

Needle Electromyography, F-Wave, and H-Reflex: A Critical Reappraisal of Their Utility in the Diagnosis of Various Sensory Symptoms in the Extremities and Spine in the Setting of Normal Neurological Examination

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Abstract

Objective: Health care providers refer their patients to electromyography (EMG) laboratories for the evaluation of various sensory symptoms in the extremities and spine. The procedure is usually performed in conjunction with transcutaneous electrical stimulation of peripheral nerves and elicitation of the F-wave and H-reflex. The present study aimed to determine the real value of these procedures in the diagnosis of sensory symptoms in the setting of a normal neurologic examination. **Method:** The EMG reports and clinical histories of 100 patients, including 10 patients evaluated by other electromyographers, were reviewed. The study was focused on those with normal neurological examinations and those without histories of ongoing medical disorders and major surgeries to the extremities and spine. **Results:** All EMGs, F-wave, and H-reflex reports reviewed were normal, including those obtained from the second procedure performed in some patients and of those who subsequently underwent spinal surgery. Neurologic examination in all patients was normal. **Conclusion:** Needle EMG, F-wave and H-Reflex examinations are predictably normal in patients with non-dermatomal, non-neuropathic sensory symptoms with normal neurologic examination and without history of pre-existing medical and surgical disorders. A good neurologic examination should determine the need to perform these procedures. Our findings have important diagnostic, therapeutic, prognostic, economic and legal implications.

Keywords

EMG, Electromyography, F-Wave, H-Reflex, Procedural Indications

1. Introduction

EMG, which is usually performed in conjunction with nerve conduction studies including elicitation of F-wave and H-Reflex, can be quite painful, uncomfortable, and time-consuming. It can also be expensive, depending on the extent of the procedure. It is a reliable procedure for documenting the presence or absence of muscle disorders. At times, however, the results of the procedure can be confusing to referring health care providers and the patients; and they can be disconcerting when the results do not correlate with the findings elicited in the clinical examination or with the findings demonstrated in the imaging studies. Despite the emphasis on the importance of the integration of the patients' clinical history to develop a proper interpretation of the EMG results, the main issue relies heavily on the ability of the electromyographer performing the procedure, to properly interpret the meaning of the phenomenology of a disease process as it relates to the expected or unexpected results obtained from the procedure. Frequently, the electromyographer would include a statement in the report, "clinical correlation is recommended". Unfortunately, this remark does not help the referring health care providers who may have little or no background in the clinical and neurophysiologic aspects of neuromuscular disorders. Its utility in the diagnosis of local musculoskeletal pain and pain in the joints, neck and lower back in the setting of a normal neurological examination has been called into question in two previous studies [1] [2].

EMG is a valid and well-established procedure for the assessment of the motor unit (cell body, motor axon, and muscle fibers innervated by the axon) but not of the sensory components of the neuromuscular system, including the various generators of pain in the spine. Nevertheless, health care providers refer their patients suffering from various sensory symptoms in the upper and lower extremities, including the neck and lower back, for EMG examination, being not fully aware that the procedure can only assess the motor unit components of the neuromuscular system. It is ironic that a patient suffering from pain, but with normal neurologic examination, will be subjected to such an uncomfortable and a painful procedure, especially when performed in conjunction with electrical nerve stimulation to elicit late action potentials such as F-Wave and H-Reflex.

Much has been written about the physiology of F-Wave and H-Reflex, but their utility in routine clinical practice of EMG, especially in the evaluation of pain, has not been critically assessed. F-Wave is a low-amplitude late motor action potential originally recorded in the small foot muscles, though it can be elicited by supramaximal stimulation of any motor or mixed nerve. The impulse travels antidromically to activate a pool of motor neurons (average of 5% - 10%). It is a pure motor response that follows the compound muscle action potential [3]. Like needle EMG, it can only assess the integrity of the motor fibers with no intervening synapses.

H-Reflex (or Hoffmann's reflex) involves afferent and efferent loops. It is the analogue of the ankle reflex, which is elicited mechanically by tapping the Achilles

tendon, which in turn stimulates the large diameter fast-conducting 1A sensory nerve fibers of the muscle spindles [3]. The H-Reflex, however, bypasses the muscle spindle by delivering a submaximal stimulus to the proximal segment of the tibial nerve in the popliteal fossa. The afferent impulse activates the alpha motor neurons, followed by subsequent activation of the motor fibers, resulting in a muscle twitch (H-Reflex). The reflex can also be elicited by stimulating the median nerve at the antecubital fossa with the recording electrode over the flexor carpi radialis muscle [4]. It supports the clinical diagnosis of C6 or C7 radiculopathy.

The present study aimed to discuss misconceptions about needle EMG, F-Wave, and H-Reflex; to determine their utility in the diagnosis of various sensory symptoms in the extremities, neck, and lower back associated with normal neurological examination; and to stress the importance of educating the public, and avoiding misunderstandings among patients, referring health care providers, the legal profession, and health insurance providers.

2. Materials and Methods

EMG reports on 100 patients (ages 20 - 65, 60 males and 40 females) referred for EMG evaluation were reviewed. They were selected from 1500 EMG procedures performed by the lead author (a board-certified neurologist and board-certified electromyographer) between 1997 and 2005, using the TECA TD 10 and Sapphire and Cadwell (Kennewick, Washington, USA) Sierra II Wedge NCV. The study period was selected because the lead author performed F-Wave and H-Reflex routinely during those years. The patients were referred by various health care providers, including primary health care physicians, physician assistants and family nurse practitioners, chiropractors, general neurologists, neurosurgeons, and orthopedic surgeons. More than half of the cases (n = 60) studied involved evaluation of various sensory symptoms in the upper (n = 28) and lower extremities (n = 32) without neck or back pain, with the remaining cases covering evaluation of suspected cervical radiculopathy (n = 20) and lumbosacral radiculopathy (n = 20) with neck or low back pain (Table 1).

One-fourth of the cases (n = 24) studied were referred for follow-up electrodiagnostic studies including neurologic examination, several months after the initial EMG examination. The magnetic resonance imaging of those patients with suspected radiculopathies consisted of varying degree of discopathies (bulging, protruding, herniated, and dessicated discs), various foraminal stenoses, and osteoarthritis. All had a normal clinical neurologic examination.

Excluded from the study were those patients with a history of diabetes, type 2 CRPS, major surgical procedures in the spine and extremities, lupus, rheumatoid arthritis, scleroderma and Sjogren disease, hepatic and renal diseases, malignancy (with or without history of radiation treatment or chemotherapy), polymyositis and muscular dystrophies, cervical and lumbosacral radiculopathies with abnormal neurological examination, and peripheral neuropathies of various etiologies. Proximal sensory mononeuropathies affecting the forearm, arm, knee, and

Table 1. Summary of Clinical and EMG Data.

Total number of cases: 110 (100 personally examined, plus 10 cases from other laboratories)
Cases evaluated for various symptoms in the extremities without neck and back pain:
<ul style="list-style-type: none"> ● Upper extremity—28 (26 personally examined, plus 2 from other laboratories) ● Lower extremity—32 (30 personally examined, plus 2 from other laboratories)
Cases evaluated for “suspected” radiculopathy with neck or back pain—40
<ul style="list-style-type: none"> ● Cervical—20 (18 personally examined, plus 2 from other laboratories) ● Lumbar-Sacral—20 (16 personally examined, plus 4 from other laboratories)
Age/years/gender:
<ul style="list-style-type: none"> ● Personally examined: 20 to 65, 60 males and 40 females ● Other laboratories: 31 to 53, 6 males and 4 females
Total number referred for second examination: 24
<ul style="list-style-type: none"> ● Upper Extremity—5 ● Lower Extremity—7 ● Cervical—5 ● Lumbosacral—7
Results of needle EMG, F-Wave and H-Reflex—all normal

thigh were also excluded. Included in this study were those whose symptoms consisted of “numbness,” tingling, burning or a cold sensation without dermatomal or neuropathic distribution, local pain and tenderness in the joints and extremities, neck and lower back pain without clear radicular symptoms, and chronic pain consistent with type 1 CRPS. They were either intermittent or sporadic, and the duration ranged from one to six months prior to examination. Trivial injuries, a remote history of fractures, vehicular accidents, work-related injuries, arthritis, repetitive activities, and poor posture were among the possible etiologic factors. This group underwent needle electromyography, routine one motor nerve (median or ulnar and peroneal) and one sensory nerve (sural) conduction studies, and F-Wave and H-Reflex conduction studies. Also included in this study were records of 10 patients (ages 31 - 53, six males and four females), whose electrodiagnostic studies were performed by other electromyographers. All were referred to the authors for a second opinion by their health care providers and fulfilled the exclusion and inclusion criteria.

Five patients with suspected cervical and seven patients with suspected lumbosacral radiculopathy, who were examined for the second time, had various degrees of discopathies and osteoarthritis, but normal neurologic examination and normal electrodiagnostic studies. All underwent spinal surgeries with fusion using either allograft or autograft.

Neurological examination was performed by the referring health care providers and by the lead author with particular attention given to the presence or absence of motor and sensory deficits and changes in muscle stretch reflexes in the upper and lower extremities. To assure accuracy and reliability, assessment of the cerebellar and cranial nerve function and mental capacity was performed at

the time of the electrodiagnostic examination. Needle EMG was performed, using monopolar electrodes to examine the segment-pointer muscles (deltoid for C5, brachioradialis for C6, triceps or flexor carpi radialis for C7, quadriceps femoris and adductor longus for L3, and tibialis anterior for L4, and extensor hallucis longus for L5, and gastrocnemius for S1). No attempt was made to sample the levels above because of lack of clinical indications. The paraspinals were not routinely sampled, especially in those patients with very tender spine, muscle spasm, and allodynia. The number of muscles sampled for the cervical and lumbar spine-related symptoms was limited to a minimum of four and maximum of five for each spine segment.

In the opinion of the authors, in the setting of non-neurological symptomatology and normal neurological examination, sampling of multiple muscles in the search for abnormalities is painful, inappropriate and impractical. EMG abnormalities were defined as increased muscle membrane irritability (trains of sharp positive waves) and active denervation (fibrillation potentials) in association with a decreased number of motor units activated during contraction and, depending on the chronicity of the condition, high-amplitude, complex, and rapid-firing motor units. Those with rare complex motor units without signs of active denervation or muscles membrane irritability were excluded from the study.

F-Wave and H-Reflex were performed according to standard techniques [5] [6] [7], with the latter performed only in the lower extremities. F-Wave latency was measured using the interside difference of the mean latency of 10 responses (normal range = 22.0 - 33.0 ms) of not more than 2.0 ms for either median or ulnar nerve-derived responses at the wrist recorded over the abductor pollicis brevis or abductor digiti minimi muscles, and not more than 3.0 ms for the peroneal nerve-derived responses (normal range = 44.0 - 55.0 ms) at the ankle recorded over the extensor digitorum brevis muscle. For those patients who were unable to tolerate supramaximal stimulation, the minimal latency of 5 - 6 responses, which represents the fast conducting nerve fibers, was measured. The determination of H-Reflex abnormalities was based on the absence of the response on the affected extremity or on the latency 3.0 ms longer than the asymptomatic side (normal range = 25.0 - 33.0 ms). The height of the patients was taken into consideration.

3. Results

Remarkably, all EMG reports (n = 100) reviewed, including those reviewed from other electromyographers' reports (n = 10), were normal. Mean and minimal F-Wave latencies were all normal. H-Reflex was present, symmetrical, and easily elicitable without facilitation in the lower extremities. There were no significant interside differences for either one of them. The second examination performed on 24 patients showed no EMG, F-Wave, or H-Reflex abnormalities. Additionally these patients' clinical neurological examinations showed no focal muscle

atrophy, fasciculations, dermatomal sensory loss, trophic changes, or changes in muscle stretch reflexes. Those patients, with normal EMG, F-Wave and H-Reflex, and who underwent cervical and lumbar spine surgeries, continued to complain of neck and low back pain without radicular neurologic deficits.

4. Discussion

The basic purpose of a medical test procedure is to explain the nature or etiology of a symptom. However, it is of paramount importance to know its accuracy and how it will effectuate the function for which it is being used. EMG, as the name indicates, is a recording of muscle fiber activities that are generated by the interaction between motor nerve fibers and muscle fibers [8]. It cannot assess the activities of the sensory components of the neuromuscular system. For many decades, EMG has been used to explain various symptoms such as pain and tenderness, numbness, tingling, stiffness, and burning and cold sensations in affected extremities. When used together with peripheral nerve conduction examination in the setting of glove-stocking sensory loss in the extremities, the diagnosis of a neuromuscular disorder, particularly peripheral neuropathy, is often made. Therefore, the presence of signs and symptoms of peripheral nerve disease bespeaks the need to perform a detailed nerve conduction examination with less emphasis on needle EMG. Otherwise, an extensive nerve conduction study is inappropriate.

When sensory symptoms are associated with normal neurological examinations, normal peripheral nerve conduction, and normal EMG, they are often construed as “non-neurological” in nature, or in most instances, attributed to various disorders, such as musculoskeletal conditions, type 1 complex regional pain, and rheumatologic, metabolic, and endocrine disorders. An effective neurological assessment will determine the presence or absence of central nervous system disorders that may present with vague sensory symptoms in the extremities.

The utility of F-Wave in the diagnosis of peripheral neuropathy, particularly that which affects the proximal segment of the peripheral nerve, is well established. However, its role in the diagnosis of radiculopathy is controversial because a nerve usually gets innervations from more than one root [9], not to mention that the action potential is a pure motor response. It is understandable that in situations when the primary symptoms are purely sensory in association with normal neurological examination, it follows that the F-Wave and its parameters will be normal, and it becomes unnecessary to perform this procedure on a patient who is already suffering from pain.

The neural pathway in H-Reflex involves the fast conducting large diameter 1A sensory fibers of the muscle spindles and the alpha motor neurons and their axons. These nerve fibers, strictly speaking, do not mediate pain in the soft tissues and spine, and are therefore of little value in the assessment of pain per se. When the ankle or triceps muscle stretch reflexes are absent or hypoactive in association with the appropriate clinical history, neurologic deficits, and absence of signs of peripheral neuropathy, the diagnosis of a proximal neural process at

the level of the roots (S1, C6, or C7) becomes certain.

The availability of information about certain medical procedures through on-line sources cannot replace face-to-face interaction between the patient and the electromyographer. A patient with local pain and tenderness in the spine or extremities who is referred for electrodiagnostic examination must be informed that EMG can only assess motor nerve fibers or muscle function, and is not a direct test for sensory symptoms, particularly pain. Therefore, it is the responsibility of either (or both) the electromyographer or the referring health care provider to convey this information to the patient. If there is a need to perform an F-Wave conduction examination, its limitations should be discussed, or it should not be performed at all if the clinical examination findings are normal. Likewise, if all the clinical abnormalities point clearly to S1, C6, or C7 nerve roots, H-reflex examination is either optional or unnecessary.

Multiple needle insertions are frequently performed by some electromyographers to diagnose a “suspected” radiculopathy. This practice, which also includes paraspinal muscle examination, is particularly inappropriate in a patient without neurologic deficits who is incapacitated by severe pain and tenderness in the spine. Moreover, EMG cannot test, assess, or localize the generators of spinal pain, which are mediated by small diameter sensory nerve fibers. Unless accompanied by unequivocal neurologic deficits, EMG in low back pain is frequently normal [2]. Likewise, EMG in patients with musculotendinous and ligamentous pain and those with joint pain unless associated with peripheral nerve entrapment, is always normal [1]. A great majority of EMG referrals consist of this type of clinical presentation, and the usual expectation is that EMG can localize the peripheral nerve or nerve root affected. Such an expectation becomes a moot point if the symptoms are not accompanied by unequivocally abnormal clinical examination findings.

The normal second EMG examination, which included performance of a normal peripheral neurological examination in 24 patients, proved beyond a doubt that a good neurological examination would predict the results of a peripheral electrodiagnostic examination. The conspicuous absence of muscle atrophy, lack of trophic changes, and preserved reflexes, ruled out spinal nerve root compromise or peripheral neuropathy in these patients.

A normal peripheral electrodiagnostic procedure as described in this study can be interpreted as a lack of pathology, and can have legal ramifications, especially when imaging studies show equivocal findings. This situation can be disconcerting to patients, who, despite the institution of extensive treatment modalities, continue to suffer from pain. It is obvious that those patients (including ours) with both normal clinical neurologic examination and electrodiagnostic procedures are suffering from musculoskeletal and/or soft tissue pain, and some may have low grade CRPS. Although thermal imaging is not widely accepted as a valid diagnostic procedure by most medical establishments, it has the ability to detect local temperature changes associated with soft tissue and joint pain (usually

warm focal segments in affected extremities), including the classic diffuse hypothermia in extremities affected by CRPS [10] [11]. This procedure was not performed in this study, but is nevertheless a good clinical examination, is sufficient and cost-effective, and remains the gold standard in the diagnosis of neuromuscular disorders and various pain syndromes [12].

The practical worth and applicability of needle EMG, F-Wave, and H-Reflex in the diagnosis of various sensory symptoms in the extremities, neck, and lower back, through normal neurological examination, although apparently undervalued by the results of this study, still remain the mainstay of peripheral electrodiagnosis if used under appropriate circumstances. Since some health care providers have little knowledge about the intricate details of these procedures, it becomes incumbent upon electromyographers to discuss the utility and limitations of the procedures, and inform patients that there are numerous generators of pain present in the musculoskeletal system—which include the myofascial tissues, joints, and fibroligamentous tissues in the spine—that cannot be assessed by the EMG method. Should the electromyographer proceed to perform the procedures with a certain expectation that the results will yield normal results? What is the economic implication of such an approach? If the results of the clinical neurological examination and imaging study are diagnostic of radiculopathy, is there a need to perform the procedure? These are important questions that are relevant in modern-day clinical practice. The answers, however, are not simple and are complicated by the fact that several medical specialists perform the procedure. There also remains the issue of the intrarater and interrater reliability of the procedure [13].

5. Conclusion

We concluded that a meticulous assessment of the clinical symptomatology and a good neurological examination should determine the indication to perform needle electromyography, F-wave, and H-Reflex including nerve conduction study. If the clinical symptoms are localized in the musculoskeletal and soft tissues or joints, and the neurologic examination is clearly normal, electrodiagnostic examination is either optional or unnecessary. Preprocedural evaluation by the referring health care provider and the electromyographer is therefore recommended. Such an approach has diagnostic, therapeutic, prognostic, economic, and legal implications.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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