Learning Objectives

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

Pathophysiology of Nerve Compression

Paradigm For Nerve Injuries

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

**Evaluation**

<table>
<thead>
<tr>
<th>COMPRESSION</th>
<th>LACERATION</th>
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<tbody>
<tr>
<td>Strong subjective evaluation</td>
<td>History of injury: timing</td>
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<tr>
<td>Posture evaluation</td>
<td>Operative notes: repair, level</td>
</tr>
<tr>
<td>Worksite analysis</td>
<td>Social history: occupation, support</td>
</tr>
<tr>
<td>Pain scale/DASH</td>
<td>Patient goals</td>
</tr>
<tr>
<td>Provocative tests</td>
<td>Pain scale/DASH</td>
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<tr>
<td>Sensory/motor eval</td>
<td>Edema</td>
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<td></td>
<td>Sensory/motor eval</td>
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</tbody>
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References:
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

Goals of therapy include:
- Preventing joint stiffness/contracture
- Positioning to avoid overstretched denervated muscles
- Avoiding substitution patterns, 
in tendonosis pattern in radial nerve injury
- Maximizing function while awaiting return

Sensory Dysfunction
Therapeutic Intervention

Loss of sensation
Compensatory techniques

Diminished sensation
Sensory re-education

Hypersensitivity
Desensitization

Laceration: predictable sensory dysfunction

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

Sympathetic Dysfunction
- Dry skin
- Increased susceptibility to injury

Desensitization

- Unmasking of inhibitory controls in the spinal cord alters tonic inhibition and causes tactile hypersensitivity
- Concept: overload "cranky" nerve with sensory input so adapts to stimuli and tolerates normal touch
- Involves PROGRESSIVE STIMULATION beginning at patient's level of tolerance

- 4 basic modalities:
  - Touch
  - Tapping
  - Textures
  - Vibration
Sensory Reeducation

- Purpose: cortical remodeling, promote normalized response to sensory input following peripheral nerve injury/repair
  - Normalize neural impulses, “find a match” in association cortex to become conscious perception
- If SR does not happen or is not effective:
  - Neural impulses go unrecognized/unnoticed
- Variety of protocols exist 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

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
- 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

Current Sensory Reeducation

- Cortical representation of the hand becomes disorganized, diminished or disappears after nerve injury
- Sensory reeducation should start immediately after nerve repair to preserve cortical hand representation

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 initiated
- Classic Wynn-Parry and Dellon training used
- Focus: re-establishing functional reinnervation of hand via cortical reorganization
  - “Forced use” and higher demand—> better sensory return
- Outcome dependent on cognition, motivation, compliance

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
    - Mirror, Sensor glove

Common Treatment Approach to Nerve Palsies

- Phase Two
  - Regain ROM and enhance sensorimotor control
    - Place/hold, biofeedback, NMES
    - Familiar visual information
  - 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
- Can be caused by prolonged pressure on the posterior humerus (Saturday Night Palsy)
- More associated with fractures mid/distal humeral shaft
  - 9-12% incidence
  - Primary injury more common than intra-operatively
  - No notable difference in recovery surgical (70%) vs non-surgical

- Combined sensory and motor syndrome
  - "Wrist drop***
  - Weak/absent wrist, finger, and thumb extension
  - +/- hyperesthesia dorsal forearm and hand

Median Nerve Palsy

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

**Radial Nerve Palsy**

Therapeutic Intervention

- ROM
- HEP

**Median Nerve Palsy**

Therapeutic Intervention

- Low

**Radial Nerve Palsy**

Therapeutic Intervention

- Avoid substitution patterns
- Maximize function

- Low profile extension orthosis
- Dynamic MCP extension orthosis

**Median Nerve Palsy**

Therapeutic Intervention

- High
  - Radial digital clawing
  - Flattened thenar mass
  - Thumb in adducted position
- Low
  - High and Low

High becomes Low!!
**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
  - Achieved by flexion and some abduction

**Median Nerve Palsy**

**Therapeutic Intervention**

**JOINT STIFFNESS/CONTRACTURES**

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

**MAXIMIZE FUNCTION**

**Avoid substitution patterns**

- FPL for OP (low injury)
- APL for APB

- Strong extrinsic flexor
  - overcompensate for lack of intrinsic thumb flexor and opposition

- Thumb movement is primarily flexion along the palm

**Thumb opposition orthosis**

**Median Nerve Palsy**

**Therapeutic Intervention**

**Avoid substitution patterns**

- FPL for OP (low injury)
- APL for APB

- Strong extrinsic flexor
  - overcompensate for lack of intrinsic thumb flexor and opposition

- Thumb movement is primarily flexion along the palm

**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 RF/SF

**Hypothenar wasting**

*Loss of palmar arch (Masse Sign)*

**Ulnar Nerve Palsy**

**Therapeutic Intervention**

**Avoid substitution patterns**

- FPL for OP (low injury)
- APL for APB

- Strong extrinsic flexor
  - overcompensate for lack of intrinsic thumb flexor and opposition

- Thumb movement is primarily flexion along the palm

**Thumb opposition orthosis**

**Ulnar Nerve Path**

- High
  - Includes FDP and Intrinsic
  - Less clawing due to no pull of FDP
- Low
  - FDP intact
  - No intrinsic
  - Clawing more prominent
**Ulnar Nerve Palsy**

**Therapeutic Intervention**

**JOINT STIFFNESS**
- ROM
- Orthotic(s) for MP flexion, PIP extension
- Prevent PIP flexion contractures
  - Dynamic
  - Static Progressive

**Avoid Substitution Patterns**
- EPL for Adductor Pollicis
- Long flexors for finger adduction
- Long extensors for finger abduction

**MAXIMIZE FUNCTION**
- Anti-claw orthosis
- Encourage active IP extension in orthosis

**Avoid Overstretched Denervated Muscles**

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

Typically caused by pressure, traction, or ischemia

**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**

- 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
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


**Therapeutic Intervention**
- **Modalities:** no definitive evidence may extrapolate for US and Iontophoresis
- **Nerve gliding** Ekstrom and Holden, 2002
  - Greatest distal excursion: Shldr 30 ABd, 10 ER; Wrist flex, UD; Fingers flex
  - Greatest proximal excursion: Shldr 110 ABd, 90 ER; Wrist neutral; Fingers neutral
- **Stretching** Ekstrom and Holden, 2002
- **Postural exercises** Novak, 2004
- **Work site evaluation/ergonomic intervention**
  - 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
- DRSN scissors between ERCL/B in pronation
- Tight watch, handcuffs 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
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
  - Sensibility 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
Clinical Provocation

- Manual compression of pronator teres

Pronator Syndrome
Clinical Provocation

- FDS arch
- Resisted MF PIP flexion
- Lacertus Fibrosis
- Resisted elbow flexion at 120-135° with full supination
- Pronator Teres
- Resisted pronation with elbow extension (+wrist flexion)

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: Ebenbichler 1998
  - Ultrasound
  - Electrical stimulation and iontophoresis

Anterior Interosseous Syndrome
Compression of AIN Branch of the Median Nerve

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

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

Clinical Examination

- Provocative tests
  - Tinel’s: over carpal canal Specificity 92%
  - Phalen’s: passive wrist flexion 1 minute Sensitivity 85% Specificity 85%
  - Pressure Provocative Phalen’s Sensitivity 90% with pressure in wrist flexion, 94% with pressure in wrist extension
  - Carpal compression/Durkan’s test
  - Scratch collapse test Sensitivity 66% Specificity 99%
  - Lumbroal incursion/Berger test Specificity 96% when includes wrist flexed
- Sensory testing
  - 2PD, light touch, vibration
- Activity assessment CTS Symptom Severity Scale, Brigham 1993
- MMT

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
Cubital Tunnel Syndrome

Clinical Assessment

- Provocative tests
  - Elbow flexion test: clinical provocation via elbow flexion 1 minute
    Sensitivity 75% Specificity 99%
  - Tinel's at cubital tunnel: Sensitivity 54-70%
  - Overhead flexion to rule out proximal contribution (double crush)
  - Scratch collapse test: Sensitivity 89% Specificity 99%

Mackinnon, SE 2011

- ROM
- MMT (ulnar extrinsics and intrinsics)
- Sensory testing
- Activity analysis
- Postural analysis

Lund AT, Amadio PC: Treatment of Cubital Tunnel Syndrome: Perspectives for the Therapist. JHT, 2006

Cubital Tunnel Syndrome

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)

Apfel E, Sigafoos G: Comparison of ROM Constraints Provided by Splints Used in Treatment of Cubital Tunnel Syndrome. JHT, 2006
Lund AT, Amadio PC: Treatment of Cubital Tunnel Syndrome: Perspectives for the Therapist. JHT, 2006

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

Lund, AT, Amadio PC: Treatment of Cubital Tunnel Syndrome: Perspectives for the Therapist. JHT, 2006

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

Cubital Tunnel Syndrome

Surgical Intervention

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 Nerve Transposition

- Flexor-pronator mass inserting on medial epicondyle; ulnar nerve tied below epicondyle
- Ulnar nerve relocated superior to epicondyle, F-P tendon lengthened then covers ulnar nerve to retain position

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 cont.

- 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: motor branch only
- Zone 3. At exit of canal: sensory branch only

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: motor branch only
- Zone 3. At exit of canal: sensory branch only
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