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SPECIAL ISSUE

What Physicians Need to Know About Surface Electromyography

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Surface electromyography, if used correctly, can be helpful in restoring lost function after a stroke or head injury. This article explains the basis for quantitative surface electromyography (QSEMG). QSEMG does not target discrete muscles; it targets a constellation of muscles in order to restore function.

When patients who have sustained a loss of function arrive for treatment, they are seeking one goal above all others: the return of function. One cause for the loss of function is a stroke. Strokes are the third leading cause of death in the United States with more than 140,000 people dying each year. It is also the leading cause of serious, long-term disability in the United States with approximately 795,000 people suffering a stroke each year (Centers for Disease Control and Prevention, 2005). Left-hemispheric ischemic strokes appear to be more frequent and often have a worse outcome than their right-hemispheric counterparts. The incidence of large-vessel ischemic strokes is higher in the left middle cerebral artery distribution, contributing to these hemispheric differences (Hedna, Jain, Rabbani, & Nadeau, 2013).

Patients treated using surface electromyography (SEMG) perform exercises to activate an agonist and relax an antagonist while the activity is displayed visually on a screen with auditory accompaniment. The therapist describes the desired muscle action by explaining and pointing to the feedback display. Early applications of this technology targeted only two muscles, limiting the feedback information available to the patient. Multiple goals were often sought, but a more realistic approach would have been to restore a specific function such as reaching, sitting independently, standing, walking with walker, etc.

Restoration of function is distinguished from muscle recruitment. Recruitment is the focus of effort on the part of the patient to activate a specific muscle group. Restoration of function can only be accomplished by the activation of a myotatic unit or constellation of muscle activity. Simons, Travell, and Simons (1999) initially defined a myotatic unit as a functional unit or group of agonist and antagonist muscles that function together as a unit and are linked by interacting reflex pathways. They later expanded the definition to include muscles that do not necessarily share common reflexes but have close functional relationships. Attending to the myotatic unit (or constellation of muscles) involved in the targeted skill leads to faster and more enduring learning (Sella, 2000). For example, the myotatic unit for restoration of the ability to reach with the right arm for a patient with a right hemiparesis may include the following muscles: gluteal, paraspinals, trapezius, deltoid, biceps, and triceps.

Failure to attend to the myotatic unit is the reason biofeedback use in rehabilitation had a brief and less than stellar legacy beginning in the 1970s and continuing to this day. A program for arm rehabilitation would target the biceps and wrist extensor/flexor bundle. While the patients may have regained some use of the arm because of the hemiparesis, their base of support was unstable and they were unable to automatically initiate the core adjustments needed to avoid falling out of a chair as they reached with their right arms. Their center of balance is altered during the reach. This adjustment is learned early in life and occurs without conscious effort in the healthy individual. For the stroke survivor, it typically needs to be relearned.

Existing literature typically compares conventional physical/occupational therapy treatment to two-channel SEMG augmented treatment. For example, of the 22 studies reviewed by Dijk, Jannink, and Hermens (2005), 15 used SEMG as the type of intervention, and of those 15, no treatment used more than two muscles in training. Failure to attend to the constellation of muscles or myotatic unit active during the range of motion using multisite SEMG decreases the likelihood of success. Woodford and Price (2007) found that: “When all the available data are combined, electromyographic biofeedback does not appear to have any positive benefit for recovery after stroke” (p. 5).

Unfortunately, the available research is a combination of biofeedback therapy during functionally goal-directed dynamic movements, mixed in with programs that target a simple movement involving one or two muscle sites unrelated to function (Glanz, Klawansky, & Chalmers, 1997; Moreland, Thomson, & Fuoco, 1998; Schleenbaker, 1993). For example, patients will likely learn to reach with their arms more quickly if they have a stable base of support.

Quantitative analysis is a means by which a signal is partitioned into its component parts based on a predetermined algorithm. For example, quantitative electroencephalography is a method of electrically processing the EEG signal to numerically represent the contributions of each brain wave frequency (Wallace, Wagner, Wagner, & McDeavitt, 2001). A common application is to monitor 19 sites over the scalp. Using spectral analysis, a segment of the electroencephalography signal is separated into its component frequencies and amplified along with the amplitude of the component frequencies.

Bolek (2012) created quantitative SEMG (QSEMG) as an approach where the patient does not seek to control discrete muscles but rather seeks to produce a patterned response based on the constellation of muscles, or myotatic unit, involved in the movement. In QSEMG, the SEMG signal from multiple sites is statistically processed so that the root mean square data is transformed into a functional time domain score where *function* is defined as the ability to use muscle recruitment to accomplish a task. The task may be anywhere on the continuum from holding a cup to throwing a 90-mile-per-hour fastball.

In QSEMG, the focus is to internalize the correct muscle pattern recruitment rather than relying only on individual muscle line tracings on a display screen. Each target muscle is selected relative to a unique and specific therapeutic threshold, which is selected by the clinician for its relevance to the functional goal. When this constellation of muscle groups is on target, the video reward is activated. Typically, some muscles need to be used and some relaxed. Failure to maintain any muscle at the therapeutic threshold (either above or below depending on the outcome desired) terminates the reward. In this way, a form of bandwidth corrective feedback (Weinstein, 1991) is employed to provide information when the patient performs outside a preset band of accuracy. Activation of a video is the preferred reward due to the ease of controlling the on/off set. Over the course of a 60-minute session, the patient may start and stop the reward many times, as the correct movement pattern is found, lost, and regained.

Bolek (2006) conducted a study where patients referred to the motor control program of the Cleveland Clinic Children's Hospital for Rehabilitation for head control, standing balance, sitting, and upper extremity use (brachial plexus injury) from 2003–2005 were included in this review, for a total of 16 patients. These children were referred to the motor control program by physical/occupational therapists after a period of traditional therapy either failed to make any progress or the child reached a plateau in attaining goals set in the initial therapy assessment. Each patient had a customized treatment plan based on the functional goal to be addressed and the myotatic unit, which constituted the SEMG treatment plan. The children ranged in age from 4 to 18 years, with the majority diagnosed with cerebral palsy. Their progress was determined by recording the percent of success in each treatment session and charting the percentages of all treatment sessions. Success was tabulated by summing the time the child maintained the correct recruitment pattern for the targeted therapy goal for the duration of the session and dividing that figure by the total minutes of the session. Periods of successful recruitment ranged from seconds in the beginning of treatment to minutes after the skill was learned. For example, successful head control was defined as the ability to maintain the head in neutral or at a 90° angle with reference to ground. In a similar manner, good form in sitting, standing, and reaching was defined by the treating therapist as formulated in the short-term goal. A typical goal for sitting was to bench sit for 10 seconds with a neutral pelvis without assistance and without falling. A goal for standing was to progress from contact guard to no assistance for 10 seconds. Because the study was a retrospective review, no attempt was made to address confounding variables. Thresholds for muscle use were subjective judgment calls, being set to correspond to when the therapist would say to the child "Good standing" (or sitting, head position, or reaching). Fourteen of the 16 children improved during motor control treatment. Success was defined according to Gottman's rule of thumb used in industrial quality control charts (Gottman & Leiblum, 1974). The first three treatment sessions were used as a baseline. The mean and standard deviation were calculated for the baseline period as well as a 2 *SD* bands above and below this mean. The percent success attained in the remaining treatment sessions was reviewed to see if at least two successive observations exceeded this band. If so, the treatment was categorized as a success. Specifically, less than 5% will exceed 2 *SD*s by chance. The number of 1-hour treatment sessions ranged from seven to 34, with a mean of 15.6 and a standard deviation of 8.4. The breakdown for patients' goals was: eight standing, three sitting, three upper extremity work, and two head control. Success was achieved in 88% of the children treated.

SEMG can be a powerful tool in the clinician's armamentarium for restoring function to patients who have lost it due to stroke, head injury, or other medical condition. The challenge for the clinician is to apply it in such a way as to maximize the likelihood of success.

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