SPASTICITY EVALUATION BY AMBULATORY EMG

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Abstract

Spasticity is a frequently encountered clinical problem in Physical Medicine and Rehabilitation. This paper details the initial methods and results of a technique for measuring spasticity by using surface EMG recordings for time periods of up to 24 hours. Complete spinal cord patients were used so that recorded spasticity would not be contaminated with voluntary motor activity. Spasticity was recorded using a Holter monitor as patients performed their usual daily activities. The raw data was then amplified,filtered, rectified, integrated, and then temporally compressed so that six hours of data could be displayed on a 14 cm. record.Virtually all spastic EMG activity was associated with some type of sensory stimuli such as transfers, wheelchair activity, stretching, catheterizations and bowel programs. Initial results indicate that this data can provide useful information about the variation of spasticity over time. The clinical usefulness of this new technique will require additional studies.

INTRODUCTION

Spasticity as demonstrated by hyperreflexia, mass motor contraction and/or clonus is a frequently encountered clinical problem of patients who suffer from upper motor neuron lesions. The clinician in physical medicine and rehabilitation relies upon subjective data derived from the history and physical exam to assess the need for therapeutic intervention in the management of spasticity. In the assessment of the degree of spasticity there is frequently a poor correlation between patient, the complaints and the physical findings, as well as between subjective measures of both intra- and inter- observers.

A number of devices which attempt to quantify spasticity [1,2,4,7,9,10,11,12,13,14,18,19] have been developed, most of which measure the muscle response to a standardized stimuli. These tests have generally been thime consuming and technically difficult to implement. In addition, tests which repeatably elicit spasticity such the pendulum test, temporally alter subsequent clinical and electromyographic responses and thereby limit the repeatability of such observations. Furthermore, these tests measure spasticity for short periods of time and do not measure spasticity over the course of hours of days.

In non-fatiguing muscles there is a consistent relationship between muscle activity and the rectified, integrated surface EMG[15] a fact that has had some clinical application. 6,20 Modern electronic and computer equipment have encouraged the development of EMG collection and analysis systems [3,5,6,8,16,17]

This report details the initial methods and results of a technique for measuring spasticity using surface EMG in complete spinal-cord injured patients as they perform their normal daily activities.

METHOD AND MATERIALS

EMG activity in complete spinal-cord injured patients was studied during periods of activity up to 24 hours. Surface EMG activity of the quadriceps muscle was recorded wotj sirface EPG gum electrodes[a] and stored on tape using a standard Holter cassette recorder[b].The slow tape speed of the recorder allowed for the storage of 24 hours of data on one side of a high-bias 60-minute audio cassette: as a consequence, however, the system frequency response was limited to 10-100 Hz. The amlifier gain was 300 and the common-mode rejection ratio was greater than 60 dB. The system allowed for two channel recording with time and event marking. The signal was replayed using a standard audio cassette player at a speed 48-times faster than the tape speed used during recording. The signal was then amplified, band pass filtered (75-10,000Hz), rectified and integrated over one-second intervals. The processed signal was then plotted using a thermal chart recorder with a paper speed of .5mm per second which results in a scale of one data-hour per 3.25 cm. Data can be temporally compressed or expanded by varying the chart speed (See Fig.1).

RESULTS

Initially, spinal-cord injured (SCI) patients were subjected to known stimuli, such as range of motion or pendulim testing to correlate expected responses with observed responses. Pendulum testing as previously demonstrated by Badj[2] showed a strong correlation between pendular motion of the leg and EMG activity of the monitored quadriceps muscles (see figure 2). However, significant changes were seen in the degree of EMG activity and in pendular motion due to identical stimuli presented over a 30-minute period. There was also significant EMG activity seen when the leg was lifted from the 90-degree position to the 0-degree position which the processed EMG - but not the pendulum tracing - demonstrates (see figure 2b).

The surface EMG was recorded in complete SCI patients over 24 hours period during these normal activites. Observed gross spastic motor activity was seen to correlate closely with recorded spastic EMG activity. Virtually all spastic EMG activity was found to be associated with some form of coinciding environmental stimuli. Stimuli which were seen to elicit spastic motor activity included positional changes stretching of hips or knees, transfers, catheterization, and bowel programs. Only minimal EMG activity has been seen during sleep. Variations in patient activity level and/or environmental stimuli were found to change the amount of spastic EMG activity recorded. Alternations in medication also resulted in modification in the recorded reflex EMG activity. The data presented in figures 4 shows six hours of a standard day for one patient attending therapies, undergoing catheterizations, and

performing other daily activities. There was association seen between various stimuli and recorded periods of spasticity. There were no adverse responses noted from the study. EOG electrodes were well tolerated. Subjects were not able to shower while being monitored.

DISCUSSION

The objective of this initial project has been to develop a reliable and accurate method for recording and displaying spasticity over thime in an active SCI patient. Future studies will determine if this will lead to improved methods of medica management. One of the more difficult aspects of measuring spasticity has been that of producing an uniform stimulus and measuring the response. The pendular tests developd by Badj[2] and tests developed by others have sought to guantitate spasticity over brief periods of time without monitoring the effects of everday stimuli. Our replication of these studies hows that spastic motor activity is variable over time even under controlled conditions. Because the clinical conswquences of spasticity are closely related to physical stimuli, it was felt that monitoring a patient over longer periods of time, such as 24 hour while the patient is engaging in normal activities would provide objective data representing functional spasticity levels.
Initial results indicated that objective measures of spasticity levels can be derived from this method. Spastic EMG activity can be effectively and accurately stored using magnetic tape in convenient cassette format. Although data can be directly printed using Holter processing and display techniques, this results in 24 page printouts which are not practical for comparisons of spastic EMG activity. In order to condense 24 hours of data into one page needs to be compressed. One-second integral periods were chosen in order to reduce the number of data points to a manageable number while not averaging excessively short motor contractions.

Motor contractions seen on Holter-type printouts correlate on a one-to-one basis with the integrated-EMG printouts. Good preservation of data has been demonstrated with printouts of one-hour periods displayed over 3.25 cm. Twenty-four-hour recordings perfomed on six patients have shown a good correlation of spastic EMG activity with clinically observed spasticity.

Using analog-to-digital conversion techniques, we have developed a computer-based system for the acquisition, analysis and display of 24 hours of EMG data. Various algorithms for analyzing and compressing the data are now under study. Manipulation and sisplay of this data can be enhanced through the ability to compress and expand time and amplitude, the use of various analysis algorithms, and the use of digital filtering techniques. This method of recording spasticity levels can be used to document the changes in spasticity seen with various medications and other techniques to control spasticity.

CONCLUSION

Spasticity has been monitored in complete spinal-cord injured patients using techniques of long-term monitoring, integrative pro-

cessing and data compression for display. Initial results indicate that this data can provide useful information about the variation of spasticity over periods of time up to 24 hours. Determination of the clinical usefulness of this technique will require additional studies.

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Directory of Suppliers

A. Surface Electrodes, Syn Cor Tracets Diagnostic ECG electrodes, 10405 Crosstown Circle, LecTec Corp; Eden Prarie, MN 55344

B. Ambulatory Cardiac Monitor, The Holter Performer, Model 8400, Applied Cardiac Systems, 1584 "A", Rockfield Boulevard, Irving, CA 92718

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ILLUSTRATIONS

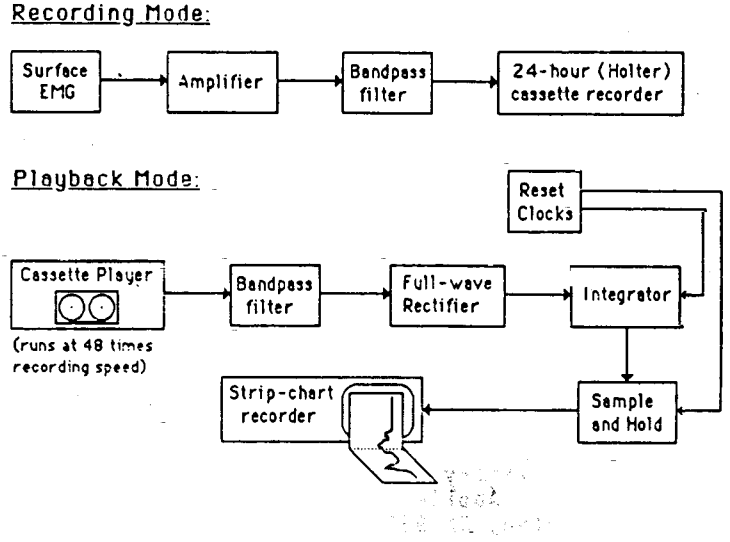

Fig 1: System design: The EMG signal was received using standard EOG surface electrodes and a standard Holter cassette recorder. The cassette tape data was played back using amplification, filtering, rectification, integration and displayed data standard chart recorder.

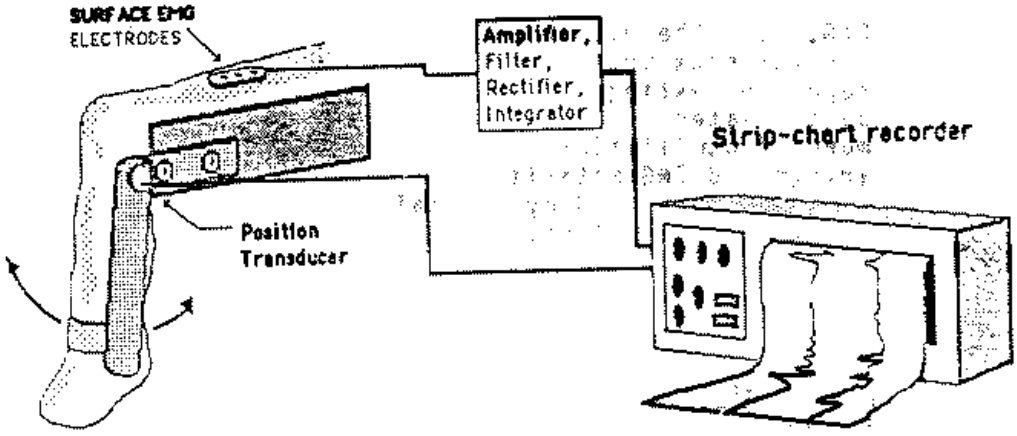

FIG.2: The pendulum test allows the extended leg to fall in flexion producing a stretch on **the quadriceps** which then contracts reflexively, **damping** the motion of the leg and producing an EMG **signal.**

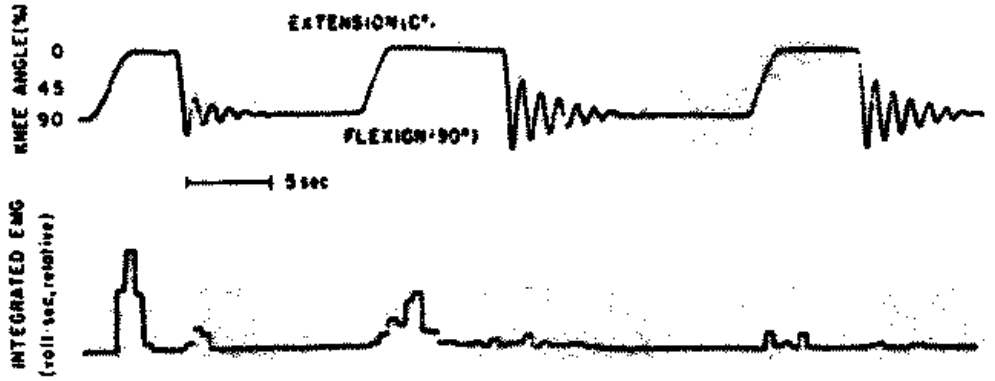

FIG. 3: The motion of the leg (fig. **3a) and the simultaneous EMG** (fig 3b) are plotted over **time. With repeated testing** the spasticity diminishes as avidenced by a greater amplitude of pendular swing, a greater **number** of oscillations, **and** a corresponding decrease **in integrated EMG activity.** The recorded EMG shows significant **activity provoked by initial** leg raising not demonstrated **by the pendulum test.**

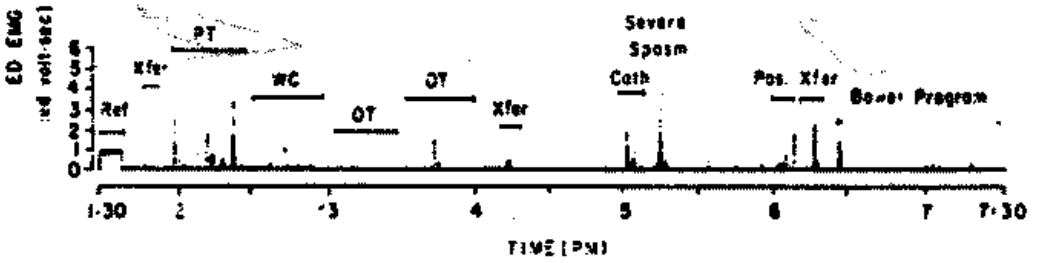

FIG.4: This is a six-hour segment of processed surface EC from a 24 hour recording from the **vastus medialis** muscle of a complete paraplegic. **Rer=reference signal; xfer= transfer to and from mat and wheelchair; wc=wheelchair activity;ot=occupational therapy; Cath=bladder catheterization;Pos=positionig patient in bed; quotations are patient comments.**