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Uncoordinated Muscular Response to Microsecond Electrical Pulses Is a Manifestation of Simultaneous Multiple Spinal Reflexes

F. Despa [1], S. Basati [1], X. Tang [1] and R. C. Lee [1]

1 Introduction

The objective is to determine the biomechanism of the spastic muscular activity in response to electrical stimuli often used by police. The spastic muscular activity is defined as a tetanic muscle response in all extremities which can be assessed by measuring the amplitude of the compound muscle action potential (CMAP). Our hypothesis is that this effect represents the manifestation of multiple spinal reflexes.

2 Materials and Methods

Spinal reflexes are graded behaviors that can result from stimulation of either pain fibers in the skin or sensory afferents in muscle tissues. The strength of the stimulus determines the amplitude of the response. A cumulative effect in the spinal neural circuitry determines the onset of a complex reflex response that produces a whole body muscle activity. We used an anesthetized swine model, using standard testing procedures, to show that, by stimulating locally a mixture of both sensory and motor nerves with electric pulses of certain characteristics, one can induce a temporary muscular incapacitation. Then, we show that this effect can be blocked by interrupting the transmission of the sensory stimuli from receptors to the spinal cord.

In the first set of experiments, individual major nerves (femoral, saphenous and ulnar) were surgically dissected and isolated with electrically insulating sheets. A sequence of electric field pulses was applied directly to the isolated nerves. CMAPs were monitored with an electromyographic (EMG) recorder (Dantec® Counterpoint) over extensor muscles in all extremities using adhesive gel surface electrodes. In the second set of experiments, we used similar electrical pulses to stimulate the chest area through electrodes inserted under the skin. The EMG activity has been recorded, again, in all swine's extremities. We measured the effect of various amplitudes, pulse durations, waveforms and frequencies of the electrical stimulus on the CMAP amplitudes to determine the dose-response functionality. Based on the different stimuli-response data, an optimum signal waveform was selected which was used to demonstrate that multiple spinal reflexes can be shaped to produce a spastic muscular activity. At some point ~10 cc of 2% lidocaine hydrochloride (4 mg/kg) was injected intramuscularly, beneath the placement of the electrode, to monitor if this blocks the EMI effect.

3 Results

We have found that a simultaneous, direct stimulation of saphenous and femoral nerves with monophasic electric pulses can produce spinal cord reflexes that yield CMAP amplitudes in all extremities (**Fig. 1**). EMG activity in all extremities was also detected during stimulations of the ulnar nerve (a mixed motor and sensory nerve) and nerves in the chest area. However, the CMAP amplitudes recorded for these stimulations are about one order of magnitude lower (not shown). Within the present experimental setup, we observed no substantial alteration of the response by changing from a monophasic pulse stimulation to a biphasic one. The CMAP amplitude does not change with the frequency. Not surprisingly, the reflex onset after stimulation onset decreases with frequency. The injection of the lidocaine in the area surrounding the stimulation site completely removed the CMAP activity (**Fig. 2**).

[1]Institute for Regenerative Medicine, Department of Surgery, MC 6035, The University of Chicago, Chicago, IL 60637

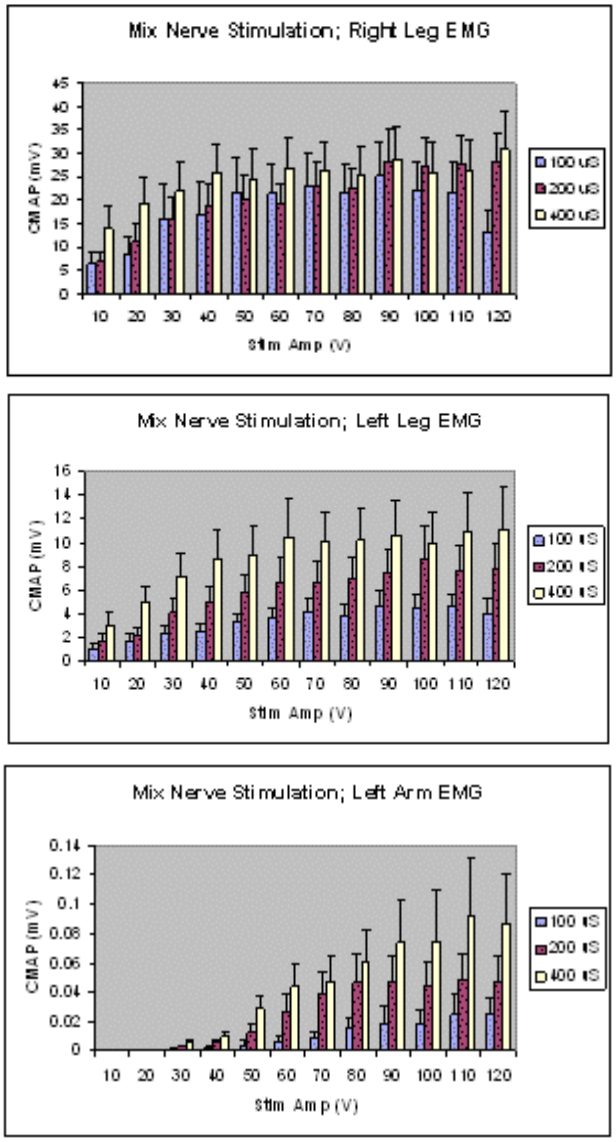

Figure 1 : EMG activity recorded in three extremities of the swine during stimulation in the fourth.

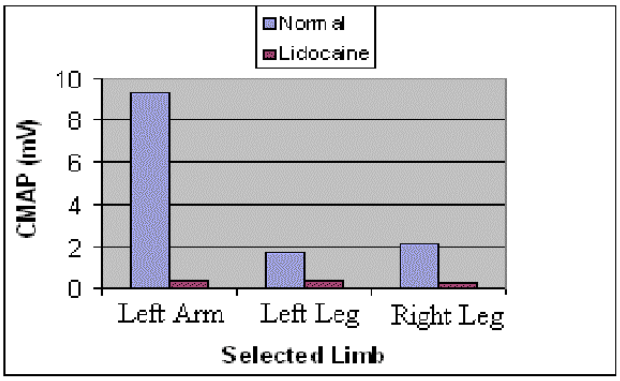

Figure 2 : The effect of lidocaine injected beneath the electrodes.

4 Conclusion

A spastic muscular activity requires a stimulation of both sensory and motor nerves, simultaneously, with electrical stimuli of certain characteristics. This effect can be blocked by interrupting the transmission of the sensory stimuli from receptors in muscles, joints and skin to the neural circuitry responsible for the motor response, which is entirely contained within the spinal cord.

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