H REFLEX

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H REFLEX

- Most easily found in muscles innervated by the tibial nerve and the S-1 root
H REFLEX

- 2-Neuron Reflex Arc
- Orthodromic Motor and Sensory
H REFLEX

- Stable shape/amplitude
- Submaximal stimuli best
- Stimulation freq. 0.5 HZ
- Amplitude changes with position; muscle contraction
H REFLEX RELEASED

- In CNS injuries below the midbrainstem
CLINICAL USES OF THE H REFLEX

- Unilateral radiculopathy, especially S-1 level
- Peripheral neuropathy
- Guillain-Barre Syndrome
- Upper motor neuron dysfunction
- Using H reflex recovery curves for drug research in Parkinsonism
H REFLEX USE

- Most popular clinical use is for S-1 radiculopathy
  - Especially unilateral S-1 radiculopathy
H REFLEX STUDY

- METHOD: Braddom & Johnson
  - Archives PM&R 1974
  - DATA: H Latency, H amplitude, Leg Length, Height, Age of Patient
  - NORMAL H FORMULA:
    \[ H \text{ Lat.} = 9.1 + 0.46 \text{ Leg Length} + 0.1 \text{ Age} \]
<table>
<thead>
<tr>
<th>VARIABLE</th>
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<th>S.D.</th>
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<td>Leg Length (cm)</td>
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<tr>
<td>H Duration (msec)</td>
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<td>H Amplitude (uV)</td>
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<td>L. Mean</td>
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<td>1723</td>
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<tr>
<td>Tibial DL (msec)</td>
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<td>Tibial NCV (M/sec)</td>
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<td>Age</td>
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H LATENCY AS A FUNCTION OF LEG LENGTH

MEAN REGRESSION LINES
FOR VARIOUS DECADES OF AGE

H LATENCY (msec)

40-50

35-

30-

25-

20-

15-

LEG LENGTH (cm)

25

30

35

40

45

50

50-60

20-30

ALL AGES
26 year old female: 36.5 cm leg length. TE-4 settings: 5 msec/cm. and 2000 microvolts.

RIGHT CALF CIRCUMFERENCE 33 cm.
RIGHT ACHILLES REFLEX 1+

LEFT CALF CIRCUMFERENCE 36.5 cm.
LEFT ACHILLES REFLEX 3+

H Latency
RIGHT: 29.0 msec
LEFT: 27.3 msec
EARLIEST REPORTS OF H REFLEX USE IN LS RADICULOPATHY

- Visser, 1965
- Bouquet and Cioffi, 1969
- Deschujterere and Rosselle, 1973
- Descuns, et al, 1973
- Braddom and Johnson, 1974
USE OF H REFLEX AMPLITUDES IN S-1 RADICULOPATHY

- Jankus, Robinson, Little Arch PM&R 1994
- In 47 normals found mean amplitude to be 9 mV (SD 4 mV)
- Amplitude range of 1 to 18 mV
- Absolute amplitudes not helpful
- Ratio of R and L amplitudes was mean of 0.74 (SD 0.17)
- Amplitude ratio of 0.4 or less is abnormal
H REFLEX IN THE QUADRICEPS

- Sabbahi and Kahlil  Arch PM&R 1990
- Standardized techniques for the FCR and the Vastus Medialis
VASTUS MEDIALIS H REFLEX FOR STUDYING L-4 RADICULOPATHY

- Probably first done by Mongia 1972
  
  Electromyography 12:179-189, 1972
VASTUS MEDIALIS H REFLEX IN UNILATERAL L-4 RADICULOPATHY

- Sabbahi and Kahlil Arch PM&R 1990
- 40 subjects with L-4 radiculopathy
- Subjects had H reflex latency increase and amplitude decrease
- Unfortunately no side to side data given
H REFLEX IN THE FLEXOR CARPI RADIALIS

- Jabre 1981 Muscle & Nerve
- Found it in 90% of 39 normal subjects
- Deschuytere et al reported it with concentric needle electrode recordings in 100% in 1974
  - Latency between sides was always <1.0 msec
Sabbahi and Khalil  Arch PM&R 1990
- Studied 37 patients with C-7 radiculopathy
- Patients had reduced amplitude and increased latency of the FCR H reflex
- Unfortunately no side to side data was given
FCR H REFLEX USE IN C-6 AND C-7 RADICULOPATHY

- Schimsheimer et al 1985
- Compared H reflexes in FCR in 32 patients with their study of 143 normals
- They found FCR H reflex lower in amplitude and longer in latency in patients with either C-6 or C-7 radiculopathy
FCR H absent after C7 Transection

- Abstract from Shanghai done by L. XU et al and R. Weber
- They used C7 nerve transfer as axon donor for complete root avulsion lesions of the brachial plexus in 5 patients
- After C7 nerve resection, FCR H reflex absent
- Suggests that C7 is predominant in the FCR H reflex
# H Reflex in 10 Patients with Known Peripheral Neuropathy

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<td>Leg Length (cm)</td>
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<td>2.9</td>
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<tr>
<td>H Latency (msec)</td>
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<td>H Duration (msec)</td>
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<td>H Amplitude (uV)</td>
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<td>297</td>
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<tr>
<td>Tibial DL (msec)</td>
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<tr>
<td>Tibial NCV (Meters/sec)</td>
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<tr>
<td>Age (years)</td>
<td>58.5</td>
<td>18.8</td>
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Braddock
What stimulus width works best for H?

- 1 msec.
- Longer stimulus gives:
  - Greater recruitment of Ia sensory axons
  - Larger H reflex amplitude with the smallest M wave amplitude at lowest stimulus intensity

H and F Useful in GBS

- 31 with GBS having EDX within 7 days of onset at Cleveland Clinic
- H absent 97%
- F abnormal 84%
- Reduced amplitude CMAPs 74%
- Prolonged DL 65%
- Low amp SNAPs UE 61%

H Abuse

- Some perform H reflexes on every lower limb EDX study
- Typically done as part of a protocol that includes F waves and many NCS
- Every patient deserves an EDX study specifically and dynamically designed specifically for them: NO PROTOCOLS
Billing Issues for H & F studies

- Do not use as part of a protocol
- All EDX must be done dynamically
- Use them only when clinically indicated (medically necessary)
- Be wary of giving an EDX diagnosis that is incompatible with the H findings
F WAVE

- An Antidromic Motor Discharge
- "Back-Firing" of a Motor Neuron
F Wave Early History

- Hoffmann saw it in 1922
- Kugelberg, and Dawson & Scott, 1949
- Magladery named the H, F and M Responses in 1950
  - Called F because it was first seen in a foot muscle
  - He mistakenly thought it was an H with slower sensory fibers
F confirmed to be motor only

- Dawson and Merton 1956
  - Based their work on Renshaw’s in cats in 1941
  - Renshaw noted that 2-3% of motor neurons have a recurrent discharge with a central delay similar to a monosynaptic reflex

- McLeod 1966 and Gassell 1965
  - Deafferentiation doesn’t eliminate the F wave
F Wave Small and Variable

- Only a few axons participate in each F wave
  - Schiller HH and Stalberg E: F responses studied with single fiber EMG in normal subjects and spastic patients. J Neurol Neurosurg Psychiatry 1978;41:45-53
Practical F Wave Measurements

- Earliest latency
- Mean latency
- F/M amplitude ratio
- Persistence
- Chronodispersion
- Repeater waves
F Wave Latency Variability

- 1-2 millisecond variability in onset latency (Chronodispersion)
- Most take the earliest latency (Weber & Piero 1978)
- Some average the F latency to get a “mean” latency (Kimura, 1975)
- F wave done with single motor units is stable in latency (Yates & Brown 1967)
How many responses are needed?
- 10 responses give accuracy within 1-1.5 msec of true value of earliest latency (Fisher)
- 20 responses give accuracy within 0.5 msec (Fisher)
F MEAN LATENCY

- More reproducible than earliest latency
- Reflects the range of F wave latencies
Classic Technique for the Ulnar F

- Weber & Piero 1978
  - Set up electrodes for ulnar motor NCV of the forearm
  - Abduct shoulder 20 degrees
  - Measure from ulnar styloid to C-7 spinous process
  - Latencies should be within 1 msec for the two upper limbs, and within 2.5 msec of predicted
Nomogram for the F Wave

- Weber & Piero
Buschbacher F Wave Values

- **Median** F wave latency mean is 26.8 SD 2.4 msecs.
  - Upper limit of normal side to side difference is 2.2 msec.

- **Ulnar** F wave latency mean is 26.5 SD 2.5
  - Upper limit of normal side to side difference is 2.5 msec.
Buschbacher F Wave Values

- **Peroneal** F wave latency mean is 50.2 msec. SD 5.5 msecs.
  - Upper limit of normal in side to side difference is 5.1 msec.

- **Tibial** F wave latency mean is 50.8 msec. SD 5.3 msec.
  - Upper limit of normal in side to side difference is 5.7 msec.
F Chronodispersion

- Difference in the minimal and maximal F Wave latencies
- Can be helpful in finding small motor neuronopathy
- Need 80-100 responses to be accurate
  - When only smaller motor axons are affected
    - Earliest onset latency normal due to normal larger motor axons
    - Increased chronodispersion
F-WAVES RECORD

STIM: Wrist

TRACE: HO / 10

LEVEL: 0 V

SWITCH: STIM / STOP

FREQUENCY: 0.7 Hz

DURATION: 0.1 ms

RECURRENT / NONREC

M LAT: 2.6 ms  M Amp: 8.659 mV

DIST: mm

LATENCY  MIN     MAX     MEAN

F  ms  29.2  31.2  30.7

F No: 100 %

F-M  ms  26.6  28.6  28.1

R. Braddock F-wave
ulnar  set 1
F Chronodispersion

- Normal Values (msec)
  - APB: 3.6 SD 1.2
  - ADM: 3.3 SD 1.1
  - EDB: 6.4 SD 0.8
  - Soleus: 2.8 SD 1.1

F wave Persistence

- Persistence is the percentage of discernible responses
  - Persistence decreases in any situation with fewer motor neurons (axonal injury)
Repeater Waves

- **Identical responses in a series of F Waves**
  - Occurs mainly in axonal injury
    - Due to decreased motor neuron pool
  - The percentage of repeater waves (%RF) = # identical waves/F waves
R. Braddock F wave
ulnar set 1
F Wave Conduction Velocity

- This can be calculated but no one has found it clinically useful
F Axillary Loop Latency

- Allows calculation of the F travel time in the axilla
  - But no study shows it is helpful
Clinical Uses of the F Wave

- Thoracic Outlet Syndrome?
  - Possibly helpful in neurogenic type

- Brachial Plexopathy?
  - Tends to have many false negatives

- Neuropathy
  - Very useful early in proximal neuropathies such as Guillain-Barre Syndrome
F Waves in Radiculopathy

- It is clear now that the F wave is not as useful as needle EMG for radiculopathy.
F Not Helpful in Radiculopathy

- F Wave is a motor study like the EMG
- Major nerves have multiple roots
  - Normal amplitude and latency can occur even if there is radiculopathy of one root
- Subtle F wave changes can’t be measured due to normal variation
F Not Helpful in Radiculopathy

- F doesn’t add anything to the diagnosis of radiculopathy.
F Not Helpful in Radiculopathy

- F abnormal in only 10-20% of radiculopathies
- This was determined in a series of over 2000 cases of radiculopathy
F Not Helpful in Radiculopathy

- In study of 24 EMG proven L-5 radiculopathies, F wave was positive in only 29%
  
Cervical roots are especially problematic, since most radiculopathies are at C5, C6 and C7. These roots are more proximal and don’t lend themselves to the usual median and ulnar F wave studies.
F Not Helpful in Radiculopathy

- Radiculopathies constitute a sharply focal lesion, but its proximal location precludes the application of segmental studies. Consequently, no currently available NCSs provide useful information in this condition. This and other characteristics make the use of the F wave untenable as a measure of radiculopathies.

F Waves in Thoracic Outlet Syndrome

- 5 patients with neurogenic TOS
- 60 stimuli
- F wave latency, side to side latency delta increased (by 2 msec)
- Decreased F Wave Persistence
  - **Study needs to be repeated with more patients**
F Wave for Neuropathies?

- Prolonged in diabetic neuropathy
  - Andersen et al (1997) showed that minimal F latency was significantly more sensitive than even sural latency or amplitude

- **Slowed or absent in Guillain-Barre Syndrome before NCV is abnormal (Kimura, 1975)**

- Shahani studied 50 general neuropathy patients in 1980 with F to APB)
  - Found 9/50 in which F was abnormal while other NCV’s were normal
F WAVE ABUSE

- F waves are frequently performed in 4 nerves in the upper limbs and 4 nerves in the lower limbs.
- Done in a rote manner as part of a protocol of NCS.
- Sole purpose of increasing billing.
F Billing Issues

- CPT code requires viewing a minimum of 10 F waves.
- If F waves are hard to get due to pathology, do a minimum of 10 stimulations and explain why in report you didn’t see 10 F waves.
Minimum of 10 F waves

- **CPT Assistant** of April 2002, Volume 12, Issue 04:

**Nerve Conduction Study with F-Wave Study (95903)**

F-wave and H-reflex studies provide information in the evaluation of radiculopathies, plexopathies, polyneuropathies (especially with multifocal conduction block or in suspected Guillain-Barre syndrome or chronic inflammatory demyelinating polyneuropathy), and proximal F-wave studies are reported in combination with the motor nerves that are examined. Although the set-up for an F-wave study is similar to the set-up for a motor NCS, the testing is performed separately from motor NCSs, utilizing different machine settings and separate stimulation to obtain a larger number of responses (usually at least 10). The number of F-wave studies that need to be performed on a given patient depends on the working diagnosis and the EDX findings already in evidence. It may be appropriate in the same patient to perform some motor NCSs with an F-wave and others without an F-wave.
Blink Reflex

Involves Cranial Nerves V and VII and the brainstem
Stimulate the Supraorbital nerve

- Record from the orbicularis oculi bilaterally
- Best done with 2 channels
Kimura’s Blink Technique

- Fig. 17-4 from Kimura Ed. 3
- Active recording electrodes are medial with the reference electrodes 2 cm. lateral
Blink Pathways

- **R1**
  - **Only Ipsilateral**
  - Mediated by main sensory nucleus of CN V in the pons
  - Kimura says it is abnormal mostly in pontine lesions

- **R2**
  - **Bilateral**
  - Mediated by spinal nucleus and tract of V in medulla oblongata
  - Kimura says it is abnormal mostly in lateral medullary lesions
Common Uses for the Blink Reflex

- Figure 17-7 from *Clinical Electromyography and Nerve Conduction Studies*. Oh SJ Third Ed. Lippincott Williams Wilkins
Future Use: Surgical Monitoring

- R1 can be obtained under general anesthesia
- Could be used to monitor the status of the Vth and VIIth cranial nerves and the brainstem during surgery
  - Deletis et al Muscle Nerve 39:642+ 2009 (From Alberta, Canada)
The A Wave

Randall L. Braddom, M.D., M.S.

Called the Axon Reflex in the past, but not really a reflex.
Classic A Wave Article

- Fullerton & Gilliatt: Axon reflexes in human motor nerve fibers. J Neurol Neurosurg Psychiat 1965, 28:1+
- Studied upper limb nerves in 25 patients with miscellaneous nerve problems
- Not really a reflex
A Wave is due to collateral sprouting of sick/injured nerves

- Stimulus goes antidromically up the motor nerve to a collateral
- Then goes orthodromically down the collateral
A Wave: Stimulus Strength

- Usually eliminated by a strong stimulus
- Strong stimulus depolarizes the whole nerve
  - Including the collateral sprout
A Wave Latency

- Usually between the M and F waves
- Can occur after the F if the collateral sprout is poorly myelinated
A Wave and F Wave

- Usually not seen together
- Increasing the stimulus intensity high enough to get an F wave
  - Usually eliminates the A wave
A Wave Usually Stable

- Latency is usually the same on multiple stimulations
- Due to using the same collateral sprout
- Stable on repetitive stimulation up to 40 Hz
- If you can stimulate at different sites, you can do a NCV of the collateral sprout
Localizing Site of Collateral

- Stimulate the nerve at various sites
- Key is that you lose A Wave immediately when you stimulate above the site of nerve branching
Diagnoses in patients with A Waves:

- **Demyelinating neuropathy (66.7%)**
  - Demyelination is the crucial underlying pathophysiologic correlate of the supramaximally stimulated A-wave.
- Diffuse axonal neuropathy (11.5%)
- Motor neuron disease (6.5%)
- Radiculopathy (3.6%)
- Mononeuropathy (3.9%)
- Normal finding (tibial nerve only) 0.7%.
Other Late Motor Responses

- Ephaptic Transmission
  - One or more dysfunctional loci on a nerve
  - Allows ephaptic transmission (cross-talk)
  - Fails at high stimulus rates
  - Responses vary in latency and waveform
    - Tomasulo, Neurology 32:712+, 1982
Other Late Motor Responses

- **Scattered Motor Response**
  - Pathologic nerves give responses of their muscles in a delayed manner as compared to the remainder of the MUAP
  - Separate from A Wave:
    - Stimulating more proximally increases latency of the scattered motor response, but shortens latency of the A Wave
Other Late Motor Responses

- **Muscle-Nerve Reverberating Loop**
  - Electrical field of MUAP re-excites an intramuscular axon ephaptically
  - Interval between the original muscle potential and the repetitive discharge remains constant regardless of the nerve stimulation point
  - Serra, 1984