Surface electromyography (SEMG) can be effective in helping patients regain motor function as long as the advantages and disadvantages of the modality are well understood. The technique has been described by researchers in the past as a “seductive muse” because of its apparent simplicity. Nevertheless, restoration of motor function can be enhanced as long as the clinician understands how to interpret SEMG amplitude, considers the constellation of muscles involved in the functional movement targeted for treatment, presents the SEMG information in a form the patient can understand, and provides for opportunities for transfer of the motor learning from the office to the patient’s everyday world.

One cool, crisp fall day Cassidy’s mother loaded the children into the van for a trip to the grocery. Cassidy, age 3, was placed in her usual front child seat, with her siblings in the back of the van. Halfway to the store, a speeding truck ran a red light, crushing Cassidy’s side of the van. The impact severed her spinal cord paralyzing her from the neck down. While her siblings recovered, Cassidy sustained severe injuries including multiple fractures and an inability to breathe on her own. When medically stable, she was fitted for a wheelchair with a ventilator attached to the rear to breathe for her. She then began the long road to recovery.

Cassidy’s goal in physical therapy was to master enough head control to be able to use position switches around her head to guide her wheelchair. At first the goal was simply to tolerate sitting in the wheelchair for 2 hours per day. Once her endurance had increased, she worked on initiating cervical extension (bringing the head up away from the chest) 10 times per session. She also practiced moving her head away from the head rest (cervical flexion), with the goal to teach her to maintain her head in midline. Midline head position was crucial, otherwise the switches attached to her wheelchair around her head would be useless. Activating one switch (with head pressure) would turn the chair left, another to the right, and so on. Cassidy was not making sufficient progress in therapy, so the physical therapist asked if surface electromyography (SEMG) might help.

Cassidy needed to be reintroduced to where her head was in space, and surface electromyography (SEMG) was the perfect medium with which to do so. In the past 15 years, there have been occasional articles on the use of SEMG in physical rehabilitation. The outcomes in some articles are described as very helpful (Nord, Ettare, Drew, & Hodge, 2001), while others held the opinion that more traditional therapies are just as effective (Dijk, Jannink, & Hermens, 2005).

SEMG measures the amount of effort a muscle is generating through electrodes placed on the skin. It is noninvasive, painless, and, in the hands of a skilled practitioner, can reveal a wealth of information on muscle function. To quote a physical therapist, “It feels like I can reach in and touch the muscles.” It is used more often in assessment than treatment and is particularly useful as a diagnostic tool in patients with muscle dysfunction.

Cassidy’s treatment took place in the Motor Control Program at the Cleveland Clinic Children’s Hospital for Rehabilitation (CCHR) in Cleveland, Ohio. The program, created by the author, expands the dimensions of SEMG to address the functional goals of the patient, not just to increase awareness of or increase muscle activity in a compromised limb (Bolek, Mansour, & Sabet, 2001; Bolek, 2003). There are many facets of SEMG that must work in concert in order to help the patient regain function of a compromised body part. “Regain function” means demonstrating the ability to perform a sequence of motor movements (often one which a healthy person takes for granted) in order to achieve a goal.

For example, a patient may set a goal to drink their morning coffee independently. This simple task is actually quite complex from a motor standpoint. One must know where the cup is, be able to see the cup accurately, organize the motor plan to reach the cup (which includes estimating the distance of the cup from the person), gauge the velocity of the reaching movement, adjust the grasp correctly (too little results in spilled coffee; too much, a damaged cup and person), and establish the return sequence to the lips. SEMG can help a patient achieve these goals, but it needs to...
be in a form the patient can understand, much like taking a computer class for beginners.

One of the reasons patients need an external aid like SEMG to relearn motor skills is that the joint receptors adapt and accommodate to the altered muscle imbalance. What was previously “abnormal” feels “normal”. A person standing with a lean to the left does not perceive the lean; it feels to him as if he is standing straight. Something (like SEMG) from the outside can teach him what “straight” is. A physical therapist could tell him, but the advantage of SEMG is that it can teach him what the muscles feel like when he is standing straight.

Applications of SEMG to motor re-education typically use 2 channels, one for the “agonist” (targeted, active muscle) and one for the “antagonist” (also targeted, but the goal is to relax this muscle). For example, a patient with a wrist drop may have a goal to extend (lift up) the wrist. In a 2-channel application, the wrist extensor bundle (on the dorsal aspect of the forearm, about 5 cm distal from the elbow) would be guided to be active, while the wrist flexor bundle (on the ventral aspect of the arm, about 5 cm from the elbow) would be trained to relax. In a typical office setting, the patient would watch a monitor that displays the amplitude of the muscles rise and fall as a line on a screen. The goal would be to increase the extensors while holding steady or reducing the flexors. The factors below highlight the problems with traditional applications of SEMG to motor control, which may account for the mixed findings on the effectiveness of SEMG mentioned earlier.

There are 6 key factors that must be kept in mind when developing, administering, and interpreting an SEMG protocol for motor re-education. First, changes in SEMG amplitude do not necessarily correlate with changes in functional performance. For example, Bolek (2003) published the first study to demonstrate that walking ability in a group of patients with foot-drop could be improved by creating a program that rewarded increased recruitment of the anterior tibialis just after foot push off during the gait cycle. In this case, simply increasing the SEMG amplitude of the anterior tibialis by having the patient contract the muscle while sitting in a chair does not improve function (Bradley et al., 1998); recruitment must occur at the right moment in the gait cycle (timing) and with enough intensity (amplitude).

Second, increases in SEMG amplitude can be due to many factors (Houtman, Stegeman, Van Dijk, & Zwarts, 2003). One cannot assume an increase in SEMG amplitude is a valid benchmark for improved function of a targeted muscle. Muscle electrical activity changes with muscle length (Kamen & Caldwell, 1996), so that interpretation of activity during dynamic contractions becomes complex, although it looks easy.

Figure 1. Second treatment session. Patient is receiving maximal support from therapist. Maintaining protection of airway is also a consideration.

Third, humans use a constellation of muscles working in concert to perform even simple movements. Simons, Travell, and Simons (1999) initially defined this constellation of muscles as a myotatic or functional unit. This group of agonist and antagonist muscles functions together as a unit. In Cassidy’s treatment, the goal was to help her find and maintain neutral (level) head position, as a precursor to learning further head control to drive her wheelchair. For head control, the myotatic unit is left and right sternocleidomastoid (SCM) (the muscles that run from the base of the chin up behind the ear) and the cervical paraspinals (CP) (muscles at the base of the neck). The SCM’s were rewarded for activity above threshold and the CP’s for activity below threshold. The reward for the correct constellation of muscle recruitment was onset of her favorite video; if the recruitment pattern was lost, the video would stop. All 4 muscles were targeted, and each had to perform within a set threshold. If one were to view a video of Cassidy’s treatment session, one would see the reward activated only when her head was in a level position, neither too far forward, nor backward, nor to one side (Figure 1).

Fourth, humans (especially children) learn most effectively when sufficiently motivated. As mentioned earlier, in 2-channel treatment, the therapist describes the desired muscle action by explaining and pointing to the muscle tracings on the screen. The patient’s job is to raise or lower the readings, depending on the setup. But with multiple-site performance-contingent (MSPC) SEMG work, the patient may become confused when viewing multiple lines on a computer screen. Whether an adult or child is involved, viewing the readings on a computer screen can become boring after a period of time, and attention wanes, even with 2-channel SEMG. In MSPC SEMG training, correct activation of the myotatic
unit (i.e., all targeted muscles) results in activation of a video within 0.5 seconds. As in the case of Cassidy, typically some muscles need to be used (above threshold) and some relaxed (below threshold). Therefore, in MSPC SEMG, the focus is to help the patient internalize the correct muscle pattern recruitment, rather than line tracings on a display screen.

Fifth, for most patients, the time interval from correct muscle activation of the myotatic unit to onset of reward is 0.5 seconds. There are patient groups, such as those with cerebral palsy or post-traumatic head injury, where phasic or short bursts of muscle activity predominate and a longer interval between muscle activation and reward onset (0.8 to 1 second) encourages the learning of tonic or longer duration muscle activation. During Cassidy’s treatment, she began to “bob” with her head as she tried to sustain cervical extension (head up away from her chest). The recruitment interval to obtain the reward was slowly increased from 0.5, 0.8, 1 second, to 2 seconds guided by a reward onset of about 80%. In this way, the task was not so difficult as to produce intolerable frustration, but was challenging enough to promote tonic rather than phasic muscle activation. The end result is increased endurance while maintaining a neutral head position (Figure 2).

Lastly, training in an office can become deceptively successful. Mastering a motor task with the aid of an SEMG program is very different from performing the same task at home. In Cassidy’s case, as soon as she was able to make the connection between her head position and the activation of the video, she was also rewarded with the verbal cue “that’s good head in the middle.” Further, during treatment she was prompted with the verbal cue “Head in the middle.” Over the course of treatment, this scenario would be repeated hundreds of times. During treatment in other therapies, such as speech and recreation therapy, visits to home, and field trips away from the hospital, she would also be prompted “Head in the middle.” Through this process, head position became part of her repertoire so that external cues were needed less, and internal cues played a larger role. After 24 treatment sessions, her capability and endurance in holding her head upright had increased to the point that she was ready to move on to learning to control her wheelchair using her head (Figure 3). With the skills learned through SEMG, she was able to embark on a program that allowed her some control over her surroundings. On follow-up 3 months after discharge from her inpatient stay, she not only maintained the skills learned, but improved in endurance and accuracy in driving her wheelchair with her head.

In the Motor Control Program at CCCHR, up to 14 muscle sites may be used in the performance-contingent reward program, which produces a profile much richer in information than that from an analysis of SEMG amplitude using only 2 sites. For example, a patient with a right hemiparesis, whose goal is to be able to reach with the right arm, may also lack a stable base of support. A typical scenario would be to target bilateral gluteus maximus, gluteus medius, lower paraspinals, mid-paraspinals, lower trapezius, rhomboids, right bicep, and right anterior deltoid in a configuration that would promote a stable base of support as well as back musculature symmetry. The patient works to master the “feel” of the muscles when the video is on. Such a task is impossible if the patient needs to rely on watching the jumble of activity of 14 muscle readings on a monitor. Very often a patient will exclaim “I got it!” upon mastery of the muscle movement, much like the sensation one recalls the first time bicycle riding was mastered without training wheels.

Effective intervention in patients with motor dysfunction involves many facets. The myotatic unit involved in the
movement must be addressed, typically involving multiple bilateral sites. A good rule of thumb is to begin assuring integrity at the base of support (typically the pelvis or abdominals) and targeting muscles on out from there. The SEMG information must be in a form the patient can understand and be sufficiently motivating to maintain interest, not only within an hour’s treatment session, but also across sessions for weeks at a time. The reward onset may have to be tailored to the patient’s unique motor recruitment pattern so as to encourage sustained (slow twitch) muscle activity. Finally, early in the treatment, verbal cues must be linked to the desired motor plan so that external aids (i.e., SEMG) are needed less and an internal sense of muscle function is increased. In this way, SEMG practitioners can help restore functioning to patients who have lost the ability to care for themselves through accident or disease.

References


Correspondence: Jeffrey Bolek, PhD, Cleveland Clinic Children’s Hospital for Rehabilitation, 2801 Martin Luther King Jr. Drive, Cleveland, OH 44104, email: bolekJ@ccf.org.