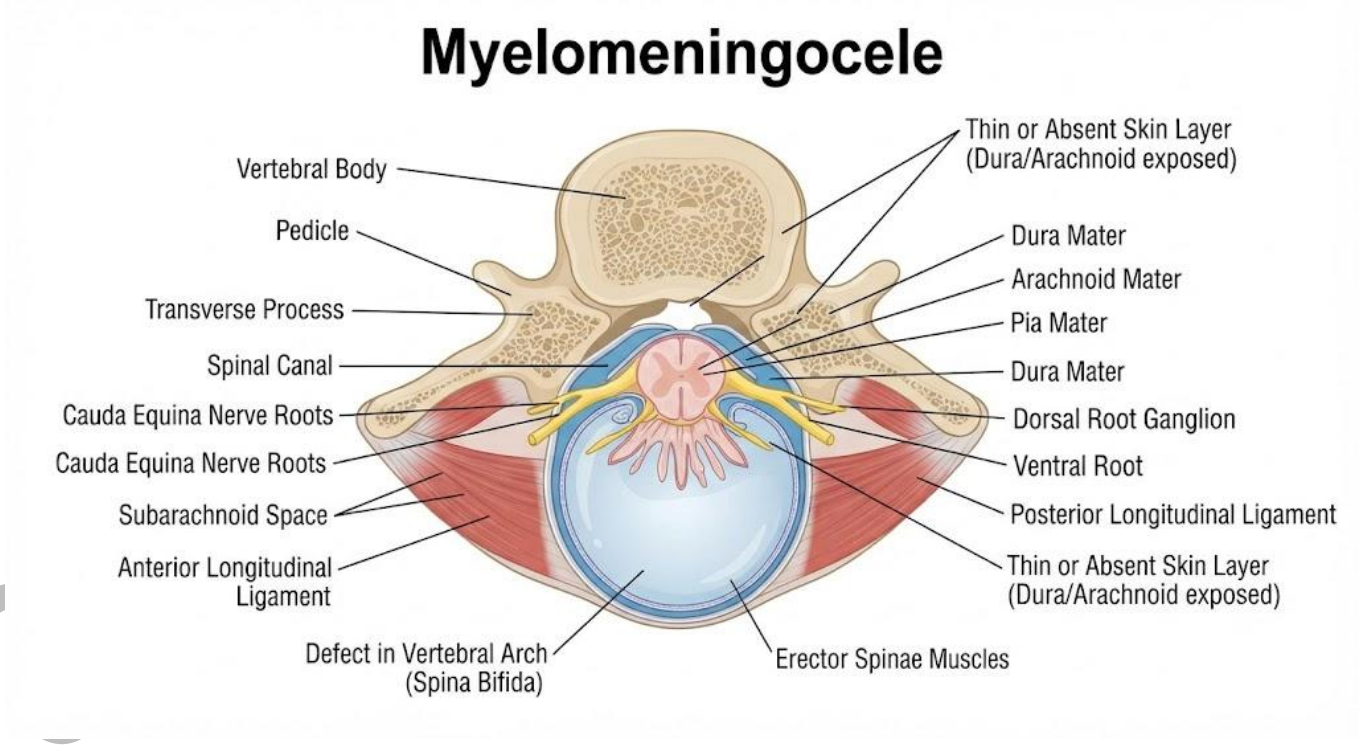

Figure 4.1: A labelled cross-sectional diagram of a myelomeningocele.

Pilot questions 4.1

- Describe the embryological process of neural tube closure. (Linked to SLO 4.1)

- Explain the role of folic acid in reducing neural tube defect risk. (Linked to SLO 4.1)
- Distinguish spina bifida occulta from spina bifida cystica. (Linked to SLO 4.2)
- Distinguish meningocele from myelomeningocele. (Linked to SLO 4.2)
- Describe the management of myelomeningocele, including fetal surgery. (Linked to SLO 4.2)

4.2 Cranial Congenital Malformations

4.2.1 encephalocele

Brain tissue herniating through a skull defect

An **encephalocele**, herniation of meninges and, in most cases, brain tissue through a congenital skull defect, most commonly occurs in the occipital region in Western populations, though frontal and nasal locations are also recognised, particularly in certain other populations, and presents as a visible, often sizeable, midline swelling covered by skin or a thin, translucent membrane.

The extent of associated neurological deficit and other congenital anomalies varies considerably depending on the amount and specific location of brain tissue involved in the herniation, and management involves surgical repair, typically undertaken in the early postnatal period, aiming to safely reduce the herniated contents where viable, repair the dural and skull defect, and provide skin coverage, with the overall prognosis depending heavily on the volume and functional significance of the involved neural tissue.

Fill in the blank: Encephalocele most commonly occurs in the _____ region in Western populations.

4.2.2 craniosynostosis

Skull sutures that fuse too early

Craniosynostosis, premature fusion of one or more cranial sutures before normal brain growth is complete, restricts skull growth perpendicular to the fused suture while allowing compensatory growth in other directions, producing a characteristic, recognisable head shape depending on which specific suture or sutures are affected, a pattern-recognition skill genuinely important for accurate clinical diagnosis before imaging confirmation.

While isolated craniosynostosis is often primarily a cosmetic concern, involvement of multiple sutures, or craniosynostosis occurring as part of a recognised genetic syndrome, carries a genuine risk of restricting overall brain growth and raising intracranial pressure, making surgical correction, typically involving remodelling of the affected skull, an important intervention in more significant cases beyond cosmetic considerations alone.

Fill in the blank: Craniosynostosis restricts skull growth perpendicular to the _____ suture.

4.2.3 chiari malformation

The cerebellum descending where it should not

Chiari malformation describes downward displacement of the cerebellar tonsils through the foramen magnum into the upper cervical spinal canal, classified into several types according to severity and associated abnormalities, with **type one**, the mildest and most common form, frequently asymptomatic and identified incidentally, though it can present with occipital headache characteristically worsened by coughing or straining, and, in more significant cases, symptoms from associated syringomyelia.

More severe types of Chiari malformation are typically associated with myelomeningocele and other significant central nervous system abnormalities, presenting in infancy with brainstem dysfunction that can be genuinely life-threatening, and management of symptomatic Chiari malformation, across the range of severity, generally involves **posterior fossa decompression**, surgically enlarging the space around the foramen magnum to relieve the crowding and restore normal cerebrospinal fluid flow at this critical anatomical junction.

Fill in the blank: Chiari malformation type one is frequently associated with occipital headache worsened by coughing or _____.

Table 4.1: Comparing encephalocele, craniosynostosis, and Chiari malformation

Condition	Structure primarily affected	Key management approach
Encephalocele	Skull defect with tissue herniation	Early surgical repair and closure
Craniosynostosis	Premature cranial suture fusion	Skull remodelling for significant cases
Chiari malformation	Cerebellar tonsil descent	Posterior fossa decompression if symptomatic

Pilot questions 4.2

1. Describe encephalocele and its typical location. (Linked to SLO 4.3)
2. Explain the management principle for a repaired encephalocele. (Linked to SLO 4.3)
3. Describe craniosynostosis and how it affects skull growth. (Linked to SLO 4.3)
4. Explain when craniosynostosis requires surgical correction beyond cosmetic concern. (Linked to SLO 4.3)
5. Describe Chiari malformation type one and its typical presentation. (Linked to SLO 4.4)

4.3 Spinal Congenital Malformations

4.3.1 tethered cord syndrome

A spinal cord anchored where it should be free to move

Tethered cord syndrome describes abnormal fixation of the spinal cord, preventing its normal upward relative movement within the spinal canal as the child grows, most commonly due to a thickened or fatty filum terminale, and, as growth continues, this fixation produces progressive traction on the cord, presenting with back pain, progressive lower limb weakness, sensory disturbance, and bladder or bowel dysfunction that can develop insidiously over months to years.

Cutaneous markers overlying the lower spine, such as a hairy patch, dimple, or lipoma already mentioned in relation to spina bifida occulta, should prompt specific investigation for an underlying tethered cord, and surgical **untethering**, releasing the abnormal fixation, is generally recommended once the diagnosis is confirmed to halt progression of symptoms, though established neurological deficit does not always fully reverse even with successful surgical release.

Fill in the blank: Tethered cord syndrome is most commonly due to a thickened or fatty filum _____.

4.3.2 syringomyelia

A fluid-filled cavity forming within the cord

Syringomyelia, a fluid-filled cavity forming within the spinal cord parenchyma, is frequently associated with Chiari malformation, though it can also arise following spinal trauma, infection, or in association with a spinal tumour, and presents with a characteristic pattern of dissociated sensory loss, loss of pain and temperature sensation with relative preservation of light touch and

proprioception, reflecting the specific anatomical tracts affected as the expanding cavity disrupts fibres crossing near the centre of the cord.

As the syrinx enlarges, progressive weakness and muscle wasting, characteristically affecting the upper limbs, and, over time, more widespread neurological deficit can develop, and management depends heavily on the underlying cause, with treatment of an associated Chiari malformation through posterior fossa decompression often leading to improvement or stabilisation of an associated syrinx, while direct syrinx drainage is reserved for cases without a clearly treatable underlying cause or that fail to respond to treatment of the primary condition.

Fill in the blank: Syringomyelia presents with dissociated sensory loss, loss of pain and temperature sensation with preserved light _____.

4.3.3 diastematomyelia

A spinal cord divided by a bony or fibrous septum

Diastematomyelia, a rare congenital malformation in which the spinal cord is split into two hemicords by a bony, cartilaginous, or fibrous septum, is frequently associated with other spinal congenital abnormalities including vertebral anomalies and tethered cord, and, like tethered cord, can present with progressive neurological deficit as the child grows and the fixed septum increasingly restricts the normal relative movement of the divided cord.

Cutaneous markers overlying the affected spinal level are again a recognised association worth actively looking for, and management of a symptomatic or progressively enlarging diastematomyelia involves surgical resection of the septum, generally combined with untethering of the cord where a tethering element coexists, since these two closely related pathologies frequently require addressing together within the same surgical procedure for a genuinely complete treatment of the underlying problem.

Fill in the blank: Diastematomyelia splits the spinal cord into two _____ by a bony, cartilaginous, or fibrous septum.

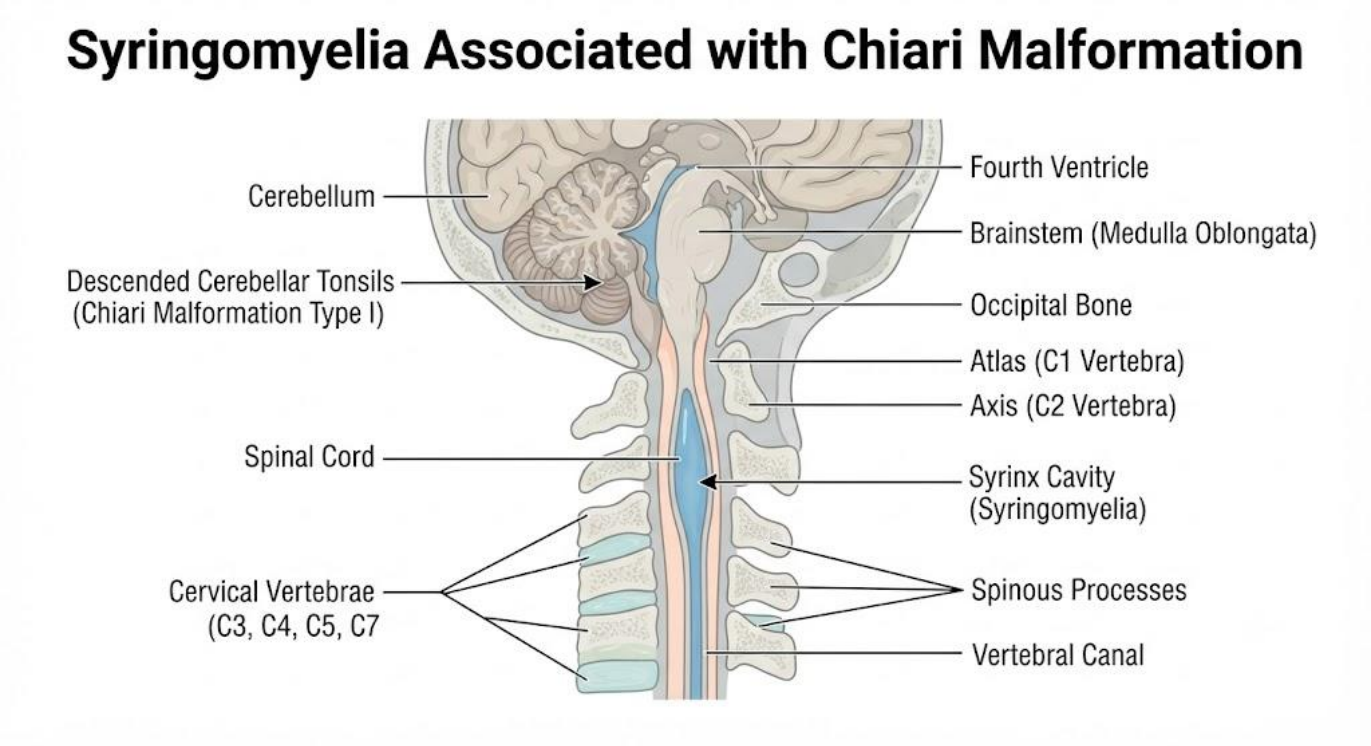

Figure 4.2: A labelled anatomical diagram of syringomyelia associated with Chiari malformation.

Pilot questions 4.3

1. Describe tethered cord syndrome and its typical cause. (Linked to SLO 4.5)
2. List cutaneous markers that should prompt investigation for tethered cord. (Linked to SLO 4.5)
3. Describe the sensory pattern characteristic of syringomyelia. (Linked to SLO 4.5)
4. Explain why treating an associated Chiari malformation can improve syringomyelia. (Linked to SLO 4.5)
5. Describe diastematomyelia and its typical management. (Linked to SLO 4.6)

4.4 General Principles of Management of Congenital Neurosurgical Malformations

4.4.1 antenatal diagnosis and counselling

Preparing families before the child is even born

Antenatal diagnosis of many congenital neurosurgical malformations, including neural tube defects and some cranial abnormalities, is now achievable through detailed antenatal ultrasound,

sometimes supplemented by fetal MRI for more detailed anatomical characterisation, allowing affected families to receive counselling about the specific diagnosis, expected severity, and available management options well before delivery.

Thorough, honest **antenatal counselling**, ideally delivered by a multidisciplinary team including obstetricians, neurosurgeons, and specialist nurses, allows a family to make informed decisions about the pregnancy and to prepare practically and emotionally for the birth of a child with a significant congenital malformation, and this counselling process itself is a genuinely important component of overall care, not merely a preliminary step before the medical management that follows.

Fill in the blank: Antenatal counselling allows a family to make informed decisions and prepare practically and _____ for the birth.

4.4.2 timing of surgical intervention

Balancing urgency against physiological readiness

The **timing** of surgical intervention for a congenital neurosurgical malformation varies considerably depending on the specific condition, from the genuine urgency of early myelomeningocele closure to reduce infection risk, through the more elective timing of craniosynostosis correction typically planned within the first year of life, to conditions such as asymptomatic tethered cord or mild Chiari malformation where surgery may be deferred indefinitely in the absence of progressive symptoms.

This variation in timing reflects the same underlying principle already discussed for congenital cardiothoracic malformations in an earlier course, balancing the severity and progression risk of the specific condition against the physiological ability of the infant or child to safely tolerate anaesthesia and surgery at a given developmental stage, a balance requiring genuine individualised clinical judgement rather than a single fixed protocol applied uniformly across every congenital neurosurgical condition.

Fill in the blank: Timing of surgery balances condition severity against the child's physiological ability to tolerate _____.

4.4.3 long-term follow-up and multidisciplinary care

A journey that continues well beyond the operating theatre

Long-term follow-up for children treated for a congenital neurosurgical malformation typically continues throughout childhood and, for many conditions, into adulthood, monitoring for late

complications such as tethering recurrence, hydrocephalus development, or syrinx progression, and supporting the child's developmental, functional, and psychosocial needs as they grow, since the initial surgical repair, however successful, rarely represents the complete resolution of the underlying condition's lifelong implications.

Multidisciplinary care, drawing on neurosurgeons, urologists, orthopaedic surgeons, physiotherapists, and specialist nurses, alongside close, ongoing collaboration with the family, is genuinely essential given the frequently multi-system nature of these congenital conditions, particularly myelomeningocele with its associated bladder, bowel, and orthopaedic implications, reflecting the same collaborative principle already emphasised across earlier Series and courses in this programme.

Fill in the blank: Long-term follow-up monitors for late complications such as tethering recurrence and _____ development.

Table 4.2: General timing principles across congenital neurosurgical malformations

Condition	Typical timing of intervention	Key consideration
Myelomeningocele	Shortly after birth, or fetal surgery	Infection and further neural injury risk
Craniosynostosis	Typically within the first year of life	Balancing brain growth against surgical timing
Asymptomatic tethered cord	May be deferred indefinitely	Monitoring for progressive symptoms

Pilot questions 4.4

1. Describe how antenatal diagnosis is achieved for congenital neurosurgical malformations. (Linked to SLO 4.7)
2. Explain the value of thorough antenatal counselling. (Linked to SLO 4.7)
3. Describe the range of timing for surgical intervention across different congenital conditions. (Linked to SLO 4.7)
4. Explain why long-term follow-up remains important after successful surgical repair. (Linked to SLO 4.8)
5. Describe the components of multidisciplinary care for a child with myelomeningocele. (Linked to SLO 4.8)

Series Summary

This Series covered congenital malformations in neurosurgery from their embryological origins through to long-term management. Part 4.1 covered neural tube defects, spina bifida, and myelomeningocele, while Part 4.2 turned to cranial congenital malformations, encephalocele, craniosynostosis, and Chiari malformation. Part 4.3 covered spinal congenital malformations, tethered cord syndrome, syringomyelia, and diastematomyelia, and Part 4.4 closed with the general principles of antenatal diagnosis, timing of surgery, and long-term multidisciplinary care.

You should now be able to describe the embryological basis, classification, and management of the congenital neurosurgical malformations covered across all four Parts of this Series, meeting the outcomes set for this Series. Series 5 turns next to evaluation of the neurosurgical patient and intracranial haemorrhage.

Glossary of Terms

1. **Chiari malformation:** downward displacement of the cerebellar tonsils through the foramen magnum.
2. **Craniosynostosis:** premature fusion of one or more cranial sutures.
3. **Diastematomyelia:** a spinal cord split into two hemicords by a bony or fibrous septum.
4. **Encephalocele:** herniation of meninges and brain tissue through a congenital skull defect.
5. **Fetal surgery:** surgical repair of a congenital defect performed before birth.
6. **Myelomeningocele:** the most severe common form of open spina bifida, with herniated neural tissue.
7. **Neural tube defect:** a congenital malformation from failure of neural tube closure.
8. **Posterior fossa decompression:** surgery enlarging the space around the foramen magnum for Chiari malformation.
9. **Spina bifida occulta:** an isolated vertebral arch defect without herniation of neural tissue.
10. **Syringomyelia:** a fluid-filled cavity forming within the spinal cord.
11. **Tethered cord syndrome:** abnormal fixation of the spinal cord preventing normal upward movement.
12. **Untethering:** surgical release of an abnormal spinal cord fixation.

Concept Check Questions [Series 4]

Objective questions

- Adequate maternal _____ intake before and during early pregnancy meaningfully reduces neural tube defect risk. (Linked to SLO 4.1)
- Encephalocele most commonly occurs in the _____ region in Western populations. (Linked to SLO 4.3)
- Chiari malformation type one is frequently associated with occipital headache worsened by coughing or _____. (Linked to SLO 4.4)
- Tethered cord syndrome is most commonly due to a thickened or fatty filum _____. (Linked to SLO 4.5)
- Timing of surgery balances condition severity against the child's physiological ability to tolerate _____. (Linked to SLO 4.7)

Short-answer questions

1. Distinguish meningocele from myelomeningocele. (Linked to SLO 4.2)
2. Describe craniosynostosis and how it affects skull growth. (Linked to SLO 4.3)
3. Describe the sensory pattern characteristic of syringomyelia. (Linked to SLO 4.5)
4. Describe diastematomyelia and its typical management. (Linked to SLO 4.6)
5. Explain why long-term follow-up remains important after successful surgical repair. (Linked to SLO 4.8)

Long-answer questions

6. Discuss neural tube defects, including the classification of spina bifida and the management of myelomeningocele. (Linked to SLO 4.1, 4.2)
7. Describe encephalocele, craniosynostosis, and Chiari malformation. (Linked to SLO 4.3, 4.4)
8. Discuss tethered cord syndrome, syringomyelia, and diastematomyelia. (Linked to SLO 4.5, 4.6)
9. Describe the principles of antenatal diagnosis and counselling for congenital neurosurgical malformations. (Linked to SLO 4.7)
10. Discuss the timing of surgical intervention and the role of long-term multidisciplinary follow-up. (Linked to SLO 4.7, 4.8)

Answers to Concept Check Questions [Series 4]

Objective questions

11. Folic acid.
12. Occipital.
13. Straining.
14. Terminale.
15. Surgery.

Short-answer questions

16. Meningocele involves herniation of meninges alone, while myelomeningocele involves herniation of both meninges and neural tissue.
17. Craniosynostosis is premature suture fusion, restricting growth perpendicular to the fused suture while allowing compensatory growth elsewhere.
18. Syringomyelia causes dissociated sensory loss, with loss of pain and temperature sensation and preserved light touch and proprioception.
19. Diastematomyelia splits the cord into two hemicords by a septum, managed with surgical resection often combined with untethering.
20. Follow-up monitors for late complications such as tethering recurrence or hydrocephalus and supports ongoing developmental needs.

Long-answer questions

21. **Basic response:** Neural tube defects result from failed closure during early gestation; spina bifida ranges from occulta to cystica, with myelomeningocele the most severe form, managed with early surgical closure or fetal surgery.

    Value-added response: A value-added response notes that adequate maternal folic acid intake meaningfully reduces the risk of neural tube defects.

22. **Basic response:** Encephalocele is herniation of tissue through a skull defect, typically occipital; craniosynostosis is premature suture fusion producing a characteristic head shape; Chiari malformation is cerebellar tonsil descent, managed with posterior fossa decompression if symptomatic.

    Value-added response: A value-added response notes that more severe Chiari types are typically associated with myelomeningocele and other significant abnormalities.

23. **Basic response:** Tethered cord syndrome is abnormal cord fixation causing progressive traction symptoms; syringomyelia is a fluid-filled cavity within the cord, often associated with Chiari malformation; diastematomyelia splits the cord with a septum.

    Value-added response: A value-added response notes that these spinal congenital conditions frequently coexist and are often addressed together surgically.

24. **Basic response:** Antenatal ultrasound, sometimes supplemented by fetal MRI, allows diagnosis before birth, with multidisciplinary counselling supporting informed family decision-making and preparation.

    Value-added response: A value-added response notes that this counselling process is a genuinely important component of overall care, not merely a preliminary step.

25. **Basic response:** Timing varies from urgent myelomeningocele closure to elective craniosynostosis correction to deferred surgery for asymptomatic conditions; long-term multidisciplinary follow-up monitors for late complications and supports developmental needs.

    Value-added response: A value-added response notes that myelomeningocele in particular requires ongoing input across bladder, bowel, and orthopaedic specialties given its multi-system implications.

Answers to Pilot Questions [Series 4]

Part 4.1

1. The neural tube forms by folding and fusion of the neural plate during the third and fourth weeks of gestation.
2. Adequate folic acid intake before and during early pregnancy meaningfully reduces neural tube defect risk.
3. Spina bifida occulta is a hidden bony defect without herniation, while spina bifida cystica forms a visible sac.
4. Meningocele involves meninges alone, while myelomeningocele involves both meninges and neural tissue.
5. Management involves early surgical closure after birth, or fetal surgery before birth in selected cases.

Part 4.2

6. Encephalocele is herniation of tissue through a skull defect, most commonly in the occipital region.
7. Management aims to safely reduce herniated contents, repair the defect, and provide skin coverage.
8. Craniosynostosis is premature suture fusion, restricting growth perpendicular to the affected suture.
9. Surgical correction is needed when multiple sutures are involved or a genetic syndrome raises intracranial pressure risk.
10. Chiari malformation type one is often asymptomatic but can cause occipital headache worsened by coughing.

Part 4.3

11. Tethered cord syndrome is abnormal cord fixation, most commonly from a thickened or fatty filum terminale.
12. Markers include a hairy patch, dimple, or lipoma overlying the lower spine.
13. Syringomyelia causes dissociated sensory loss with pain and temperature loss and preserved light touch.
14. Treating Chiari malformation restores normal cerebrospinal fluid flow, often improving an associated syrinx.
15. Diastematomyelia splits the cord with a septum, managed with surgical resection often combined with untethering.

Part 4.4

1. Antenatal diagnosis uses detailed ultrasound, sometimes supplemented by fetal MRI.
2. Thorough counselling allows informed family decision-making and practical and emotional preparation.
3. Timing ranges from urgent early closure to elective correction within the first year to deferred surgery if asymptomatic.
4. Follow-up is important because initial repair rarely represents complete resolution of lifelong implications.
5. Multidisciplinary care draws on neurosurgeons, urologists, orthopaedic surgeons, and specialist nurses.

References and Attributions [Series 4]

1. Greenberg, M. S. (2020). Handbook of Neurosurgery (9th ed.). Thieme.
2. Winn, H. R. (2016). Youmans and Winn Neurological Surgery (7th ed.). Elsevier.
3. Coran, A. G. (2012). Pediatric Surgery (7th ed.). Elsevier.
4. Ellis, H., & Mahadevan, V. (2019). Clinical Anatomy (14th ed.). Wiley-Blackwell.

Figures, Plates, Tables, and Boxes

1. Figure 4.1: A labelled cross-sectional diagram of a myelomeningocele. AI-generated using the prompt: "Create a clean, accurate labelled cross-sectional anatomical diagram titled Myelomeningocele, showing a transverse section of the lower spine with a labelled defect in the vertebral arch and herniation of the meninges and spinal cord tissue through the opening. Educational anatomical diagram style, no photographic content."
2. Table 4.1: Comparing encephalocele, craniosynostosis, and Chiari malformation. AI-generated using the prompt: "Create a clean reference table titled Comparing Encephalocele, Craniosynostosis, and Chiari Malformation, listing condition, structure primarily affected, and key management approach. Simple clinical reference table style with outside border."
3. Figure 4.2: A labelled anatomical diagram of syringomyelia associated with Chiari malformation. AI-generated using the prompt: "Create a clean, accurate labelled anatomical diagram titled Syringomyelia Associated with Chiari Malformation, showing a sagittal view of the craniocervical junction with descended cerebellar tonsils at the foramen magnum and a labelled fluid-filled syrinx cavity within the cervical spinal cord below. Educational anatomical diagram style, no photographic content."
4. Table 4.2: General timing principles across congenital neurosurgical malformations. AI-generated using the prompt: "Create a clean reference table titled General Timing Principles Across Congenital Neurosurgical Malformations, listing condition, typical timing of intervention, and key consideration. Simple clinical reference table style with outside border."

Course code: SUG 605

Course title: Neurosurgery

Course credit load: 2 Units

Series 5: Evaluation of the Neurosurgical Patient and Intracranial Haemorrhage

- **Part 5.1: Neurological Examination and Evaluation**
  - Sub Part 5.1.1: Principles of neurological history taking
  - Sub Part 5.1.2: Cranial nerve examination
  - Sub Part 5.1.3: Motor and sensory examination
- **Part 5.2: Neuroimaging and Preoperative Evaluation**
  - Sub Part 5.2.1: CT and MRI in neurosurgery
  - Sub Part 5.2.2: Cerebral angiography
  - Sub Part 5.2.3: Preoperative assessment and optimisation
- **Part 5.3: Subarachnoid Haemorrhage and Aneurysms**
  - Sub Part 5.3.1: Subarachnoid haemorrhage: presentation and diagnosis
  - Sub Part 5.3.2: Cerebral aneurysms
  - Sub Part 5.3.3: Management and complications of subarachnoid haemorrhage
- **Part 5.4: Intracerebral and Other Intracranial Haemorrhage**
  - Sub Part 5.4.1: Intracerebral haemorrhage
  - Sub Part 5.4.2: Arteriovenous malformations
  - Sub Part 5.4.3: Principles of management of intracranial haemorrhage

Introduction

This final Series brings together the examination and imaging skills that underpin every neurosurgical diagnosis discussed across the course, before turning to intracranial haemorrhage, a category of neurosurgical emergency distinct from the trauma-related haematomas covered in Series 1, arising instead from ruptured aneurysms, vascular malformations, and spontaneous bleeding into the brain itself. **Evaluation of the neurosurgical patient** is the thread running through every Series in this course, and this closing Series makes that thread explicit.

The aim of this Series is to equip you with the ability to perform a structured neurological history and examination, including cranial nerve, motor, and sensory assessment, describe the role of CT, MRI, and cerebral angiography in neurosurgical evaluation, and describe the presentation, diagnosis, and management of subarachnoid haemorrhage, cerebral aneurysms, intracerebral haemorrhage, and arteriovenous malformations.

This Series opens with **neurological examination and evaluation**, moves through **neuroimaging and preoperative evaluation** and **subarachnoid haemorrhage and aneurysms**, and closes with **intracerebral and other intracranial haemorrhage**.

Series Learning Outcomes

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

- **SLO 5.1:** describe the principles of neurological history taking and cranial nerve examination
- **SLO 5.2:** describe motor and sensory examination in the neurosurgical patient
- **SLO 5.3:** discuss the role of CT, MRI, and cerebral angiography in neurosurgical evaluation
- **SLO 5.4:** describe preoperative assessment and optimisation of the neurosurgical patient
- **SLO 5.5:** describe the presentation and diagnosis of subarachnoid haemorrhage
- **SLO 5.6:** discuss cerebral aneurysms and the management of subarachnoid haemorrhage
- **SLO 5.7:** describe intracerebral haemorrhage and arteriovenous malformations
- **SLO 5.8:** discuss the principles of managing intracranial haemorrhage

5.1 Neurological Examination and Evaluation

5.1.1 principles of neurological history taking

Localising the lesion before ever touching the patient

A thorough **neurological history** aims to localise the underlying lesion anatomically and characterise its likely nature before examination even begins, covering the onset, progression, and specific character of symptoms such as headache, weakness, sensory disturbance, visual change, or seizures, since the temporal pattern, sudden versus gradual onset, and the specific combination of symptoms reported together meaningfully narrow the differential diagnosis.

Headache in particular warrants careful characterisation, since certain features, sudden onset described as the worst headache of the patient's life, associated neck stiffness, or new headache in an older patient, are recognised red flags that should prompt urgent further evaluation for a potentially serious underlying cause, such as the subarachnoid haemorrhage discussed later in this Series, rather than being attributed reflexively to a benign primary headache disorder.

Fill in the blank: A sudden headache described as the worst of the patient's life is a recognised red flag requiring _____ evaluation.

5.1.2 cranial nerve examination

Twelve nerves, each with its own story to tell

Cranial nerve examination is performed systematically from the first to the twelfth nerve, assessing smell, visual acuity and fields, pupillary response, eye movements, facial sensation and movement, hearing, palatal and pharyngeal function, tongue movement, and shoulder shrug, with abnormalities in specific combinations of cranial nerves helping to localise a lesion to a specific anatomical region, such as the brainstem, cavernous sinus, or cerebellopontine angle.

A single cranial nerve palsy in isolation, such as an isolated third nerve palsy producing ptosis and a dilated, unreactive pupil, carries particular diagnostic weight and should prompt urgent evaluation for a compressive lesion, such as a posterior communicating artery aneurysm, given the third nerve's specific anatomical course adjacent to this vessel, a genuinely important clinical association worth actively remembering.

Fill in the blank: An isolated third nerve palsy with a dilated pupil should prompt urgent evaluation for a compressive _____.

5.1.3 motor and sensory examination

Mapping function limb by limb, dermatome by dermatome

Motor examination systematically assesses tone, power, and reflexes in each limb, with power conventionally graded on a standardised scale from zero, no movement, to five, normal strength against resistance, and the specific pattern of weakness, whether affecting a single limb, one side of the body, or both legs, provides essential localising information about the level and nature of the underlying lesion.

Sensory examination assesses light touch, pinprick, vibration, and proprioception in a systematic, dermatomal pattern, and, combined with the motor findings, allows a specific anatomical level of pathology to be proposed with reasonable confidence, a skill directly applicable to the spinal cord lesions already discussed in Series 3 as well as to intracranial pathology affecting specific sensorimotor pathways.

Fill in the blank: Motor power is conventionally graded on a standardised scale from zero to _____.

Figure 5.1: A clinician testing facial nerve function during cranial nerve examination.

Pilot questions 5.1

- Explain why the temporal pattern of symptom onset matters in neurological history taking. (Linked to SLO 5.1)
- List red flag features of headache that warrant urgent evaluation. (Linked to SLO 5.1)
- Describe the systematic approach to cranial nerve examination. (Linked to SLO 5.1)
- Explain the significance of an isolated third nerve palsy with a dilated pupil. (Linked to SLO 5.1)
- Describe the standardised scale used to grade motor power. (Linked to SLO 5.2)

5.2 Neuroimaging and Preoperative Evaluation

5.2.1 ct and mri in neurosurgery

Two complementary windows into the brain and spine

Computed tomography, rapidly available and excellent for detecting acute haemorrhage, bony injury, and mass effect, remains the first-line investigation in the emergency setting for suspected intracranial pathology, including head injury and suspected acute stroke, given its speed and wide availability, even though it offers less detailed soft tissue characterisation than magnetic resonance imaging.

Magnetic resonance imaging, providing considerably superior soft tissue contrast and multiplanar imaging without ionising radiation, is generally preferred for detailed characterisation of tumours, demyelinating disease, and spinal pathology, and for surgical planning, though its longer acquisition time and lesser suitability for acutely unstable patients means CT frequently remains the more practical first investigation in an emergency, with MRI following once the patient is sufficiently stable.

Fill in the blank: MRI provides considerably superior soft tissue contrast without ionising _____.

5.2.2 cerebral angiography

Directly visualising the cerebral blood vessels

Cerebral angiography, performed either as conventional catheter angiography or non-invasively as CT or MR angiography, directly visualises the cerebral vasculature and remains

essential for characterising a suspected aneurysm or arteriovenous malformation, precisely delineating its anatomy to guide the choice between surgical and endovascular treatment, a decision genuinely dependent on the specific vascular anatomy demonstrated.

Conventional catheter angiography offers superior spatial and temporal resolution compared with CT or MR angiography, and, since it also permits immediate endovascular treatment during the same procedure where appropriate, remains the gold standard investigation for many cerebrovascular conditions despite being more invasive than the cross-sectional alternatives, a genuine trade-off between diagnostic superiority and procedural risk that must be weighed for each individual patient.

Fill in the blank: Conventional catheter angiography permits immediate endovascular _____ during the same procedure where appropriate.

5.2.3 preoperative assessment and optimisation

Preparing the patient, not just planning the operation

Preoperative assessment of the neurosurgical patient includes a thorough general medical evaluation alongside the specific neurological assessment already discussed, since comorbidities such as cardiovascular disease, diabetes, and anticoagulant use meaningfully affect both anaesthetic and surgical risk and require careful, proactive optimisation before elective neurosurgery wherever this is genuinely feasible given the clinical circumstances.

Anticoagulant and antiplatelet management deserves particular attention, since these medications must generally be stopped before elective neurosurgery to reduce bleeding risk, but doing so itself carries a competing risk, such as stroke or cardiac event, that must be carefully weighed and managed, typically in close consultation with the prescribing specialist, reflecting the genuinely individualised risk-benefit judgement required for each specific patient before proceeding to surgery.

Fill in the blank: Anticoagulant management before surgery requires weighing bleeding risk against the competing risk of stroke or cardiac _____.

Table 5.1: Comparing CT, MRI, and cerebral angiography

Investigation	Key strength	Typical first-line use
CT	Rapid, excellent for acute haemorrhage	Emergency assessment of head injury or stroke
MRI	Superior soft tissue contrast, no radiation	Tumour, demyelination, spinal pathology, surgical planning

Cerebral angiography	Direct vascular visualisation	Characterising aneurysm or arteriovenous malformation

Pilot questions 5.2

1. Explain why CT is generally the first-line investigation in emergency neurosurgical assessment. (Linked to SLO 5.3)
2. Describe the advantages of MRI over CT. (Linked to SLO 5.3)
3. Explain the role of cerebral angiography in characterising an aneurysm or arteriovenous malformation. (Linked to SLO 5.3)
4. Describe a specific advantage of conventional catheter angiography over CT or MR angiography. (Linked to SLO 5.3)
5. Explain the challenge posed by anticoagulant management before elective neurosurgery. (Linked to SLO 5.4)

5.3 Subarachnoid Haemorrhage and Aneurysms

5.3.1 subarachnoid haemorrhage: presentation and diagnosis

The headache that must never be missed

Subarachnoid haemorrhage, bleeding into the subarachnoid space most commonly from a ruptured cerebral aneurysm, classically presents with sudden-onset, severe headache, often described as the worst headache of the patient's life, reaching maximal intensity within seconds, alongside neck stiffness, photophobia, vomiting, and, in more severe cases, reduced conscious level, a presentation that, as already flagged in Part 5.1, constitutes a genuine diagnostic red flag never to be dismissed without thorough evaluation.

Diagnosis relies first on non-contrast CT of the head, which is highly sensitive if performed within the first six to twelve hours of symptom onset, though sensitivity diminishes over subsequent days, and **lumbar puncture**, looking for xanthochromia, a yellow discolouration of the cerebrospinal fluid from breakdown blood products, remains an essential investigation when CT is negative but clinical suspicion nonetheless remains genuinely high, since a normal CT scan alone does not fully exclude the diagnosis.

Fill in the blank: Lumbar puncture looks for xanthochromia, a yellow discolouration from breakdown blood _____.

5.3.2 cerebral aneurysms

Weak points in the vessel wall, often clustered predictably

Cerebral aneurysms, focal dilatations of a cerebral artery most commonly occurring at arterial branch points around the circle of Willis, are frequently asymptomatic until rupture, though an unruptured aneurysm can occasionally present with mass effect on adjacent structures, most notably the isolated third nerve palsy already discussed in relation to a posterior communicating artery aneurysm, a specific clinical association genuinely worth remembering.

Risk factors for aneurysm formation and rupture include hypertension, smoking, family history, and certain connective tissue disorders, and, once identified, an unruptured aneurysm's rupture risk is assessed according to its size, location, and morphology, informing a genuinely individualised decision between prophylactic treatment and continued observation with serial imaging, since not every identified aneurysm carries sufficient rupture risk to justify the risks of intervention.

Fill in the blank: Cerebral aneurysms most commonly occur at arterial branch points around the circle of _____.

5.3.3 management and complications of subarachnoid haemorrhage

Securing the aneurysm, then watching closely for what follows

Management of a ruptured aneurysm causing subarachnoid haemorrhage centres on securing the aneurysm promptly to prevent rebleeding, either through **surgical clipping**, placing a clip across the aneurysm neck via craniotomy, or **endovascular coiling**, filling the aneurysm with detachable coils via catheter, with the choice between these two approaches guided by aneurysm location, morphology, and patient factors, generally decided collaboratively between neurosurgical and interventional neuroradiology teams.

Vasospasm, delayed narrowing of cerebral blood vessels typically occurring between days four and fourteen after haemorrhage, is a genuinely serious complication that can cause secondary ischaemic stroke even after the aneurysm itself has been successfully secured, requiring active monitoring and, where it develops, specific treatment including induced hypertension and, in refractory cases, direct endovascular intervention to dilate the affected vessels.

Fill in the blank: Vasospasm typically occurs between days four and _____ after subarachnoid haemorrhage.

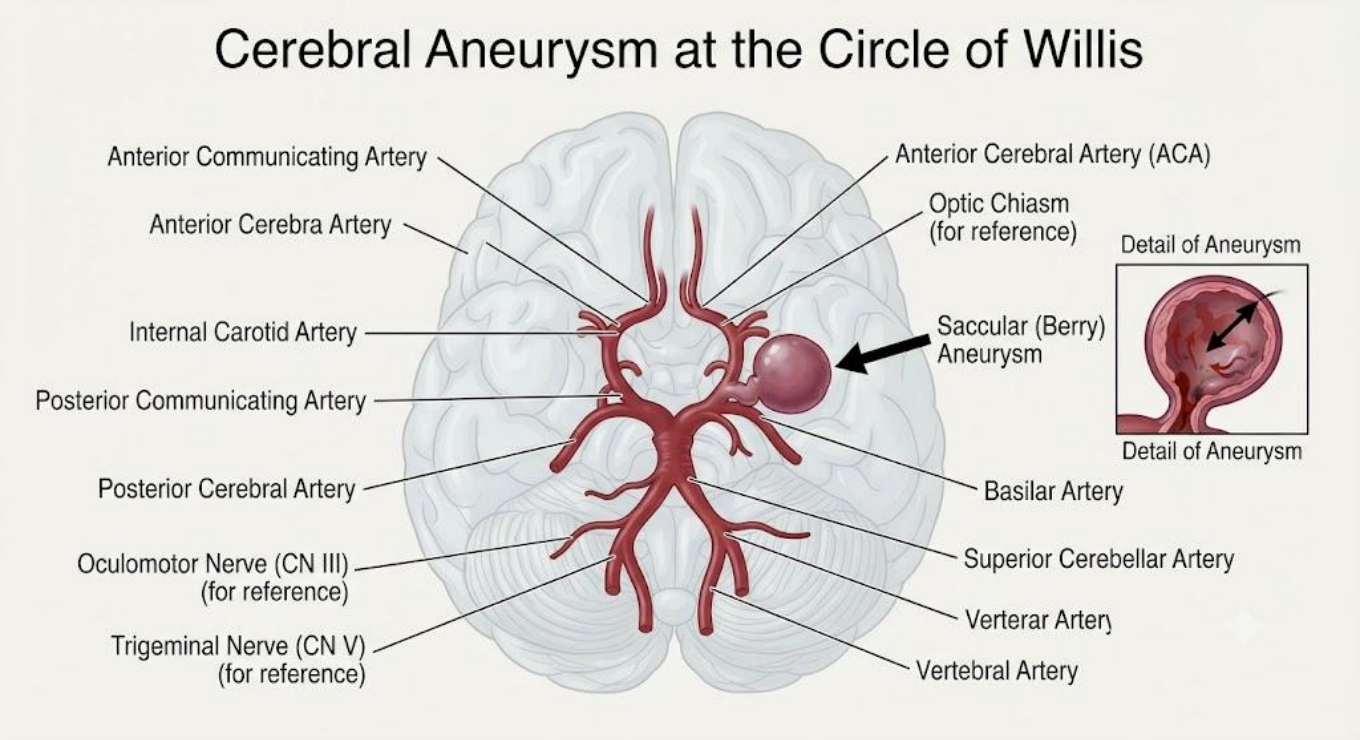

Figure 5.2: A labelled diagram of the circle of Willis showing a saccular aneurysm at the posterior communicating artery.

Pilot questions 5.3

1. Describe the classic presentation of subarachnoid haemorrhage. (Linked to SLO 5.5)
2. Explain the role of lumbar puncture when CT is negative but suspicion remains high. (Linked to SLO 5.5)
3. Describe the typical location of cerebral aneurysms. (Linked to SLO 5.6)
4. Distinguish surgical clipping from endovascular coiling. (Linked to SLO 5.6)
5. Describe vasospasm and its clinical significance. (Linked to SLO 5.6)

5.4 Intracerebral and Other Intracranial Haemorrhage

5.4.1 intracerebral haemorrhage

Bleeding directly into the brain tissue

Intracerebral haemorrhage, bleeding directly into the brain parenchyma, most commonly results from chronic hypertension causing rupture of small perforating arteries, particularly in the basal ganglia, thalamus, cerebellum, and brainstem, and presents with sudden-onset focal neurological deficit and, frequently, headache and reduced conscious level, a presentation that can be genuinely difficult to distinguish clinically from an ischaemic stroke without imaging.

Amyloid angiopathy, deposition of amyloid protein within small cerebral vessel walls, is an important alternative cause of intracerebral haemorrhage, particularly relevant in older patients and typically affecting more peripheral, lobar locations rather than the deep structures characteristic of hypertensive haemorrhage, a distinction with genuine relevance to underlying cause, recurrence risk, and long-term management planning.

Fill in the blank: Amyloid angiopathy typically affects more peripheral, _____ locations rather than deep structures.

5.4.2 arteriovenous malformations

A direct, abnormal connection between arteries and veins

An **arteriovenous malformation**, an abnormal tangle of blood vessels providing a direct connection between arteries and veins without an intervening capillary bed, is a congenital vascular anomaly that can present with haemorrhage, seizures, or, less commonly, progressive neurological deficit from a phenomenon sometimes called vascular steal, where blood is diverted away from adjacent normal brain tissue through the abnormal, low-resistance pathway the malformation provides.

Management options for a symptomatic or high-risk arteriovenous malformation include surgical resection, endovascular embolisation, and stereotactic radiosurgery, used alone or in combination depending on the malformation's size, location, and specific angiographic features, with the overall goal of eliminating the abnormal connection to prevent future haemorrhage while genuinely minimising the risk of causing new neurological deficit during treatment itself.

Fill in the blank: Vascular steal describes blood diverted away from adjacent normal brain tissue through the abnormal, low-resistance _____.

5.4.3 principles of management of intracranial haemorrhage

A consistent underlying approach across haemorrhage types

General management principles across the different types of intracranial haemorrhage covered in this Series share genuine common ground: rapid diagnosis through appropriate imaging, correction of any coagulopathy or reversal of anticoagulation where relevant, careful blood pressure control to reduce the risk of further bleeding while maintaining adequate cerebral perfusion, and close monitoring for both neurological deterioration and the specific complications associated with each individual cause of haemorrhage.

The decision between conservative management and surgical or endovascular intervention depends on the specific type, size, and location of the haemorrhage, the underlying cause where identified, and the patient's overall clinical trajectory and premorbid function, reflecting the same individualised, multidisciplinary decision-making principle already emphasised throughout this course, and closing the Series on a genuinely unifying theme that has run through every category of neurosurgical condition covered.

Fill in the blank: Management of intracranial haemorrhage includes correcting coagulopathy and careful blood _____ control.

Table 5.2: Comparing intracerebral haemorrhage and arteriovenous malformation

Feature	Intracerebral haemorrhage	Arteriovenous malformation
Common cause	Chronic hypertension	Congenital vascular anomaly
Typical location	Basal ganglia, thalamus, cerebellum	Variable, anywhere in the brain
Key management option	Blood pressure control, selected surgery	Resection, embolisation, or radiosurgery

Pilot questions 5.4

1. Describe the typical cause and location of hypertensive intracerebral haemorrhage. (Linked to SLO 5.7)
2. Distinguish amyloid angiopathy from hypertensive haemorrhage by location. (Linked to SLO 5.7)
3. Describe an arteriovenous malformation and how it can present. (Linked to SLO 5.7)
4. Explain the concept of vascular steal. (Linked to SLO 5.7)

5. List the general management principles shared across types of intracranial haemorrhage. (Linked to SLO 5.8)

Series Summary

This final Series brought together the evaluation skills underpinning the whole course and closed with intracranial haemorrhage. Part 5.1 covered neurological history taking and cranial nerve, motor, and sensory examination, while Part 5.2 turned to neuroimaging with CT, MRI, and cerebral angiography, and preoperative assessment. Part 5.3 covered subarachnoid haemorrhage and cerebral aneurysms, and Part 5.4 closed with intracerebral haemorrhage, arteriovenous malformations, and the general principles of managing intracranial haemorrhage.

You should now be able to perform a structured neurological evaluation, describe the relevant investigations, and describe the presentation and management of subarachnoid haemorrhage, intracerebral haemorrhage, and arteriovenous malformations, meeting the outcomes set for this Series. Across the full course, Series 1 covered head injury and spinal trauma, Series 2 covered common surgical intracranial lesions, Series 3 covered spinal cord lesions, Series 4 covered congenital malformations in neurosurgery, and this Series has closed the course with evaluation of the neurosurgical patient and intracranial haemorrhage, together forming a comprehensive foundation in neurosurgery.

Glossary of Terms

1. **Amyloid angiopathy:** deposition of amyloid protein in small vessel walls, causing lobar haemorrhage in older patients.
2. **Arteriovenous malformation:** an abnormal direct connection between arteries and veins without a capillary bed.
3. **Cerebral aneurysm:** a focal dilatation of a cerebral artery, most commonly at branch points.
4. **Cerebral angiography:** imaging directly visualising the cerebral blood vessels.
5. **Endovascular coiling:** filling an aneurysm with detachable coils via catheter to prevent rupture.
6. **Intracerebral haemorrhage:** bleeding directly into the brain parenchyma, commonly from hypertension.

7. **Subarachnoid haemorrhage:** bleeding into the subarachnoid space, most commonly from a ruptured aneurysm.
8. **Surgical clipping:** placing a clip across an aneurysm neck via craniotomy to prevent rupture.
9. **Third nerve palsy:** cranial nerve dysfunction causing ptosis and pupil dilation, associated with certain aneurysms.
10. **Vascular steal:** diversion of blood away from normal brain tissue through an arteriovenous malformation.
11. **Vasospasm:** delayed narrowing of cerebral vessels after subarachnoid haemorrhage, risking ischaemia.
12. **Xanthochromia:** yellow discolouration of cerebrospinal fluid from breakdown blood products.

Concept Check Questions [Series 5]

Objective questions

- A sudden headache described as the worst of the patient's life is a recognised red flag requiring _____ evaluation. (Linked to SLO 5.1)
- MRI provides considerably superior soft tissue contrast without ionising _____. (Linked to SLO 5.3)
- Lumbar puncture looks for xanthochromia, a yellow discolouration from breakdown blood _____. (Linked to SLO 5.5)
- Cerebral aneurysms most commonly occur at arterial branch points around the circle of _____. (Linked to SLO 5.6)
- Amyloid angiopathy typically affects more peripheral, _____ locations rather than deep structures. (Linked to SLO 5.7)

Short-answer questions

1. Explain the significance of an isolated third nerve palsy with a dilated pupil. (Linked to SLO 5.1)
2. Describe the advantages of MRI over CT. (Linked to SLO 5.3)
3. Distinguish surgical clipping from endovascular coiling. (Linked to SLO 5.6)
4. Describe an arteriovenous malformation and how it can present. (Linked to SLO 5.7)
5. List the general management principles shared across types of intracranial haemorrhage. (Linked to SLO 5.8)

Long-answer questions

6. Discuss the principles of neurological history taking and cranial nerve, motor, and sensory examination. (Linked to SLO 5.1, 5.2)
7. Describe the roles of CT, MRI, and cerebral angiography, and preoperative assessment in neurosurgical evaluation. (Linked to SLO 5.3, 5.4)
8. Discuss the presentation, diagnosis, and management of subarachnoid haemorrhage and cerebral aneurysms. (Linked to SLO 5.5, 5.6)
9. Describe intracerebral haemorrhage and arteriovenous malformations. (Linked to SLO 5.7)
10. Discuss the general principles of managing intracranial haemorrhage. (Linked to SLO 5.8)

Answers to Concept Check Questions [Series 5]

Objective questions

11. Urgent.
12. Radiation.
13. Products.
14. Willis.
15. Lobar.

Short-answer questions

16. An isolated third nerve palsy with a dilated pupil should prompt urgent evaluation for a posterior communicating artery aneurysm.
17. MRI offers superior soft tissue contrast, multiplanar imaging, and no ionising radiation compared with CT.
18. Surgical clipping places a clip via craniotomy, while endovascular coiling fills the aneurysm with coils via catheter.
19. An arteriovenous malformation is an abnormal artery-to-vein connection that can present with haemorrhage, seizures, or progressive deficit.
20. Principles include rapid imaging diagnosis, correcting coagulopathy, blood pressure control, and close monitoring.

Long-answer questions

21. **Basic response:** History aims to localise the lesion through symptom onset and character; cranial nerve examination is systematic from nerves one to twelve; motor and sensory examination assesses tone, power, reflexes, and sensation systematically.

    Value-added response: A value-added response notes that red flag headache features should prompt urgent evaluation rather than reassurance.

22. **Basic response:** CT is rapid and first-line for acute haemorrhage; MRI offers superior soft tissue detail for planning; cerebral angiography visualises vasculature for aneurysm or malformation characterisation; preoperative assessment optimises comorbidities and anticoagulation.

    Value-added response: A value-added response notes that conventional catheter angiography permits immediate endovascular treatment during the same procedure.

23. **Basic response:** Subarachnoid haemorrhage presents with sudden severe headache, diagnosed with CT and lumbar puncture if needed; aneurysms occur at branch points and are managed with clipping or coiling once ruptured.

    Value-added response: A value-added response notes that vasospasm is a serious delayed complication requiring active monitoring even after the aneurysm is secured.

24. **Basic response:** Intracerebral haemorrhage commonly results from hypertension affecting deep structures, or amyloid angiopathy affecting lobar regions; arteriovenous malformations are congenital vascular anomalies presenting with haemorrhage, seizures, or vascular steal.

    Value-added response: A value-added response notes that distinguishing hypertensive haemorrhage from amyloid angiopathy by location has genuine relevance to recurrence risk.

25. **Basic response:** Management includes rapid imaging diagnosis, correction of coagulopathy, blood pressure control, and close monitoring, with intervention decisions individualised by type, size, location, and patient factors.

    Value-added response: A value-added response notes that this individualised, multidisciplinary approach reflects a unifying theme across every category of neurosurgical condition in this course.

Answers to Pilot Questions [Series 5]

Part 5.1

1. The temporal pattern, sudden versus gradual onset, helps narrow the differential diagnosis considerably.
2. Red flags include worst headache of life, sudden onset, neck stiffness, and new headache in an older patient.
3. Examination proceeds systematically from the first to the twelfth cranial nerve.
4. It suggests compression by a posterior communicating artery aneurysm, given the nerve's anatomical course.
5. Power is graded from zero, no movement, to five, normal strength against resistance.

Part 5.2

6. CT is rapid, widely available, and excellent for detecting acute haemorrhage in an emergency.
7. MRI offers superior soft tissue contrast and multiplanar imaging without ionising radiation.
8. Cerebral angiography directly visualises vascular anatomy to guide treatment choice.
9. Catheter angiography permits immediate endovascular treatment during the same procedure.
10. Stopping anticoagulation reduces bleeding risk but carries a competing risk of stroke or cardiac event.

Part 5.3

11. Subarachnoid haemorrhage presents with sudden, severe headache reaching maximal intensity within seconds.
12. Lumbar puncture detects xanthochromia when CT is negative but suspicion remains high, since CT sensitivity diminishes over days.
13. Cerebral aneurysms most commonly occur at arterial branch points around the circle of Willis.
14. Clipping uses a surgical clip via craniotomy, while coiling fills the aneurysm via catheter without open surgery.
15. Vasospasm is delayed vessel narrowing that can cause secondary ischaemic stroke even after the aneurysm is secured.

Part 5.4

1. Hypertensive haemorrhage commonly affects the basal ganglia, thalamus, cerebellum, and brainstem.

2. Amyloid angiopathy affects peripheral, lobar locations, while hypertensive haemorrhage affects deep structures.
3. An arteriovenous malformation is an abnormal artery-vein connection presenting with haemorrhage, seizures, or deficit.
4. Vascular steal describes blood diverted away from normal brain tissue through the malformation's low-resistance pathway.
5. Shared principles include rapid imaging, correcting coagulopathy, blood pressure control, and close monitoring.

References and Attributions [Series 5]

1. Greenberg, M. S. (2020). Handbook of Neurosurgery (9th ed.). Thieme.
2. Winn, H. R. (2016). Youmans and Winn Neurological Surgery (7th ed.). Elsevier.
3. Ellis, H., & Mahadevan, V. (2019). Clinical Anatomy (14th ed.). Wiley-Blackwell.
4. Douglas, G., Nicol, F., & Robertson, C. (2013). Macleod's Clinical Examination (13th ed.). Churchill Livingstone.

Figures, Plates, Tables, and Boxes

1. Figure 5.1: A clinician testing facial nerve function during cranial nerve examination. AI-generated using the prompt: "Create a realistic clinical illustration titled Facial Nerve Examination, showing a clinician observing a patient's face as they smile and raise their eyebrows during a neurological examination, examination room setting. Clean clinical illustration style, no text."
2. Table 5.1: Comparing CT, MRI, and cerebral angiography. AI-generated using the prompt: "Create a clean reference table titled Comparing CT, MRI, and Cerebral Angiography, listing investigation, key strength, and typical first-line use. Simple clinical reference table style with outside border."
3. Figure 5.2: A labelled diagram of the circle of Willis showing a saccular aneurysm at the posterior communicating artery. AI-generated using the prompt: "Create a clean, accurate labelled anatomical diagram titled Cerebral Aneurysm at the Circle of Willis, showing the arteries forming the circle of Willis at the base of the brain with a labelled saccular aneurysm bulging from the posterior communicating artery. Educational anatomical diagram style, no photographic content."

4. Table 5.2: Comparing intracerebral haemorrhage and arteriovenous malformation. AI-generated using the prompt: "Create a clean reference table titled Comparing Intracerebral Haemorrhage and Arteriovenous Malformation, listing feature, intracerebral haemorrhage, and arteriovenous malformation. Simple clinical reference table style with outside border."