Peripheral Nerve Disorders

Nerve Structure And Function

- Peripheral nerves are bundles of axons conducting efferent (motor) impulses from cells in the anterior horn of the spinal cord to the muscles, and afferent (sensory) impulses from peripheral receptors via cells in the posterior root ganglia to the cord.
- They also convey sudomotor and vasomotor fibres from ganglion cells in the sympathetic chain.
- Some nerves are predominantly motor, some predominantly sensory; the larger trunks are mixed.
- Each axon is, in reality, an extension or elongated process of a nerve cell, or neuron.
- In the peripheral nerves, all motor axons and the large sensory axons serving touch, pain and proprioception are coated with myelin, a multilayered lipoprotein membrane derived from the accompanying Schwann cells.
- Every few millimetres the myelin sheath is interrupted, leaving short segments of bare axon called the nodes of Ranvier.
- Depletion of the myelin sheath causes slowing – and eventually complete blocking – of axonal conduction.
- Outside the Schwann cell membrane the axon is covered by a connective tissue stocking, the endoneurium.
- The axons that make up a nerve are separated into bundles (fascicles) by fairly dense membranous tissue, the perineurium.
- The groups of fascicles that make up a nerve trunk are enclosed in an even thicker connective tissue coat, the epineurium.
- The nerve is richly supplied by blood vessels that run longitudinally in the epineurium before penetrating the various layers to become the endoneurial capillaries.
- The tiny blood vessels have their own sympathetic nerve supply coming from the parent nerve, and stimulation of these fibres (causing intraneural vasoconstriction) may be important in conditions such as reflex sympathetic dystrophy and other unusual pain syndromes.

Pathology

- Nerves can be injured by:
  - ischaemia,
  - compression,
  - traction,
  - laceration
  - burning.
- Damage varies in severity from transient and quickly recoverable loss of function to complete interruption and degeneration.
Types

**Transient Ischaemia**
- Acute nerve compression causes numbness and tingling within 15 minutes, loss of pain sensibility after 30 minutes and muscle weakness after 45 minutes.
- Relief of compression is followed by intense paraesthesiae lasting up to 5 minutes (the familiar ‘pins and needles’ after a limb ‘goes to sleep’); feeling is restored within 30 seconds and full muscle power after about 10 minutes.
- These changes are due to transient endoneurial anoxia and they leave no trace of nerve damage.

**Neurapraxia**
- Seddon (1942) coined the term ‘neurapraxia’ to describe a reversible physiological nerve conduction block in which there is loss of some types of sensation and muscle power followed by spontaneous recovery after a few days or weeks. It is due to mechanical pressure causing segmental demyelination and is seen typically in ‘crutch palsy’, pressure paralysis in states of drunkenness (‘Saturday night palsy’) and the milder types of tourniquet palsy.

**Axonotmesis**
- This is a more severe form of nerve injury, seen typically after closed fractures and dislocations. The term means, literally, axonal interruption. There is loss of conduction but the nerve is in continuity and the neural tubes are intact. Distal to the lesion, and for a few millimetres retrograde, axons disintegrate and are resorbed by phagocytes. This wallerian degeneration (named after the physiologist, Augustus Waller, who described the process in 1851).
- The axonal processes grow at a speed of 1–2 mm per day.

**Neurotmesis**
- In Seddon’s original classification, neurotmesis meant division of the nerve trunk, such as may occur in an open wound, recovery will not occur.
- Regenerating fibres mingle with proliferating Schwann cells and fibroblasts in a jumbled knot, or ‘neuroma’, at the site of injury.

**The ‘Double Crush’ Phenomenon**
The there is convincing evidence that proximal compression of a peripheral nerve renders it more susceptible to the effects of a second, more peripheral injury. This may explain why peripheral entrapment syndromes are often associated with cervical or lumbar spondylosis. A similar type of ‘sensitization’ is seen in patients with peripheral neuropathy due to diabetes or alcoholism.

**Classification Of Nerve Injuries**
Seddon’s description of the three different types of nerve injury (neurapraxia, axonotmesis and neurotmesis) served as a useful classification for many years. Increasingly, however, it has been recognized that many cases fall into an area
somewhere between axonotmesis and neurotmesis. Therefore, following Sunderland (1978), a more practical classification is offered here:

I. **First degree injury**
   This embraces transient ischaemia and neurapraxia, the effects of which are reversible.

II. **Second degree injury**
   This corresponds to Seddon’s axonotmesis. Axonal degeneration takes place but, because the endoneurium is preserved, regeneration can lead to complete, or near complete, recovery without the need for intervention.

III. **Third degree injury**
   This is worse than axonotmesis. The endoneurium is disrupted but the perineurial sheaths are intact and internal damage is limited.

IV. **Fourth degree injury**
   Only the epineurium is intact. The nerve trunk is still in continuity but internal damage is severe. Recovery is unlikely; the injured segment should be excised and the nerve repaired or grafted.

V. **Fifth degree injury**
   The nerve is divided and will have to be repaired.

### Clinical Features

- **Acute nerve injuries**
  - are easily missed, especially if associated with fractures or dislocations.
  - Always test for nerve injuries following any significant trauma.
  - If a nerve injury is present, it is crucial also to look for an accompanying vascular injury.
  - Ask the patient if there is numbness, paraesthesia or muscle weakness in the related area.
  - Then examine the injured limb systematically for signs of abnormal posture (e.g. a wrist drop in radial nerve palsy), weak-ness in specific muscle groups and changes in sensibility.
  - The neurological examination must be repeated at intervals so as not to miss signs which appear hours after the original injury, or following manipulation or operation.

- **In chronic nerve injuries**
  - The anaesthetic skin may be smooth and shiny, with evidence of diminished sensibility such as cigarette burns of the thumb in median nerve palsy or foot ulcers with sciatic nerve palsy.
  - Muscle groups will be wasted.
  - Postural deformities may become fixed.

### Motor Power Is Graded:

0  No contraction.
1  A flicker of activity.
2  Muscle contraction but unable to overcome gravity.
3 Contraction able to overcome gravity.
4 Contraction against resistance.
5 Normal power.

Principles Of Treatment

Nerve exploration
✓ Closed low energy injuries usually recover spontaneously.
✓ Exploration is indicated:
  1. if the nerve was seen to be divided and needs to be repaired
  2. if the type of injury (e.g. a knife wound or a high energy injury) suggests that the nerve has been divided or severely damaged.
  3. if recovery is inappropriately delayed and the diagnosis is in doubt.
✓ Vascular injuries, unstable fractures, contaminated soft tissues and tendon divisions should be dealt with before the nerve lesion.

Primary repair
✓ A divided nerve is best repaired as soon as this can be done safely.
✓ Primary suture at the time of wound toilet has considerable advantages.

Delayed repair
✓ Late repair, i.e. weeks or months after the injury, may be indicated because:
  1. a closed injury was left alone but shows no sign of recovery at the expected time;
  2. the diagnosis was missed and the patient presents late
  3. primary repair has failed.

Nerve grafting
✓ Free autogenous nerve grafts can be used to bridge gaps too large for direct suture.
✓ The sural nerve is most commonly used; up to 40 cm can be obtained from each leg.

Nerve transfer
✓ The spinal accessory nerve can be transferred to the suprascapular nerve.
✓ Intercostal nerves can be transferred to the musculocutaneous nerve.

Care of paralysed parts
✓ While recovery is awaited the skin must be protected from friction damage and burns.
✓ The joints should be moved through their full range twice daily to prevent stiffness.
✓ ‘Dynamic’ splints may be helpful.

Tendon transfers
✓ Motor recovery may not occur if the axons, regenerating at about 1 mm per day, do not reach the muscle within 18–24 months of injury.
✓ In such circumstances, tendon transfers should be considered.
PROGNOSIS

- Type of lesion  Neurapraxia always recovers fully; axonotmesis may or may not; neurotmesis will not unless the nerve is repaired.
- Level of lesion  The higher the lesion, the worse the prognosis.
- Type of nerve  Purely motor or purely sensory nerves recover better than mixed nerves, because there is less likelihood of axonal confusion.
- Size of gap  Above the critical resection length, suture is not successful.
- Age  Children do better than adults. Old people do poorly.
- Delay in suture  This is a most important adverse factor. The best results are obtained with early nerve repair. After a few months, recovery following suture becomes progressively less likely.
- Associated lesions  Damage to vessels, tendons and other structures makes it more difficult to obtain recovery of a useful limb even if the nerve itself recovers.
- Surgical techniques, skill, experience and suitable facilities are needed to treat nerve injuries. If these are lacking, it is wiser to perform the essential wound toilet and then transfer the patient to a specialized centre.

REGIONAL SURVEY OF NERVE INJURIES

Brachial Plexus Injuries

Pathological Anatomy

- The brachial plexus is formed by the confluence of nerve roots from C5 to T1
- It is vulnerable to injury – either a stab wound or severe traction caused by a fall on the side of the neck or the shoulder.
- Traction injuries are generally occur in motorcycle accidents: his neck and shoulder are wrenched apart.
- In the most severe injuries the arm is practically avulsed from the trunk, with rupture of the subclavian artery.
- An important distinction is made between preganglionic and postganglionic lesions.
- Avulsion of a nerve root from the spinal cord is a preganglionic lesion, i.e. disruption proximal to the dorsal root ganglion; this cannot recover and it is surgically irreparable.
- Rupture of a nerve root distal to the ganglion, or of a trunk or peripheral nerve, is a postganglionic lesion, which is surgically reparable and potentially capable of recovery.
- Brachial plexus injuries are often overshadowed by other, life-threatening trauma which needs immediate attention. Associated injuries, such as rupture of the subclavian or axillary artery, should be sought and attended to.
The Level Of The Lesion

- **Upper plexus injuries**: the shoulder abductors and external rotators and the forearm supinators are paralysed. Sensory loss involves the outer aspect of the arm and forearm.
- **Lower plexus injuries**: are rare, the Wrist and finger flexors are weak and the intrinsic hand muscles are paralysed. Sensation is lost in the ulnar forearm and hand.
- ** Entire plexus**: is damaged, the whole limb is paralysed and numb.

Management

- The patient is likely to be admitted to a general unit where fractures and other injuries will be given priority.
- Emergency surgery is required for brachial plexus lesions associated with penetrating wounds, vascular injury or severe (high energy) soft-tissue damage whether open or closed.

Obstetrical Brachial Plexus Palsy

- Obstetrical palsy is caused by excessive traction on the brachial plexus during childbirth, e.g. by pulling the baby’s head away from the shoulder or by exerting traction with the baby’s arm in abduction.
- Three patterns are seen:
  1. **upper root injury** (Erb’s palsy), typically in overweight babies with shoulder dystocia at delivery
  2. **lower root injury** (Klumpke’s palsy), usually after breech delivery of smaller babies
  3. **total plexus injury**
- The diagnosis is usually obvious at birth: after a difficult delivery the baby has a floppy or flail arm. Further examination a day or two later will define the type of brachial plexus injury.

Erb’s Palsy

- is caused by injury of C5, C6 and (sometimes) C7.
- The abductors and external rotators of the shoulder and the supinators are paralysed.
- The arm is held to the side, internally rotated and pronated.
- There may also be loss of finger extension.
- Sensation cannot be tested in a baby.

Klumpke’s Palsy

- is due to injury of C8 and T1.
- The baby lies with the arm supinated and the elbow flexed; there is loss of intrinsic muscle power in the hand.
- Reflexes are absent and there may be a unilateral Horner’s syndrome.
**Total plexus injury**
the baby’s arm is flail and pale; all finger muscles are paralysed and there may also be vasomotor impairment and a unilateral Horner’s syndrome.

**X-rays**
should be obtained to exclude fractures of the shoulder or clavicle (which are not uncommon and which can be mistaken for obstetrical palsy).

**Management**
Over the next few weeks one of several things may happen.
- Paralysis may recover completely
- Many (perhaps most) of the upper root lesions recover spontaneously.
- A fairly reliable indicator is return of biceps activity by the third month.
- A total lesion may partially resolve, leaving the infant with a partial paralysis.
- Paralysis may remain unaltered This is more likely with complete lesions, especially in the presence of a Horner’s syndrome.
- While waiting for recovery, physiotherapy is applied to keep the joints mobile.
- If there is no biceps recovery by 3 months, operative intervention should be considered.

**Long Thoracic Nerve**
- The long thoracic nerve of Bell (C5, 6, 7) may be damaged in shoulder or neck injuries (usually an axonotmesis) or during operations such as first rib resection, transaxillary sympathectomy or radical mastectomy.
- However, serratus anterior palsy is also seen after comparatively benign events, such as carrying loads on the shoulder, and even viral illnesses or toxoid injections.

**Clinical Features**
- Paralysis of serratus anterior is the commonest cause of winging of the scapula.
- The patient may complain of aching and weakness on lifting the arm.
- Examination shows little abnormality until the arm is elevated in flexion or abduction.
- The classic test for winging is to have the patient pushing forwards against the wall or thrusting the shoulder forwards against resistance.

**Treatment**
- Except after direct injury or division, the nerve usually recovers spontaneously, though this may take a year or longer.
- Persistent winging of the scapula occasionally requires operative stabilization by transferring pectoralis minor or major to the lower part of the scapula.

**Spinal Accessory Nerve**
- The spinal accessory nerve (C2–6) supplies the sternomastoid muscle and then runs obliquely across the posterior triangle of the neck to innervate the upper half of the trapezius.
Because of its superficial course, it is easily injured in stab wounds and operations in the posterior triangle of the neck (e.g. lymph node biopsy).

It is occasionally injured in whiplash injuries.

Clinical Features
- Following an open wound or operation, the patient complains of severe pain and ‘stiffness’ of the shoulder.
- Examination reveals asymmetry or drooping of the shoulder, reduced ability to hitch or hunch the shoulder and weakness on abduction of the arm.
- Often the true nature of the problem is not appreciated and diagnosis is delayed for weeks or months. In late cases there may be wasting of the trapezius.

Treatment
- Stab injuries and surgical injuries should be explored immediately and the nerve repaired.
- If the exact cause of injury is uncertain, it is prudent to wait for about 8 weeks for signs of recovery.

Axillary Nerve
- The axillary nerve (C5, 6) arises from the posterior cord of the brachial plexus.
- Runs along subscapularis and across the axilla just inferior to the shoulder joint. It emerges behind the humerus, deep to the deltoid.
- The landmark is 5 cm below the tip of the acromion.
- More often it is injured during shoulder dislocation or fractures of the humeral neck.
- Iatrogenic injuries occur in transaxillary operations on the shoulder and with lateral deltoid-splitting incisions.

Clinical Features
- The patient complains of shoulder ‘weakness’, and the deltoid is wasted.
- Although abduction can be initiated (by supraspinatus), it cannot be maintained.
- Retropulsion (extension of the shoulder with the arm abducted to 90 degrees) is impossible.
- Careful testing will reveal a small area of numbness over the deltoid (the ‘sergeant’s patch’).

Treatment
- Nerve injury associated with fractures or dislocations recovers spontaneously in about 80 per cent of cases.
- If the deltoid shows no sign of recovery by 8 weeks, EMG should be performed; if the tests suggest denervation then the nerve should be explored.
Radial Nerve

The radial nerve may be injured at the elbow, in the upper arm or in the axilla.

Clinical Features

- **Low lesions**:
  - usually due to fractures or dislocations at the elbow
  - local wound
  - Iatrogenic lesions of the posterior interosseous nerve where it winds through the supinator muscle are sometimes seen after operations on the proximal end of the radius.
  - The patient complains of clumsiness and, on testing, cannot extend the metacarpophalangeal joints of the hand.
  - In the thumb there is also weakness of extension and retroposition.
  - Wrist extension is preserved because the branch to the extensor carpi radialis longus arises proximal to the elbow.

- **High lesions**
  - occur with fractures of the humerus or after prolonged tourniquet pressure.
  - There is an obvious wrist drop, due to weakness of the radial extensors of the wrist, as well as inability to extend the metacarpophalangeal joints or elevate the thumb.
  - Sensory loss is limited to a small patch on the dorsum around the anatomical snuffbox.

- **Very high lesions**
  - may be caused by trauma or operations around the shoulder.
  - More often, though, they are due to chronic compression in the axilla; this is seen in drink and drug addicts who fall into a stupor with the arm dangling over the back of a chair (‘Saturday night palsy’) or in thin elderly patients using crutches (‘crutch palsy’).
  - In addition to weakness of the wrist and hand, the triceps is paralysed and the triceps reflex is absent.

Treatment

- Open injuries should be explored and the nerve repaired or grafted as soon as possible.
- Closed injuries are usually first or second degree lesions, and function eventually returns.
- In patients with fractures of the humerus it is important to examine for a radial nerve injury on admission, before treatment and again after manipulation or internal fixation.
- If the palsy is present on admission, one can afford to wait for 12 weeks to see if it starts to recover.
- If it does not, then EMG should be performed; if this shows denervation potentials and no active potentials then a neurapraxia is excluded and the nerve should be explored.
- If it is certain that there was no nerve injury on admission, and the signs appear only after manipulation or internal fixation, then the chances of an iatropathic
injury are high and the nerve should be explored and – if necessary – repaired or grafted without delay.

- While recovery is awaited, the small joints of the hand must be put through a full range of passive movements.
- The wrist is splinted in extension to ‘avoided fixed contractures.
- If recovery does not occur, the disability can be largely overcome by tendon transfers: pronator teres to the short radial extensor of the wrist, flexor carpi radialis to the long finger extensors and palmaris longus to the long thumb abductor.

**Ulnar Nerve**

Injuries of the ulnar nerve are usually either near the wrist or near the elbow, although open wounds may damage it at any level.

**Clinical Features**

- **Low lesions**
  - are often caused by cuts on shattered glass.
  - There is numbness of the ulnar one and a half fingers.
  - The hand assumes a typical posture in repose – the **claw hand** deformity – with hyperextension of the metacarpophalangeal joints of the ring and little fingers, due to weakness of the intrinsic muscles.
  - Hypothenar and interosseous wasting may be obvious.
  - Finger abduction is weak and this, together with the loss of thumb adduction, makes pinch difficult. The patient is asked to grip a sheet of paper forcefully between thumbs and index fingers while the examiner tries to pull it away; powerful flexion of the thumb interphalangeal joint signals weakness of adductor pollicis and first dorsal interosseous with overcompensation by the flexor pollicis longus (**Froment’s sign**).

- **High lesions**
  - occur with elbow fractures or dislocations.
  - The hand is not markedly deformed because the ulnar half of flexor digitorum profundus is paralysed and the fingers are therefore less ‘clawed’ (the ‘high ulnar paradox’).
  - Otherwise, motor and sensory loss are the same as in low lesions.

- **‘Ulnar neuritis’**
  - may be caused by compression or entrapment of the nerve in the medial epicondylar (cubital) tunnel, especially where there is severe valgus deformity of the elbow or prolonged pressure on the elbows in anaesthetized or bedridden patients.

**Treatment**

- Exploration and suture of a divided nerve are well worthwhile, and anterior transposition at the elbow permits closure of gaps up to 5 cm.
- While recovery is awaited, the skin should be protected from burns.
- Hand physiotherapy keeps the hand supple and useful.
- Tendon transfers.
Median Nerve

The median nerve is most commonly injured near the wrist or high up in the forearm.

Clinical Features

- **Low lesions**
  - may be caused by cuts in front of the wrist or by carpal dislocations.
  - The patient is unable to abduct the thumb, and sensation is lost over the radial three and a half digits.
  - In longstanding cases the thenar eminence is wasted and trophic changes may be seen.

- **High lesions**
  - are generally due to forearm fractures or elbow dislocation, but stabs and gunshot wounds may damage the nerve at any level.
  - The signs are the same as those of low lesions but, in addition, the long flexors to the thumb, index and middle fingers, the radial wrist flexors and the forearm pronator muscles are all paralysed.
  - Typically the hand is held with the ulnar fingers flexed and the index straight (the ‘pointing sign’).
  - Also, because the thumb and index flexors are deficient, there is a characteristic pinch defect.

Lumbosacral Plexus

- The plexus may be injured by massive pelvic trauma.
- These lesions are usually incomplete and often missed.
- The patient may complain of no more than patchy muscle weakness and some difficulty with micturition.
- Sensation is diminished in the perineum or in one or more of the lower limb dermatomes.
- Some patients, however, have significant problems with incontinence, impotence and neurogenic pain.
- Plexus injuries should always be sought in patients with fractures of the pelvis.

Femoral Nerve

The femoral nerve may be injured by a gunshot wound, by pressure or traction during an operation or by bleeding into the thigh.

Clinical Features

- Quadriceps action is lacking and the patient is unable to extend the knee actively.
- There is numbness of the anterior thigh and medial aspect of the leg.
- The knee reflex is depressed.
- Severe neurogenic pain is common.

Treatment

- This is a fairly disabling lesion and, where possible, counter-measures should be undertaken.
A thigh haematoma may need to be evacuated.
A clean cut of the nerve may be treated successfully by suturing or grafting but results are disappointing.
The alternative would be a caliper to stabilize the knee, or tendon transfers of hamstrings to quadriceps.

**Sciatic Nerve**
- Division of the main sciatic nerve is rare except in gunshot wounds.
- Traction lesions may occur with traumatic hip dislocations and with pelvic fractures.
- Intraneural haemorrhage in patients receiving anticoagulants is a rare cause of intense pain and partial loss of function.
- Iatropathic lesions are sometimes discovered after total hip replacement.

**Clinical features**
- In a complete lesion the hamstrings and all muscles below the knee are paralysed.
- The ankle jerk is absent.
- Sensation is lost below the knee, except on the medial side of the leg which is supplied by the saphenous branch of the femoral nerve.
- The patient walks with a drop foot and a high-stepping gait to avoid dragging the insensitive foot on the ground.
- Electrodiagnostic studies will help to establish the level of the injury.
- In late cases the limb is wasted, with fixed deformities of the foot and trophic ulcers on the sole.

**Treatment**
- If the nerve is known to be divided, suture or nerve grafting should be attempted
- While recovery is awaited, a below-knee drop-foot splint is fitted.
- Great care is taken to avoid damaging the insensitive skin and to prevent trophic ulcers.
- Sometimes can be managed by transferring tibialis posterior to the front in order to counteract the drop foot.
- If there is no recovery whatever, amputation may be preferable to a flail, deformed, insensitive limb.

**Peroneal Nerves**
Injuries may affect either the common peroneal (lateral popliteal) nerve or one of its branches, the deep or superficial peroneal nerves.

**Clinical features**
- The common peroneal nerve is often damaged at the level of the fibular neck by severe traction when the knee is forced into varus (e.g. in lateral ligament injuries and fractures around the knee, or during operative correction of gross valgus deformities), or by pressure from a splint or a plaster cast, from lying with the leg externally rotated, by skin traction or by wounds.
- The patient has a drop foot and can neither dorsiflex nor evert the foot.
He or she walks with a high-stepping gait to avoid catching the toes.
Sensation is lost over the front and outer half of the leg and the dorsum of the foot.
Pain may be significant.

**Treatment**

- Direct injuries of the common peroneal nerve and its branches should be explored and repaired or grafted wherever possible. As usual, the earlier the repair, the better the result.
- While recovery is awaited a splint may be worn to control ankle weakness.
- Pain may be relieved and drop foot is improved in almost 50 per cent of patients, especially those who are operated on early.
- If there is no recovery, the disability can be minimized by tibialis posterior tendon transfer or by hind-foot stabilization; the alternative is a permanent splint.

**Tibial Nerves**

The tibial (medial popliteal) nerve is rarely injured except in open wounds. The distal part (posterior tibial nerve) is sometimes involved in injuries around the ankle.

**Clinical features**

- The patient is unable to plantarflex the ankle or flex the toes.
- Sensation is absent over the sole and part of the calf.
- Because both the long flexors and the intrinsic muscles are involved, there is not much clawing.
- With time the calf and foot become atrophic and pressure ulcers may appear on the sole.

**Treatment**

- A complete nerve division should be sutured as soon as possible.
- A peculiarity of the tibial nerve is that injury or repair (especially delayed repair) may be followed by causalgia.
- While recovery is awaited, a suitable orthosis is worn (to prevent excessive dorsiflexion) and the sole is protected against pressure ulceration.
- In suitable cases, weakness of plantar flexion can be treated by hindfoot fusion or transfer of the tibialis anterior to the back of the foot.