Learning Objectives

- Delineate pathology and presentation of compression vs. laceration in nerve injury
- Identify historical and current concepts of sensibility retraining in nerve injury
- Identify common UE nerve palsies, rehabilitation phases, treatment approaches, and associated orthoses
- Identify common nerve compression syndromes, anatomical features, provocative tests, differential diagnoses and therapeutic interventions

Paradigm For Nerve Injuries

<table>
<thead>
<tr>
<th></th>
<th>Compression</th>
<th>Neuropaxia</th>
<th>Axonotmesis</th>
<th>Neurotmesis</th>
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<tbody>
<tr>
<td>Postural Changes</td>
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<tr>
<td>Repetitive Trauma</td>
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<td>Crush</td>
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<tr>
<td>Stretch</td>
<td>X</td>
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<tr>
<td>Laceration</td>
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Paradigm for Therapeutic Approach to Nerve Injuries

Evaluation

<table>
<thead>
<tr>
<th></th>
<th>COMPRESSION</th>
<th>LACERATION</th>
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</thead>
<tbody>
<tr>
<td>Strong subjective evaluation</td>
<td></td>
<td>History of injury: injury</td>
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<tr>
<td>Posture evaluation</td>
<td></td>
<td>Operative notes: repair, level</td>
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<tr>
<td>Worksite analysis</td>
<td></td>
<td>Social history: occupation, support</td>
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<tr>
<td>Pain scale/DASH</td>
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<td>Patient goals</td>
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<tr>
<td>Patient goals</td>
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<td>Pain scale/DASH</td>
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<tr>
<td>Provocative tests</td>
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<td>Edema</td>
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<td>Sensory/motor evaluation</td>
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**Paradigm for Therapeutic Approach to Nerve Injuries**

**Treatment**

<table>
<thead>
<tr>
<th>COMPRESSION</th>
<th>LACERATION</th>
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<tbody>
<tr>
<td>Patient education</td>
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<tr>
<td>Sleep positioning</td>
<td>Sensory training/injury</td>
</tr>
<tr>
<td>Work-site modifications</td>
<td>prevention</td>
</tr>
<tr>
<td>Orthosis to limit re-injury/compression</td>
<td>Orthotic intervention</td>
</tr>
<tr>
<td>Modalities</td>
<td>ROM</td>
</tr>
<tr>
<td>ROM/elongate tight structures</td>
<td>Pain management</td>
</tr>
<tr>
<td>Strengthen weak musculature</td>
<td>Desensitization</td>
</tr>
<tr>
<td>Postural exercise/correct imbalance</td>
<td>Motor re-ed following tendon/nerve</td>
</tr>
<tr>
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<td>transfers</td>
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<tr>
<td></td>
<td>Sensory re-education</td>
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**Laceration: specific motor dysfunction**

**Potential negative effects of unopposed antagonists:**

- "Prolonged immobility results in restriction of joint motion"
- Overstretched denervated muscles
- Potential development substitution patterns
- Loss of function

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**Sensory Dysfunction**

**Therapeutic Intervention**

- Treatment based on principles of learning
- Tailored to patient’s interests and ability
- Evaluation of sensation is crucial

**Loss of sensation**

**Compensatory techniques**

**Diminished sensation**

**Sensory re-education**

**Hypersensitivity**

**Desensitization**

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**Desensitization**

- Involves PROGRESSIVE STIMULATION beginning at patient’s level of tolerance
- 4 basic modalities:
  - Touch
  - Tapping
  - Textures
  - Vibration

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**Sensory Reeducation**

- Purpose: cortical remodeling, promote normalized response to sensory input following peripheral nerve injury/repair
- Variety of protocols existed with similar principles:
  - Dellon - Patient with sensory deficit learns to reinterpret the altered pattern of impulses elicited by stimulation of the involved area of skin
  - Wynn Parry
  - Turner
  - Callahan
  - Nakada and Uchida

---

**Sensory Dysfunction**

- Dysesthesia
- Loss of tactile discrimination
- Loss of protective sensation

**Sympathetic Dysfunction**

- Dry skin
- Increased susceptibility to injury

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Previous Guide to Sensory Reeducation

- Early phase: reeducate specific perception and correct localization
- Begin when 30 cps vibration and/or moving touch returned
- Progress through moving touch, constant touch, and 256 cps vibration
- Include touch localization in post-stimulus recognition

Current Sensory Reeducation

- Late phase: guide recovery of tactile gnosis or object recognition
- Begin when moving and constant touch and/or 256 cps vibration perceived at fingertips with good localization
- Sequence with/without vision
- Grade size, shape, weight, and temperature of objects
- Progress to function and vocation specific objects

SR Phase 1

- Begins immediately after nerve repair
- Initial period lasts several months, no regenerating fibers reach senseless hand
- Lasts until measurable sensibility in hand via Semmes-Weinstein monofilaments
- Focus is maintaining cortical hand representation
  - Sensory imagery
  - Cortical visuo-tactile interaction
  - Cortical audio-tactile interaction

SR Phase 2

- Begins with measurable sensibility in palm via Semmes-Weinstein monofilament (6.65)
- Once “some” protective sensibility localized correctly in fingertips, touch discrimination and identification is initiated
- Classic Wynn-Parry and Dellon training used
- Focus is re-establishing functional reinnervation of hand via cortical reorganization

Common Nerve Palsies in the Hand/UE

- Radial Nerve Palsy
- PIN Palsy
- Median Nerve Palsy
- Ulnar Nerve Palsy

Common Treatment Approach to Nerve Palsies

- Phase One
  - Protect surgical repair (if surgery)/rest overused structures/avoid nerve compression or traction
  - Edema management
  - Protect areas of altered sensibility
  - AROM of uninvolved joints
  - Sensory substitution
Common Treatment Approach to Nerve Palsies

- Phase Two
  - Regain ROM
  - Enhance sensorimotor control
  - Sensory reeducation
  - Maximize function but maintain biomechanical positioning
  - Maintain PROM of affected and surrounding joints

- Phase Three
  - Strengthening
  - Aerobic conditioning
  - Restore prior functional level
  - Reevaluate compensation vs continual improvement or need for further surgical intervention

Radial Nerve Palsy

- Typically occurs in the spiral groove of the humerus
- Associated with fractures mid/distal humeral shaft
- Can be caused by prolonged pressure on the posterior humerus (Saturday Night Palsy)
- Combined sensory and motor syndrome
  - "Wrist drop"***
  - Weak/absent wrist, finger, and thumb extension
  - +/- hyperesthesia dorsal forearm and hand

Radial Nerve Palsy

Therapeutic Intervention

- ROM
- HEP

Median Nerve Palsy

- Flattened thenar mass
- Thumb in adducted position
- Radial digital clawing
- Includes FDS and FDP I, II
- Less flexed position due to loss of extrinsic component
Median Nerve Injury

- Loss of true opposition
- Note tip to tip posture on uninjured left hand
- Note thumb TIP TO SIDE of small finger in INJURED right hand

Median Nerve Palsy

Therapeutic Intervention

**JOINT STIFFNESS/CONTRACTURES**

Avoid thumb adduction contractures with C-bar orthosis for web stretch

**MAXIMIZE FUNCTION**

Median Nerve Palsy

Therapeutic Intervention

Avoid substitution patterns
- FPL for OP
- Interossei for IP extension
- APL for APB

Strong extrinsic flexors overcompensate for lack of intrinsic thumb flexors and opposition

Thumb movement is primarily flexion along the palm (Haymaker, et al, 1976)

Thumb opposition orthosis

Ulnar Nerve Palsy

Classic Presentation:
- Weak pinch (loss of AP, FDI)
- Difficulty holding objects/opposing between thumb and ring/small fingers
- Loss of cupping posture
- Inability to spread fingers (keyboarding and instrument playing)
- “Sunken hand” (loss of intrinsic bulk)

Intrinsic wasting (1st DI), clawing

Duchenne’s sign: clawing of RS/IF

Hypothenar wasting

“Loss of palmar arch (Masse Sign)"

Ulnar Nerve Palsy

Therapeutic Intervention

**JOINT STIFFNESS**

- ROM
- Orthotic(s) for MP flexion, PIP extension
- Dynamic
- Static Progressive

Ulnar Nerve Palsy

Therapeutic Intervention

**AVOID SUBSTITUTION PATTERNS**
- EPL for Adductor Pollicis
- Long flexors for finger adduction
- Long extensors for finger abduction

**MAXIMIZE FUNCTION**

**AVOID OVERSTRETCHED DENERVATED MUSCLES**

- Anti-claw orthosis
- Encourage active IP extension in orthosis
NERVE COMPRESSIONS

- PIN Syndrome
- Radial Tunnel Syndrome
- Wartenberg’s Syndrome
- Pronator Syndrome
- Carpal Tunnel Syndrome
- Cubital Tunnel Syndrome
- Ulnar Tunnel Syndrome

**Radial Nerve**

Course through dorsal forearm

**Radial Tunnel Syndrome**

- Radial nerve compression at Arcade of Frohse
  - Site of nerve piercing two heads of supinator muscle
- Lateral elbow and forearm pain 4-5 cm distal to lateral epicondyle
- Pain: deep, burning, aching
  - Symptoms increase with pronation and wrist flexion
  - Resting and night pain common
- Sensory and motor complaints rare

**Posterior Interosseous Syndrome**

- Radial nerve compression under supinator muscle
- No pain or sensory complaints; primarily motor
- Orthosis to support fingers and thumb in extension—may not need wrist support if ECRL strong
- Weakness in some/all PIN innervated musculature: ECRB, supinator, EDC, EDM, ECU, APL, EPL, EPB, EIP

**Radial Tunnel Syndrome**

**Provocative Tests**

- Tenderness to palpation 4-5 cm distal to lateral epicondyle
- Resisted middle finger with elbow extension
- Resisted supination

**Differential Diagnosis**

- Lateral Epicondylitis
- Brachial Plexus Neuritis
- Cervical Radiculopathy
- Anconeus Tendonitis
- Extensor Compartment Syndrome
- Radiocapitellar pathology
Scenarios that Increase Risk of Radial Tunnel Syndrome

- Exertion greater than 1kg F > 10x/hour
- Static pinching or squeezing of tools
- Working with elbow extended
- Maintained position of supination or pronation


Radial Tunnel Syndrome

Therapeutic Intervention

- Modalities: no definitive evidence may extrapolate for US and Iontophoresis
- Nerve gliding Ekstrom and Holden, 2002
- Stretching Ekstrom and Holden, 2002
- Postural exercises
- Work site evaluation/ergonomic intervention
- Orthotics: LAO with elbow flexed, forearm supinated & wrist extended; Wrist extension orthosis (prefabricated)

Wartenberg’s Syndrome

- Compression of superficial radial nerve as it exits distally between BR and ECRL
- Tight watch can cause symptoms
- Pain/paresthesias
  - Dorsal/radial surfaces of distal third of forearm
  - Dorsal hand, thumb, IF, and/or MF
- Differentiate from DeQuervain’s
  - APL and EPB strong and painless
  - Finkelstein’s test increases numbness but not painful
- Orthosis: forearm based thumb spica

Pronator Syndrome

Clinical Provocation

-RM compression of pronator teres
-FDS arch
-Resisted MF PIP flexion
-Lacertus Fibrosis
-Resisted elbow flexion at 120-135° with full supination

Pronator Syndrome

Proximal Median Nerve Compression

- Sites of compression
  - Between 2 heads of pronator teres
  - Under ligament of Struthers (can serve as anomalous origin of pronator teres muscle)
  - FDS arch
- Pain and paresthesias in median distribution
  (Notably the palmar cutaneous branch)
  - Sensitivity of thenar eminence with high specificity, sensitivity, and predictive value for proximal median nerve compression
  - Rosenberg et al., 2001
- Non-localized forearm pain
- Subjective complaints of weakness
- Pain with activity rather than at night
- Negative Phalen’s
Pronator Syndrome
Therapeutic Intervention

• Rest
• Avoidance of repetitive rotation and forceful grasp
• Posterior elbow orthosis with 90° elbow flexion and forearm in neutral. Removed only for gentle ROM for 2 weeks
• Modalities
  - Ultrasound
  - Electrical stimulation and iontophoresis
  - Nerve Gliding

Anterior Interosseous Syndrome
Compression of AIN Branch of the Median Nerve

• Weakness of precision pinch
• No sensory complaints
• Lost function of FPL and FDP to IF (MF)
• Weak pronation- PQ tested by resisting pronation with elbow in maximum flexion
• Median nerve compression occurs at tendinous origin of deep head of PT

AIN PALSY: Impaired prehension skills

Median Nerve
Wrist level

Carpal Tunnel Syndrome
Median Nerve Compression at the Wrist

• Pain and paresthesias in distal median nerve distribution
• Nocturnal pain
• Numbness of radial 3 1/2 digits
• +/- Atrophy of thenar muscles
• Cold sensitivity
• Compression occurs under transverse carpal ligament

Carpal Tunnel Syndrome
Clinical Examination

• Provocative tests
  - Tinel’s: over carpal canal
  - Phalen’s: passive wrist flexion 1 minute
  - Carpal compression test
  - Scratch collapse test
  - Lumbrical incursion
• Sensory testing
  - 2PD, light touch, vibration
• Activity assessment
• MMT
### Carpal Tunnel Syndrome

**Therapeutic Intervention**

- Wrist orthosis (neutral)
  - Full time vs night
  - Wrist vs MCP block
- Modalities (pulsed US)
- Nerve gliding
- AROM wrist/TGE
- Manual therapy (carpal mobs + flexor retinaculum stretch)
- Yoga
- Activity modification


### Surgical/Electrodiagnostic

**Consult for CTS**

- Atrophy in opponens muscle
- SW monofilament MF tests >3.61 (blue)
- Constant daytime paresthesia
- No improvement in nocturnal pain
- (+) provocative testing after 1 week of night orthotic


### Cubital Tunnel Syndrome

**Symptoms**

- Ulnar nerve compression may occur in several sites around elbow:
  - Osborne’s band
  - Bony retrocondylar groove
  - Arcade groove
  - Arcade of struthers
  - Medial intermuscular septum
- Sharp or aching pain on medial proximal forearm
- Paresthesias, coldness in ulnar aspect of hand
- Muscle weakness (less clawing with proximal lesion due to weak FDP); weak finger crossover

### Clinical Assessment

- Provocative tests
  - Elbow flexion test: clinical provocation via elbow flexion 1 minute
  - Tinel’s at cubital tunnel
  - Overhead flexion to rule out proximal contribution (double crush)
  - Scratch collapse test

Mackinnon, SE 2011

### Therapeutic Intervention

- Activity modification (worksite)
- Rest: (Night) orthosis; elbow in 30-45°/comfortable flexion, wrist/forearm neutral. Hely & Weber orthosis commonly sited.
- Protect: Wear soft elbow pad during the day to prevent nerve pressure
- Postural exercises/awareness
- Nerve gliding
- Modalities (pulsed US)
Cubital Tunnel Syndrome
Surgical Intervention

Ulnar Nerve Decompression
- Incision made posterior to medial epicondyle
- Fascial bridge between olecranon & medial epicondyle released
- Elbow flexed and extended to make sure nerve glides freely intra-op

Treatment (3-5 days post-op)
- Edema control
- Active ROM & gentle PROM
- 6 weeks post-op: progressive strengthening exercises

Anterior Subcutaneous Transposition of Ulnar Nerve (with Eaton Sling)
- Ulnar nerve transferred anterior to medial epicondyle
- A segment of flexor-pronator fascia used to form ulnar nerve sling

Treatment
- 10-14 Days: Edema management
  - LAO: between exercise & at night
  - Elbow 90 degree flexion, forearm & wrist neutral
- 3 weeks post-op: AROM initiated
- 6 weeks post-op: PROM - progressive strengthening
- 8 weeks post-op: Work conditioning

Ulnar Nerve Transposition

Anterior Submuscular Transposition of Ulnar Nerve
- Origins of superficial head of FCU, FCR, PL, PT, and portion of FDS resected from medial epicondyle
- Ulnar nerve released & placed deep to these muscles
- Flexor-pronator mass reattached to origin at medial epicondyle

Treatment
- 10-14 Days: Edema management
  - LAO: elbow 90 degrees flexion, forearm pronated, wrist neutral
  - AROM to elbow (forearm pronated, extension to 30)
- 3 weeks post-op: Full AROM (avoiding extrinsic flexor stretch)
- 6 weeks post-op: PROM - progressive strengthening
- 8 weeks post-op: Work conditioning

Ulnar Tunnel Syndrome
Compression at 1 of 3 sites
- Guyon’s canal: volar carpal ligament, hook of the hamate, and hamate
- Zone 1. At wrist and proximal to the canal: both motor and sensory symptoms
- Zone 2. At exit of canal: involves deep motor branch only
- Zone 3. At exit of canal: only sensory branch

Ulnar Tunnel Syndrome
Therapeutic Intervention
- Conservative management
  - Orthosis
  - Reduce or remove aggravating activity
  - Nerve gliding
- Surgical release
- Post-operative care
  - Scar management
  - ROM
  - Intrinsic strengthening
THANK YOU!

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References

• Afriel E, Sigafoos G. Comparison of ROM Constraints Provided by Splints Used in the Treatment of Cubital Tunnel Syndrome: A Pilot Study. JHT 2006;384-391
• Brand, PW. Rehabilitation of the hand with Motor and Sensory Impairment. Orthop Clin N Am, 4: 1135, 1973
• Chan RK. Splinting for peripheral nerve injuries in the upper limb. Hand Surg 2002;7:251
• Clark BD, Barr AE, Safadi FF. Median nerve trauma in rat model of work related musculoskeletal disorders. J Neurotrauma. 2003;20:681-95

References cont.

• Cleary CK. Management of Radial Tunnel Syndrome: A Therapist’s Clinical Perspective. JHT 2006; 19:186-91
• Ebenbichler GR, Resch KL, Nicolakis P, Ghanem AH & Fliaha V. Ultrasound treatment for treating the carpal tunnel syndrome: randomised “sham” controlled trial. BML 1998; 316:731
• Ekstrom RA & Holden K. Examination of and Intervention for a Patient With Chronic Lateral Elbow Pain With Signs of Nerve Entrapment. Physical Therapy 2002; 82(11):1077-80
• Fox IK & Mackinnon SE. Adult Peripheral Nerve Disorders- Nerve Entrapment, Repair, Transfer and Brachial Plexus Disorders. Plast Reconstr Surg 2011; 127(5)
• Lund AT & Amadio PC. Treatment of Cubital Tunnel Syndrome: Perspectives for the Therapist. JHT 2006; 19(2):170-9
• Muller M, Tsui D, Schnurr R, Biddulph-Deisroth L & Hart J. Effectiveness of Hand Therapy Interventions in Primary Management of Carpal Tunnel Syndrome: A Systematic Review. JHT 2004; 17:210-28

References cont.

• O’Connor D, Marshall SC, Masay-Westropp N & Pitt V. Non-surgical treatment (other than steroid injection) for carpal tunnel syndrome 2003 (Cochrane Review)
• O’Connor D, Marshall SC, Masay-Westropp N. Ergonomic positioning or equipment for treating carpal tunnel syndrome (Review) 2012 (Cochrane Review)
• Rosenberq D, Conolly J & Dellon AL. Thaner eminence quantitative sensory testing in the diagnosis of proximal median nerve compression. JHT 2001; 14(4):258-65
References cont.

- Topp KS & Boyd BS. Peripheral Nerve: From the Microscopic Functional Unit of the Axon to the Biomechanically Loaded Macroscopic Structure. JHT 2012; 25:142-52