Late Responses
The F Wave & A Wave

AAET Education Committee
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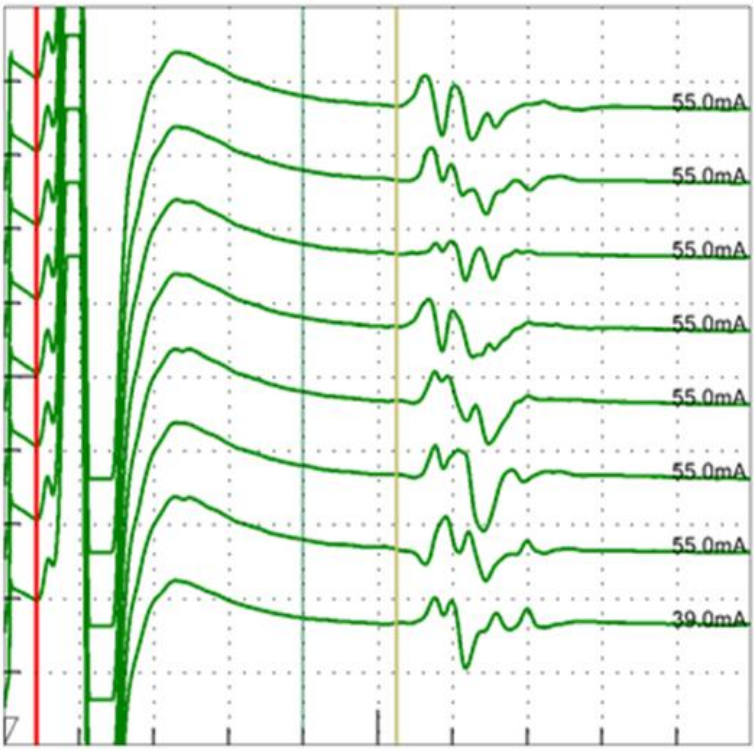


In this paper there will be discussion about two late responses, the F wave and the A wave, or axon reflex. We will look at the physiologic aspects, measurements, calculations, waveform differences, temperature effects and clinical correlations.

The F Wave

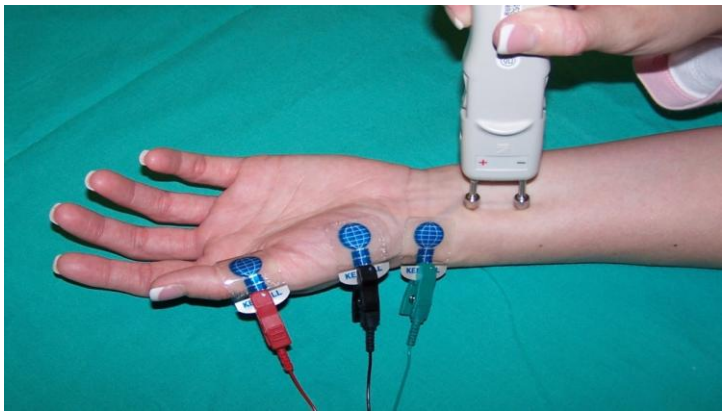
The F wave was named by Magladery and Mcdougal in 1950 because it was first recorded from the intrinsic muscles of the foot (Preston and Shapiro, 1990). The F wave uses supramaximal stimulation of a motor nerve and records compound muscle action potentials from a muscle supplied by that nerve, along the most proximal segment. It results from the backfiring of antidromically activated horn cells. The F wave occurs after the direct motor potential or the M response. With more proximal stimulation the latency of the M response increases while the F decreases. This indicates that the impulse to elicit the F wave travels away from the recording electrodes toward the spinal cord before it returns to the activated distal muscles. Most motor and mixed nerves can be stimulated but some are tested more frequently than others. The main nerves tested are the median, ulnar, peroneal and tibial nerves. Less frequently tested are the radial, facial and femoral nerves (Mesrati, Vecchierini 2004). Stimulation can occur at any point along the path of the nerve to elicit an F wave, but the distal portion is the most common.

Below are the parameters for a median motor F wave and a photo of recording and stimulation points.

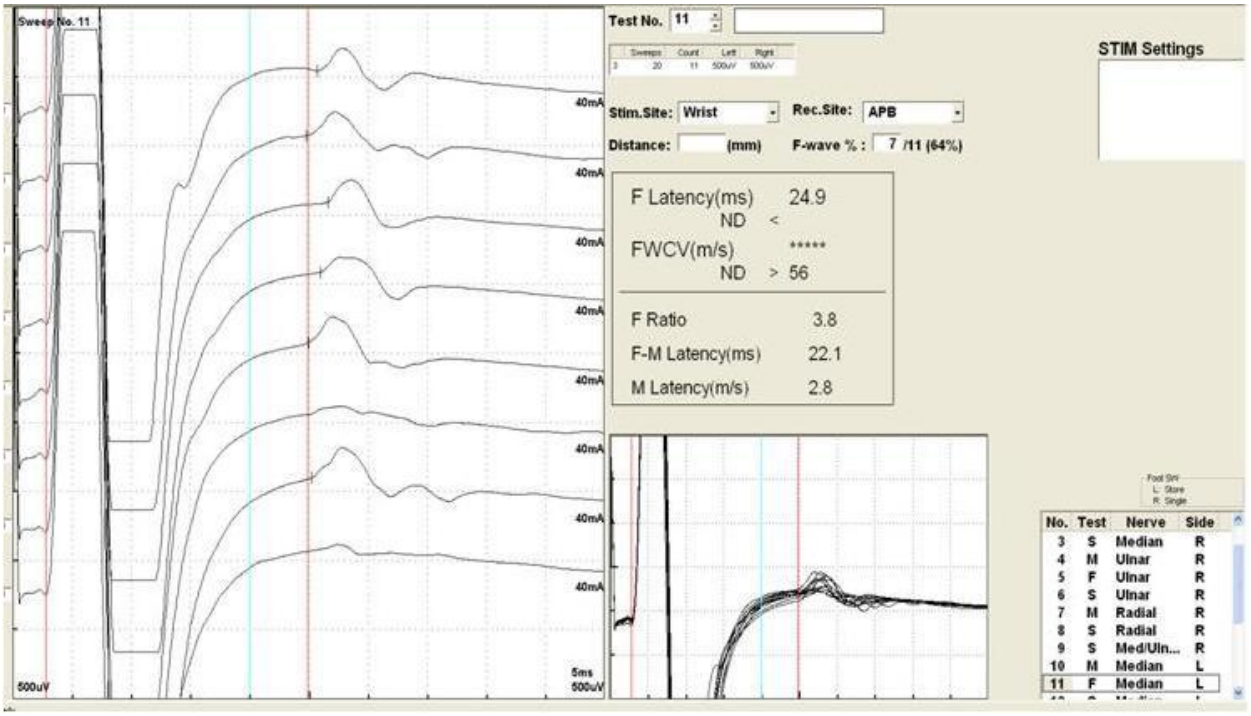
F Wave Study of the

Median Nerve

Patient Position:	Supine with arm supinated and extended at side
Skin Prep:	Wipe with alcohol, temperature check
Recording site:	
Active:	Placed over the belly of the Abductor Pollicis Brevis (APB) ½ distance between the metacarpophalangeal (MCP) joint of thumb and midpoint of distal wrist crease
Reference:	Placed on the distal phalanx of the thumb
Ground:	Placed between the stimulating and recording electrodes
Stimulation:	(cathode proximal)
Wrist:	Applied 2 cm proximal to the distal wrist crease between the flexor carpi radialis (FCR) and palmaris longus (PL) tendons
Measurements:	Shortest F wave latency out of a series of 10
Settings:	Sweep Speed: 5 msec/div (upper limbs) 10 msec/div (lower limbs)
Sensitivity/Gain:	200 or 500 uV/div
Filters:	Motor Stimulation: Supramaximal for motors



F Wave Study of the Median Nerve



Depending on the level of stimulation, about half of the motor neurons stimulated at threshold produce F waves. With submaximal stimulation F waves will be reduced even more. The collision technique (Kimura, 2001) uses simultaneous stimulation, to create an interaction of two action potentials propagated toward each other from opposite directions on the same nerve fiber so the refractory periods of the two potentials prevent propagation past each other. For instance stimulation of an orthodromic impulse from the axilla and an antidromic impulse from the wrist collide. It will leave an M response from the wrist and an F wave from the axilla. This will help isolate the F wave for easy detection.

F- wave parameters include the latency, F/M ratio, amplitude, duration, persistence and velocity. There are three latency parameters for an F wave, the minimal, mean and the maximal latency. The minimal F wave has the fastest conducting fibers, while the maximum has the slowest conducting fibers reflecting the longest latency. The most often reported F- wave latency is the mean, it tends to be most accurate for clinical lab use. In routine nerve conduction studies seven to ten recordable F waves may be sufficient (Mesrati,Vecchierini), For a more difficult study, such as diagnosing a demyelinating disorder or nerves with severe axonal loss, ten to fifteen F waves may be necessary.

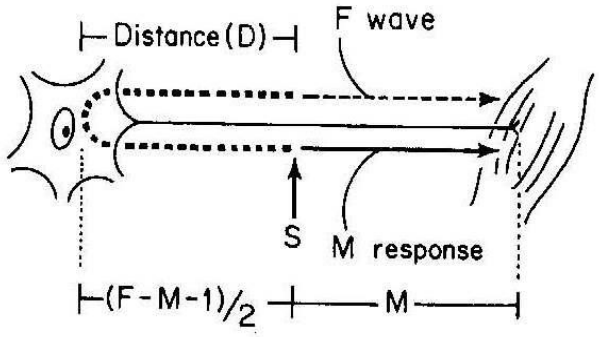
Latency and amplitude of an F wave have varying factors related to height, length of the limb and motor neuron excitability. F waves can have up to a few milliseconds difference between the earliest and latest recording. The latency changes can be due to the speed of the propagated impulse and the length of the terminal fibers in each muscle fiber. The distance between the recording electrodes to the motor endplate and the hyper-excitability of the motor neuron all play a role in facilitating an F wave.

The average minimal F- wave latencies tend to be 25-32 msec. in the upper extremities and 45-56 msec in the lower extremities, height dependent (Preston and Shapiro, 2005).

A latency difference between two of the same nerves bilaterally or two on a limb can be useful in detecting an abnormality.

At times an F wave may be difficult to elicit. A Jendrassik maneuver such as contracting and relaxing of muscles in another limb or in the jaw may elicit the F wave without obscuring it (Daube,Rubin 2009).

Central latency is the conduction time from the stimulus to the spinal cord and back down. There is a one msec delay turn around time at the anterior horn cell that is subtracted and then divided by two. Formula (F-M-1) / 2 (Kimura, 2001).



The F/M ratio (F-M-1) /2M (Kimura, 2001) compares proximal and distal segments and is useful in evaluating conduction time from stimulation site to spinal cord.

Amplitude of an F wave is measured from peak to peak and reflects motor neuron excitability. Duration is measured in msec; it is the length of the wave from the first deflection until it returns to baseline, while persistence is the number of measurable F waves divided by the number of waves stimulated. Ten to fifteen F waves are an adequate amount of information for

an estimate of persistence. The approximate nerve length divided by the conduction time from the spinal cord makes up the F- wave velocity. For example in a median nerve, measure the limb length in millimeters from the stimulation site to the corresponding spinal segment, C7 and down to the wrist stimulation site. This is multiplied by two, since it goes to the cord and back down, (2D). 2D is divided by the latency difference between F and M and the 1 millisecond turn-around time subtracted (F-M-1) (Kimura, 2001).

Formula, FWCV= (2D) / (F-M-1) (Kimura, 2001).

Now that we know how to measure an F wave, let us put it to clinical use. What types of illnesses or syndromes affect F waves? People who have diabetic neuropathy will show F wave changes. By evaluating the nerve across the longest length like we do with the F wave, abnormality is easier to evaluate. If the neuropathy is in its early stage, the delayed F wave may be the first indication for the diagnosis. Guillain-Barre Syndrome can affect any segment of the nerve, but it will commonly affect the most proximal segment first. If the patient is tested early in their illness, the nerves may be normal and F waves present. As the disease progresses, the F waves will become increased in latency or become absent, showing demyelination. The waveforms may be dispersed or show a conduction block. As the patient starts to recover the F waves that were absent will start to return, or the latencies that were prolongated will return to a more normal value.

Another injury that affects the F wave is spinal shock (Kimura, 2001). This is due to the altered state of excitability of the motor neurons. In acute paraparesis, the waves below the injury or lesion in the spinal cord will be absent or prolonged very soon after injury and may not return for days or weeks following.

A case study

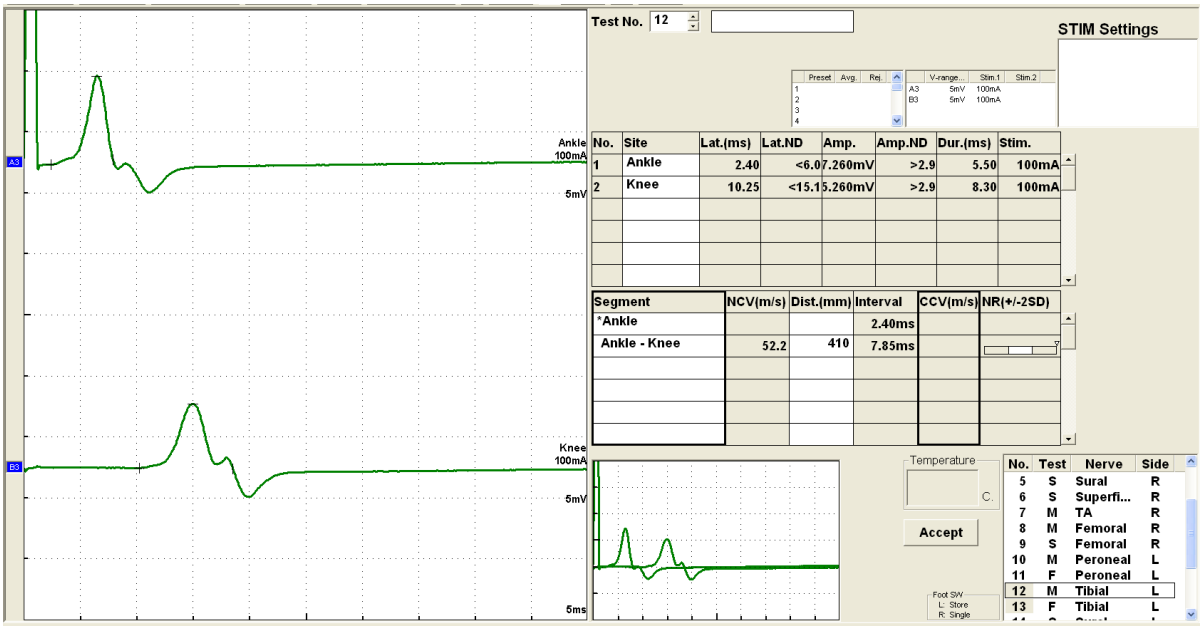
This next section will give a patient history and a few waveforms that went with her studies. This patient presented on January 27th with left arm numbness, tingling and mild chest pain. EKG and lab work up was normal. She went home and a few days later had bilateral arm numbness and left leg weakness with an inability to walk. Lumbar puncture was performed and CT and MRI of the brain. Nerve conduction studies were performed with prolonged F waves and reduced amplitude CMAP's. These findings initially fit the clinical picture of Guillain-Barre Syndrome. Her CSF studies were inconclusive, so a cervical spine MRI was ordered. On the MRI, a lesion was found in the posterior C6-C7. From this, it could be a question of transverse myelitis. After treatment with prednisone, her symptoms did not improve.

On January 31st, another EMG was performed to evaluate. She now had progression of demyelination and prolongation of F-waves. EMG studies on February 7th were believed to be consistent with the known spinal lesion.

Days later, February 17th, the patient reports some improvement with physical therapy. She must still use a walker, has decreased sensation in right hand and foot, but without weakness and has no use of her left hand or fingers. To make the final diagnosis many differentials may need to be addressed and repeat studies done, depending on how the patient presented and the progression of the illness.

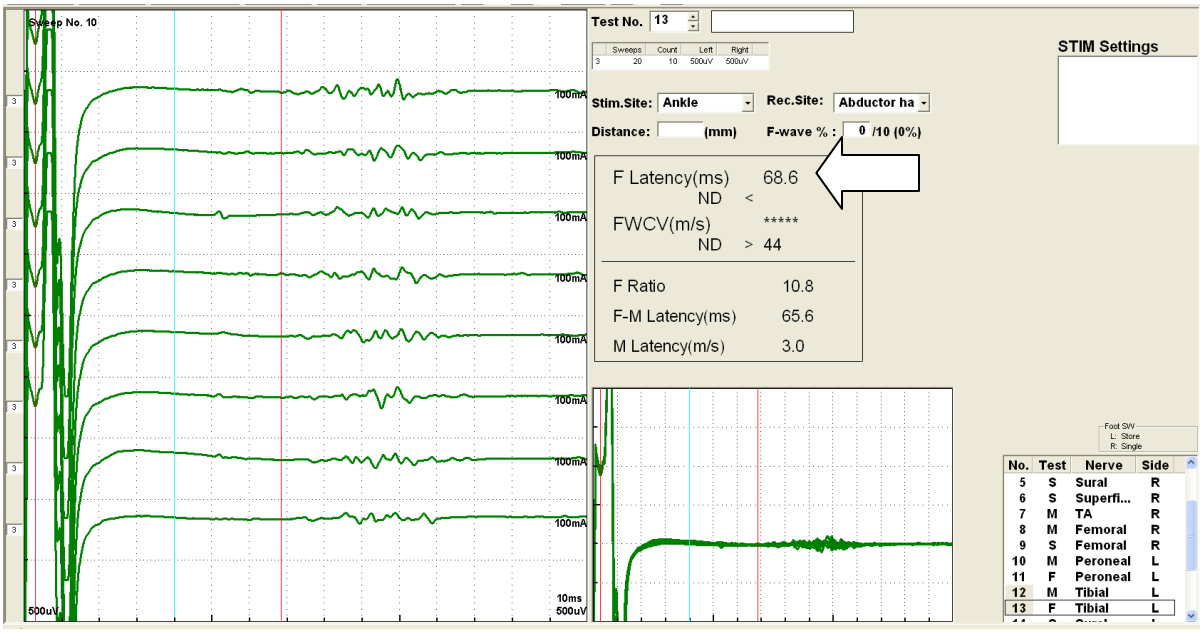
What at first seemed to be Guillain-Barre Syndrome, now is being followed as spinal inflammation or spinal shock with a lesion in the spinal cord, possibly due to infarction/malformation. The question of a resolving demyelinating lesion in the spinal cord still remains a differential. Below are a few of her CMAPs and F waves as she returned for repeat studies.

Left tibial motor 1/31/10

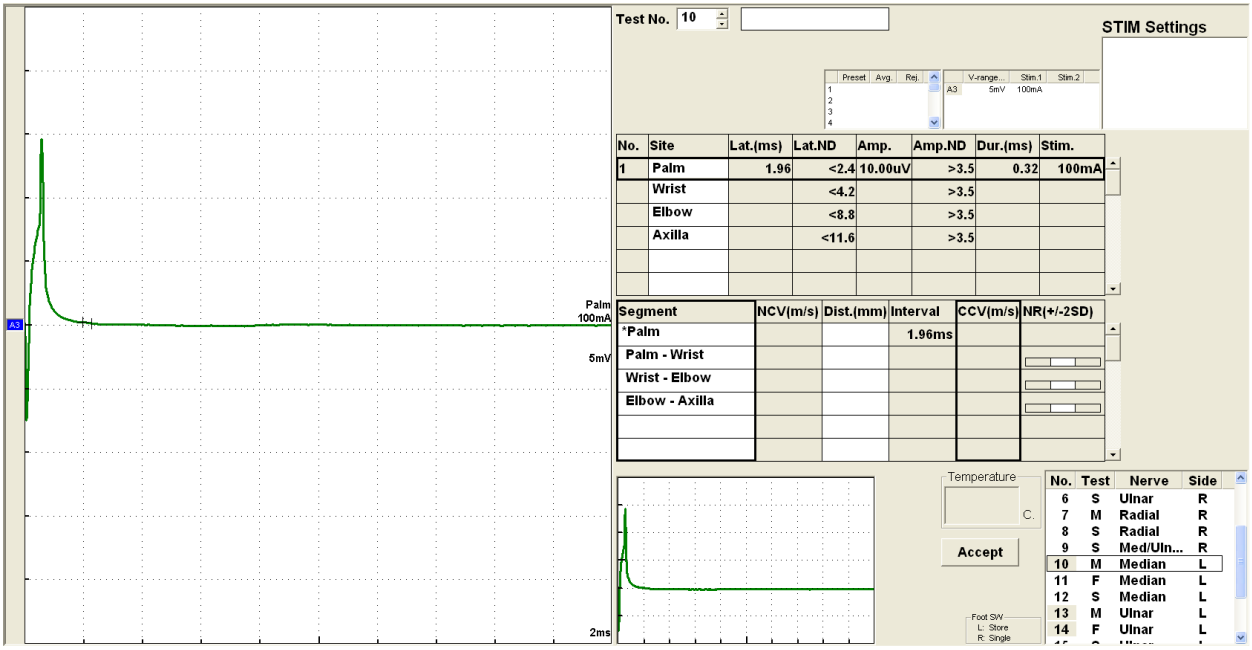


Left tibial F wave 1/31/10

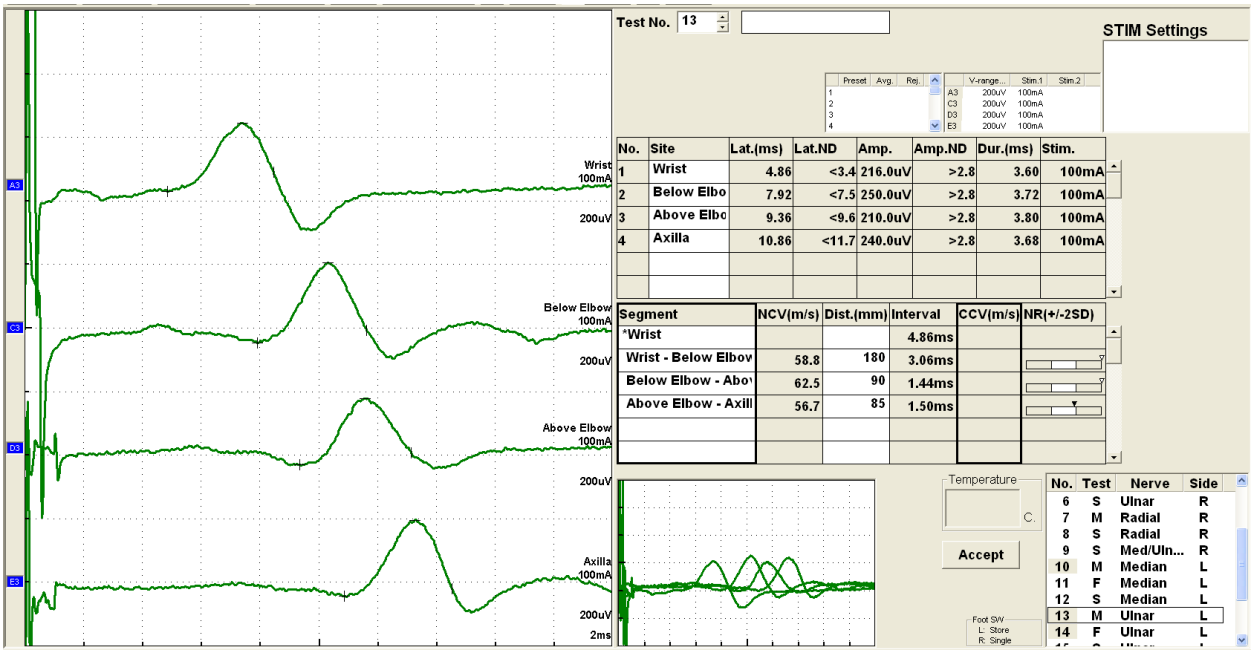
Latency 68.6



Left median 2/7/10

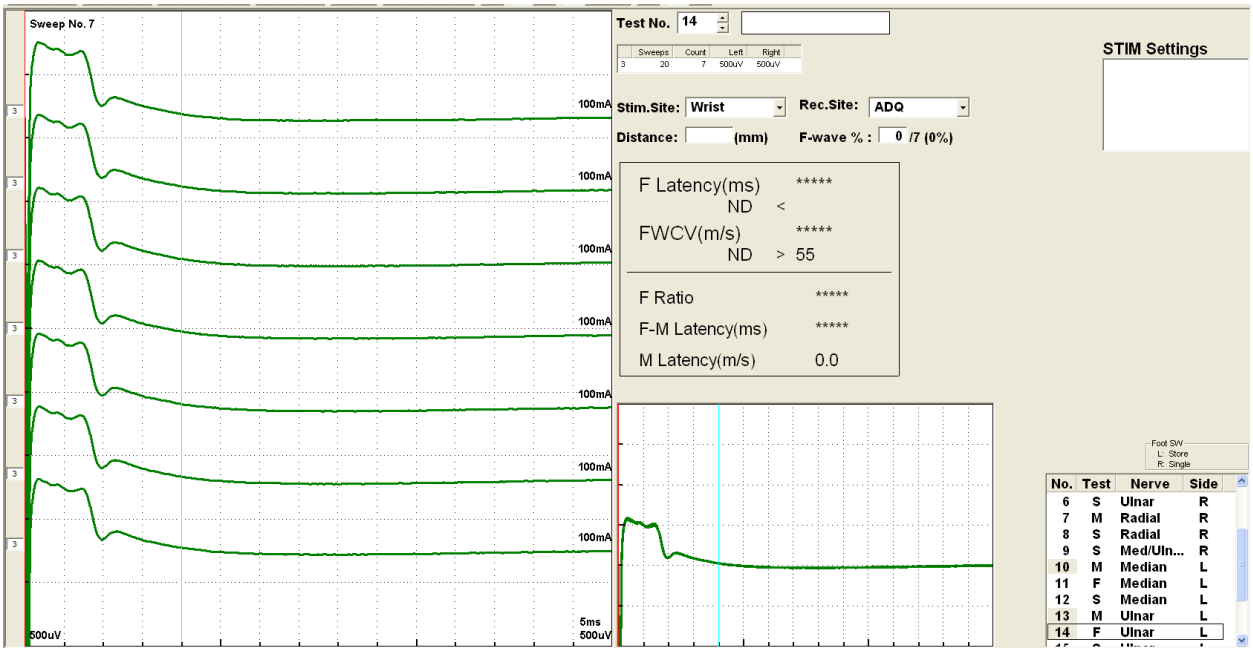


Left ulnar 2/7/10

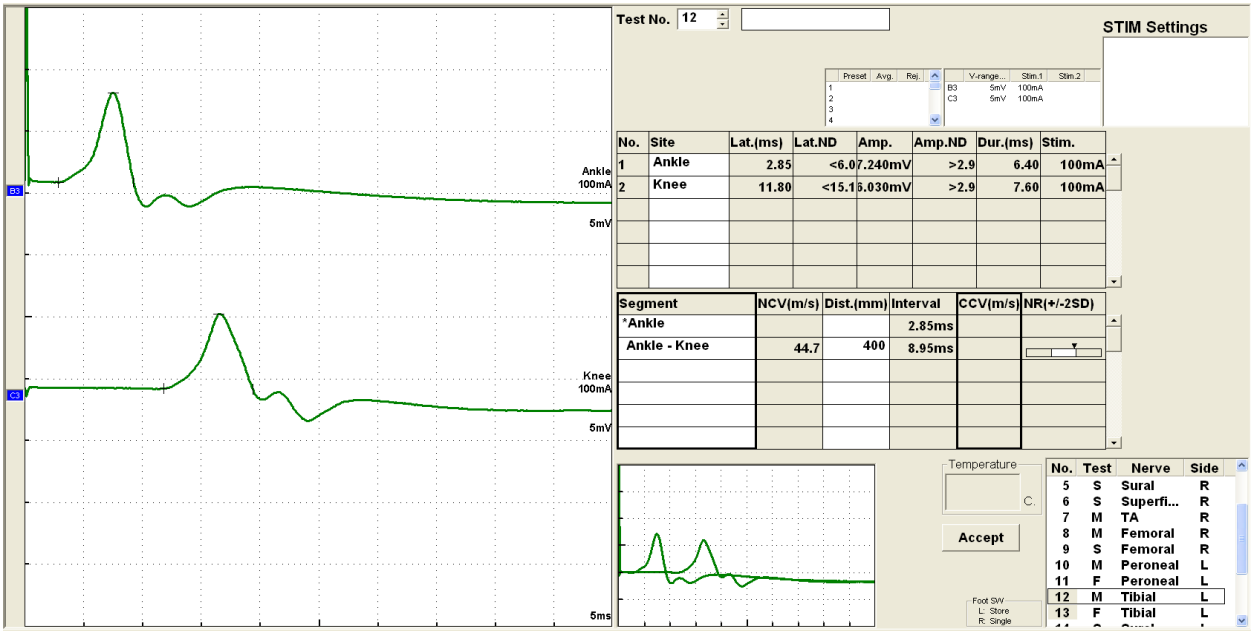


Left ulnar F wave 2/7/10

Latency No response

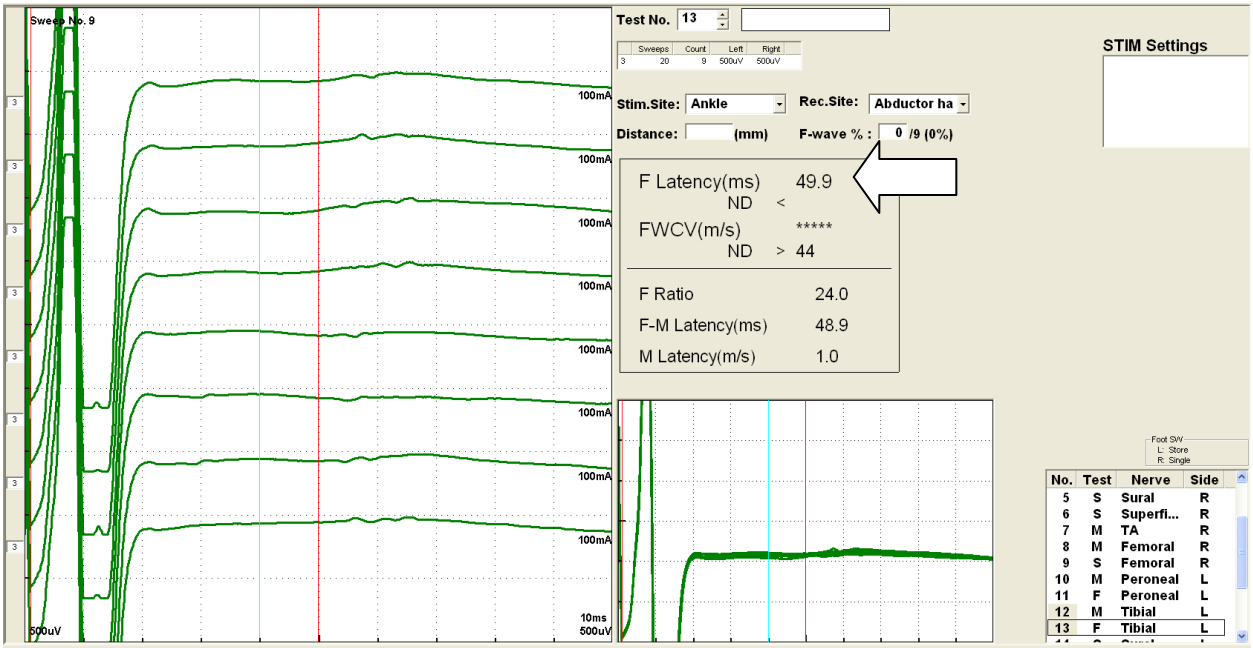


Left tibial motor 2/7/10

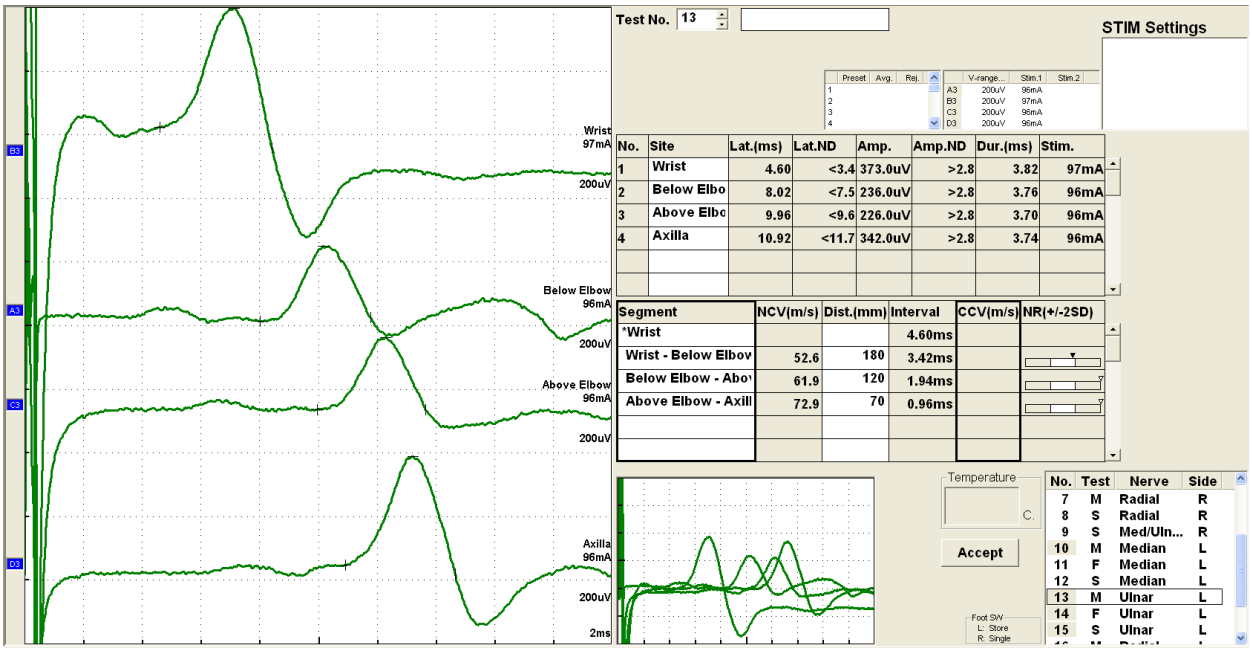


Left tibial F wave 2/7/10

Latency 49.9

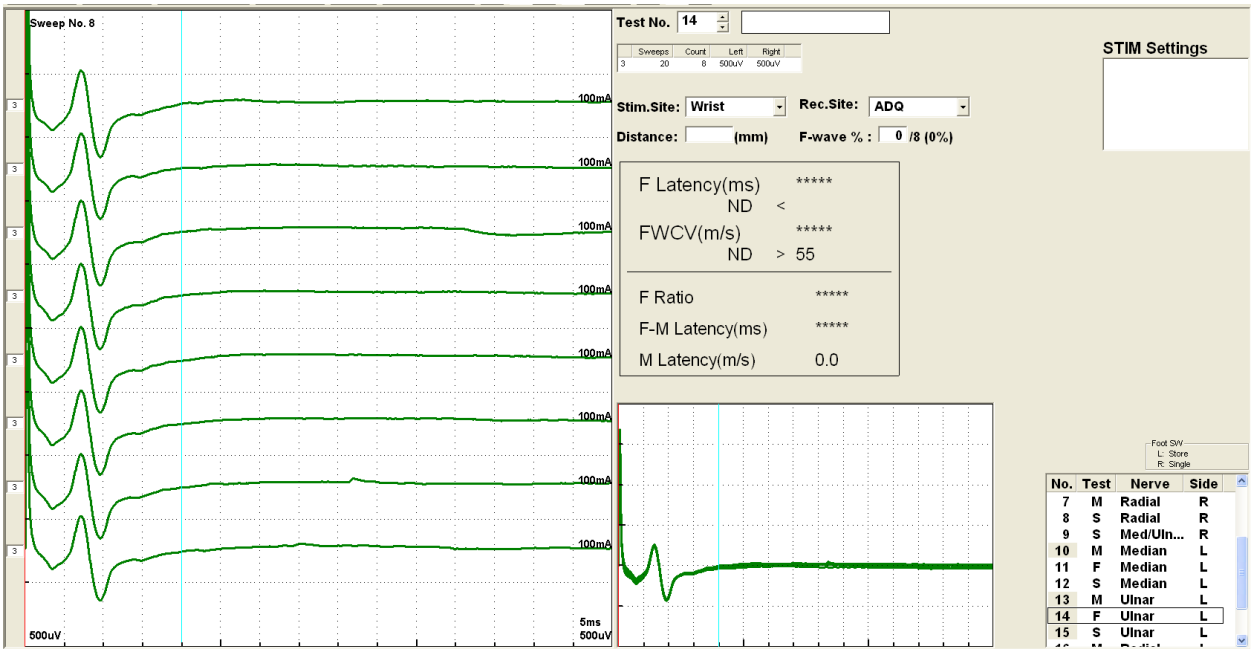


Left ulnar motor 2/17/2011

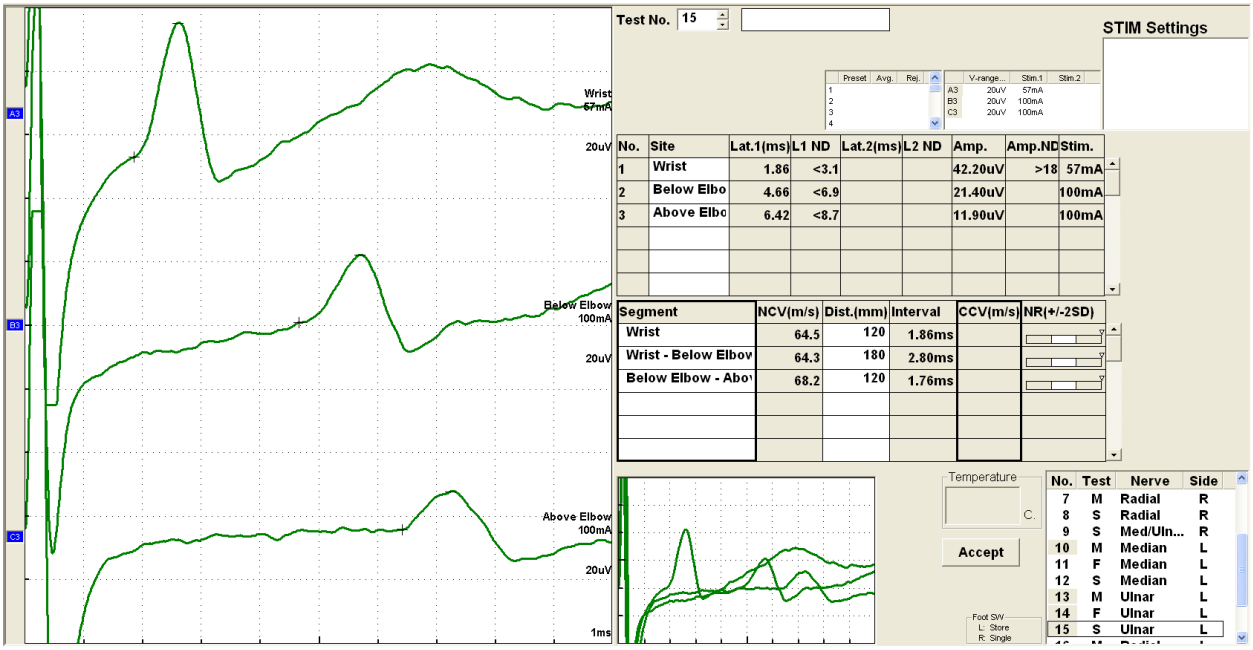


Left ulnar F wave 2/17/11

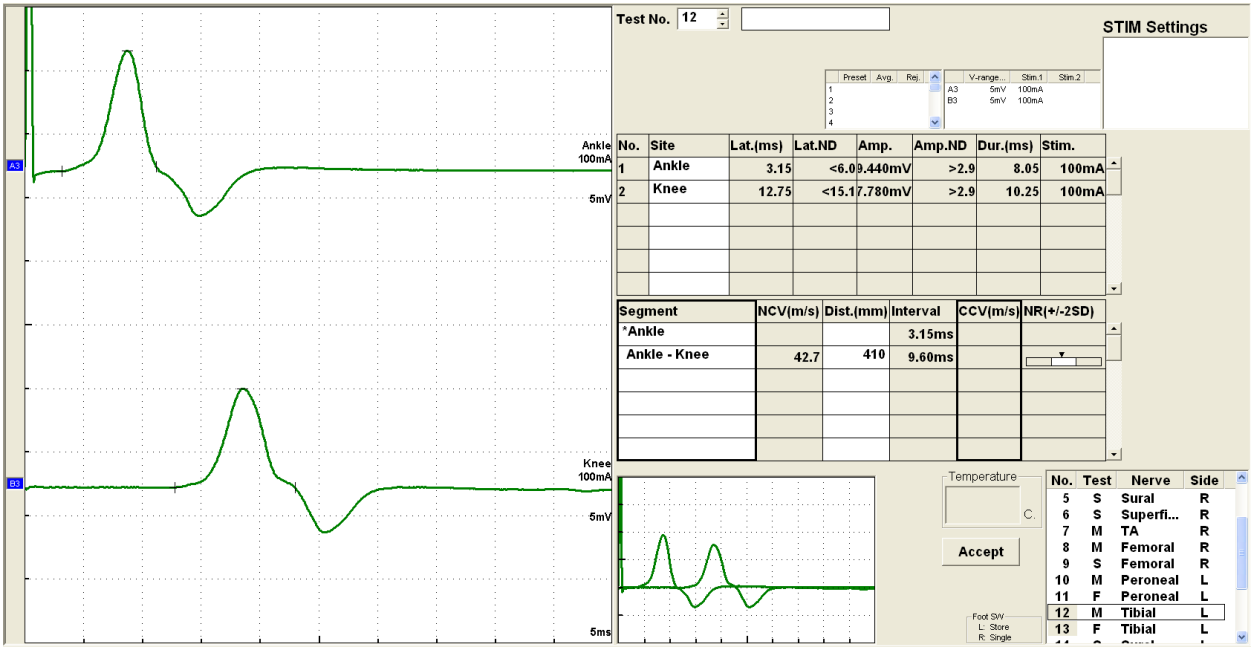
Latency No response



Left ulnar sensory 2/17/2011

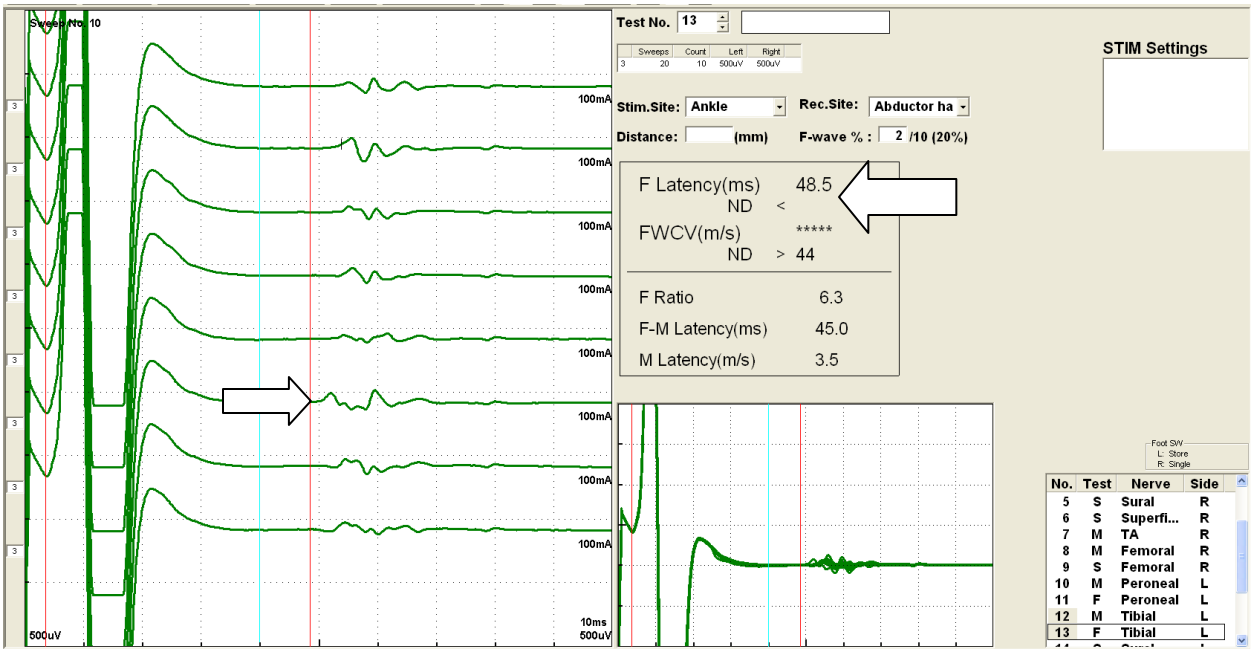


Left tibial motor 2/17/2011



Left tibial F wave 2/17/11

Latency 48.5



Temperature

How can temperature affect an F wave? Nerves conduct faster at a higher body temperature. The colder a patient is, the longer the latency may be. Each lab has a standard temperature value. The patient is either warmed to the adequate body temperature, or a calculation may be done. We use our height chart to determine the minimum latency. In our lab, the University of Iowa we have a standard value of 32 degrees Celsius. Our formula for correction is velocity x .04 x difference in temperature from standard lab value. Then subtract that number from the velocity and the F wave is corrected (Kimura, 2001).

Temperatures and Velocity~

- Lab value temperature 32 C
- The patient temperature taken 30 C
- F velocity measured was 45msec

An example of temperature correction would be:

45(velocity) x .04(percent) =1.8

Difference in temperature 32-30=2

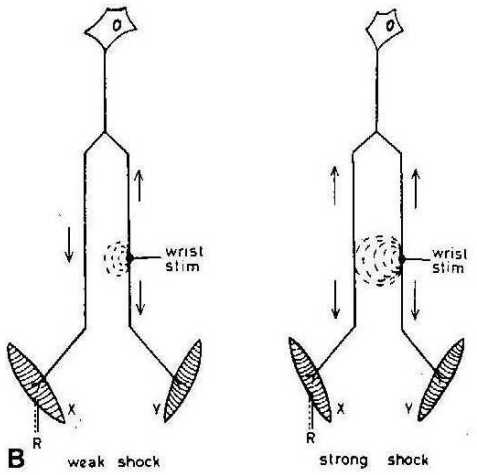
1.8(percent) x 2(difference in temp) =3.6

45(velocity)-3.6(difference) = 41.4 corrected value

From F waves to A waves~

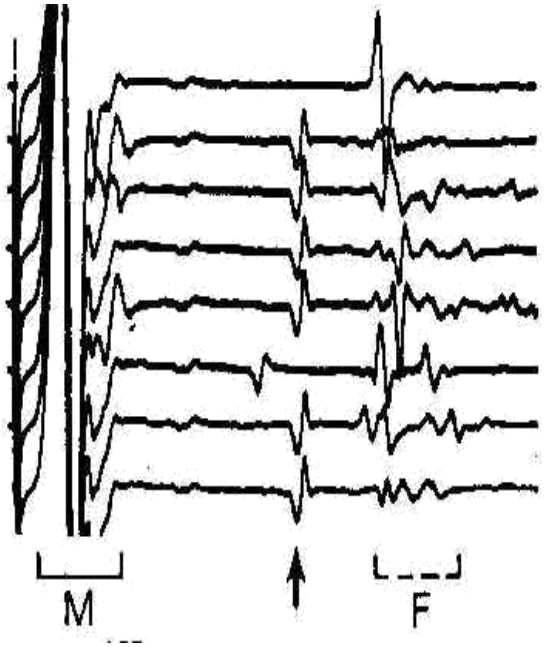
The A Wave or Axon Reflex

The A wave also known as the axon reflex is another late response, described by Fullerson and Gilleat in 1965, (Bischoff, Stalberg, Falck, et al.1996). Whereas, the F wave has variability, the A wave has a constant latency and morphology. The A wave tends to occur after the M response and before the F wave. An A wave is generated by collateral sprouting, if supramaximal stimulation is not reached and only one branch of the axon is excitable, the antidromic impulse propagates up to the point of branching and then turns around to the second the axon.



submaximal & supramaximal stimulation of an axon

A waves do not usually occur in healthy nerves, they are a sign of abnormality either from demyelination or regeneration. A waves are sometimes seen in cervical root lesions, Guillain Barre Syndrome, diabetic neuropathy, brachial plexus lesions, Charcot Marie Tooth disease and some entrapment syndromes.



A Wave

In conclusion, some may feel that the information F waves provide us with are not as relevant as those of the motor and sensory responses. However, as pointed out in this paper, late responses are useful tools in diagnosing many types of neuropathies and proximal nerve lesions. Therefore, without F waves, early or mild abnormalities may remain undetected.

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