CHAPTER 11

TECHNOLOGY REVIEW: DYNAMIC ELECTROMYOGRAPHY IN GAIT AND MOTION ANALYSIS

American Association of Electrodiagnostic Medicine American Academy of Physical Medicine and Rehabilitation

Introduction

Dynamic electromyographic measurements have been incorporated into studies of human gait and, in a broader sense, studies of human limb motion and even human torso motion, since the early 1950s. Initially, these measurements were purely investigational in nature, but the instrumented study of gait and motion has emerged as a clinical tool. Because of member interest in dynamic electromyography (EMG) in general, the American Association of Electrodiagnostic Medicine (AAEM) has undertaken a review of the literature in an effort to examine the clinical role of dynamic EMG measurements in gait and motion analysis. The papers cited below were viewed as representative of the literature on the subject in general and form a basis of the present document.

BACKGROUND: TECHNICAL ASPECTS

It is important to realize that there are 2 forms of dynamic electromyographic measurements which have found popularity in the studies of human motion. The first type of dynamic EMG is surface electromyography (SEMG) which utilizes button electrodes taped to the skin over the muscles of interest. The second type is fine-wire electromyography (FWEMG) which incorporates fine-wire electrodes. These electrodes are on the order of 50 microns in diameter, that is, about one eighth of the diameter of the 27-gauge needle electrode commonly used in needle EMG. These fine wires are inserted into

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the muscle of interest in a 25-gauge hypodermic needle that is then withdrawn, leaving the fine wire in place. Thicker wires apparently are not flexible enough to allow dynamic measurements to be made. Whether the SEMG button electrodes or the FWEMG wire is used, the EMG signal detected is then transmitted to an amplifier and recorder either by radio signal or by a hard-wire apparatus attached to the subject or patient. Recordings are made for the duration of some physical activity, for example, the gait cycle. Usually, simultaneous measurements and/or observations are made of the motions of the subject during the duration of the activity. The electromyographic activity of the muscle being studied can then be correlated to the time sequence of the particular motion or position of the subject. Generally, the activity of many muscles is recorded at the same time, so that at any given time during an activity, a picture of the significant accompanying muscle activity can be obtained.

The data generated by the SEMG and the FWEMG are not equivalent. The SEMG electrode samples a larger area of muscle, has a smaller band-pass centered around a lower frequency, is more subject to cross-talk from nearby muscles, is more reliable from day to day, 16,24 and is less disruptive to the gait pattern than the fine-wire counterpart. There is, however, some evidence that both techniques disrupt gait in some fashion.54 Other differences between SEMG and the FWEMG are that SEMG is sometimes more comfortable¹⁵ and more readily utilized by nonmedical personnel. Which electrode is chosen may be somewhat dependent on the reason that the study is being conducted, for example, large muscle groups distant from antagonists versus single muscles in the vicinity of dissimilar acting muscles. The literature suggests, however, that different laboratories favor 1 technique or the other. This would not be true of deeper muscles since they can only be measured by the fine-wire electrodes. For the purpose of this paper, the term dynamic EMG represents either SEMG or FWEMG; therefore, no differentiation between the 2 will be made.

The 2 types of dynamic measurement differ significantly from needle EMG which is utilized in the diagnosis of

lower motor neuron disorders or primary muscle disease. Dynamic EMG (SEMG or FWEMG) measurements are made during periods of significant muscle activity and no attempt is made to interpret individual motor unit size, shape, or duration of activity, although an envelope of activity of many units is often observed. Recruitment frequency, in general, is not observed in detail in dynamic EMG measurements. Spontaneous activity, a key element in the needle electromyographic diagnosis of neuromuscular disorders, is also not measured. Finewire techniques potentially may be able to observe recruitment frequency and spontaneous activity, although the upper band-pass cutoff, 1 kHz, may limit sensitivity. However, in the motion studies reviewed, none of the studies described these variables. SEMG measurements have far too low an upper limit of frequency cutoff, that is, 350 Hz, to effectively measure these variables. Neither of the dynamic EMG techniques can observe insertional activity, another variable important to needle electromyographic diagnosis.

BACKGROUND: DATA ANALYSIS

Different types of information are elicited for motion and gait studies from electromyographic measurements. Most commonly, the laboratory is interested in the presence or absence of the particular muscle's activity during a portion of the cycle. This leads to an understanding as to whether a particular muscle is firing at the appropriate time in the gait sequence, for example. Since studies of normal gait are available,32,37 the temporal firing pattern of the various muscles can be determined so that inappropriate firing of abnormal muscles can be identified. Surgical correction can then be prescribed with some assurance that the muscle being modified is indeed causing the deviation of gait away from normal. There seems to be fair agreement⁵⁰ that surgical intervention to tendons does not change the firing patterns of the muscle postoperatively but only the effect of the inappropriate firing in a mechanical sense.

Most gait studies where dynamic EMG has been useful are of patients with upper motor neuron lesions, such as cerebral palsy and cerebral vascular accidents. These patients have resulting spasticities so that ablation of a particular spastic muscle's mechanical effect can be beneficial. There is very little literature on the clinical use of dynamic EMG measurements with lower motor neuron lesions, primary muscle disease, or mechanical gait etiologies such as amputation, although gait kinematic measurements have been widely utilized with these problems and investigational studies have been conducted.

A second type of data utilization⁵² involves study of the dynamic EMG envelope shape as opposed to the simple on/off activity of the muscle. The shape is studied to see if a particular muscle is abnormal in the sense of time versus amplitude behavior during its burst of activity. There are only a few papers in the literature purporting to use this as a clinical measurement.

Lastly, there is a long history in SEMG literature ^{27,56} and dynamic EMG literature to relate some measure of EMG signal intensity to muscle effort. In isometric measurements some laboratories are successful in this measurement. The nonisometric conditions encountered in motion laboratories do not allow a quantitative relationship to be obtained. Some laboratories⁵³ try to relate the integrated amplitude of intensity of the muscle activity to the integrated amplitude of the muscle intensity of the same muscle in another part of the cycle or to the same muscle on the other side of the body. This requires some type of normalization process. There are several techniques by which this can be accomplished, with varying degrees of success.

Each of these applications has inherent difficulties.³⁶ There are legitimate differences of opinion on the criteria for the determination of onset of a muscle's electrical activity⁶ and the relationship of the electrical firing activity to the onset of the mechanical force exerted by the muscle. Based on this review, however, almost all laboratories utilizing dynamic EMG as part of gait and motion studies make use in some way of the off/on temporal pattern of muscle firing revealed by the dynamic EMG measurements. Far fewer laboratories appear to make use of the envelope of activity, and force measurements are not commonly reported.

This review found no single publication with a comparison of surgical results between when (a) the surgical procedure was chosen with the help of gait measurements incorporating dynamic EMG and (b) the procedure was chosen based on clinical examination alone. In that sense, dynamic EMG has not been evaluated, let alone established as a proven benefit in surgical preoperative or postoperative evaluations. Numerous publications, however, have attested to the usefulness of dynamic EMG in surgical decision making.5,46 No literature was found in this review denigrating its use. It is impossible to state a use rate for this technique for clinicians but at many major centers, it appears to be available. To what degree the data generated are utilized in surgical decisions, however, was also not determinate from the present review.

CONCLUSIONS

The following observations reflect current practice:

- 1. Dynamic EMG capabilities, utilizing either finewire electrodes or surface electrodes, are available in a significant number of major laboratories.
- 2. The percentage of motion laboratories that conduct measurements of dynamic EMG during kinematic studies is not known from the review.
- 3. In those laboratories where dynamic EMG is utilized, the percentage of patients measured and their selection criteria is not readily evident. In those laboratories publishing in the gait literature, all patients seem to be investigated but many laboratories are not represented in the literature.
- 4. The extent of the utilization of data generated and the percentage of cases where clinical decisions without the dynamic EMG would have been different is not clear from the literature.
- 5. In numerous laboratories, 4,7,8,18-23,25,34,35,44,47,55 preoperative motion studies are performed on patients who are candidates for corrective orthopaedic procedures. Many of these laboratories incorporated dynamic EMG into their studies. The literature suggests that candidates for corrective orthopaedic procedures form a subgroup of the total number of patients undergoing gait analysis. This particular subgroup is best defined as those patients with upper motor neuron lesions, cerebral palsy, cerebral vascular accidents, traumatic brain injury, or spinal cord injury with accompanying spasticity of the musculature. Generally, the surgery contemplated is orthopaedic in nature. There is some indication that the techniques are also utilized after rhizotomy procedures.4
- 6. From the literature alone, one can conclude that dynamic EMG is a legitimate clinical tool for evaluating patients with certain known diagnoses. It is no longer simply an investigational tool; however, its utility in preoperative planning has not been proven in well-designed, large, multicenter studies.
- 7. There remains many legitimate differences of opinion as to the relative benefits of surface versus fine-wire techniques that future studies will need to resolve. Also in doubt is the best way of determining onset of electrical activity and other

- technical variables. That problem, however, apparently has not stopped laboratories from utilizing this information in clinical decision making.
- 8. Not a single paper reviewed from the gait literature suggested that dynamic EMG is used for diagnosis. In all cases where the results were reviewed for preoperative planning, the techniques were used for extension of clinical evaluations of patients with known diagnoses. This represents a major departure from the use of needle EMG which is used primarily for diagnostic evaluations. There perhaps is some overlap of function between dynamic EMG and needle EMG in the area of prognosis, although future studies will be needed to clarify this overlap.
- 9. Dynamic EMG, as part of comprehensive motion analysis, has found applications in the optimization of athletic performance. The subjects in these studies are not patients in the classic sense and did not necessarily carry any type of medical diagnosis. This literature was not reviewed at this time.

There is also a growing literature^{1-3,9-14,17,26,28-31,33,38-} 43,45,48,49,51 related to dynamic EMG's investigational use in athletic injuries. The review suggested that this type of application of dynamic EMG was in an earlier stage of development than the application to central nervous systems conditions and will require additional validation. It may be that this type of utilization will parallel the early amputee work and lead to a better understanding of athletic kinematics and kinetics that has clinical utility without its becoming particularly useful in individual clinical measurements of specific injuries. Since there is a readily imagined relationship between optimization of athletic performance in athletic tasks and the measurement of functional capacity of a worker in a vocational task, there undoubtedly will be an attempt to utilize gait laboratories in this type of application in the future. Most laboratories, however, are not engaged in this type of activity at the present time and its application would be investigational in nature until well-established literature supports its use. The early literature in this area suggests that, if this eventually becomes useful in functional planning, a higher level of laboratory/equipment sophistication with Fourier transform capabilities will be necessary. Currently, this equipment does not appear to be readily available.

DISCLAIMER

This report is provided as an educational service of the AAEM. It is based on an assessment of the current scientific and clinical information. It is not intended to include all possible methods of care of a particular clinical problem, or all legitimate criteria for choosing to use a specific procedure. Neither is it intended to exclude any reasonable alternative methodologies. It addresses the use of dynamic EMG in one area only and its application, if any, to the practice of electrodiagnostic medicine. This statement is not intended to address all possible uses of, or issues regarding, dynamic EMG and in no way reflects upon the usefulness of dynamic EMG in those areas not addressed. The AAEM recognizes that specific patient care decisions are the prerogative of the patient and his/her physician and are based on all of the circumstances involved. This review was not written with the intent that it be used as a basis for reimbursement decisions.

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