

Intro

• M/C upper extremities → impair hand function

• Cost ff, rehab

Basic Sci x Anatomy :)

CNS → PNS → targets

• ant. 1° ramus → Brachial plexus (C5-T1)

C5-6 upper trunk
C7 middle trunk
C8-T1 inferior trunk

anterior deviation < lateral cord } flexor muscle
posterior deviation posterior cord } extensor muscle

post 1° ramus → muscle + skin of posterior part of neck & trunk

* Martin Gruber: 15% ant. interosseous & ulnar n.

* Riche - Cannieu: motor branch of ulnar n. + thenar branch of median n.

Neuron: dorsal root ganglia → cell bodies { motor
sensory: pseudo unipolar

Central part: oligodendrocyte + astrocyte
peripheral part: schwann cell

Nerve trunk: enclosed in bundle
anterior collagen → perineurium
epineurium
collagen + fibroblast
fascicle: space in fascicle
endothelium
fluid, @ pressure
mp cd + cdg

C6			C8			
C5		C7		TH1		
Serratus anterior			Flexor digitorum superficialis		Opponens pollicis Abductor pollicis brevis Flexor pollicis brevis	
Deltoid	Biceps and brachialis	Pronator teres	Palmaris longus Flexor carpi radialis		Flexor pollicis longus	Adductor pollicis
		Extensor carpi radialis longus				
			Abductor pollicis longus Extensor pollicis brevis	Hypothenar		
		Extensor carpi radialis brevis	Extensor pollicis longus			
Shoulder rotators	Brachio-radialis		Extensor digitorum	Flexor digitorum profundus (index and long finger)		
		Extensor indicis, Extensor digiti minimi	Extensor carpi ulnaris			
	Supinator	Flexor carpi ulnaris	Flexor digitorum profundus (ring and little finger)	Interosseus		
		Latissimus dorsi				
Pectoralis major						

N. ulnaris	N. supracapularis	N. thoracicus longus
N. medianus	N. musculocutaneus	N. thoracodorsalis
N. radialis	N. axillaris	Nn. pectorales med and lat

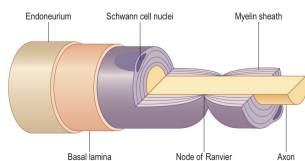


Fig. 32.4 Close-up of myelinated axon and the node of Ranvier.

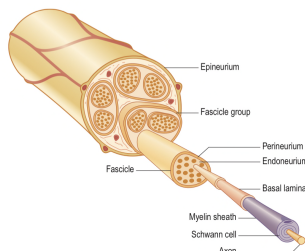


Fig. 32.5 Schematic presentation of a peripheral nerve. Colors for identical structures are the same as in Fig. 32.4.

Blood supply

trunk: segmental blood vessel in epi, peri, endoneurium

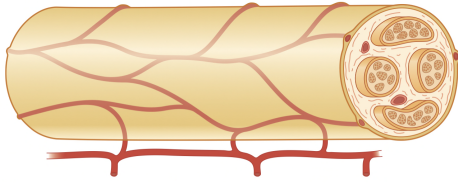


Fig. 32.6 Principal blood supply of nerve segment, highlighted in red.

Physiology

action potential: axon ions → extracellular space
node of Ranvier
myelinated fiber

Degen & Regen: axon injury

Schwann cell: apoptosis, mp
transsection / avulsion: axon resected & tip → retraction
signal

factors
survival & growth
• β-fibroblast growth factor
• cytokines: ciliary neurotrophic factor, leukemia-inh. factor
• insulin-like growth factor
→ (NGF) of neurons

Dx & Presentations

1. Neuropraxia

- 1st degree injury: block of conduction
no architecture involve
→ external compression, traction
local ischemia
✓ complete recovery: days - 3, 4 m.

2. Axonotmesis

- 2nd degree injury: Axonal damage to distal
(wallerian degeneration)
intact Schwann cells
✓ Tinel's sign
✓ Full recovery
✓ regen rate: 1-2 mm/day
- 3rd degree: disrupted perineurium + axonal damage
✓ hard predict clinical outcome
✓ Tinel sign

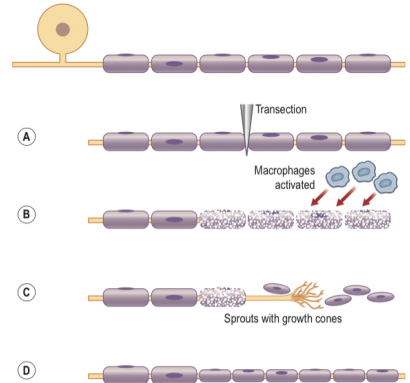
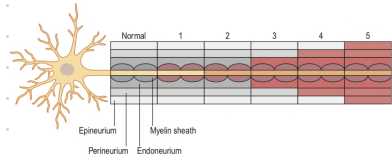


Fig. 32.7 As the nerve is severed (A), activated macrophages and Schwann cells will immediately start the removal of myelin and remnants of the disintegrated axon, to allow for a conducive environment for the regenerating axons (B). Within just a few hours numerous sprouts emerge from the distal part of each axon and form the sprout growth cone that will guide the regeneration process distally (C), until nerve regeneration is complete (D).

* Apoptosis: programmed cell death

mitochondria: xido pro-apoptotic mlt
intrinsic p/w
"Apoptosis"
extrinsic p/w
Death cell surface receptor (Fas, TNF1)



3. Neurotmesis

- 4th degree: intact epineurium, impair axonal regen
✓ neuronal death
✓ no sign of recover
✓ microsurgery repair
- 5th degree: completely transection
- 6th degree: mixed injury
neurotomy
failure regen
✓ electrodiagnostic study

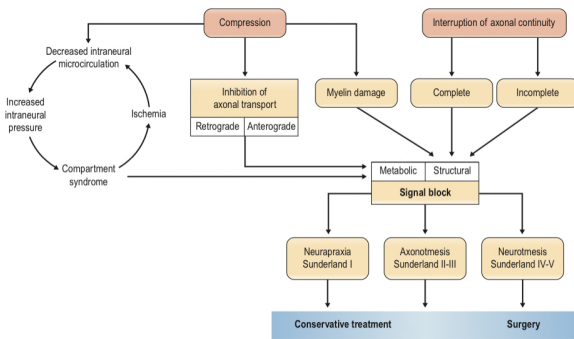


Fig. 32.8 Schematic flowchart of neuronal response to nerve compression and interruption of axonal continuity.

Clinical exam

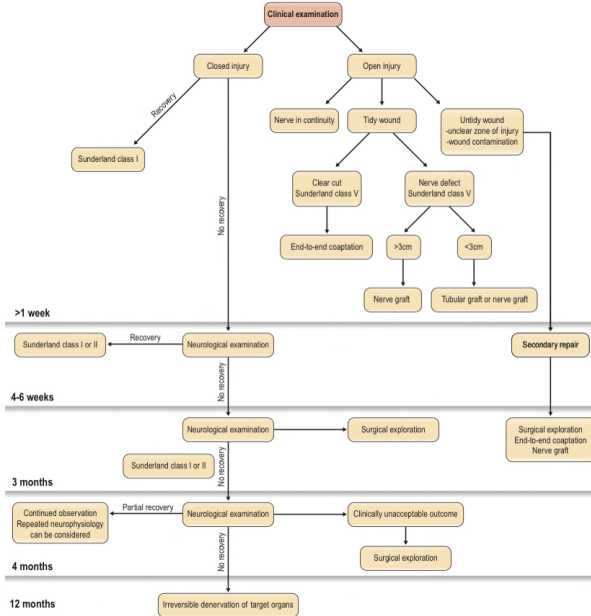
- ★ **Functional** : motor & sensory
 - pinch
 - 2 point discrim
 - grade
 - sympathetic function

- ★ **Electromyography/neurography**
 - iden branch
 - intraop → higher sense
 - 4-6 wks. axon injury

- ★ **wound inspection**

Types & Treat

Seddon	Sunderland	MacKinnon	Description
Neuropraxia	1		Local physiologic block with paralysis but no anatomic disturbance of the nerve. Full recovery is expected
Axonotmesis	2		Nerve injury with degeneration of the distal segment. Intact endoneurium and perineurium. Full recovery occurs at rate of 1.5 mm/day
	3		Endoneurial damage with subsequent scarring and incomplete regeneration. Variable recovery
Neurotmesis	4		Nerve damaged with complete internal structural disorganization. Nerve trunk remains intact. No functional recovery unless operative intervention
	5		Nerve trunk cut completely. Early operative intervention necessary for restoration of some function
	6		Mixed nerve injury



Wound Condition

- Clean → early repair
- untidy → DB, remove nonviable tissue
- severe → multiple DB
- a zone of injury distal/proximal

Surgical Techniques

- immediate suture : no tension, 2° repair, ± nerve graft
- 80% end-to-end : 9-0 nylon

Timing : immediate = 48 hr, (1-3 wks)
 1st suture → scar
 delayed ≥ 3 wk, 1st suture → nerve graft

- Approach : wide exposure
- Approach to viable tissue, 1st non viable amput
- Tourniquet

- 1st microsurgical scissors : 1st intraneural suture
- align nerve end : fascicular pattern → outcome of tag nerve end after non-absorbable
- prevent retraction
- normal excursion : 1.5 cm at wrist
- Tension free repair

Principles

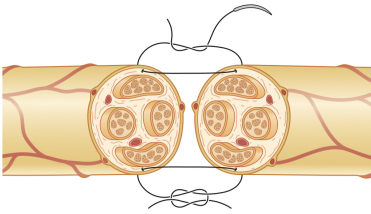


Fig. 32.13 Standard epineurial repair with nylon sutures. To get proper fascicular alignment, nerve endings are aligned based on the pattern of the blood vessels within the epineurium.

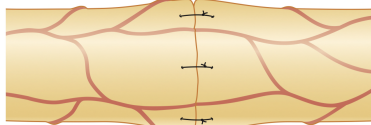


Fig. 32.18 End-to-end coaptation. Note that the epineurial vessels match.

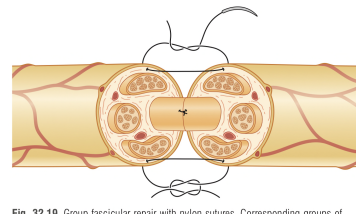


Fig. 32.19 Group fascicular repair with nylon sutures. Corresponding groups of fascicles are sutured through the interfascicular epineurium.

• Epineurial VS Fascicular Repair **

- prefer นวัตกรรม
- จัดการ ไม่ดี
- ศักยภาพ sensory / motor distinct
ex. ulnar nerve at wrist
- region ที่รับ (ทางกายภาพ)
- ศักยภาพ

• End - to - Side - ผ่าตัด แยกกัน

• Wound closure & immobilization

- interrupted suture
- ปลายที่ตรงกัน : blunt
- ปลายที่ : release tension ไม่ให้ตึงเกินไป
- ex. ข้อ flex 30°
- MP 70°
- digital n. repair = 3 wks
- larger n. = 6 wks

• Autograft *

- donor selection : size, surrounding tissue
- Small : Sural n., medial & lateral antebrachial cutaneous n.

gap

length of graft

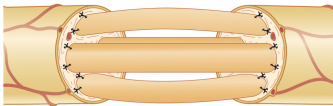


Fig. 32.21 Schematic presentation of autograft repair. Each segment is coapted to the corresponding group of fascicles of the nerve endings. Note how the individual grafts are applied quite loosely.

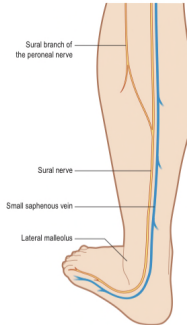


Fig. 32.22 Course of the sural nerve in the lower leg, shown in orange.



Fig. 32.24 Area of diminished or absent sensation after harvest of the sural nerve.

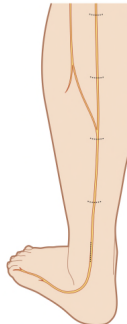


Fig. 32.23 Incisions to enable harvest of the sural nerve, shown by dotted lines.

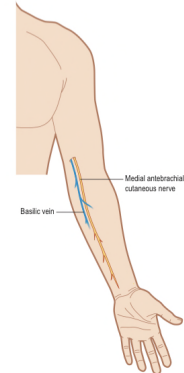


Fig. 32.25 Medial antebrachial cutaneous nerve shown in orange, and basilic vein.

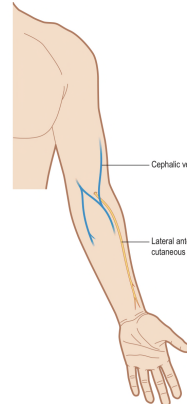


Fig. 32.27 Lateral antebrachial cutaneous nerve shown in orange and cephalic vein.

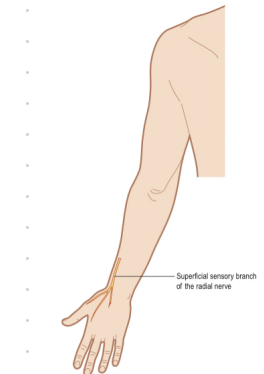


Fig. 32.30 Superficial sensory branch of the radial nerve.

Table 32.3 Common nerves used as autografts

Donor nerve	Length (cm)	Sensory defect
Sural nerve	30–40 cm	Dorsal aspect of lower leg and lateral foot
Medial antebrachial cutaneous nerve	10–12 cm* 8–10 cm†	Medial forearm
Lateral antebrachial cutaneous nerve	10–12 cm	Lateral forearm
Superficial sensory branch of the radial nerve	25 cm	Radial dorsal hand

*Above elbow.

†Below elbow.

Post-op care **

1. movement training

- Dorsal splinting 3 weeks
- Elevate hand 1st week

2. Sensory re education



Post-op dysfunction

* CRPS : complex regional pain syndrome

- regional pain + autonomic dysfunction + functional impairment + dystrophy
- no specific test to confirm Dx
- type
 - I : no peripheral n. injury
 - II : damage nerve structure
- risk
 - * ผู้ป่วยนี้
 - * female
 - * age ~ 45 y.
 - * high pre-op pain
 - * psychi : depression
 - * pain catastrophizing (PC)
 - * immobilization

common site : dorsal branch of ulnar n.
(79% limbs)
palmar cutaneous branch of median n.
sup. branch of radial n.

symptoms : burning or aching

trophic change : edema
diffuse
change of skin, nail, hair



3. factors affect outcomes

- age : ยิ่งสูงยิ่งรักษาได้ยาก require
- nerve
 - digital : microdx ดี
 - trunks : ใช้นาฬิกา watch monitor
- Level of injury : ถ้า proximal รักษาได้
- type of repair : repair ดีกว่าพวก graft
- type of injury : ถ้าฉีก nerve continuity รักษาได้ยากกว่า

* CRPS *

pain

Allodynia : ลมพัดก็เจ็บปวด

Dysesthesia : unpleasant abnormal sensation

hyperalgesia : รู้สึกปวดรุนแรงกว่าปกติ

Table 23.1 Diagnostic criteria for complex regional pain syndrome (CRPS)

Must report at least one symptom in three of the following categories:	Must display at least one sign* at time of evaluation in at least two of the following categories:
1. Sensory: Reports of hyperalgesia and/or allodynia	1. Sensory: Evidence of hyperalgesia (to pinprick) and/or allodynia (to light touch and/or deep somatic pressure and/or joint movement)
2. Vasomotor: Reports of temperature asymmetry and/or skin color changes and/or skin asymmetry	2. Vasomotor: Evidence of temperature asymmetry and/or skin color changes and/or asymmetry
3. Sudomotor/edema: Reports of edema and/or sweating changes and/or sweating asymmetry	3. Sudomotor/edema: Evidence of edema and/or sweating changes and/or sweating asymmetry
4. Motor/trophic: Reports of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nail, skin)	4. Motor/trophic: Evidence of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nail, skin)

*A sign is counted only if it is observed at time of diagnosis.
(Reproduced with permission from Harden RN, Oaklander AL, Burton AW, et al. Complex regional pain syndrome: practical diagnostic and treatment guidelines. Pain Med. 2013;14:180-229.)

Diagnosis

Hx: burning / shooting ache
severe pain without clear cause

* Dupuytren's flare response
(earlier dupuytren's fix)

PE: อาการบวม ร้อน ผื่นแดง / คัน / เจ็บปวด

edema, shiny skin, Temp. change

gentle palpation : รู้สึกปวดเมื่อกดเบาๆ, ร้อน, ระวังพวก scar neuroma

Clinical diagnostics

Specific tests in the physical examination

Motor examination If the patient can tolerate it, a focused motor examination can provide useful information. Nerve entrapment can result in subtle changes in strength. The maneuvers proposed by Hagert are useful for assessing nerve entrapments.⁴¹ This examination technique assesses bilateral muscle strength simultaneously. By testing bilateral muscle groups at the same time, the examiner can see subtle differences between the two sides, suggesting areas of nerve pathology.

Cold perception Patients with nerve injuries or entrapments will often have changes in perception of temperature and these changes can localize injured nerves. In clinic, a quick inexpensive way to assess cold perception is to place a piece of ice in the finger of an exam glove and test the patient's cold perception on various nerve distributions.

Tinel's sign The Tinel's sign has long been used to assess nerve pathology. It is easy and quick and can help localize areas of nerve compression. However, this test has low sensitivity/specificity and wide variability between providers.⁴²⁻⁴³ Thus Tinel's sign provides information but should be used as one small piece of a full physical exam.

Clinical tips

Diagnostic blocks

Provider education This is crucial if another provider is performing the block. The provider of the block needs to understand what results are useful to the surgeon.

1. First, only one nerve is to be blocked at a time. A "field block" or a brachial plexus block, which anesthetizes the whole arm, does not provide enough information on what particular nerve is generating the pain signals. If several nerves are involved, then sequential blocks separated by hours or days will allow the patient to assess the amount of pain generated by each nerve.
2. Second, the location of the block needs to be clearly documented. The surgeon needs to know where along the course of the nerve the block was placed. For example, a block of the ulnar nerve at the wrist or above the elbow will be testing very different potential pain generators.

Patient education The patient needs to understand that the primary goal of the block is to diagnose the pain generator not treat it. This means there is no expectation of prolonged pain relief after the injection. If the patient does not understand that the critical time is the first hour after the block, the patient may report the "block did not work" because the pain returned after the anesthetic wore off. During the block, the patient must also assess the distribution of numbness. This information provides quality control, ensuring the nerve of interest was blocked and its corresponding sensory distribution was numb.

Diagnostic block pearls

- Have the patient document the percentage of pain relief during the first hour after the block.
- Have the patient try the usually painful activities during the hour after the block and document the percentage of pain relief.

Clinical tips

Scratch collapse test This is a newer test that is a useful addition to the physical exam.⁴⁴⁻⁴⁵ For this technique, the patient is seated with upper arms at their sides and elbows at 90° of flexion. The patient is asked to resist as the examiner pushes medially on forearm (loading shoulder external rotation). The examiner then lightly scratches the skin directly over the area of the suspected nerve entrapment. Then the examiner immediately repeats the loading of the shoulder external rotation. If the patient's external rotation is weaker, i.e., "collapses", this is a positive test. This test is particularly useful for less common proximal nerve entrapments such as radial tunnel, pronator syndrome, and thoracic outlet. The scratch collapse test is one more tool to help localize an area of nerve pathology.

Diagnostic testing

Neuro-diagnostic testing Neuro-diagnostic studies are key diagnostic tests for assessing peripheral nerve pathology. These studies can assess for neuropathy, localize nerve compression, and exclude more proximal spinal pathology. After trauma, patients have swelling, which can result in painful nerve entrapments, such as carpal tunnel syndrome. Treating the nerve entrapment is a key part to treating the pain. However, it is important to understand the limitations of these studies. There are patients with symptomatic nerve entrapments with normal neuro-diagnostic tests.⁴⁶ This is particularly true for proximal nerve entrapments such as radial tunnel or thoracic outlet. Remember, a negative nerve study does not rule out entrapment. These tests, like many of the others, provide one more piece of information for consideration.

Ultrasound Ultrasound is being increasingly utilized in evaluating nerve pathology.⁴⁷⁻⁴⁸ Ultrasound is attractive as it is not painful, dynamic, and does not expose the patient to

radiation. Ultrasound can identify swelling and changes in nerve architecture. As the nerves become smaller, the utility of ultrasound decreases. At this time, the role of ultrasound in the diagnosis of nerve injury/entrapments in the upper limb is still evolving.

Magnetic resonance imaging (MRI) MRI technology continues to improve, resulting in more detailed imaging of the nerves. However, like ultrasound, as the nerves become smaller, the utility of the exam decreases. MRI neurogram is a technique specifically designed to image nerves and it can also provide information about the surrounding tissue (presence of ganglions, etc.).⁴⁹ MRI neurogram assesses T2-weighted images looking for increased signal that identify the area of nerve injury or entrapment.⁵⁰⁻⁵¹ MRI neurogram is currently useful for looking at larger nerve lesions such as thoracic outlet and cubital tunnel (Fig. 23.4).

Hybrid imaging techniques such as positron emission tomography (PET)/MRI are new innovations that expand the information provided. In this technology, the patient undergoes a PET scan and MRI of the affected area. Then the anatomic images of the MRI and the biological marker images of the PET are overlapped, providing more detail on the pathologic process⁵² (Fig. 23.5).

Diagnostic blocks Diagnostic blocks with local anesthetic are the most important tool for identifying the area of pain generation. If a patient has significant pain relief after a block, then the pain generator is somewhere distal to the blocked nerve. Diagnostic blocks are also useful as blocking one nerve can unmask a second site of pain. These anesthetic blocks can be done by the surgeon or in collaboration with a pain medicine specialist. There are several steps, described below, that are needed to ensure the diagnostic block generates the most useful information.

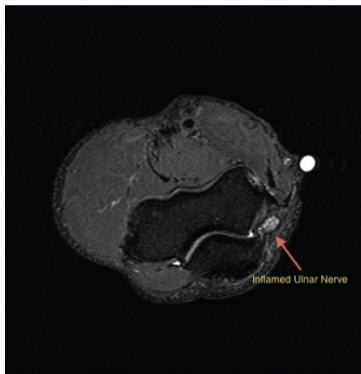


fig. 23.4 Magnetic resonance imaging of the ulnar nerve.

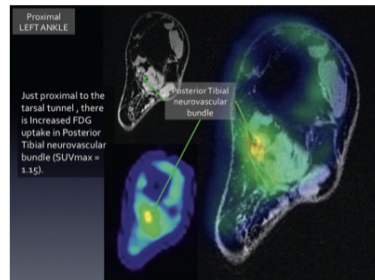


Fig. 23.5 Positron emission tomography (PET) magnetic resonance imaging (MRI) showing the merging of the bright PET signal on the anatomy of the MRI. (Courtesy of Sandip Biswas.)

Peri-op Treatment

pre Sx : gabapentin

Sx { preemptive neural blockade (LA, RA)
ketamine (NMDA antagonist)

post Sx multi modality pain control

Post-injury Tx

psycho : TCAS, SSRI
cognitive behavior therapy

medication : anti neuropathic med.
gabapentin
SNRI SSRI
TCAS

Physical modality

Surgical TX (if fail med)

• Neuroma : excision + reconstruction
end-to-side coaptation

• Nerve compression : release
ex, CRS, CTS

Neurostimulation

Block pain signal : "gate theory"

Others
www

1st VITC 1st and 2nd DER tx 1st and 2nd CAPS

kpewkpew S.

Category	Criteria
Sensory	Hyperesthesia or allodynia
Vasomotor	Temperature asymmetry, skin-color changes, or skin-color asymmetry
Sudomotor/edema	Edema, sweating changes, or sweating asymmetry
Motor/trophic	Decreased range of motion, motor dysfunction (weakness, tremor, dystonia), or trophic changes (hair, nails, skin)

The diagnosis requires at least one symptom (ie, reported by the patient) in three of the four categories and at least one sign (ie, observed at the time of evaluation) in two of the four categories in a patient with continuing pain disproportionate to an inciting event.

ADAPTED FROM HARDEN RN, BRUEHL S, STANTON-HICKS M, WILSON PR. PROPOSED NEW DIAGNOSTIC CRITERIA FOR COMPLEX REGIONAL PAIN SYNDROME. PAIN MED 2007; 8:326-331. USED WITH PERMISSION. COPYRIGHT 2007, JOHN WILEY AND SONS.