A Recording System for Continuous Evoked Electromyography

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Two basic techniques in use for the study of neuromuscular events in the intact limb are the recording of evoked mechanical activity and the recording of the compound muscle action potential (EMG). The first has been widely employed, in part because of the apparent ease of stimulating a motor nerve and observing the muscle response or recording it by kymograph or strain-gauge and polygraph.

The observation of the evoked EMG with modern preamplifiers and memory oscilloscopes is likewise simple, but recording it is not. A frequency bandpass of at least 10 to 1,000 Hz is necessary. Traditionally, this has meant a photographic recording medium, either oscilloscope camera in one of several forms or an oscillograph mirror galvanometer system. Both are subject to possibilities of loss of data in the photographic process, and (especially) high cost of recording material.[1] The latter is particularly vexing with the EMG when periods of continuous recording are necessary. Since the EMG lasts approximately 20 milliseconds from stimulus, continuous study of each of a series of single twitches at 5-second intervals necessitates the waste of 99.6 per cent of the rapidly moving recording medium and produces great quantities of blank record to be handled and stored. The alternative of a triggered sweep recorded across slowly moving film (*i.e.*, perpendicular to film motion) may be employed, but is not suited to multichannel recording when other variables are simultaneously of interest. The recording of tetanic stimulus trains (at film speeds of 250 to 1,000 mm/sec to distinguish individual responses) is especially costly.

The study of neuromuscular changes for several hours after administration of blocking drugs necessitated development of a simple, straightforward way to record and display the EMG, free of the above-mentioned limitations. We found it feasible to use the time-base expansion available with magnetic tape recording to do so. By using an intermediate, reusable storage medium, the permanent display can be done on an ink-writing polygraph. Furthermore, it proved easy to discard the output retrieved during the vast majority of the quiet time between stimuli, thus packing the data onto the display medium for ease of analysis and storage. During data collection, the high-speed electrical events are monitored on a storage oscilloscope.

The basic system comprises three components. A clock-driven programmer was used to close two switches. At 5-second intervals these did the following: 1) switched on a 1-volt dc pulse; 2) approximately 50 milliseconds later, actuated a standard Grass S-8 stimulator; 3) approximately 150 milliseconds later, switched off the dc pulse. The pulse is thus on for approximately 4 per cent of the elapsed time, bracketing the stimulus.

The dc pulse is recorded on one channel of any high-quality FM instrumentation tape recorder, operating at 30 inches/sec. The EMG is recorded (after amplification) on a second channel, as are other events of interest, such as tension output, etc. The preamplifier (here, a Grass P-15) is used with a 0.1-Hz to 10-KHz setting (6 db points).

Unattended playback and ink recording on a polygraph take place at 1⅞ inches/sec, a time expansion of 1:16. The dc pulse is therefore present at the tape recorder output for approximately 3 seconds in every 80 (fig. 1). It is used as a command signal to start and stop the ink-writing recorder. Chart speed is 25 mm/sec, corresponding to 400 mm/sec in real time. The chart, however, is actually driven for only 4 per cent of the time, thus including only the critical period around the stimulus. (The Beckman Dynograph has been shown to come to full speed

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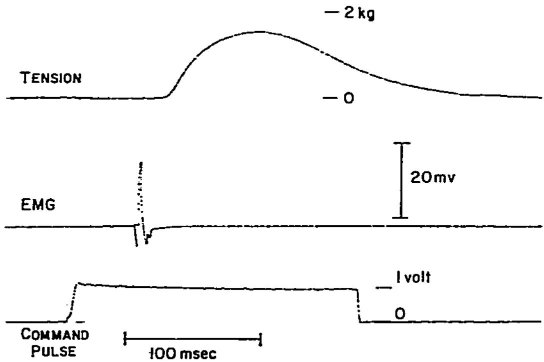

FIG. 1. Polygraph tracing of magnetic tape data, polygraph running continuously at 25 mm/sec, tape at 1/16 original speed. The command pulse when high, bottom channel, normally activates the polygraph for EMG playback. Real-time playback may be used to evaluate twitch height, for which wide band-pass recording is unnecessary.

in approximately 200 msec, well in advance of the stimulus.) Economy of recording material through packing of the data and the use of an inexpensive medium are thus achieved. Most important, the packed data are easily handled and analyzed, and long lengths of record do not need to be sifted.

A second mode of the control signal clock is used to display a tetanus. A long dc pulse, initiated by the same programmer switch but sustained by a relay closure, is used to span the duration of tetanus. The duration of the relay closure is in turn adjusted by controlling the time constant of an RC network which provides a latching current. The nerve stimulator is reset to give a 5-second train of stimuli. During playback, the dc pulse turns on the polygraph for a full 80-second time interval.

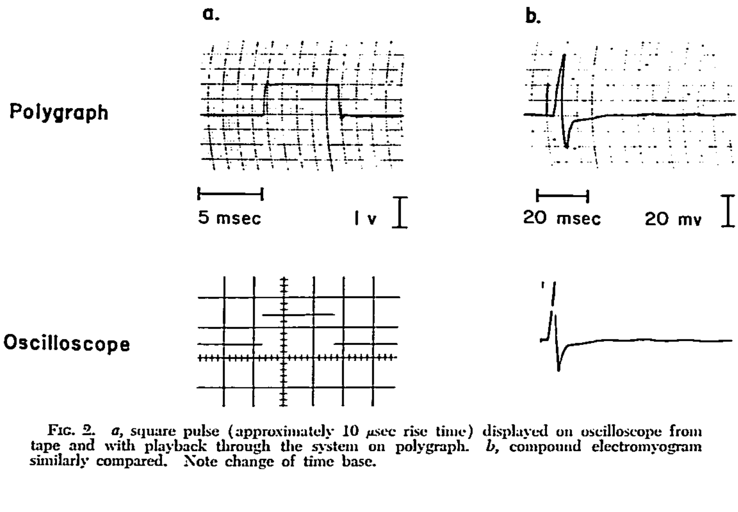

FIG. 2. *a*, square pulse (approximately 10 μsec rise time) displayed on oscilloscope from tape and with playback through the system on polygraph. *b*, compound electromyogram similarly compared. Note change of time base.

The 4-meter length of inked paper used to record each tetanus is relatively more permanent and vastly cheaper than an equivalent length of photographic medium.

The success of the technique is critically dependent on the ability of the multichannel direct writer to reproduce transients with sufficient fidelity. With the ordinary frequency response adjustments outlined in the manual, our Beckman-Offner Dynograph reproduced the form of a 1-cm-high square pulse introduced into the system (fig. 2*a*) with a real time rise to 90 per cent of value equivalent to less than 0.25 msec. The system band pass, including the P-15 preamplifier, was from 0.1 Hz to more than 2,500 Hz (6 db points) with the time expansion. The form of an EMG displayed from tape on a storage oscilloscope is compared with the system output in figure 2*b*.

In short, the system meets the criteria for faithful reproduction of these high-speed events, for ease of use, economy of material, and accessibility of large amounts of data. It comprises mostly laboratory instruments of general use and availability which need not be dedicated solely to this function. Therefore, the effective cost compares favorably with costs of other, less versatile, research equipment specifically committed to high-frequency recording. It has proved indispensable in following changes in the EMG under clinical conditions during periods of several hours following the administration of drugs.

Reference

1. Lee ASJ: Technical aspects of monitoring systems, Patient Monitoring. Amsterdam, Excerpta Medica Monograph ISBN 90 219 2026 3, 1970, pp 30–44

Accuracy of the Inspiratory Oxygen Tension with the Bennett MA-1 Ventilator

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Undesirable pulmonary complications characterized by atelectasis, pulmonary consolidation, and hyaline membrane formation are associated with prolonged mechanical ventilation with high inspired oxygen concentration.[1] Accordingly, the percentage of inspiratory oxygen from a ventilator should be easily and predictably adjustable over a range from air to 100 per cent oxygen. The Bennett MA-1 ventilator is ideally suited in this respect, as it has a direct dial.

This study was designed to test the accuracy of inspired oxygen concentrations delivered by the Bennett MA-1 ventilator.

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Method

Patients who needed prolonged mechanical ventilation and who were being ventilated with a Bennett MA-1 ventilator were selected for the study. The tidal volume and rate were approximately 15 ml/kg and 12/min, respectively, and P_{CO_2} was maintained slightly be-