Anomalous Innervations: Detection using Routine Nerve Conduction Studies

I. Upper Extremity Anomalies

A. Martin-Gruber (M-G) Anastomosis

1. Anatomy

   a) Cadaver studies – Martin-1763; Gruber-1870

   b) Anomaly found in 15% by cadaver anatomy, and 28 - 31% of subjects using electrophysiologic techniques, and may occur bilaterally.

   c) Anomaly found in 62% of family members of 5 subjects, suggesting autosomal dominant inheritance.

   d) Normal Anatomy

      (1) Median nerve: innervates thenar muscles- abductor pollicis brevis (APB), opponens pollicis (OP), superficial head of the flexor pollicis brevis, (FPB); and the radial two lumbricals

      (2) Ulnar nerve: innervates hypothenar muscles including abductor digiti minimi- (ADM), thenar muscle- the deep head of the flexor pollicis brevis, (FPB), adductor pollicis (ADP), interossei- including first dorsal interosseous (FDIH), and remaining lumbricals

   e) M-G Anastomosis results in median-to-ulnar nerve communication by descending median nerve motor axons, crossing in the forearm to join the ulnar nerve and then innervating one of the following ulnar innervated muscles:
(1) Hypothenar muscle - abductor digiti minimi (ADM)

(2) First dorsal interossei (FDIH)

(3) Thenar muscles (deep head of flexor pollicis brevis-FPB) and/or adductor pollicis-ADP

(4) Combination of above

f) Classification of M-G Anastomosis by cadaver anatomy\(^1\)

(1) Type I - anastomosis by one branch (most frequent) and Type II - anastomosis with two branches

(2) Type I - sub-classified as

(a) Type a - anastomosis arose from branch to superficial forearm flexors

(b) Type b - anastomosis arose from median nerve itself, between origin to superficial forearm flexors and anterior interosseous nerve

(c) Type c - anastomosis arose from the anterior interosseous nerve (most common type reported)

g) Classification of M-G Anastomosis by all possible theoretical median/ulnar nerve communications and then placing documented cases/case series into this theoretical classification scheme\(^2\)

(1) Type I - 60%

(a) Anastomosis from median-to-ulnar nerve and continues into hand to innervate thenar muscles, normally innervated by the median nerve

(b) Above plus some axons innervate ulnar hand muscles


(2) Type II - 35%
   (a) Anastomosis from median-to-ulnar nerve and
       innervates ulnar hand muscles

(3) Type III - 3%
   (a) Anastomosis from ulnar nerve to median nerve to
       innervate median hand muscles

(4) Type IV - 1%
   (a) Anastomosis from ulnar to median nerve to
       innervate ulnar hand muscles
   (b) Above plus innervate median hand muscles

2. Electrodiagnostic recognition and approach of M-G Anastomosis
   a) Important to recognize anomaly to
      (1) Avoid faulty interpretation of electrophysiologic data
      (2) Understand how anomaly changes interpretation of data
           in setting of both an M-G and carpal tunnel syndrome
      (3) Understand an M-G may mimic an ulnar mononeuropathy
   b) M-G Anastomosis with Hypothenar (ADM) innervation
      (1) Manifests during routine ulnar motor nerve conduction
           studies
      (2) Suspect when the ulnar NCS hypothenar CMAP amplitude
           is disproportionately higher with wrist than with below-
           elbow stimulation (> 1.0 mV difference or >10 % drop in
           CMAP amplitude with below-elbow stimulation).
      (3) This may be misinterpreted as an ulnar mononeuropathy
           with conduction block secondary to drop in amplitude
           with proximal, below-elbow, ulnar NCS. Also must exclude
           submaximal stimulation at the below-elbow site or
           excessive stimulation at wrist with volume conduction or
           co-stimulation of median nerve.
(4) Confirm with median nerve stimulation at the elbow (keep recording electrodes on hypothenar muscle) where median nerve motor axons destined for hypothenar muscle have not yet crossed over in the M-G anastomosis to the distal portion of the ulnar nerve.

(5) If no M-G anomaly then a small positive deflection will be recorded as volume conduction from the muscles. Also should only see volume conduction if stimulate median nerve at wrist and record hypothenar CMAP as median axons destined for ADM have already crossed.
c) M-G Anastomosis with FDIH innervation

(1) Similar to above with M-G anastomosis to ADM. In general, only a problem if recording ulnar NCS from FDIH to evaluate deep palmer branch of the ulnar nerve.

(2) Recognized when ulnar NCS recording at FDIH the CMAP amplitude is disproportionately higher with wrist than with elbow stimulation (greater than 1.0 mV difference)

(3) Confirm with median nerve stimulation at the elbow (keep recording electrodes on FIDH).
d) **M-G Anastomosis with Thenar (FPB) or ADP innervation**

(1) **Manifests on routine median nerve studies**

(2) **Recognized when recording routine median NCS from APB-abductor pollicis brevis and CMAP with proximal, elbow stimulation is GREATER than wrist stimulation by at least 1.0 mV.**

(a) Motor axons that originated from the proximal median nerve now innervated the normally ulnar innervated ADP-adductor pollicis or FPB-flexor pollicis brevis via the M-G anastomosis.

(b) The ADP/FPB muscles are deep to the superficial APB-abductor pollicis brevis, but contribute to the CMAP with proximal, elbow stimulation of the median nerve and result in a larger CMAP amplitude.

(3) **Confirm with ulnar nerve stimulation at the wrist and below-elbow**

(a) Normally, stimulating the ulnar nerve will result in a CMAP with the recording electrode over the APB resulting in a CMAP from the deeper ulnar innervated muscles. And this CMAP will be similar in size when stimulating the ulnar nerve below-elbow and at the wrist.

(b) However, if an M-G is present the CMAP will be much LARGER when stimulating at the ulnar nerve at the WRIST compared to below-elbow.
e) M-G Anastomosis and co-existent Carpal Tunnel Syndrome

(1) Proximal median CMAP may have *initial positivity* (dip).

(2) Median nerve conduction *velocity is surprisingly fast*, > 70-75 m/sec.

(a) When stimulate routine median NCS at the wrist and record APB, these fibers must travel through the carpal tunnel. If a carpal tunnel lesion is present these axons to the APB will have a slowed distal latency (DL).

(b) When stimulate routine median NCS at the elbow, also have axons from the M-G anastomosis that do not pass through the carpal tunnel, as travel on ulnar nerve, and innervate ADP and/or FPB, under the APB, with a an on-time DL contributing to the overall CMAP. The faster arrival time of the DL results in the initial positive deflection (dip).

(c) Conduction velocity is the distance divided by the proximal DL (on-time from M-G axons) minus distal DL (delayed from carpal tunnel). Given the distal DL is delayed this artificially shortens the time while the distance remains the same and the conduction velocity is artificially faster.
B. All Median Hand

1. Special Considerations

   a) Severe ulnar nerve lesion and do not detect a change distally, because distal hand muscles are innervated by median nerve

   b) Median nerve lesion – fibrillations and positive waves on needle EMG in normally ulnar innervated muscle. Don’t confuse with radiculopathy.

   Martin-Gruber anastomosis and carpal tunnel syndrome. Routine median motor study, recording the abductor pollicis brevis, stimulating wrist (top trace) and antecubital fossa (bottom trace). There is a prolonged distal latency at the wrist stimulation site. At the antecubital fossa site, there is a positive dip and a factitiously fast conduction velocity due to some median fibers stimulated at the antecubital fossa bypassing the carpal tunnel via the anastomosis. Also, note slightly higher amplitude at the proximal stimulation site. (DL = distal latency; PL = proximal latency; CV = conduction velocity.)
C. Other

1. Ulnar-to-Median crossover
   a) Reported, but rare
   b) Findings present similar pattern to M-G anastomosis except when stimulating ulnar nerve and recording hypothenar.
      (1) The ulnar CMAP elicited by elbow stimulation is larger in amplitude and probably duration, than the CMAP elicited by wrist stimulation.
      (2) If recording thenar, the CMAP from wrist stimulation can be more than 50% higher than elbow stimulation of the median nerve.

2. Multiple variations – including all ulnar hand

3. Congenital absence of thenar muscles - should not be confused with CTS

4. Musculocutaneous nerve
   a) Normally innervates biceps brachii and coracobrachialis
   b) Has been found to contribute innervation to median flexor muscles and part of thenar group in one case

II. Lower Extremity Anomalies

A. Accessory Deep Peroneal Nerve

1. Anatomy
   a) Normal anatomy – common peroneal divides at fibular head
      (1) Deep peroneal to anterior tibialis, extensor hallucis longus, extensor digitorum brevis, peroneus tertius, extensor digitorum longus
      (2) Superficial peroneal to peroneus longus and brevis
      (3) Deep and superficial fibers pass anterior to lateral malleolus
   b) Anomalous anatomy
      (1) Lambert, Kennedy 1970s
(2) Branch of superficial peroneal nerve passes posterior to lateral malleolus

(3) Supplies lateral portion of extensor digitorum brevis (EDB)

(4) Dominant inheritance

(5) Found in 20 - 28% of normal subjects

2. Electrodiagnostic recognition
   a) Peroneal nerve stimulation - the CMAP is a larger amplitude when stimulating at the fibular head (knee) than at the ankle.
   b) Stimulate POSTERIOR to the lateral malleolus and a recordable CMAP will be obtained.

3. Special Considerations
   a) Accessory deep peroneal nerve with lesion at deep peroneal – EDB not weak- may confuse diagnosis
   b) Can calculate axon contributions by adding responses – accessory CMAP + ankle CMAP = fibular head (knee) CMAP

References: