Ultrasound of Median Nerve

Neuromuscular Conference

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History

• In 1978, in an article on parathyroid sonography, Sample et al. [1] first indicated the possibility of delineating the minor neurovascular bundle (MNB) as a 5-mm structure within the tracheoesophageal groove.

• In 1985, Dr. Solbiati [2], was the first person to study utility of nerve sonography formally. He studied 3 cadavers and confirmed that structure they were looking at was recurrent laryngeal nerve. He applied this findings in 9 idiopathic RLN palsy and was able to find thyroid, parathyroid nodules compressing nerve.

• Fornage and Rifkin (1988) mentioned the sonographic features of the median nerve in the carpal tunnel

Brachial Plexus - Origin of the Median Nerve
Course of the Median Nerve - Arm and Forearm
Median Nerve Cutaneous innervation - Palmar view
Technical aspects of sonography

- *Electromechanical transducer* within a probe converts electrical signals into ultrasonic waves.
- *Piezoelectric effect* - At the boundary of two tissues with different echogenic properties (interface) the ultrasonic waves are reflected and subsequently received by the transducer again.
- Average velocity of sound through various soft tissues is relatively constant (1540 m/s),
- Musculoskeletal ultrasound: *linear array* transducers
- Resolution: Contrast and Spatial (axial and lateral)
Technical aspects of sonography

• Peripheral nerves requires the use of transducers with high insonation frequencies (usually 7–12 MHz or more).
• How to improve axial resolution? (increase insonation frequency, disadvantage)
• How to improve lateral resolution? (smaller beam width, decrease frame rate, multiple rows of crystals)
• Compound imaging: repeated overlapping sequences of frames of different predetermined view angles.
Technical Limitations

• Deeply situated nerves are difficult to visualize.
• Nerves are difficult to visualize if surrounded by fat or beneath bone.
• Relatively small field of view, extended-field-of-view technique to reconstruct a panoramic view.
• Correct positioning: If probe not perpendicular to nerve, may falsely be interpreted as being hypoechoic (anisotropy – change angle around)
• Pressure on the skin should be kept to a minimum in order to avoid artificial deformation of small superficial structures.
Normal nerves were seen as markedly echogenic tubular structures with parallel internal linear echoes on longitudinal scans (e.g. median nerve)
How normal nerve should look like

- on transverse scans, oval-to-round echogenic sections occasionally with internal punctate echoes (median nerve at wrist)
How normal nerve should look like

• The internal structure of the cadaveric nerves as multiple hypoechoic parallel but discontinuous linear areas separated by hyperechoic bands when scanning in a longitudinal plane and scanning transversely as multiple rounded hypoechoic areas in a homogeneous hyperechoic background (fascicular or honeycomb pattern – not always seen).

• Hypoechoic areas – fascicles; hyperechoic background - epineurium

• Sonograms underestimated the number of fascicles may be due to:
  1. The inability to depict fascicles unless they are perpendicular to the ultrasound beam
  2. Poor lateral resolution that results in coalescence of adjacent structures of similar echogenicity.
How normal nerve should look like

Differentiation from muscles and tendons:

• Tendons appeared to have numerous fine parallel hyperechoic lines separated by fine hypoechoic lines (fibrillar pattern).
• Relative immobility of nerves during flexion–extension manoeuvres
• Perineurium of the sciatic nerve produced bright boundary echoes and variation of the insonation angle reduced echogenicity of the nerve to a lesser extent than that of muscles or tendons.*

Normal Dimensions

- Modern ultrasound machines are usually equipped with software to easily perform these measurements accurate to the tenth of a millimeter.
- Many studies do not report whether they include or exclude the hyperechoic rim surrounding the nerve, most investigators perform measurements within this rim as it is not always present and its outer margin may be difficult to define.*
- A correlative cadaver study found that sonography was a very precise method to assess the dimensions (dorsopalmar diameter, radioulnar diameter, perimeter and area) of the median nerve at the carpal tunnel. (Kamolz et al. (2001))
- Nerve thickness has a Gaussian distribution and did not correlate with the subjects' height, weight or age.** (some studies found that normal values might be different in men and women.)

Median nerve

- Ultrasonographic Reference Values for Assessing the Normal Median Nerve in Adults*
- Note they looked at whole course of median nerve.
- They also looked at amount of muscle in CT (lumbricles and FD).
- 4 sonographers, first established inter-rater reliability.
- 50 subjects, 100 arms looked at the six sites were: (1) distal wrist crease, (2) mid-forearm (mid-point between distal wrist crease and elbow crease), (3) proximal forearm (where the nerve enters the pronator teres muscle), (4) antecubital fossa, (5) mid-humerus (mid-point between elbow crease and axilla), and (6) axilla

* Francis O. Walker, MD @ Wake Forest, NC Journal of Neuroimaging, Volume 19, Number 1, January 2009, pp. 47-51(5)
Both images are taken at the distal wrist crease and show a cross-section of the median nerve. In the top image, the nerve is the oval hypoechoic structure in the center, and in the bottom image the nerve is outlined with the trace function. This nerve measures 10.2 mm².
The cross-sectional area of the median nerve at six sites is depicted. From distal to proximal, the sites are: (1) distal wrist crease, (2) mid-forearm, (3) pronator teres, (4) antecubital fossa, (5) mid-humerus, and (6) axilla. Measurements are in mm² (SD).
Really?

• the nerve was largest at the most distal region, the size of the nerve
did not vary greatly throughout its entire length (7.5 to 9.8 mm2).
• 14.6 mm2 (the mean plus 2 SD) would be a cut off for the upper limit
of normal. (others report a cut off value between 9 and 12 mm2).
(too high, age and weight)
• the amount of muscle in the carpal tunnel in patients with CTS could
be measured with ultrasound.
• Sonographers were not blinded
• nerve conduction studies were not performed to evaluate for
subclinical neuropathy.
• Nerve ultrasound can provide anatomic information, such as the
presence of intraneural masses or cysts
• Ultrasound as complementry to NCS. (e.g. ECHO to EKG)
Neuropathies that may lead to nerve thickening

Entrapment neuropathies
Hereditary neuropathies
  - Hereditary neuropathy with liability to pressure palsies
  - Hereditary motor and sensory neuropathy
  - Neuropathy in Refsum’s disease
  - Neuropathy in familial amyloidosis
Inflammatory neuropathies
  - Chronic inflammatory demyelinating neuropathy
  - Multifocal inflammatory demyelinating neuropathy
  - Multifocal motor neuropathy
Localized hypertrophic neuropathy
Neuropathy in leprosy
Acquired amyloid neuropathy
Sarcoidosis
Acromegaly
Neurofibromatosis
Peripheral nerve tumors and neuromas
Common clinical presentations

Carpal Tunnel Syndrome:

- In 1913, Marie and Foix first talked about compression of median nerve at carpal tunnel causing thenar atrophy.
- Presentation: both hands involvement, dominant more common, sensory changes in median distribution, nocturnal distribution, upward progression of pain, flick sign, tinel’s at wrist, phalen’s sign, weakness/atrophy of thenar muscles, might have double crush syndrome (cervical radiculopathy).
- Predisposing conditions: wt. gain, diabetes, hypothyroidism, arthritis.
- NCS: prove that conduction across the wrist is prolonged,
Pronator Terese Syndrome:
• Anatomy, presentation may mimic CTS, weakness of muscles proximal to wrist, tinel’s at site of entrapment, aggravated by pronation, elbow flexion and 2\textsuperscript{nd} digit flexion. Abnormal needle exam of median innervated forearm muscles.

Anterior Interosseous Syndrome:
• Pinch maneuver: FPL, PQ, 2\textsuperscript{nd} digit FDP

Ligament of Struthers
• Need to know this because of interventional cardiologist
Where to put probe in CT

- Promixal level: radioulnar articulation
- Middle level: level of pisiform
- Distal level: level of hook of hamate
Take home message

- The main pathological changes that can be demonstrated are nerve enlargement and increased hypoechogenicity.
- The best studied peripheral neuropathy is the carpal tunnel syndrome in which ultrasonography.
- US cheap, readily available, non invasive, safe (operator dependent, small field of view, can’t go deep)
- the final aim of all examinations in CTS is to determine the cause(s) of upper limb paresthesiae, not simply if there is a median nerve lesion at wrist or not.
- Most common cause of peripheral neuropathy world wide?
- Nerve imaging atlas
  http://nerveatlas.ucsf.edu/atlas.html
- Let’s play with real thing