Chapter 6.3

The F wave

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Definition and general description

The name F wave was derived from the initial recordings which were in the small muscles of the foot. The F wave is a compound action potential evoked by supra-maximal antidromic stimulation of a motor nerve. The pathway for the F wave involves antidromic excitation of all stimulated motor axons travelling to the spinal cord with reactivation of a small proportion of the anterior horn cells’ axon hillocks, and orthodromic action potentials of one or more motor axons travelling to the muscle. Renshaw cell activation is also probably involved. F-wave latency, amplitude and shape varies from trial to trial (see Fig. 1). Its amplitude is normally <5% of the maximum M wave recorded from the same muscle (Eisen and Oduose 1979). The small amplitude of the F wave reflects the small number of anterior horn cells in which the axon hillock becomes reactivated in response to the stimulus. F waves can be recorded from any muscle but because the latency shortens with more proximal stimulation the response becomes hidden in the M wave. F waves are useful in the assessment of proximal conduction slowing. They also increase in amplitude in spasticity.

Methodology

Recording

F waves are recorded in the same manner as are CMAPs during routine motor nerve conduction studies. The active (G1) electrode is placed over a muscle belly, and the reference (G2) over the tendon. A ground electrode is based placed between the recording and stimulating electrodes. The small muscles of the hands (the APB/thenar and ADM/hypothenar) and feet (EDB and AH) are used most commonly. The high-pass (low-frequency) filter is set at 2–20 Hz, but restricting the low frequency filter to 100 Hz (see Fig. 1), gives a much cleaner base line, and makes it easier to measure onset latencies of individual F waves. The sensitivity is set at 100–200 \( \mu \)V per division; the minimum amplitude for an interpretable F wave is about 40 \( \mu \)V (20 to 50 \( \mu \)V among different laboratories). A sweep of 5 ms/division for the upper limbs, and 10 ms/division for the lower limbs is optimum. For hand muscles the latency of F waves is about 28 ms so the total sweep should be about 50 ms. For foot muscles the F-wave latency is about 50 ms so the total sweep should be about 100 ms. However, if few or no F waves are evoked, the sweep should

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motor latency. Stimulus intensity is adjusted to be supramaximal (about 20–30% supramaximal). Stimuli are delivered at a frequency of 0.5 Hz (every 2 s) or less. 10–20 consecutive stimuli should be administered.

**Measurements**

*Latency (minimum, maximum and mean).* The single most useful F-wave measurement is minimum latency. This is the shortest latency to onset of the initial deflection (either negative or positive) of all recorded F waves. Most laboratories define the upper limit of normal for minimum F-wave latency for different ranges of height. Table 1 shows typical upper limits (estimated mean plus 2 standard errors) for the height regression, which contains about 97.5% of the normal population.

The upper limits for normal minimum latency may be further adjusted for age. The values in Table 1 are true for adults up to age 40 years. These limits increase by about 0.5 ms per decade over age 40 years. For evaluating unilateral symptoms or signs, side-to-side comparison of minimum F-wave latency is useful. The following are nervespecific upper limits of asymmetry (set at mean difference + 2 SD): median, 2.3 ms; ulnar, 2.7 ms; peroneal, 3.5 ms; tibial, 3.5 ms. Chronodispersion is the difference in the shortest and longest of the F-wave onset latencies. It is of dubious clinical utility (Panayiotopoulos 1979).

*Amplitude: absolute, F wave/M wave ratio* F-wave amplitude is very variable; however, relating the mean F-wave amplitude to the maximum CMAP (F wave/CMAP × 100) can be useful. Values of ≥5% are common in upper motor neuron diseases (Eisen and Odusoe 1979).

*Persistence of the F wave*  
The persistence is the percentage of stimuli that produce F waves. The lower limit of persistence is 5% for the peroneal nerve in some normal series, so even the absence of peroneal F waves must be interpreted cautiously. However, persistence for the median, ulnar and tibial nerve is normally 40% or above. High persistence (80–100%) occurs in upper motor neuron lesions, especially when spasticity is

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Fig. 1. Top: superimposed F-waves. Twenty sweeps recorded. Lower: same 20 sweeps as a raster recording. Band pass 100 Hz–10 kHz. In this normal example the F-wave was evoked in 14/20 sweeps giving a persistence of 70%.

*Stimulation*  
Standard bipolar surface stimulation as used for routine motor nerve conduction studies is satisfactory, but the cathodal pole is oriented proximal to the anode. The cathode is usually positioned at the exact same site utilized for distal stimulation at the wrist or ankle. The anode is then rotated 180 degrees from this position for obtaining the distal
TABLE 1

NORMAL F-WAVE LATENCIES (MS)

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>150</th>
<th>160</th>
<th>170</th>
<th>180</th>
<th>190</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>25.0</td>
<td>26.5</td>
<td>28.0–28.5</td>
<td>29.6–30.0</td>
<td>31.1–32.0</td>
</tr>
<tr>
<td>Ulnar</td>
<td>25.0</td>
<td>26.8–27.0</td>
<td>28.5–29.0</td>
<td>30.2–31.0</td>
<td>32.0–33.0</td>
</tr>
<tr>
<td>Peroneal</td>
<td>43.0–43.5</td>
<td>46.0–47.8</td>
<td>49.0–52.0</td>
<td>51.0–56.2</td>
<td>54.0–60.5</td>
</tr>
<tr>
<td>Tibial</td>
<td>41.2–44.0</td>
<td>45.4–48.0</td>
<td>49.6–53.0</td>
<td>53.8–57.0</td>
<td>58.0–62.0</td>
</tr>
</tbody>
</table>

present. F-wave persistence is also increased when recording from a non-relaxed muscle. Even very slight contraction will significantly increase the ease with which F waves are elicited.

Clinical application

(1) Determination of proximal conduction slowing in demyelinating neuropathies. F-wave studies are most sensitive in detecting acquired demyelinating polyneuropathies, where they may be quite prolonged. In acute IDP this may be the only conduction abnormality. In CIDP, F waves may be absent (Fisher 1985, 1998; Kimura 1989).

(2) Their use in radiculopathy is more controversial. Minimum latency is unlikely to be prolonged because slowing through the short segment of nerve that is potentially demyelinated will be diluted by a very long length of normally conducting nerve. In any event, F waves are far less sensitive than EMG studies when assessing motor involvement in radiculopathy.

(3) In true neurogenic thoracic outlet syndrome the ulnar F wave is frequently prolonged whereas that of the ipsilateral median is normal. In other plexopathies, F waves may be prolonged or difficult to obtain if there is a significant demyelinating element.

(4) An increased mean F-wave amplitude/CMAP is a good reflection of spasticity. The mean F-wave amplitude is >5% of the M wave and often >10% of the M wave.

References


