Surgery of Peripheral Nerves

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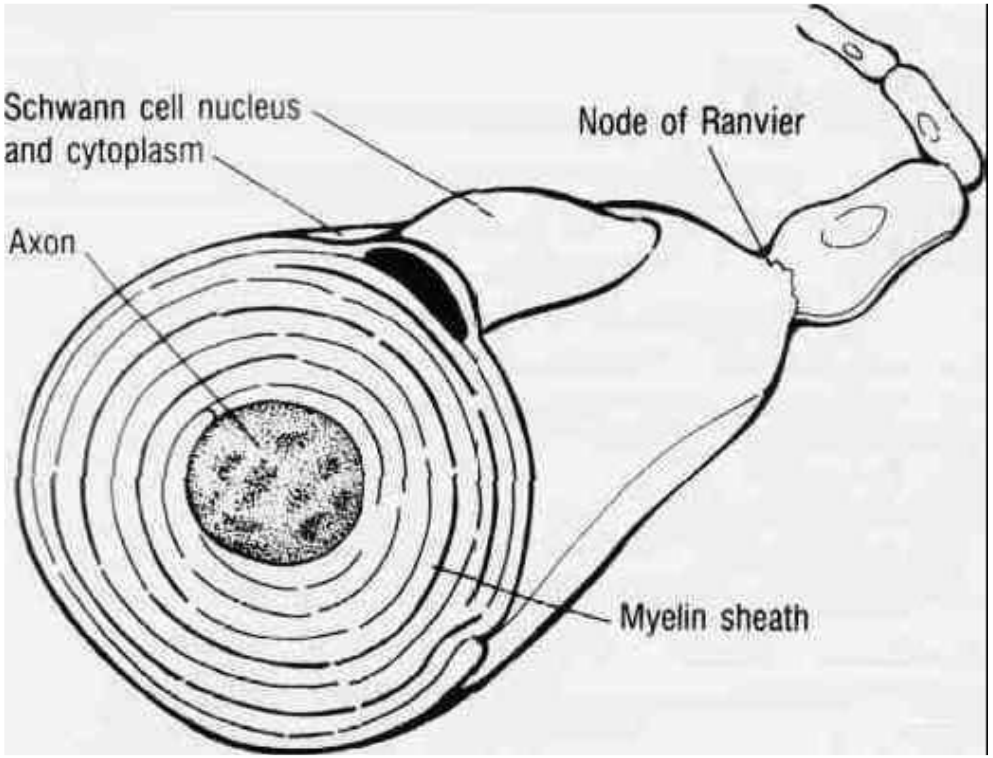
BASIC ANATOMY

Peripheral nerves include *motor, sensory,* and *autonomic fibers.*

Nerve fibers are composed of a central *axon* surrounded by a single layer of *Schwann cells.*



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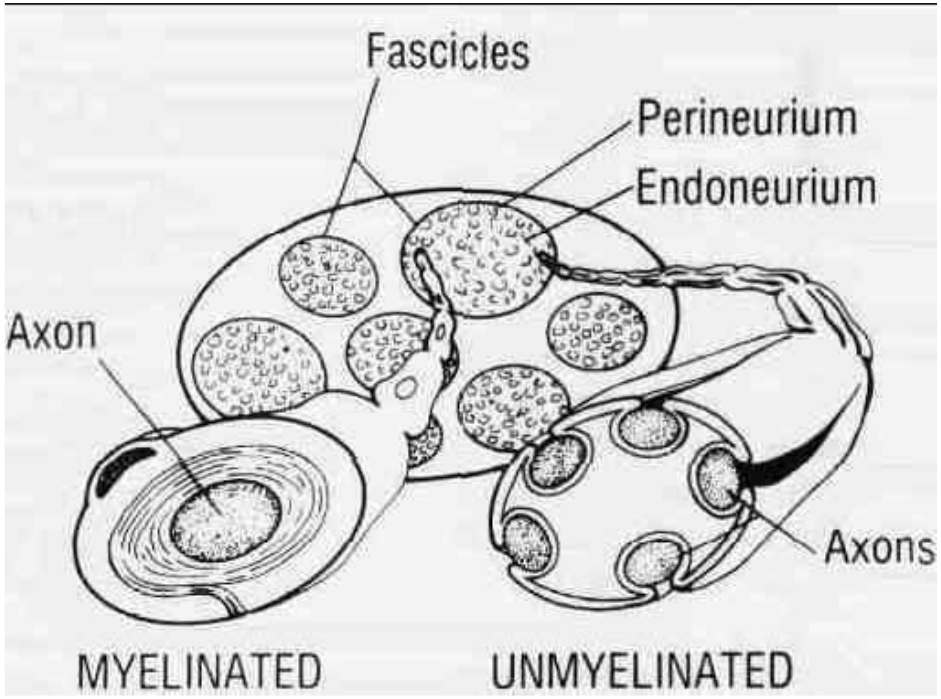


- The outer basement membrane of the Schwann cell, seen only by electron microscopy, is referred to as the *endoneural sheath.*
- Individual nerve fibers—and their Schwann cell sheaths in the case of myelinated axons—are surrounded by a thin tubule of collagen fibers, the *endoneurium.*
- Groups of nerve fibers are collected into bundles, or *fascicles,* encircled by the *perineurium,* another collagen sheath.

INITIAL EVALUATION OF PERIPHERAL NERVE LESIONS

When a patient presents with a peripheral nerve lesion, three important factors should be noted in the first examination.

The physician must determine

(1) the type of injury,

(2) the time the injury occurred, and

(3) the clinical condition of the patient at the time of the examination.

TYPES OF INJURY

1. The median nerve is *compressed* by the flexor retinaculum, resulting in the clinical presentation of carpal tunnel syndrome. The S 1 nerve root is compressed with a hemiation of the L5-S1 disk, resulting in a loss of the Achilles reflex, decreased sensation of the lateral aspect of the foot, and decreased plantar strength.
2. A nerve is *contused* by the sudden onset of blunt force. Trauma to the arm that may fracture the humerus may also contuse the radial nerve in the arm. Also, a severe crush injury to a nerve may occur in relation to massive limb trauma.

3. Peripheral nerves may be *lacerated* by an assortment of objects: a knife, the sharp edges of a broken window, unintentional laceration by an angiographer's needle or a surgeon's scalpel. The laceration may divide the whole nerve or divide only a portion of the fascicles.
4. Motorcyclists thrown from their vehicles and landing on the head and shoulder will *stretch* several roots or nerves within the brachial plexus. If the stretch injury to the brachial plexus is particularly severe, the nerve root(s) may be detached or *avulsed* from the spinal cord.

5. Nerves are also affected by extreme *cold* and *heat.*
6. Even though a *missile* may not directly strike a nerve during its course through an extremity, the nerve may still be injured by the shock waves that spread out around the missile tract, thereby damaging tissue which, may include the neural elements.
7. *Ischemic injury.* Limb trauma with sufficient hemorrhage or swelling may render nerves variably ischemic as they pass within involved muscles.
8. *Injection injury.* Improperly placed needles may enter the radial nerve in the arm or the sciatic nerve in the buttock.

ANATOMIC-PHYSIOLOGIC CLASSIFICATION

Neurapraxia is an injury to the nerve where the nerve tissue remains intact but the surrounding myelin sheath at the site of injury may be disrupted. The result is slowed conduction velocity lasting weeks to months.

Axonotmesis is an injury where the axon and surrounding myelin are disrupted but the surrounding perineurium and epineurium remain intact.

Neurotmesis is a complete disruption of the nerve such as would result from a laceration.

Sunderland further categorized nerve injuries according to degree.

In a *first degree injury,* there is interruption of conduction at the site of injury, but preservation of the anatomical components of the nerve trunk, including the axon. This is equivalent to neurapraxia of Seddon.

With *second degree injury,* the axon is severed or the axon below the level of the lesion fails to survive; however, the endoneurial tube is preserved despite wallerian degeneration. Regrowth of sensory fibers may be followed by *Tinel's sign.* This sign is positive when tapping along the nerve elicits distal paresthesias in the sensory distribution of the nerve.

In *third degree injury,* the trauma is more severe. There is some disorganization of the internal structure of the fascicles. There may be intrafascicular fibrosis, which can prove an obstacle to regeneration.

A *fourth degree injury* results in bundles of nerve fibers being so disorganized that they are no longer sharply demarcated from the epineurium in which they are embedded.

Fifth degree injury implies loss of continuity of the nerve trunk. Distances of interruption vary, but the nerve ends remain separated.

RATES OF REGENERATION

After nerves are anastomosed, several days to weeks are required for an axon to cross the site of anastomosis, but once axons reach the distal nerve sheath, regeneration occurs at the rate of 1 to 1.5 mm per day or 2.5 to 4.5 cm per month, depending on the particular nerve and the distance of the injury from the cell body.

TIMING OF SURGICAL INTERVENTION

Another factor important in determining whether reinnervation after injury will be successful is the timing of *surgical intervention.*

1. *Lacerations.* Repair within first 48 h. If injury is several days old, wait about 2 weeks for edema to subside.
2. *Blunt trauma.* Allow at least 6 weeks for evidence of recovery from a possible neurapraxic injury.

CARPAL TUNNEL SYNDROME

Carpal tunnel syndrome occurs when the median nerve is compressed beneath the flexor retinaculum.

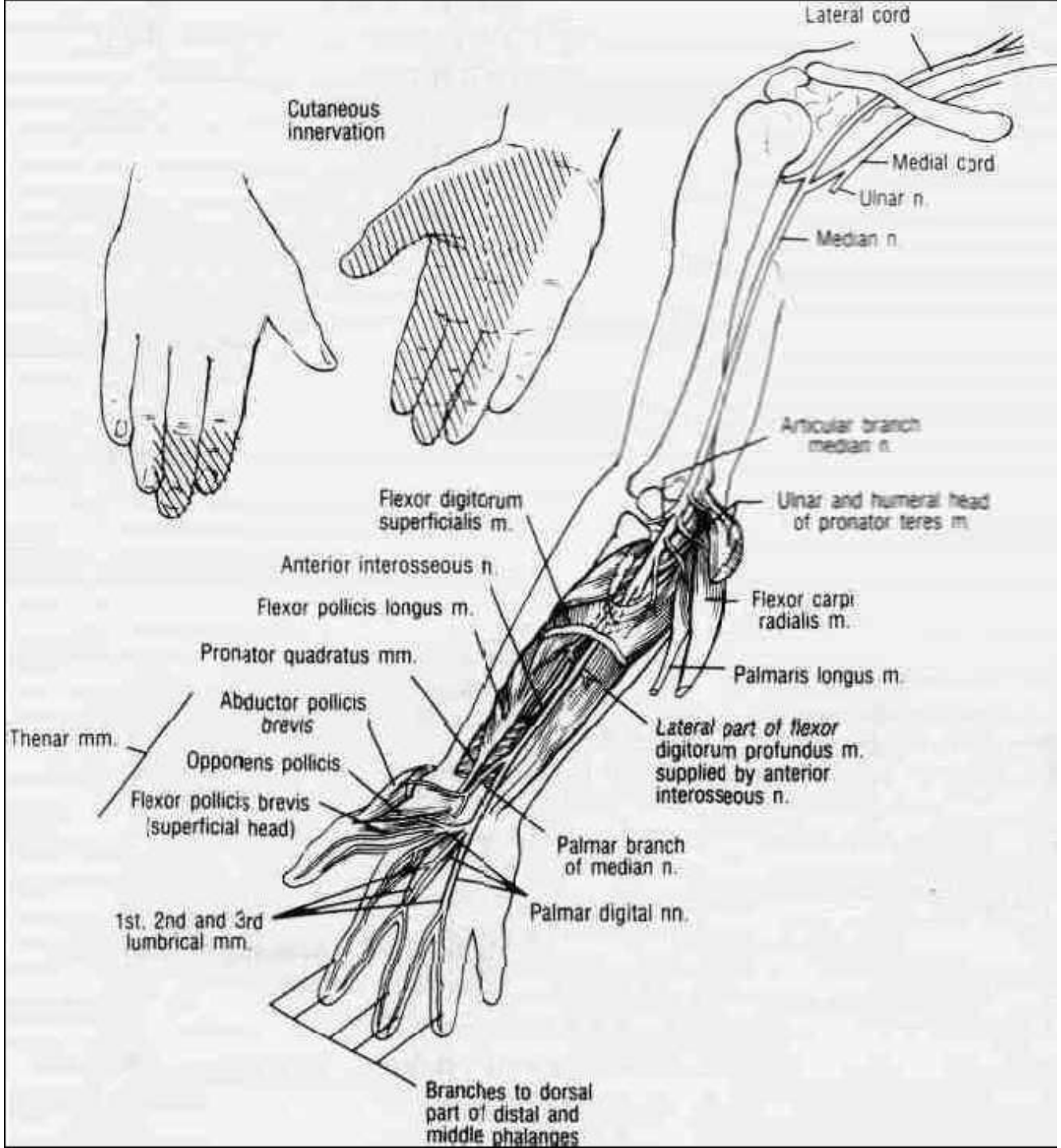
Median nerve compression may occur in pregnancy, amyloidosis, diabetes, thyroid disease, and arthritis. The patient complains of pain at the wrist and into the thumb and index fingers. The pain usually occurs at night and may awaken the patient.

On examination, the thenar muscle group may demonstrate atrophy. The sensory deficit is over the palmar surface of the thumb, index, middle, and thenar half of the ring fingers. A Tinel's sign is present at the wrist approximately 50 percent of the time; therefore, it is of little diagnostic value.

Conservative treatment may be effective.

In patients with persistent symptoms and prolonged latency of the median nerve at the wrist by nerve conduction studies, decompression by division of the flexor retinaculum is indicated.

Anatomy of median nerve.



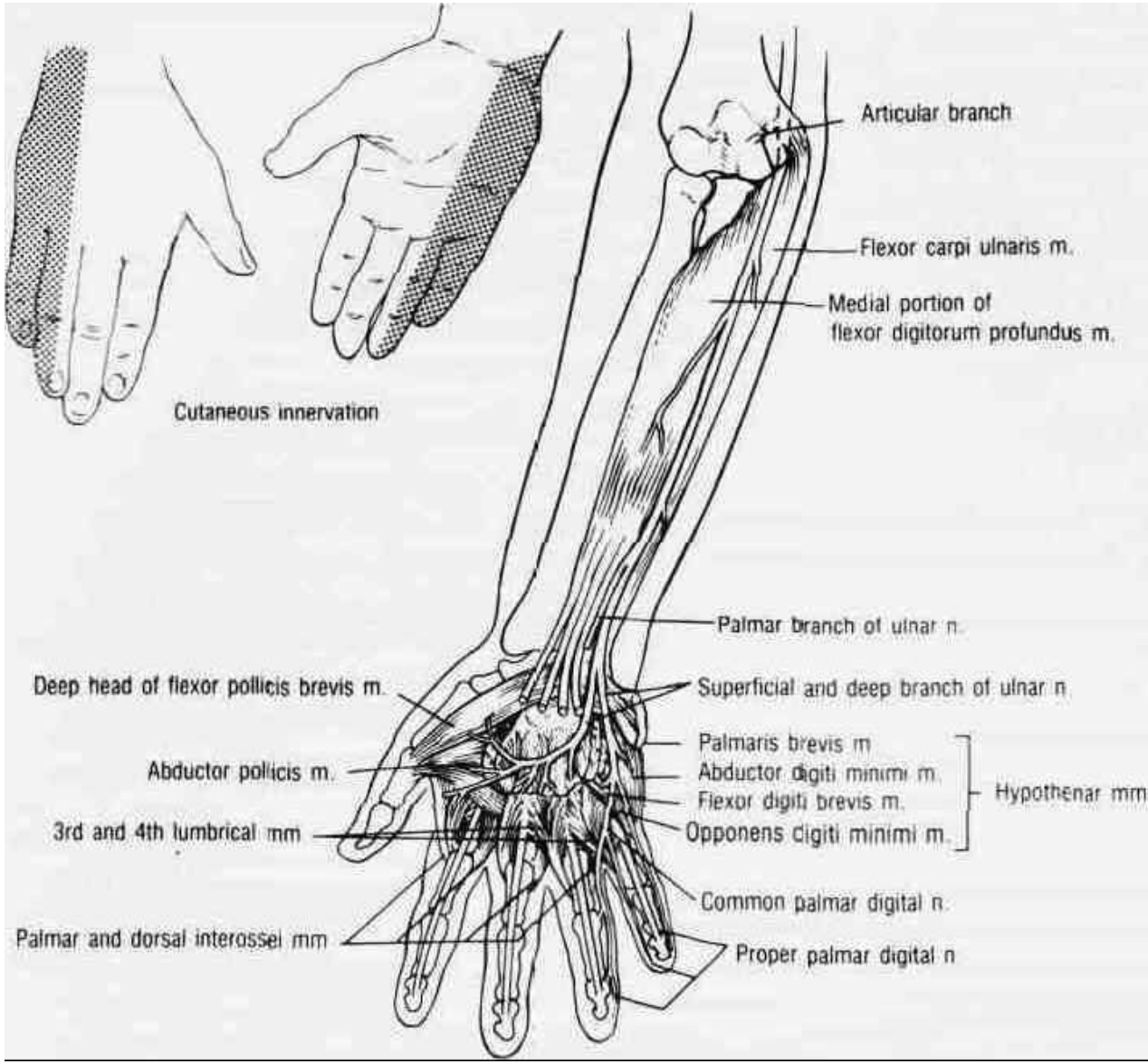
ULNAR ENTRAPMENT AT THE ELBOW

Ulnar entrapment at the elbow has also been called *tardy ulnar palsy.*

Patients present with pain and numbness in the ulnar side of the hand. Clinical examination reveals a Tinel's sign as the ulnar nerve travels over the medial epicondyle or as the nerve passes through the cubital tunnel.

In the presence of appropriate physical findings, the diagnosis is confirmed by nerve conduction velocity studies and electromyography. The first findings are slowed conduction velocities followed by prolonged motor latencies. Neurotmesis can result from injury to the nerve.

Anatomy of ulnar nerve from elbow distally.



RADIAL NERVE INJURY

Fractures of the midshaft of the humerus sometimes result in a radial nerve injury as this nerve travels in the spiral groove of the humerus.

The patient develops weakness in all muscles of the extensor compartment of the forearm. Characteristic wrist and finger drop makes the diagnosis fairly easy.

Usually, function of the triceps muscle is normal, innervation to the triceps having exited from the radial nerve proximal to the spiral groove. Electromyography 2 to 3 weeks after the injury will aid in the diagnosis.

Exploration of the radial nerve is warranted in the injury that shows no improvement within 3 to 4 months following the humeral fracture.

PERONEAL NERVE INJURY

Compression of the peroneal nerve commonly occurs as the nerve crosses in the area of the fibular neck. The nerve is vulnerable to injury as it crosses the fibula through the opening in the peroneus muscle.

Direct blunt trauma, fracture of the neck of the fibula, repeated compression from crossing the legs, or pressure from leaning on one side may cause paresis in the distribution of the peroneal nerve.

Pain laterally in the leg and foot is a common symptom. Some patients may present with a painless foot drop, i.e., loss of motor function without sensory changes.

BRACHIAL PLEXUS INJURIES

Open injuries may accompany serious, or even fatal, vascular or pulmonary injuries.

If the injury is by a sharp object (knife, glass, needles, or other sharp object), it warrants early surgical intervention as described in the section on timing of surgical intervention.

Blunt injuries may be observed for a variable period of time, depending on the proximal or distal location of the injury.

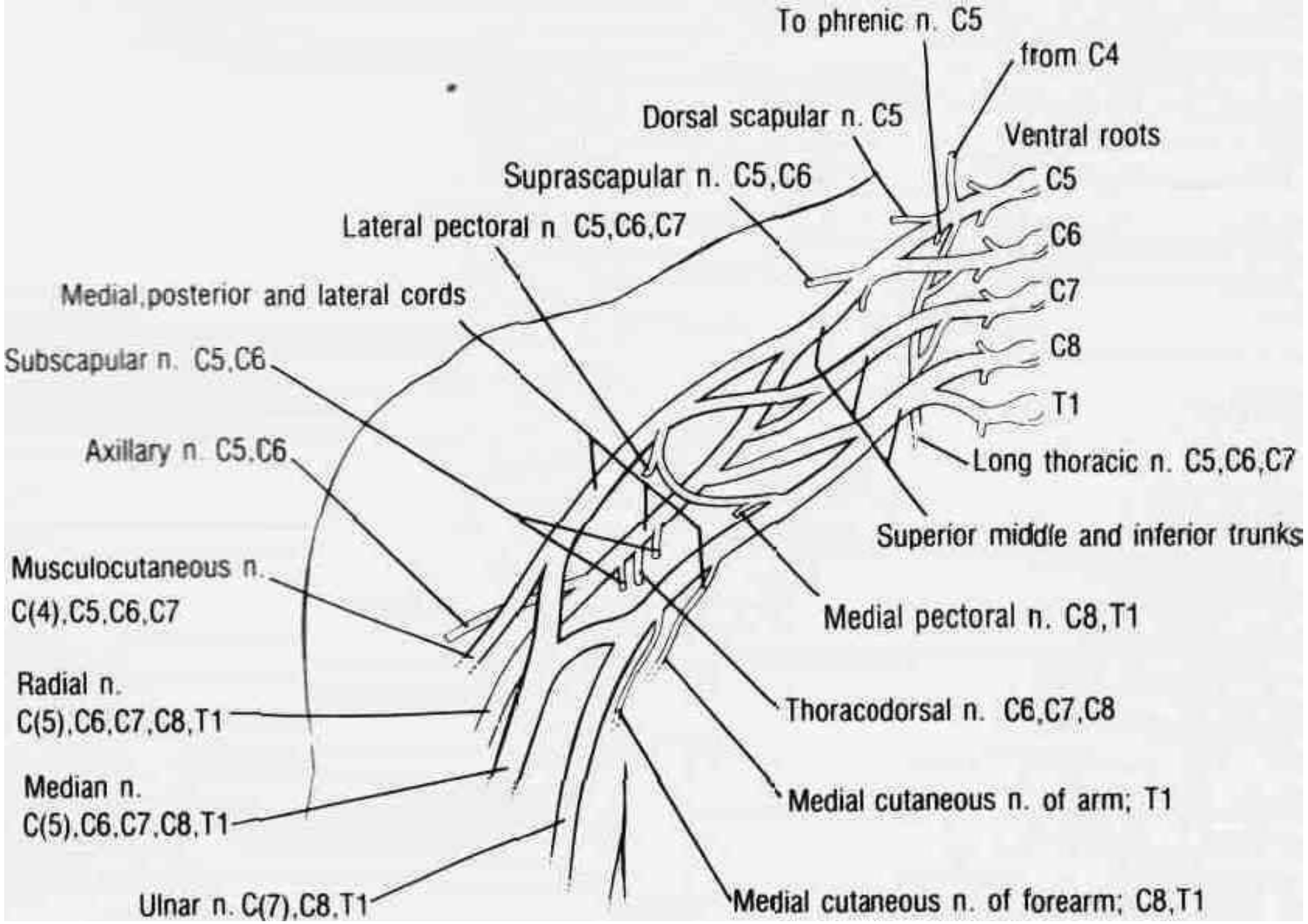
Gun shot wounds in the region of the brachial plexus may require a waiting period of up to 3 months to help establish the degree of neural injury.

Closed injuries of the plexus can be further subdivided into *supraclavicular* and *infraclavicular* injuries. Infraclavicular injuries have a better prognosis and are usually the result of bony injuries in the shoulder region.

Clavicular fractures or callus formation may compress the plexus.

Supraclavicular injuries usually occur after high-speed motor vehicle accidents, often when a rider is thrown from a motorcycle, resulting in severe stretch injuries or avulsion of roots from the cord.

An upper plexus lesion that also presents with a Homer's syndrome (myosis, ptosis, and anhydrosis of the face) has a poor prognosis. The Homer's syndrome results from injury to the upper sympathetic chain located near the dorsal root ganglia of C8 through T2.



Anatomy of brachial plexus.

Diagnostic evaluation after a brachial plexus injury should include plain cervical spine films. (Fractured cervical transverse processes provide good presumptive evidence of nerve injury.) Cervical myelography or magnetic resonance imaging of the cervical spine usually demonstrates traumatic pseudomeningoceles at the site of avulsed nerve roots. These studies should be carried out 2 to 4 weeks after the injury.

SURGICAL PROCEDURES

Prognosis for the extent of recovery is based on two factors:

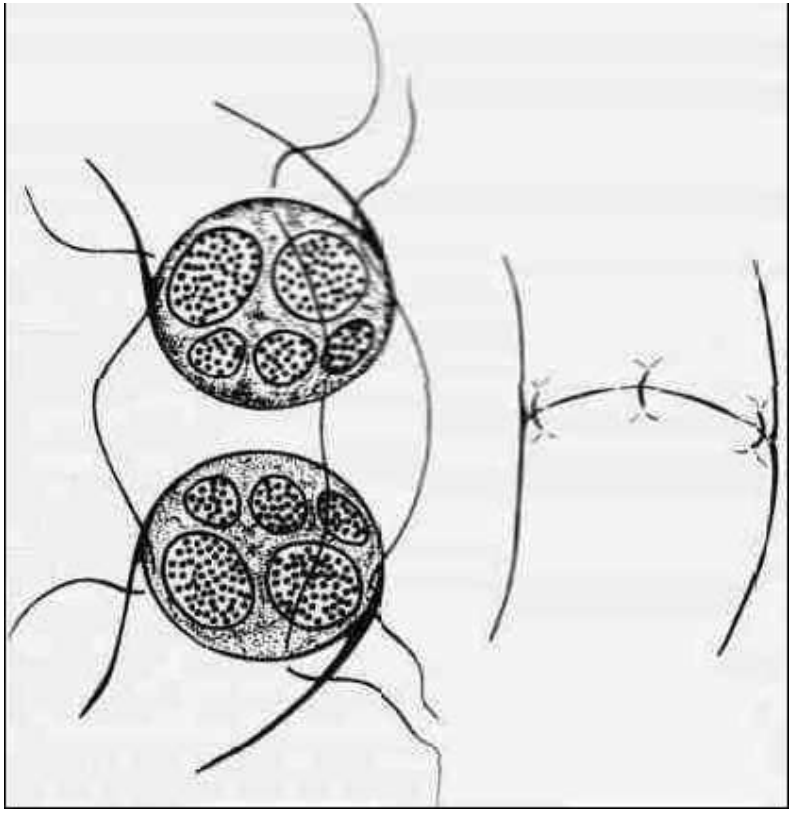
(1) At each site of anastomosis approximately 10 percent of the axons will not cross; therefore, in general, external recovery is better with primary neurorrhaphy compared to cable grafting.

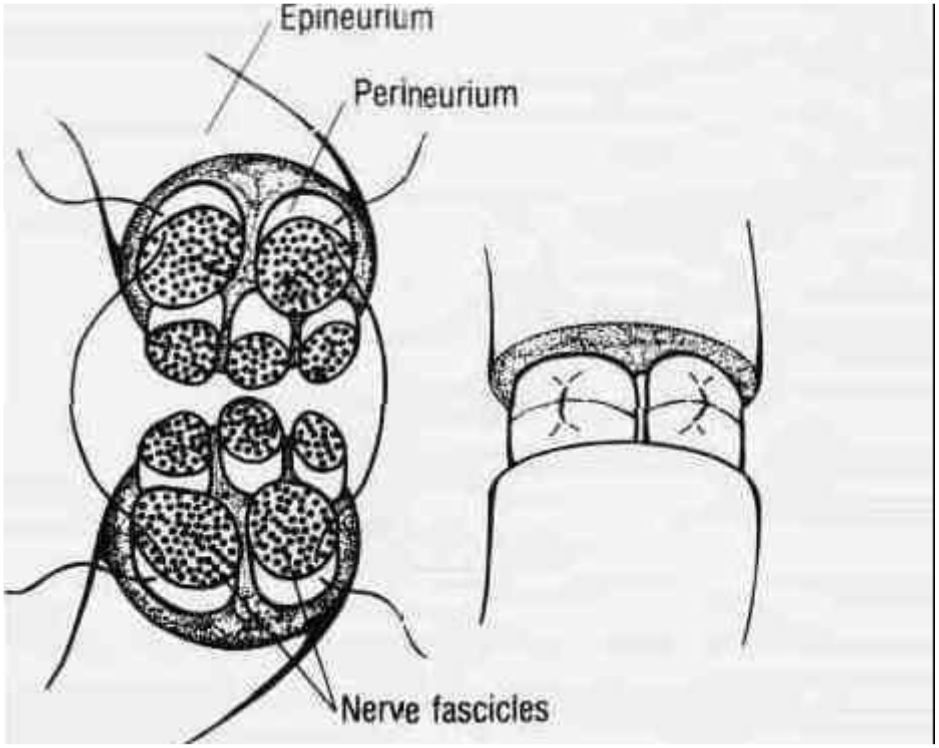
(2) Primary repair of the two ends of the injured nerve leads to better recovery if the anastomosis is not under tension.

There is debate as to whether *epineural* or *intrafascicular repair* is preferable.

Fascicular repair is technically more challenging but is more traumatic to the nerve because of the necessary dissection. In a few instances, this technique may be better, but

Epineural repair appears appropriate for most cases.

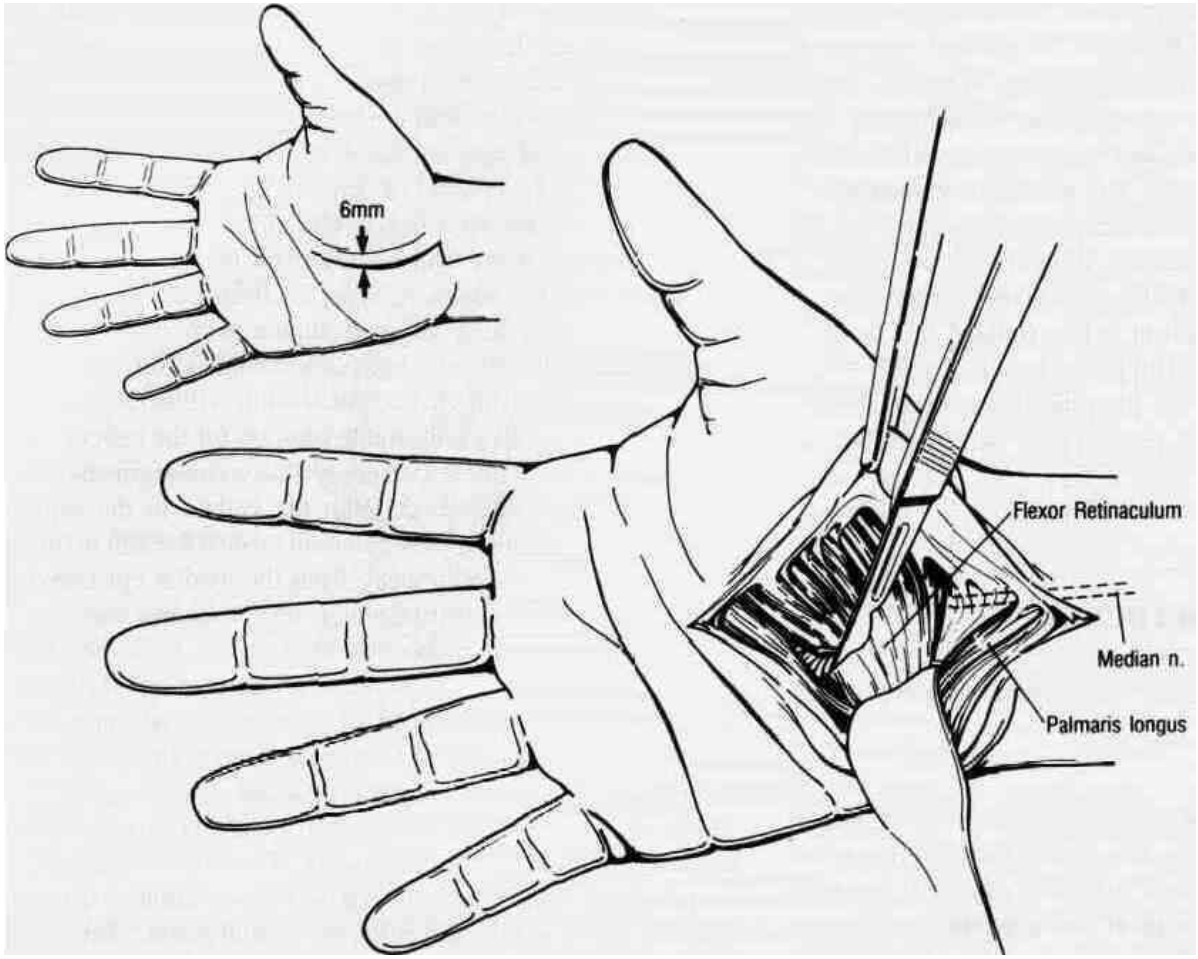


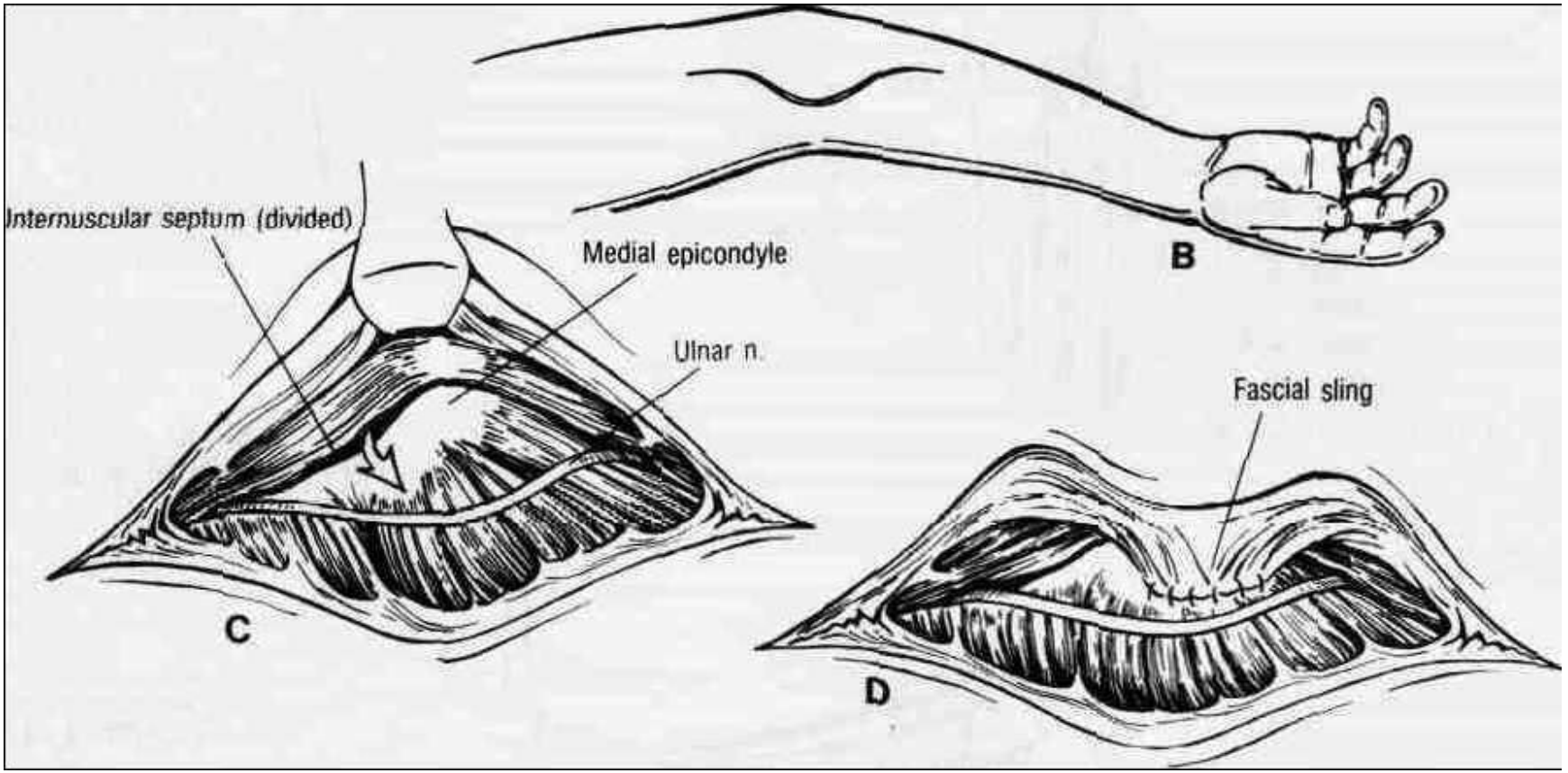


Epineural and intrafascicular repair.

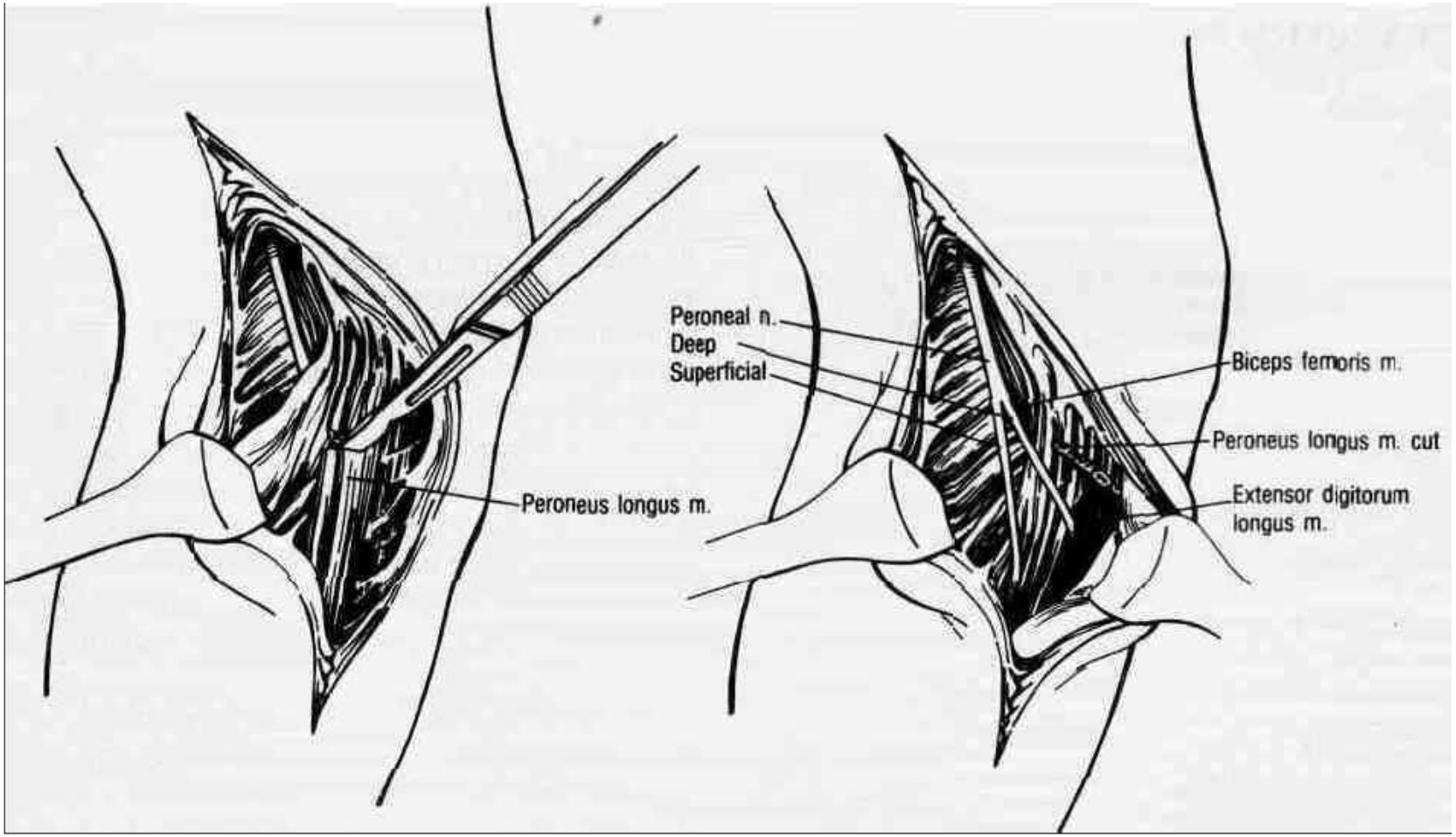
DECOMPRESSIVE PROCEDURES

Carpal tunnel release.





Transposition of ulnar nerve.



Decompression of peroneal nerve.

SUMMARY

In patients with peripheral nerve injuries, concurrent injuries that might be life-threatening must be treated first, and then the peripheral nerve injury approached systematically. The type of injury, its time of occurrence, initial deficit, and degree of recovery expected are important issues in establishing the treatment plan, which may range from skilled observation to extensive surgical intervention.