13 Neurosurgery

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Introduction

Modern neurosurgery has its humble beginnings in the late nineteenth and early twentieth centuries. Significant breakthroughs in the scientific understanding of the nervous system and progress in technology- such as image-guided surgery, microscopy and neuroimaging- make neurosurgery one of the most technically advanced and fascinating surgical disciplines.

It encompasses the management of a diverse spectrum of cranial and spinal pathologies in both children and adults.

This chapter is by no means comprehensive. We have chosen few of the simplest procedures that medical students will be expected to recognise, understand and hopefully participate in.

Core Knowledge

Anatomy of the Central Nervous System

The central nervous system consists of the brain, brain stem and spinal cord. The brain is surrounded by the meninges and the skull. The brain's convoluted surface, the cerebral cortex, consists of gyri and sulci, protruding and receding peaks and troughs, respectively. It is composed of the frontal, temporal, parietal and occipital lobes. Various functions are ascribed to each area of the brain. Symptoms and signs can therefore provide clues as to the anatomical location of underlying pathology.

The cranium (part of the skull) is the protective cage of the brain, consisting of the frontal, parietal, temporal, occipital bones, sphenoid and ethmoid bones. These bones interface at the sutures of the skull.

The anterior, middle and posterior cranial fossae accommodate the brain. The frontal lobes lie in the anterior fossa, the temporal lobes in the middle fossa and the brainstem and cerebellum in the posterior fossa. Foramina in the skull permit passage of arteries and nerves. The brainstem becomes the spinal cord as it passes through the foramen magnum in the posterior fossa.

Intervertebral foramina are the route by which peripheral nerves connect to the spinal cord. There are 8 cervical, 12 thoracic, 5 lumbar and 5 sacral nerves. Nerves C1-7 leave the spinal cord above their corresponding pedicle; for example, cervical nerve 2 leaves by travelling superior to the pedicle of the 2nd cervical vertebra. In contrast, after cervical nerve 8 passes under the pedicle of cervical vertebra 7, the remaining nerves travel inferior to their corresponding pedicle- for example, nerve L3 travels inferior to the pedicle of the 3rd lumbar vertebra.

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© Springer International Publishing Switzerland 2017
R.A. Fisher et al. (eds.), *Introduction to Surgery for Students*, DOI 10.1007/978-3-319-43210-6_13

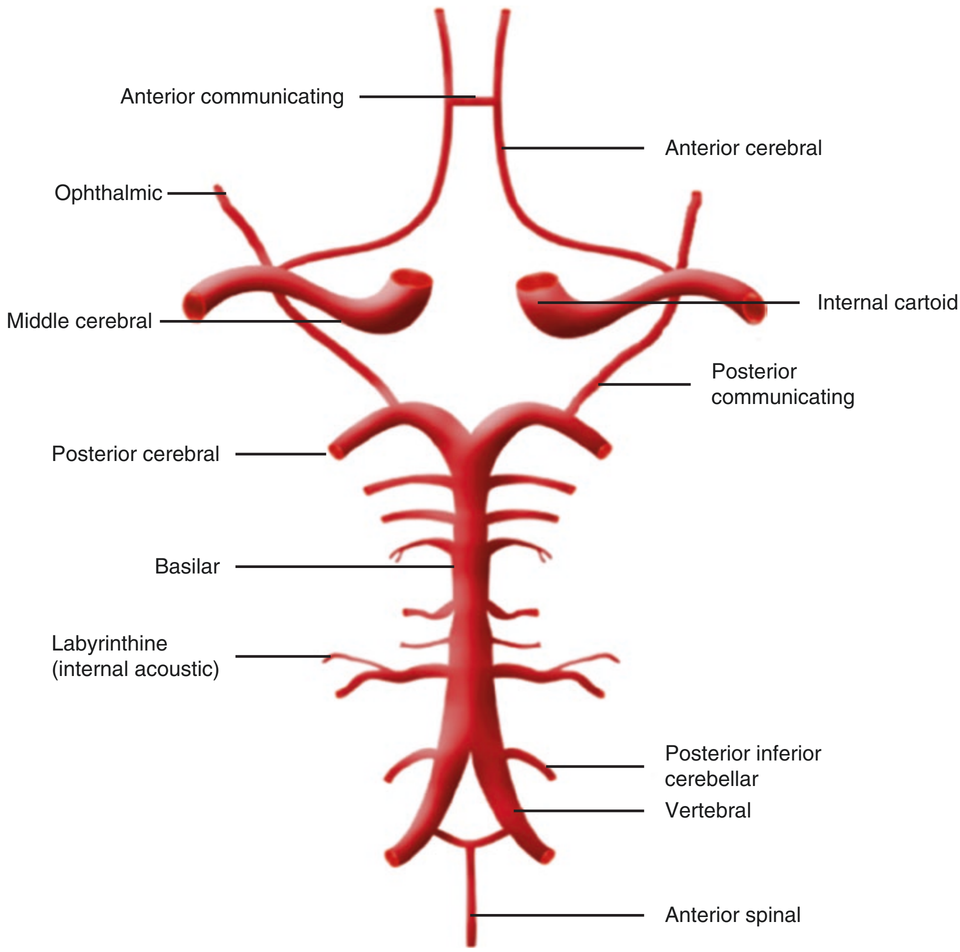

Fig. 13.1 Arterial supply of the cerebrum

The brainstem is a continuation of the brain. It consists of the midbrain, pons and medulla. Descending through the foramen magnum, the brainstem becomes the spinal cord and descends in adults to L1, inferior to which the remaining nerves descend as a bundle named the cauda equina- remembered easily as the Latin for “horse’s tail”.

Arterial Blood Supply

The brain is supplied by 4 main vessels: the left and right vertebral and internal carotid arteries. A thorough appreciation of the vasculature and functional anatomy of the brain is essential to understanding pathological lesions of the neurovasculature and their effects (Fig. 13.1).

Venous Drainage

This system drains into the internal jugular vein. Notably, the bridging veins of the superior sagittal sinus are vulnerable to rupture upon impact, leading to subdural haematoma (Fig. 13.2).

Meninges

The meninges are a trio of connective tissue layers covering the central nervous system named the dura mater, arachnoid mater and pia mater. The pia mater lies the deepest, immediately sur-

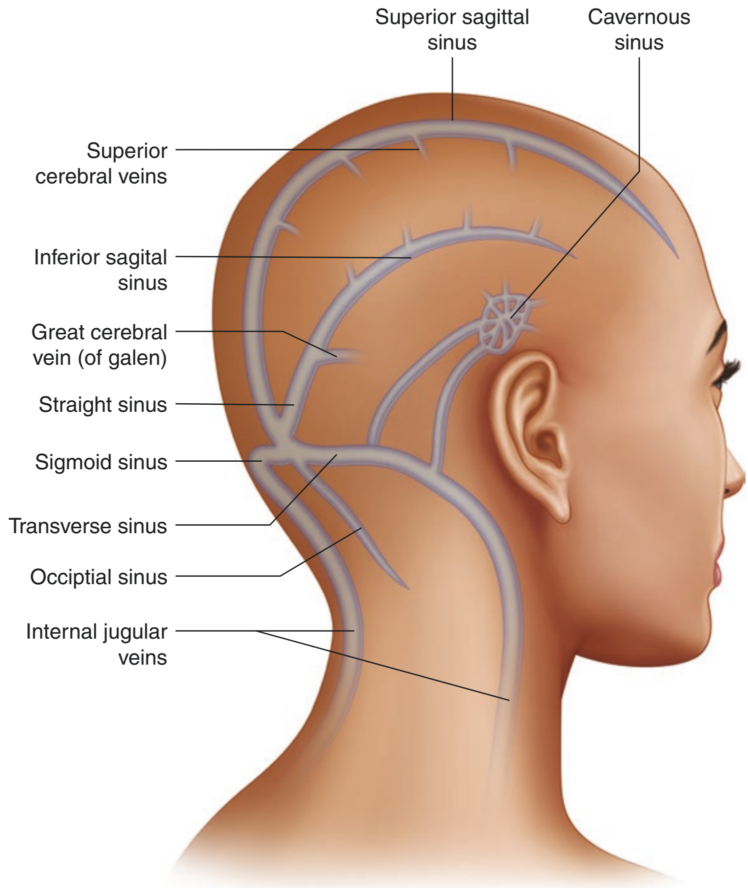

Fig. 13.2 Venous drainage supply of the cerebrum

rounding the brain, whereas the dura mater is the most superficial, lying just deep to the bones of the skull. Between the dura and arachnoid mater lies the subdural space. Between the arachnoid mater and pia mater lies the cerebrospinal fluid-filled subarachnoid space. The understanding of these anatomical structures is key to the understanding of various pathological processes including subdural, subarachnoid and extradural haemorrhage.

Folds of dura mater also make up the falx cerebri and tentorium cerebelli. The falx cerebri runs between the left and right hemispheres in the longitudinal fissure. The tentorium cerebelli overlies the superior aspect of the cerebellum and separates it from the inferior aspect of the occipital lobes.

Intracranial Pressure

Intracranial pressure (ICP) is normally 7–15 mm Hg in the supine position; at 20–25 mm Hg, the upper limit of normal, treatment to reduce ICP may be needed. It varies in children from adults.

Under normal conditions, the blood flow to the brain is auto-regulated to remain within homeostatic limits. This is maintained physiologically at cerebral perfusion pressures between 50–150 mmHg (mean arterial pressure). The mean cerebral blood flow is 750 ml/min. If perfusion pressure deviates from these values, decompensation can occur with increases or decreases in cerebral blood flow (Fig. 13.3).

It is also important to appreciate the physiological relationship between intracranial pressure

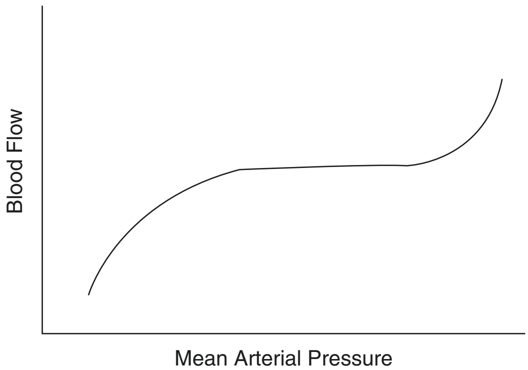

Fig. 13.3 The intracranial pressure-cerebral blood flow relationship

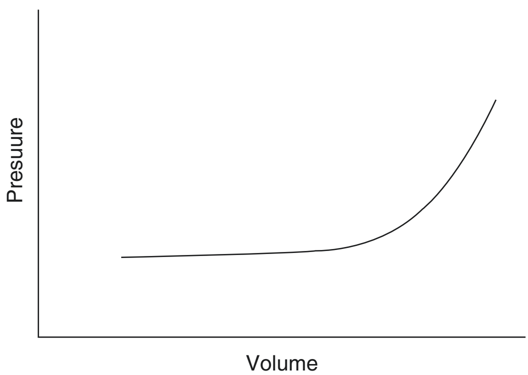

Fig. 13.4 The intracranial pressure-volume relationship

and volume. Increasing volume, for example as a result of a tumour or an expanding intracranial haematoma, can result in drastically rising ICP. An increasing ICP can eventually exceed the cerebral perfusion pressure, resulting in critically reduced brain perfusion.

Certain neurosurgical conditions require an emergent intervention to interrupt this sequence of events before catastrophic consequences to brain function; e.g. craniotomy for evacuation of a traumatic extradural or subdural haematoma; external ventricular drainage with diversion of CSF in acute hydrocephalus (Figs. 13.4 and 13.5).

The Glasgow Coma Scale

The Glasgow Coma Scale (GCS) is a tool allowing an objective assessment of the conscious state of a patient (see Table 13.1). It originated in the assessment of trauma patients but is widely used in all brain surgery conditions. The score takes into account eye opening, motor and verbal responses to various stimuli. A total score of 15 is possible. A score of 8 or below is considered to be indicative of a comatose patient and the minimum score possible, 3, indicates a totally

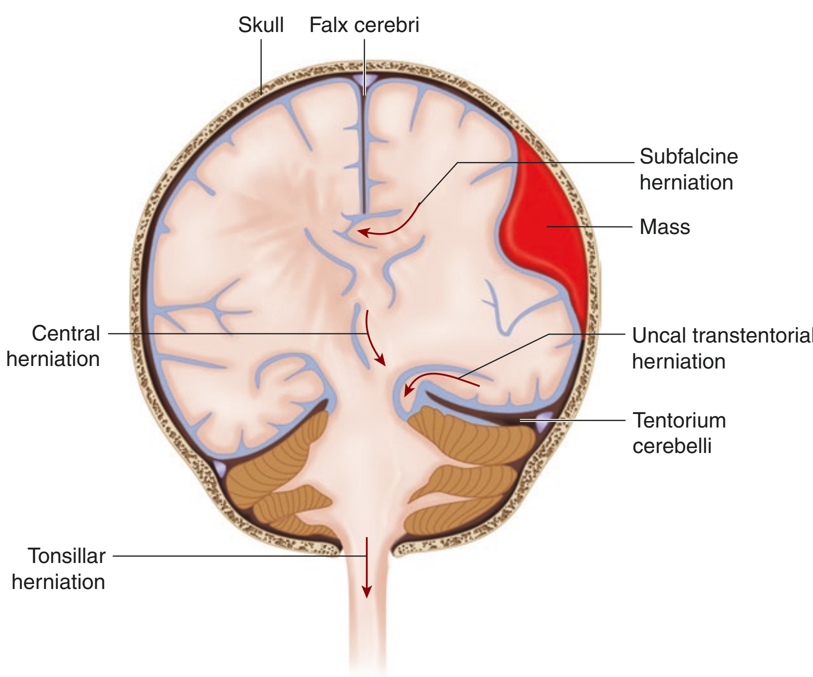

Fig. 13.5 Types of intracranial herniation

unresponsive patient. Notably, a different version of the scale is used in paediatric practice.

The paediatric scale features a modified **verbal response** scale (Table 13.2):

Hydrocephalus

This condition is characterised by dilatation of the ventricular system due to an obstruction to cerebrospinal fluid flow. This can be classified as communicating hydrocephalus (due to no obvious obstruction of the ventricular system, but presumed reabsorption deficit), or non-communicating hydrocephalus (due to an obstruction within the ventricular system). Many conditions can lead to hydrocephalus, including congenital malformations, subarachnoid haemorrhage, trauma, abscesses and tumours.

Acute Subdural Haematoma

This condition usually results from tearing and bleeding of the bridging veins of the superior sagittal sinus or other trauma to the brain or skull. A haematoma accumulates in the subdural space, raising intracranial pressure and potentially precipitating rapid neurological decline (Fig. 13.6).

Chronic Subdural Haematoma

Chronic subdural haematomas have a similar aetiological mechanism to acute subdural haematomas but develop insidiously. They are more common in the elderly and often the insulting trauma is minor and never identified.

Table 13.1 The Glasgow coma scale

Glasgow coma scale	Score
Best motor response	
None	1
Extensor response to pain	2
Abnormal flexion to pain	3
Flexes to pain	4
Localises to Pain	5
Responds to commands	6
Eye opening	
None	1
To pain	2
To speech	3
Spontaneous	4
Best verbal response	
None	1
Incomprehensible sounds	2
Words, incoherent	3
Disoriented conversation	4
Normal conversation	5

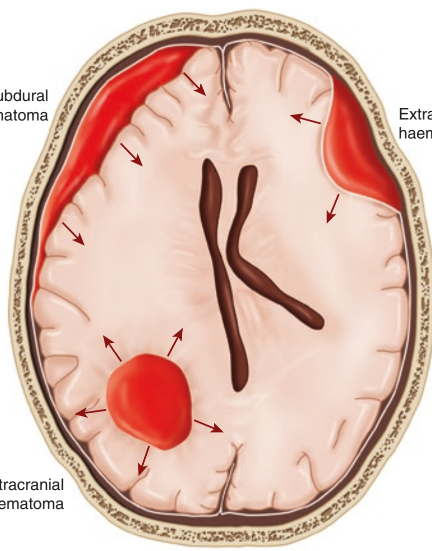

Fig. 13.6 Types of intracranial haemorrhage

Table 13.2 Modified GCS verbal score for paediatric patients

6–10 years	2–5 years	<2 years	1
None	None	None	2
Incomprehensible sounds	Grunts	Grunts	3
Inappropriate words	Cries or screams	Inappropriate crying	4
Appropriate but confused words	Monosyllabic	Cries only	5
Fully orientated	Any words	Appropriate non-verbal response	6

Traumatic Brain Injury

Traumatic brain injury describes a spectrum of clinical states categorised by GCS. They are a significant cause of mortality and morbidity in young people and range from concussion to comatose state. Pathologies requiring neurosurgical attention may result from traumatic brain injury, including subdural haematoma.

Intervertebral Disc Prolapse

Adjacent vertebrae are separated by intervertebral discs. These consist of the *annulus fibrosus*, a series of concentric fibrocartilaginous layers; and the *nucleus pulposus*, a water-based gelatinous core. Age-related changes in the annulus fibrosus allow the herniation of the nucleus pulposus through it, placing pressure on surrounding structures, including nerve roots, the cauda equina and the spinal cord above its termination point which is usually at L1/2 in adults (Fig. 13.7).

Cauda Equina Syndrome

Cauda equina syndrome is a relatively rare condition usually associated with a space-occupying lesion in the lumbosacral spine, most often a disc prolapse. It presents with pain, motor and sensory loss and bowel and bladder dysfunction. Symptoms and signs can be subtle and a high index of suspicion is necessary given the need for urgent treatment by surgical decompression of spinal canal.

Core Operations

Some of the most common neurosurgical operations are described briefly below. The aim is to provide a basic understanding and to cultivate the curiosity to delve into detailed texts.

External Ventricular Drainage

This is also called an external ventriculostomy and aims at providing a minimally invasive access to the brain's ventricular system. It allows the drain-

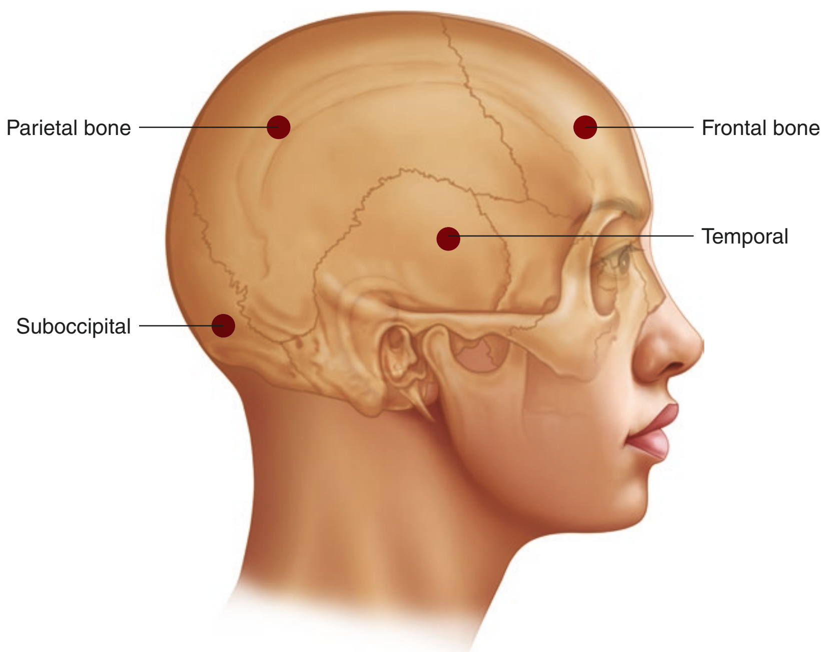

Fig. 13.7 Burr hole drainage sites

age of excess accumulated CSF and the sampling of CSF for chemical, haematological, microscopic, microbiological and other purposes.

Indications

- Raised intracranial pressure (ICP), for example due to:
  - Traumatic brain injury
  - Acute 'communicating' hydrocephalus e.g. secondary to subarachnoid haemorrhage
  - 'Non-communicating' (i.e. obstructive) hydrocephalus, e.g. secondary to an intracranial tumour
  - Intraventricular haemorrhage
- Externalisation of an infected ventriculoperitoneal shunt system

Contraindications

- Coagulopathies

Presentation of Raised ICP

- Drowsiness
- Nausea and vomiting
- Headaches (of raised intracranial pressure)
- Gait apraxia
- Cognitive disturbance
- Incontinence (urinary / faecal)
- Neurological deficit (e.g. hemiparesis; ocular palsy)
- ***Investigations*** CT: during acute presentation to exclude haemorrhage; ventricular obstruction; to monitor ventricular size
- MRI: to visualise tumour, better detail of parenchyma and ventricles.
- Lumbar puncture: only indicated if the hydrocephalus is non-obstructive, i.e. communicating (otherwise, there is a risk of 'coning', which is downward herniation of brainstem through foramen magnum due to a pressure gradient)

Clinical Anatomy

Kocher's point is a common site of entry for external ventricular drains. This point is located 1 cm anterior from the coronal suture and 3–4 cm lateral to the midline. It provides access to the frontal horn of the ipsilateral lateral ventricle.

Step-by-Step Summary: Extraventricular Drainage

1. Positioning: Supine neutral head position with head of bed slightly elevated
2. Shave right frontal access point (right side is preferable as it is the non-dominant side in the vast majority of patients)
3. Longitudinal incision centred over Kocher's point
4. Drill until the inner cranial table is breached
5. Dural opening
6. Insertion of external ventricular drain tubing to 5 cm depth, looking for release of CSF
7. Save CSF sample for analysis
8. Securing of EVD to scalp and connection to closed external drainage system
9. Scalp closure with sutures
10. Determine manometer pressure above which CSF will drain

Complications

- Drain blockage
- Infection including ventriculitis
- Drain misplacement / displacement
- Haemorrhage

Follow-Up

- Vigilant observation for infection
- If EVD is required beyond 1 week, consider EVD change to avoid colonisation
- If patient remains EVD-dependent, conversion to a Ventriculo-Peritoneal shunt may be necessary
- CT scan to assess volume changes

Surgeons' Favourite Questions for Students

1. What are the indications for EVD?
2. What is the location of the access burr-hole?
3. Potential complications of brain injury secondary to misplacement in relation to gross brain anatomy?
4. What is a normal ICP?

Burr Hole Drainage of Chronic Subdural Haematoma

Indications
- Chronic blood is liquefied, whereas acute blood is jelly-like in viscosity. The former is more amenable to burr hole drainage.

Contraindications
- Coagulopathy

Presentation
- Hemiparesis
- Ataxia
- Confusion, variable conscious state
- Seizures
- Headache
- Nausea, vomiting
- Trauma not always described- minor repetitive injuries are commoner in the elderly, who often do not remember a specific traumatic event.

Investigations
- CT: shows age of blood (isodense or hypodense)

Step-by-Step Summary: Burr Hole
1. Positioning: Supine with head tilted so as to expose the affected side up, with shoulder support, to avoid overstretching of the neck.
2. Shave access point(s); the burr holes are positioned over the cranial convexity at location where haematoma is thickest. Either one or two burr holes are used.
3. Longitudinal incision
4. Drill until the inner cranial table is breached. Handheld or mechanical drills can be used.
5. Dural opening
6. Copious wash-out of haematoma between the burr holes until no further blood visible

Complications
- Re-accumulation of haematoma
- Seizures
- Focal brain injury
- Subdural empyema
- Tension pneumocephalus

Follow-Up
- Repeat CT if patient's neurological status does not improve or improves then regresses

Craniotomy

Brain tumours occur in 15–20 per 100,000. Secondary tumours due to metastases are the most common of these tumours- 20–30 % of patients with systemic cancer will have brain metastases. Brain tumours comprise 10 % of all malignancies and 20 % of paediatric neoplasms. Brain tumours can be classified by parenchymal location (extrinsic or intrinsic), malignancy (primary or secondary) cell of origin (neuroepithelial, meninges, blood vessel etc.) and histological grading (WHO Grades I-V).

Indications
- Acute extradural haematoma
- Acute subdural haematoma / empyema
- Intracranial tumour
- Trauma

Contraindications
- Coagulopathy
- Anaesthetic considerations

Presentation
- Hemiparesis
- Confusion, variable conscious state to coma
- Seizures
- Headache
- Nausea and vomiting
- Trauma

Investigations
- CT: better for acute haemorrhage and skull fracture
- MRI: better detail for soft tissue anatomy, including brain parenchyma, tumours and their relations

Clinical Anatomy
Students are advised to revise gross brain anatomy including lobar localisation and speech and language areas, motor and sensory cortices, basal ganglia and inter-hemispheric commissures.

Step-by-Step Summary: Craniotomy
1. Positioning: the head is often secured in Mayfield pins to eliminate intra-operative movement. Neuronavigation is used to design the position of the scalp flap.

2. Limited hair shave.
3. Prepare the skin and drape
4. Scalp incision
5. Perioesteal elevation
6. Burr holes along the outline of craniotomy window. A drill is used to run between these.
7. The bone flap is elevated.
8. Dural opening
9. Corticotomy along brain surface to gain access to target lesion.
10. Special high-tech instruments allow precise resection of tumours in eloquent areas, such as an ultrasonic aspirator and micro-instruments, under specialised microscope.
11. Small "dog bone"-shaped metallic plates are used to connect the bone flap to the surrounding skull in order to secure it back in place.

Complications

- Seizures
- Intracerebral haemorrhage
- Focal brain injury
- Subdural empyema
- Tension pneumocephalus

Follow-Up

Follow up will be tailored to the target pathology e.g. MRI for tumours, angiography for vascular abnormalities (such as aneurysms or arteriovenous malformation).

Surgeons' Favourite Questions for Students

1. How can one classify brain tumours?
2. Which is the commonest brain tumour?
3. How common are brain tumours?
4. How do intracranial malignancies compare with all tumours?
5. How is the bone flap secured back in place at the end of the operation?

Lumbar Microdiscectomy

Lumbar disc prolapse involves herniation of the nucleus pulposus through the annulus fibrosus. An L4/L5 prolapse will affect the L5 nerve root. Far lateral or extra-foraminal prolapses at this level would affect the L4 nerve root. CSF leakages may cause complications such as pseudomeningocoele, headaches and in extreme cases subdural haematoma. Conus Medullaris syndrome refers to a syndrome resulting from insult to the most inferior part of the spinal cord, the conus medullaris, which usually lies around L1-L2 before becoming the cauda equine inferiorly. An injury here will cause mixed upper and lower motor neurone symptoms and signs, usually affecting the perineum and lower extremities.

Indications

- Lumbar disc herniation: refractory to medical management, progressive symptoms
- Cauda Equina Syndrome: neurosurgical emergency affecting bladder, bowel and sexual function (see above).

Contraindications

- Anaesthetic considerations

Presentation

- Leg Pain
- Back pain
- Numbness
- Weakness
- Paraesthesia
- Cauda Equina Syndrome (urinary / faecal incontinence, saddle anaesthesia, uni- or bilateral lower limb symptoms)

Investigations

- MRI: to exclude cauda equina compression via central canal occlusion, most commonly from a central disc prolapse; to assess for nerve root compression

Step-by-Step Summary: Lumbar Microdiscectomy

1. Prone position on a frame such as the Montreal mattress or the Wilson frame

2. X-ray localisation: it is paramount that before skin incision the correct spinal level to be operated upon is identified radiographically
3. Prepping of the skin and draping the patient
4. Unilateral stripping of subperiosteal muscle off the spinous process and lamina, to expose the entry point into the canal
5. Retractor system: this helps hold the retracted muscle away, thus maintaining access
6. X-ray confirmation of level: it is good practice to confirm that the surgeon is at the correct spinal level by repeating an x-ray intraoperatively
7. Microscope: its use has revolutionised lumbar disc microsurgery with the associated magnification and illumination
8. Entry into the spinal canal via fenestration through ligamentum flavum
9. Identification and decompression of the affected nerve root
10. Identification of disc prolapse and its resection by incising the annulus and removing the loose fragment
11. Haemostasis and closure in layers

Complications

- Nerve root or cauda equina injury
- Dural tear / pseudomeningocele
- Discitis (sterile or septic)

Follow-Up

- Immediate mobilisation and physiotherapy
- In the event of a CSF leak, the patient is often kept flat on bed-rest for 24–48 h

Surgeons' Favourite Questions for Students

1. An L4/5 disc prolapse will affect which nerve?
2. When will an L4/5 disc prolapse affect the L4 nerve root?
3. What are some complications of CSF leakage?
4. What is Conus Medullaris syndrome?
5. Does any removed disc material need to be replaced?

Tips for Placement

1. Revise simple neuroanatomy and neurophysiology
2. Attend neuroradiology meetings
3. Attend multidisciplinary meetings for subspecialties (e.g. neuro-oncology, neurovascular, complex spine, skull base, paediatric, pain and functional)
4. Shadow the on-call neurosurgical trainees
5. Scrub in theatre to see up-close and personal what the procedures are all about

Careers

Within neurosurgery there is a great deal of choice of subspecialisation, including paediatric neurosurgery, neurotrauma, neurovascular surgery, surgical neuro-oncology, functional and epilepsy neurosurgery, skull base surgery and spinal surgery.

Entry is competitive with some of the highest competition ratios for ST posts. Application to training posts is through a national selection process currently hosted by Yorkshire and Humber Deanery. This training lasts for 8 years (ST1-8). This is a run-through programme. Trainees proceed through a structured curriculum including optional attachments in neuro-intensive care and neuro-rehabilitation. There is the opportunity to undertake an attachment in a sub-speciality of specific interest towards the end of training (fellowship).

Progression also depends upon completion of professional examinations and contribution to teaching, research and audit. Often candidates for consultant posts will have completed an MD or PhD.

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