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Case report

Emergence of F-waves after repetitive nerve stimulation

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ABSTRACT

Aim: Absence of the F-wave may represent the inability of spinal motor neurons to be excited after periods of inactivity. Repetitive stimulation in an otherwise immobile patient acts as a voluntary movement therefore allowing for the production of an F-wave in a patient with previously demonstrated absent F-waves. Through this case report, we attempt to highlight that the absence of the F-wave may result from inexcitability of spinal motor neurons after reduced mobilization.
Case: We present the case of a 48-year-old woman who had been hospitalized in an ICU setting for almost one month due to a subarachnoid hemorrhage, pancreatitis, and respiratory failure. An electromyogram and nerve conduction study (NCS) was performed for weakness in all four extremities. On routine NCS, her F-waves were absent, but after repetitive stimulation was performed, her F-waves appeared.
Discussion: This may be further evidence that the absence of the F-wave may result from inexcitability of spinal motor neurons after immobilization or reduced mobility rather than true pathology of the peripheral nerve. The ability to recover F-waves after an initial absence could assist in differentiating between inexcitability of the anterior horn cell and proximal nerve conduction block. This case presentation is an attempt to show that repetitive nerve stimulation may prove to be a useful technique to restore F-waves in patients who are unable to voluntarily contract their muscles, which may help exclude certain pathologic processes.
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1. Introduction

The F-wave is a late muscle response, which results from the antidromic activation of motor neurons following electrical stimulation of the peripheral nerve (Weber, 1998). F-waves are measured in a variety of ways and clinical situations described previously (Fisher, 1992). Minimum latency (F min) and F-wave persistence are two of the more commonly used parameters in the diagnostic evaluation of peripheral nerve disorders. The absence of F-waves or diminished F-wave persistence is usually taken as a sign of demyelinating conduction block of the proximal motor axons or reduced spinal cord excitability. Various conditioning maneuvers that alter motor neuron excitability have been shown to produce measurable changes in F-wave parameters, especially persistence (Lin and Floeter, 2004). We report a technique that may be useful to either re-establish the presence of F-waves or to improve the persistence of F-waves when a patient is unable or minimally able to voluntarily contract a muscle.

2. Case report

A 48-year-old woman with no past medical history presented to the hospital with a syncopal event and was found to have a subarachnoid hemorrhage from a basilar tip aneurysm. She underwent coiling of the aneurysm and had a complicated hospital course requiring an extra-ventricular drain for treatment of hydrocephalus. She also developed acute pancreatitis and respiratory failure requiring intubation. During her recovery, she was noted to have flaccid weakness in all four extremities. On examination, the cranial nerves demonstrated no abnormalities. She had 2/5 strength throughout. Deep tendon reflexes were trace in the upper

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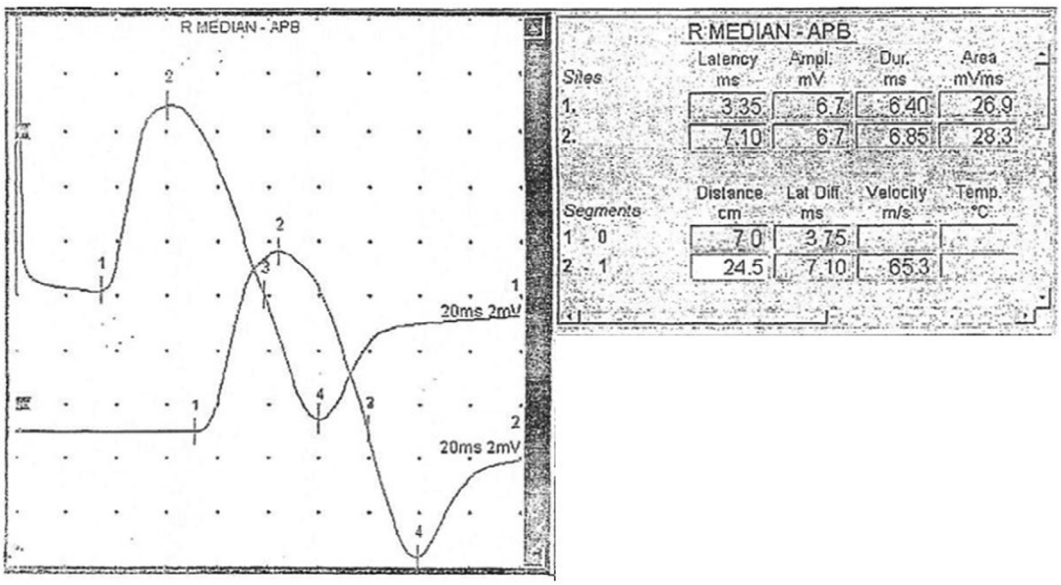

Fig. 1. Right median motor nerve before 20 Hz stimulation; supramaximal stimulation at wrist and forearm, recording APB. Site 1 – Wrist. Site 2 – Forearm. Right median motor nerve distal latency, CMAP amplitude, and conduction velocity are normal.

limbs and 1+ in the lower limbs. Plantar responses were flexor. Her sensory exam was intact to light touch and pinprick throughout.

An EMG/NCS was requested to evaluate for critical illness neuropathy, myopathy, or other causes of her weakness. A four-limb needle EMG and NCS study was performed. The nerve conduction studies including CMAP amplitudes, latencies, and velocities were normal (Fig. 1). However, initial recordings from the median nerve at the abductor pollicis brevis demonstrated absent F-waves (Fig. 2). After performing a 1-second burst of 20 Hertz (Hz) repetitive nerve stimulation of the median nerve, F-waves were easily obtained 1 s after RNS was completed (Fig. 3). No other motor nerve F-responses were tested. No H-reflex studies were performed. Needle EMG findings of select proximal muscles demonstrated fibrillation potentials and short duration polyphasic low amplitude motor unit potentials. These needle EMG findings were felt to result from a mild – rather than a moderate or severe – case of critical illness myopathy (CIM), given that more severe CIM cases often demonstrate abnormal NCV data in the form of reduced motor nerve CMAP amplitudes and/or prolonged CMAP durations. It should be noted that no direct muscle stimulation was performed, which is a technique used on occasion to corroborate the presence of absence of CIM.

3. Discussion

F-wave persistence; namely, the number of measurable F responses divided by the number of stimuli, can be of great importance in the detection of proximal nerve demyelinating conduction block. The F-wave is commonly abnormal in acute or chronic

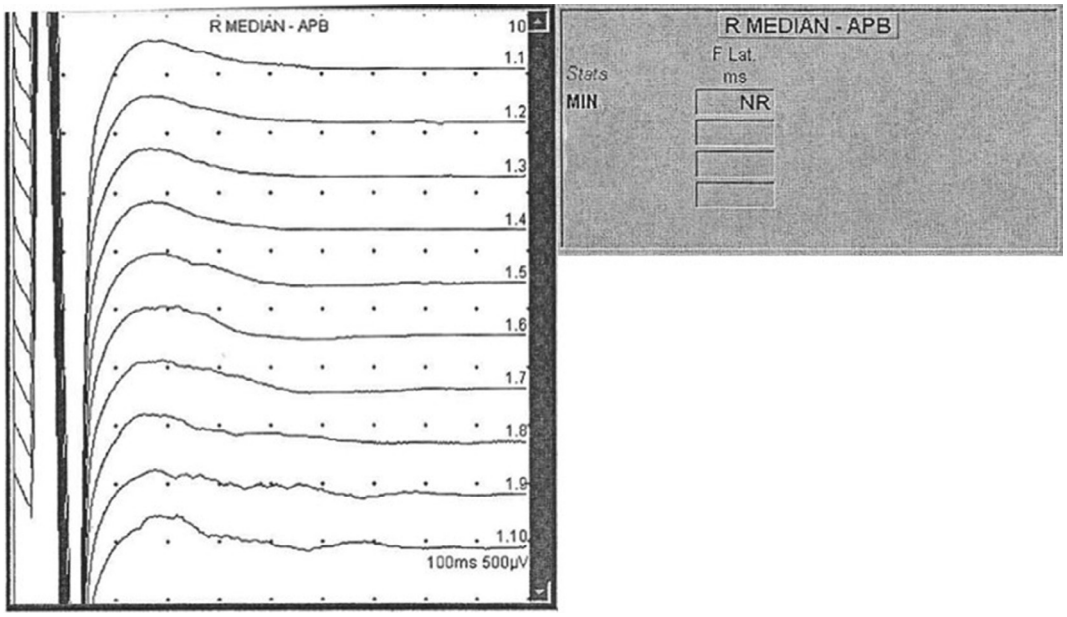

Fig. 2. Right median motor F-waves: 10 trials of supramaximal stimulation delivered at 1/s, before a brief 20 Hz stimulation. As you see, there are no F-waves. Clinically, the patient has 2/5 flaccid weakness (Medical Research Council scale for muscle strength). Right median motor nerve stimulated at wrist, recording APB (abductor pollicis brevis).

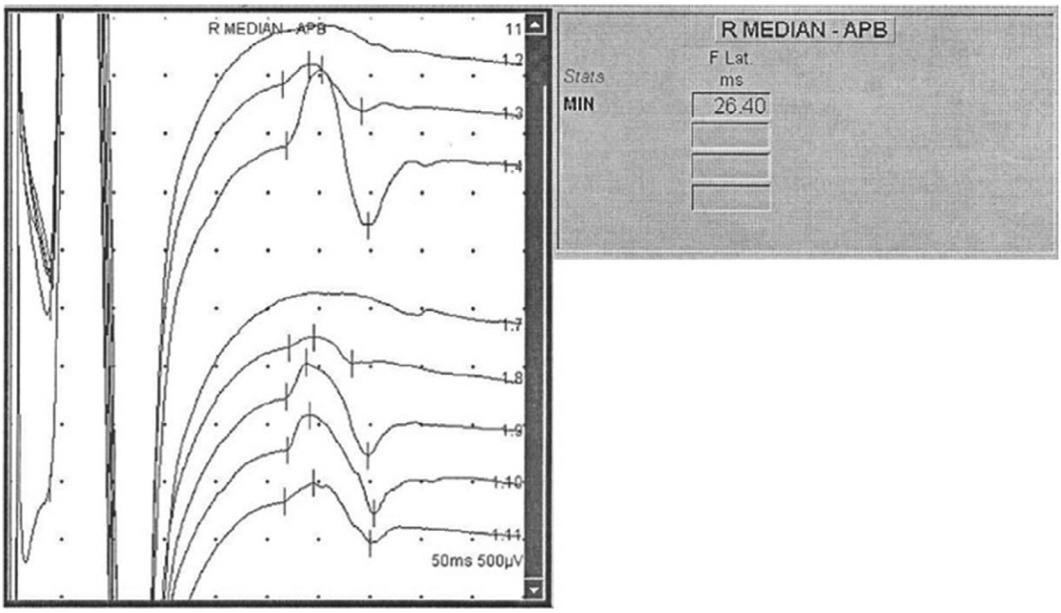

Fig. 3. Right median motor F-waves: 8 trials visualized on the graph, using supramaximal stimulation delivered at 1/s, after a brief (1 s) 20 Hz stimulation. As you see, the emergence of F-waves is pronounced. Persistence is normal (>50% of stimulations produces an F-wave). Right median motor nerve stimulated at wrist, recording APB (abductor pollicis brevis).

inflammatory demyelinating polyneuropathy (AIDP or CIDP), but may also be abnormal in diabetic neuropathy, uremic neuropathy, hereditary motor sensory neuropathy, amyotrophic lateral sclerosis, and radiculopathies. F-wave persistence may be reduced, or F-waves may be absent in the early days of AIDP even while distal motor conduction studies remain normal, indicating that the lesion may be too proximal to detect (Fisher, 1992). However, proximal nerve lesions are not the only factor that may influence F-wave persistence. F-wave persistence is low in anterior horn cell diseases and in peripheral neuropathies where there is a depletion of motor neurons and motor axons respectively (Panayiotopoulos and Chroni, 1996). It has been demonstrated in the literature that there are factors that affect the anterior horn cell's ability to generate an F-wave which are not related to pathology of the motor neuron. External factors such as vibration have been shown to inhibit F-wave persistence (Fisher, 1992), as has ipsilateral cutaneous electrical stimulation, while both contralateral cutaneous electrical stimulation and contraction of a contralateral muscle can improve F-wave persistence (Lin and Floeter, 2004).

When patients with narcolepsy experience a sleep attack, there is a reduction in F-wave persistence, which is likely related to depression of motor neuron excitability during the rapid eye movement phase of sleep (Yokota et al., 1992). It has also been reported that F-waves recorded from the abductor pollicis brevis in healthy subjects showed a progressive suppression after twelve hours of volitional muscle relaxation. The F-wave responses quickly recovered after a voluntary muscle contraction (Okada et al., 2004). This would indicate that prolonged muscle relaxation decreases the excitability of the motor neuron and the history of activity of a muscle should therefore be taken into account in clinical testing, especially when the study of a paretic muscle shows abnormal F-wave excitability (Taniguchi et al., 2008b). Alternatively, the effect of motor/motion imagery yields re-emergence of the F-waves (Hara et al., 2010; Taniguchi et al., 2008a). It has also been reported in the literature that when a motor neuron has few F-responses at rest, the frequency of F-responses increases under activation of the contralateral or ipsilateral muscle (Schiller and Stålberg, 1978).

In our patient, the initial lack of F-waves likely represented decreased motor neuron excitability due to a prolonged period of reduced mobility. The ultimate diagnoses in our patient included critical illness myopathy, pancreatitis, respiratory failure, subarachnoid hemorrhage, hydrocephalus, and deconditioning due to prolonged bed rest and reduced immobility resulting from the above-mentioned medical and neurological abnormalities. The ability to produce F-waves helped exclude a pathologic process affecting the proximal nerves.

Unlike the healthy volunteers previously studied (Taniguchi et al., 2008b), our patient could not voluntarily move normally due to a variety of medical and neurological issues. Therefore, we decided to try repetitive nerve stimulation to "wake up" the motor neurons and to re-establish the F waves. Indeed, the F-waves returned in an immediate and dramatic fashion. This supports the notion that our patient's initial lack of F-waves was physiological, rather than due to an underlying pathology. While there are a multitude of pathophysiological causes for the absence of F-waves, we believe that our patient's initial lack of F-waves resulted from simple motor inactivity. Thus, the patient's CIM plus the remaining neurological and medical conditions are not felt to be the primary culprit causing the initial lack of F-responses. Rather, it is our opinion that the patient's reduced mobility (due to the aforementioned abnormalities) caused the initial lack of F-responses.

While further subjects are needed, our results support the findings noted in the literature that absence of F-waves may result from inexcitability of spinal motor neurons rather than conduction block of the proximal peripheral nerve. The ability to recover F-waves after an initial absence could assist in differentiating between inexcitability of the anterior horn cell and proximal nerve conduction block. Therefore, repetitive nerve stimulation, given for 1 s at 20 Hz, may prove to be a useful technique to restore F-waves in patients who are unable to voluntarily contract their muscles. Other means of recovering F-waves through motion/motor imagery may suffice in patients unable to move, but who retain awareness (Hara et al., 2010; Taniguchi et al., 2008a).

Please note that 1 Hz stimulation is not enough to activate motor neurons since that should be seen on the regular F-wave

test. Therefore to "reawaken" F-waves, it appears to require a stimulation frequency of more than 1 Hz. Furthermore, while our patient's strength was reduced (2/5 in the upper and lower limbs), the patient was not plegic (0/5). Thus, as opposed to prior articles (Okada et al., 2004; Taniguchi et al., 2008a,b; Hara et al., 2010), it appears that an absence of any strength (0/5) is not necessary in order to lose the F-wave responses.

Future studies, using different firing rates and stimulus durations on multiple nerves as a means of triggering F-wave re-emergence might be considered as well. Another option for future studies is to stimulate one nerve at high frequency (i.e. tibial nerve) and then perform the F-responses on a different nerve (i.e. median nerve). This may help determine if stimulating a nerve different from the one we record the F-wave from yields a generalized arousal of all nerves or a local "wake-up" call. It should be noted that in volunteers previously studied (Taniguchi et al., 2008b), they did not have their nerves stimulated at high frequency (as in this study) in order to "wake up" their F-responses nor has this been previously described by others to my knowledge.

4. Financial disclosures

The authors Simon Zimnowodzki, Matthew Butrum, Jun Kimura, Erik Stålberg, Shalini Mahajan, and Leland Gao report no disclosures relevant to the manuscript.

5. Study funding

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6. Data availability statement

All data relevant to the study has been described within the article. No other data is available. Data was collected per the methods described in the manuscript.

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