Clinical Utilization of Surface Electromyography and Needle Electromyography: A Comparison of the Two Methodologies

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Needle and surface electromyography are 2 distinct modalities. They are both electro-physiological techniques aimed at the investigation of neuromuscular dysfunction. The clinical utilization of each technique is insufficiently known to the nonspecialist or to the typical patient. The present article aims at presenting a succinct description of each modality and the differences between the two in the clinical context.

Introduction
Clinicians who deal with needle electromyography (EMG) face the question as to whether there is any value in adding surface electromyography (SEMG) to their practice. Clinicians who deal with SEMG wonder if there is any value in referring any case for needle EMG or adding needle EMG to their practice. A scientific, detailed comparison between these 2 main electrophysiologic modalities requires a long chapter or monograph. This article presents a synopsis of the subject, written for those who may be unfamiliar with one or both of these methodologies.

What are these 2 electrophysiological modalities? They are technologies that evaluate and interpret in different ways the electrical currents generated by nerve or muscle action potentials. The needle EMG modality evaluates the normality of the motor end-plate. It assesses (at the tip of the insertional needle) at most 6 neuromotor end-plates (Albers, 1982). The SEMG in the amplitude domain tests the multiple unit action potentials coursing between 2 active electrodes placed along the main vectorial direction of a target muscle. It can also test the spectrum of the muscle fibers action potential firing frequency (spectral analysis and median frequency) (Basmajian & DeLuca, 1985). Needle EMG is only an investigative technique. SEMG is both an investigative and a rehabilitative technique. Reliable testing with both modalities is valid only within the framework of the physical examination and the clinical presentation. Neither of these electrophysiological modalities may replace the other or is superior to the other. They each evaluate different sources of information generated by nerve and muscle. This article is meant to concentrate only on the clinical applications and differences between these 2 motor testing modalities.

Needle EMG
Needle EMG is utilized in the investigation of the following symptoms and/or conditions:

(a) painful limb(s);
(b) painful cervical and/or lower back region(s);
(c) peripheral diseases of peripheral nerves—polyneuropathy (polyneuropathy is a general term that indicates a disease or a variety of diseases of peripheral nerves);
(d) diffuse loss of strength;
(e) primary muscular disorders—myopathy (myopathy indicates a disease or a variety of diseases of skeletal muscles);
(f) neuromuscular junctional disorders;
(g) diseases of the nerve roots—radiculopathy and polyradiculopathy (radiculopathy indicates a disease or a variety of diseases of the nerves, as they come out of the spinal chord. Polyradiculopathy refers to diseases of several nerves as they leave the spinal chord) (Sunderland, 1978).

SEMG
SEMG is an investigative tool aimed at various aspects of muscular function and dysfunction. It is also a rehabilitative tool: It helps the individual to learn neuromuscular self-control and to improve the motor and proprioceptive engrams (Sella, 2000a, Donaldson, Sella, & Mueller, 2001). An engram is a memory cluster of a repeated neural event. The larger the number of repetitions, the larger the cluster in the brain. A motor engram refers to a cluster of movement-related events. An example would be the act of shooting
at a target. The more the person exercises the shooting act, the more “focused” the motor representation of the act. A proprioceptive engram refers to a focused representation in the brain or cluster of the body, body sensations, or body parts, as they relate to the body’s position in space in a given moment.

SEMG is a good indicator of the effort required to perform a given activity (Kumar & Mital, 1996). There are 2 kinds of SEMG tests: static and dynamic (Sella, 2002). The static testing applies to the axial skeleton (standing or sitting). The active electrodes are applied simultaneously to the paraspinal muscles from C1 to S1. The testing is conducted with well-defined clinical protocols. The dynamic SEMG protocols involve bilateral testing of homologous contralateral muscles during activity and rest. The results are analyzed statistically and compared for normality with a standardized database (Sella, 2000b; Sella, 2001a).

The general areas of neuromuscular investigation that can benefit from the use of SEMG include the following:

a) **Muscular fatigue:** SEMG can investigate muscular fatigue with the frequency domain, i.e., the spectral analysis of the target muscle (Basmajian & DeLuca, 1985). Muscle fibers fire their action potentials at different rates per units of time. The spectral analysis refers to the SEMG visual observation of the frequency of firing of a particular muscle per unit of time. The firing frequency tends to slow down in time as the energy potentials need to be regenerated;

b) **Loss of strength (LOS):** SEMG can evaluate the amplitude potential during motion and rest (ROM) (Sella, 2000a; Sella, 2002; Gerhardt & Sella, 2002);

c) **Joint loss of motion:** SEMG can help assess the muscular energy changes during a loss of joint ROM (Sella, 2003);

d) **Laterality:** SEMG can assess the symmetry of muscular electric output in asymptomatic and symptomatic muscles. Asymptomatic muscles amplitude potentials at rest or during motion show differences within 25%, with a median of 12%. Symptomatic muscles show difference within or above 50%, with a median of 25% (Sella, 2000a);

e) **Agonism—synergism and antagonism:** synergism refers to 2 or more muscles inserted in the same joint working together to move the joint in one form of contraction, concentric or eccentric; antagonism refers to 2 or more muscles inserted in the same joint moving in opposite ways, i.e., 1 or more muscles move the joint by concentric contraction and the others “oppose” the motion by eccentric contraction. An example would be the biceps and the brachialis flexing the elbow in concentric contraction (synergism) while the triceps goes in eccentric contraction (antagonism). SEMG regression analysis studies have established the positive and negative relationships among 183 skeletal muscles (Sella, 2000b; Sella, 2003);

Other parameters that SEMG can assess include the following:

a) **Mirror image:** Mirror image pertains to rotation or bending motions of the muscles of the neck and trunk. The values and activity curves are similar in asymptomatic muscles and differ in symptomatic ones; (Sella, 2000a);

b) **Cocontraction:** This is a learned phenomenon of muscles of the limbs, where there is a tonus increase in a resting muscle without actual joint motion while the contralateral muscle is in motion. While this phenomenon is usually observed first in a muscle affected by pathology, e.g., paresis, it may be observed later in the unaffected contralateral side. The presence of cocontraction may explain the clinical finding of fatigue in diseased muscles at rest during the time that their uninvolved contralaterals are in motion (Sella, 2001b; Sella, 2003).

c) **Coactivation:** This is a related phenomenon. It refers to the cocontraction of a contralateral muscle from another girdle. It has been found in the condition of fibromyalgia. The phenomenon was observed bilaterally. This may throw a new light on the symptom of generalized fatigue in the conditions of chronic fatigue and fibromyalgia (Donaldson, Mueller, Donaldson, & Sella, 2003);

d) **Pain:** This parameter of muscle dysfunction has its “print” on SEMG (Sella, 2000b; Sella, 2003). The affected muscle usually shows an abnormally elevated resting tonus and activity tonus. A muscle in pain is usually unable to rest and re-energize and has to make an effort at recruiting an adequate number of contractile elements. The pain pattern is observed for any segment of motion during which the muscle suffers;

e) **Hypoactivity:** This is a muscular activation phenomena encountered in conditions such as protective guarding and gait dysfunction (Sella, 2000a; Sella, 2000b). The affected person learns to protect the injured body parts by activating minimally the pertinent muscles (Sella, 2001a).

An array of specific SEMG parameters are involved in muscular dysfunction. These include the following:

a) **(Electric) spasm:** The appearance of the amplitude potentials is quite similar during activity and rest (Sella,
Can SEMG Complement the Investigations and Findings of Needle EMG?

Returning to the area of assessment and diagnosis, we will review each area of neuromuscular problems, and review evidence that SEMG can complement the diagnostic value of the needle EMG.

Painful Upper and Lower Limb

In terms of investigation of the painful upper and lower limb, SEMG testing uses ROM dynamic protocols involving commonly several pairs of contralateral muscles. Resting and activation potentials are tested in sequence. Since most conditions of pain in a limb are unilateral, the bilateral SEMG investigation can throw new light on any needle EMG finding. Unilateral abnormal resting and activity potentials found on SEMG concurring with abnormal needle EMG findings improve the depth of the diagnosis. SEMG of muscles afflicted by pain show abnormal resting and activity potentials parameters. These include spasm, hypertonus, hypotonus, fasciculations, cocontraction and/or coactivation. Those findings may be more indicative of central neuromotor engram changes and sympathetic modified responses. Needle EMG findings of abnormal motor end-plate may elucidate further the diagnosis. While needle EMG is only an investigative tool, SEMG can be utilized successfully as a treatment modality in the rehabilitation of painful limb muscles. The neuromuscular program is aimed at CNS neuromodulation, including modification of the motoneuronal engram of the affected limb (Donaldson et al., 2001; Moss et al., 2003).

Painful Cervical and Lower Back Regions

In terms of the investigation of the painful cervical and lower back regions, SEMG offers static and dynamic protocols (Sella, 2000a). While the needle EMG testing is very useful in the investigation of the paraspinal muscles of the entire column in terms of ruling out radiculopathy versus plexopathy, the procedure is invasive and painful (Daube, 1991). The SEMG static protocol may offer a good index of electrical output normality of the paraspinal musculature in the standing or sitting position “at rest.” Conversely, it may indicate the presence of spasm, hypertonus, hypotonus, or the zig-zag pattern associated with postural dysfunction. The presence and differential diagnosis of these parameters can be obtained only by conducting SEMG dynamic studies. The finding of loss of mirror image of paracervical or paraspinal muscles, as shown by the dynamic motions of rotation and bending may be indicative of splinting or protective guarding (Sella, 2003). Loss of mirror image may coincide with the findings of central neuromotor engram changes and sympathetic modified responses.
of unilateral hyper or hypoactivity of the action potentials. SEMG can be utilized successfully as a treatment modality in the rehabilitation of painful cervical and thoracic and lumbo-sacral muscles. The neuromuscular program is aimed at improving the stability and laterality of the gait through the rebalancing of the homologous contralateral muscles of the spinal column (Moss et al., 2003; Sella, 2005).

**Polyneuropathy and Radiculopathy**

In terms of the investigation of polyneuropathy and radiculopathy, SEMG can complement needle EMG studies (Wilbourne & Aminoff, 1988; Basmajian & DeLuca, 1985; Sella, 2003). Appropriate dynamic protocols have been devised and described (Sella, 2003). The protocols are bilateral and involve the ROM of the pertinent limb. Testing is done on the muscles innervated by the pertinent roots or nerves. It is unlikely that normal results from muscles innervated by the same roots via different nerves or by the same nerves would be compatible with either neuropathy or radiculopathy. Abnormal results in terms of electric potential behavior during rest and activity are utilized in the differential diagnostic process of neuropathology. Radiculopathy is usually associated with loss of strength of the roots and muscles involved. The acute SEMG muscular response is that of recruitment of a larger number of contractile elements in order to enable the muscle to perform the required task. This may give rise first to hyperactivity, then to spasm, and eventually to hypotonus. The differences between the activation levels of the asymptomatic homologous contralaterals and the affected muscles are quite evident when compared with the activation values of the normative database (Sella, 2001a). In fact, the activation abnormalities observed on SEMG are evident within 24 hours, far earlier than the classic 1 month delay observed on needle EMG studies. SEMG can be utilized successfully as a treatment modality in the rehabilitation of muscles affected by neuropathology and radiculopathy. It is relevant to rehabilitate the neuromotor engram, including the issue of proprioception. The affected person may learn to utilize the muscles in a more effective manner and to provide adequate rest (Donaldson et al., 2001, 2003).

**Diffuse Loss of Strength**

In terms of the investigation of diffuse loss of strength, SEMG dynamic studies can show a variable degree of abnormal activation potentials. A weak muscle reacts at first with increased recruitment of contractile elements, observable on the amplitude domain as increased amplitude potentials during motion. The frequency domain usually shows a decreased frequency band compared to the normal contralateral muscles (Basmajian & DeLuca 1985). The median frequency of the spectrum of the involved muscles decrements rapidly, within 60 seconds of ROM activity. In time, the amplitude potentials of the resting tonus may show an inability to return to normal resting potential values. If the nerve supply is compromised further, the overall amplitude potentials during activity decrease to the point of hypoactivity. In situations where the trophic neural factor is absent, such as in poliomyelitis, the SEMG amplitude potentials are quite flat at levels of ≤ 1 µV, i.e., contracture. SEMG can be utilized in the overall rehabilitation program of diffuse muscular weakness to help the sufferer understand the engram dysfunction and to monitor improvement in a non-invasive manner.

**Primary Muscular and Neuromuscular Junctional Disorders**

There is little documentation as yet on the subject of SEMG investigation of primary muscular disorders (myopathy) and neuromuscular junctional disorders (Sunderland, 1978). The involvement of this modality refers only to the symptoms of these conditions. When muscles are weak, SEMG investigation will show the findings described and defined above. The SEMG treatment is aimed at functional maintenance and improved control of the resting tonus and activity tonus. Where there is a chance of improvement of the neuromotor engram, SEMG is the rehabilitation modality of choice (Donaldson et al., 2001, 2003).

**Summary**

Needle EMG and SEMG are 2 distinct electrophysiological modalities. Extensive research has documented that each one is a valid modality for documenting muscular pathology or dysfunction. The subject of comparison of differences and similarities is quite vast. This short article has endeavored to present the fact that these 2 modalities are complementary and can both be used to improve one’s diagnostic work-up and neuromuscular rehabilitation treatment.

1 Trophic neural factor is a substance, whose composition remains unknown, which nerves carry to muscles. If the nerve to a muscle is cut off, even if the muscle has good blood supply, the muscle will wither away or atrophy. If a nerve is implanted anew in the muscle, the muscle may start to “come back to life”, or reverse the atrophy.

2 Poliomyelitis, or polio, is a disease of viral etiology, which affected many thousands of children and adults in America, including President Franklin Roosevelt. The virus destroys the nerves going to muscles and the muscles paralyze. This is why the disease is also known as “infantile paralysis.” The disease almost disappeared since the advent of the Salk and Sabin vaccines. All American babies are vaccinated against the disease.


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