

Field Distribution of Compound Muscle Action Potentials of the Calf Muscles in Rabbits

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ABSTRACT

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The purpose of this study is to verify that compound muscle action potentials (CMAPs) generated a stationary potential and to examine extension of the CMAPs away from the stimulated muscle. A referential derivation and/or bipolar derivation to record the stationary potentials were carried out following tibial nerve stimulation at the popliteal fossa in 10 rabbits. After recording a bipolar and/or referential derivation, wave changes were monitored before and after severing the tibial nerve. The change of the wave by compressing or direct electrical stimulation to the calf muscle was also monitored. In referential derivatives, the stationary waves were observed on top of the skull in all the rabbits examined with the peak latency of the potentials from 3.78 msec to 5.04 msec. In bipolar derivations, the upper limits of the stationary waves recorded were the trunks. The peak latencies were from 2.35 msec to 5.46 msec with an average of 4.12 msec. By analyzing the results from severing the tibial nerves, compressing the calf muscles, and direct electrical stimulation of the calf muscle, the origin of these stationary potentials was determined to be CMAPs of the calf muscles. These findings suggest contamination of the stationary potentials originated by CMAPs for recording of any evoked potentials when motor nerves are stimulated.

INTRODUCTION

Human spinal evoked potentials were first recorded by Magladery et al. from electrodes in the subarachnoid space after posterior tibial nerve stimulation in 1951 (1).

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Others recorded spinal evoked potentials with epidural (2) or surface electrodes (3). The authors recorded evoked potentials from the sciatic nerve and lumbar nerve roots following tibial nerve stimulation in rabbits. The evoked potentials obtained consisted of two components. The first component, observed in all, was found to be the ascending impulse to the spinal cord. The second component was considered to be of two origins. One was recorded at the weak stimulation and considered to be the impulse descending from the spinal cord. The other, recorded at strong stimulation, was a stationary potential regardless of the recording sites along the sciatic nerve. By severing the sciatic nerve distal to the stimulation site, this stationary potential disappeared. Therefore we concluded this wave originated from compound muscle action potentials (CMAPs) of the calf muscles (4). The purpose of this study was to verify that compound muscle action potentials generate a stationary potential and to examine extension of the CMAPs away from the stimulated muscle.

MATERIALS AND METHODS

Ten rabbits were studied according to requirements of the ethics committee of Tohoku University. The subject was fixed prone on the operating table after tiopental intravenous anesthesia. A 10 cm longitudinal skin incision was made in the popliteal region. The skin and subcutaneous tissues were reflected to expose the sciatic nerve, the tibial nerve and the gastrocnemius. The common peroneal nerve was compressed and severed with a hemostat at a point 0.5 cm distal to its bifurcation from the sciatic nerve in order to prevent contamination of the peroneal nerve innervated muscle's CMAPs. The tibial nerve was electrically stimulated at the popliteal fossa with needle electrodes touching the nerve. The cathode was located 1.5 cm proximal to the anode. The stimulus was 0.1 msec in duration. The intensity was adjusted so as to induce a twitch of the ankle. For recording stationary potentials originating from the calf muscle's CMAPs, multiple electrodes were placed in 5 cm increments along the ipsilateral sciatic nerve, the spinous process and the head (Fig. 1). The '0' level represented the intersection of a line drawn through the top of the bilateral iliac crests and a line drawn through spinous process with the other recording sites indicated by a number from the zero level, assigning a [+] sign proximally, and [-] sign distally. At each point, the skin was incised exposing the fascia. Surface electrodes were attached to the fascia with conductive jelly.

A referential derivation registered the input from each of the 9 or 10 active electrodes, depending on the size of the rabbits, [-2] through [+6] or [+7] on top of the head as G1 of each channel with G2 on the tip of the contralateral ear. A bipolar derivation was carried out connecting two adjacent leads with G1 distal to G2, i.e., [-2] to [-1] through [+6] to [+7]. Each test consisted of an average of 10 to 600 summated responses with a frequency response of 10 Hz-3 kHz.

Calf muscle CMAPs were simultaneously monitored over the ipsilateral calf muscle with flat-surfaced electrodes soaked with conductive jelly to keep the impedance less than 5 k Ω . The cathode and anode were placed over the calf muscle

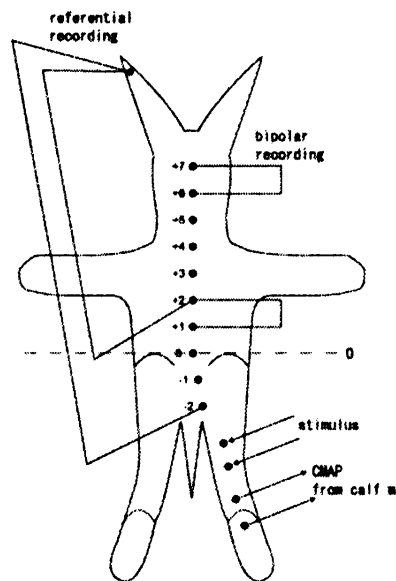


Fig. 1. Recording method. The tibial nerve was stimulated at the popliteal fossa. Multiple electrodes were placed in 5 cm increments along the ipsilateral sciatic nerve, the spinous process and the head. The '0' represented the level of a line drawn through the top of the bilateral iliac crests and with the other recording sites indicated by a number from the zero level, assigning a [+] sign proximally and [-] sign distally. A referential derivation registered the input from each of the 11 active electrodes, [-2] through [+6] or [+7] on top the skull, depending on the size of the rabbits, as G1 of each channel with G2 on the tip of the contralateral ear. A bipolar derivation was carried out connecting two adjacent leads with G1 distal to G2, i.e., [-2] to [-1] through [+5] to [+6] or [+6] to [+7], depending the size of the rabbits.

and the heel respectively. A flat-surfaced ground electrode was placed on the muscle between the stimulating and recording electrodes.

After recording a bipolar and/or referential derivation, the changes of the wave were monitored before and after severing the tibial nerve proximal to the stimulating point followed by severing the nerve distal to the stimulating point.

The change of the wave when the calf muscle was compressed with forceps was monitored in two rabbits while recording the derivations.

In one rabbit, the calf muscle was electrically stimulated with needle electrodes inserted into the muscle. And a referential derivation registered the input from the active electrode '+7' with calf muscle CMAPs monitored over the ipsilateral calf muscle in the same manner. A Cadwell 5200A was used for stimulation and data production.

RESULTS

Referential derivation was carried out in nine rabbits out of ten. In referential derivatives, the stationary potentials could be observed at any recording site in all the

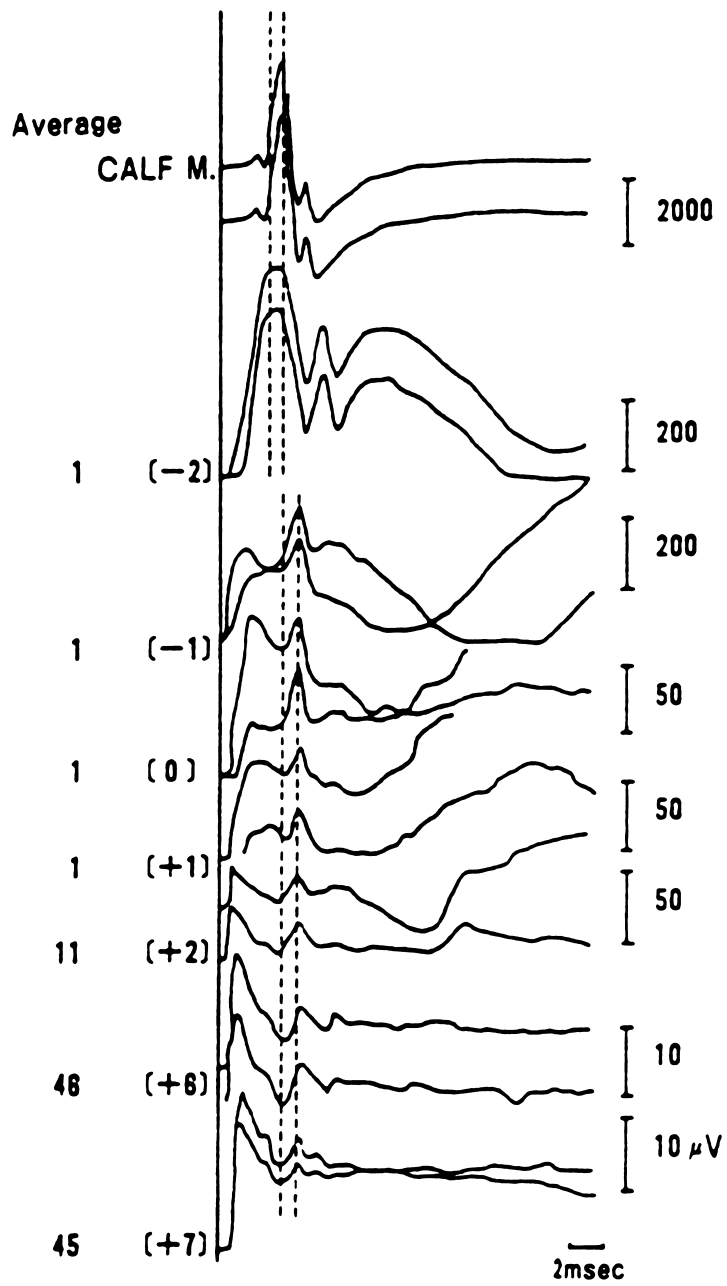


Fig. 2A. Referential derivation (rabbit $\text{\textcircled{Z}}$). The stationary wave with the peak latency of 3.78 msec was observed from [-1] through [+7]. The amplitude of the wave gradually decreased as it went distally.

Table 1. Upper limits of recording the stationary potentials by referential and bipolar derivations.

Rabbit no.	Recording site	Recording	Upper recording limit	Peak latency (ms)	Recording	Upper recording limit	Peak latency (ms)
①	-2~+6	Referential	+6	4.02	Not performed		
②	-2~+7	Referential	+7	4.16	Not performed		
③	-2~+7	Referential	+7	4.50	Bipolar	+2	2.53
④	-2~+7	Not performed			Bipolar	+3	5.46
⑤	-2~+6	Referential	+6	5.04	Bipolar	+2	3.02
⑥	-2~+7	Referential	+7	4.19	Bipolar	+6	5.37
⑦	-2~+7	Referential	+7	3.78	Bipolar	+3	3.78
⑧	-2~+6	Referential	+6	4.36	Bipolar	+4	4.70
⑨	-1~+7	Referential	+7	4.11	Bipolar	+3	4.11
⑩	-2~+6	Referential	+6	4.53	Bipolar	+3	4.20
				4.32			4.12

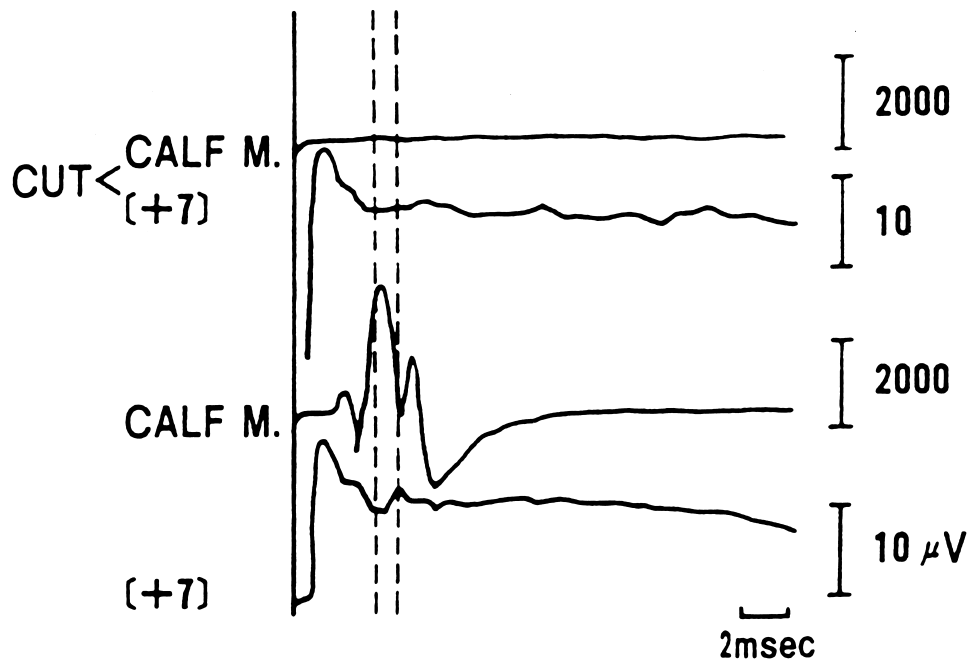


Fig.2B. The simultaneously recorded CMAPs of the calf muscles and the stationary potential at the recording site [+7] disappeared after severing the tibial nerve distal to the stimulating site.

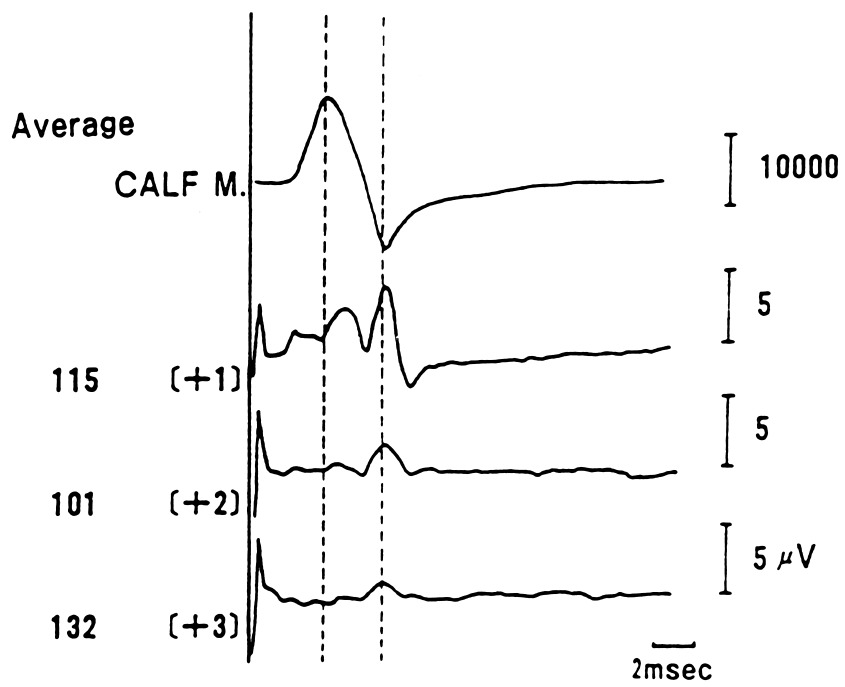


Fig. 3A. Bipolar derivation (rabbit ④). The stationary wave with the peak latency of 5.46 msec was observed through [+3].

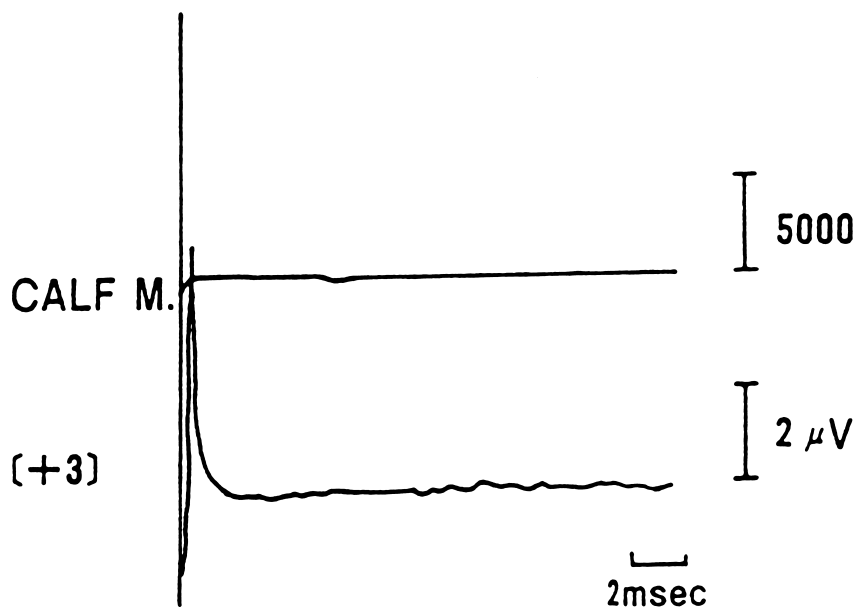


Fig. 3B. The simultaneously recorded CMAPs of the calf muscle and the stationary potential at the recording site [+3] disappeared after transection of the tibial nerve distal to the stimulating site.

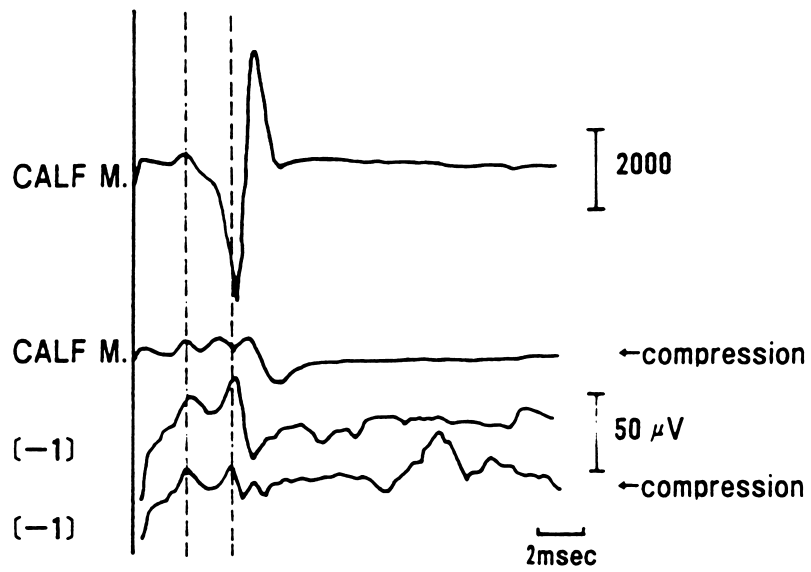


Fig. 4. The shapes of the stationary potential as well as of the CMAPs recorded over the calf muscle changed by compressing the calf muscle.

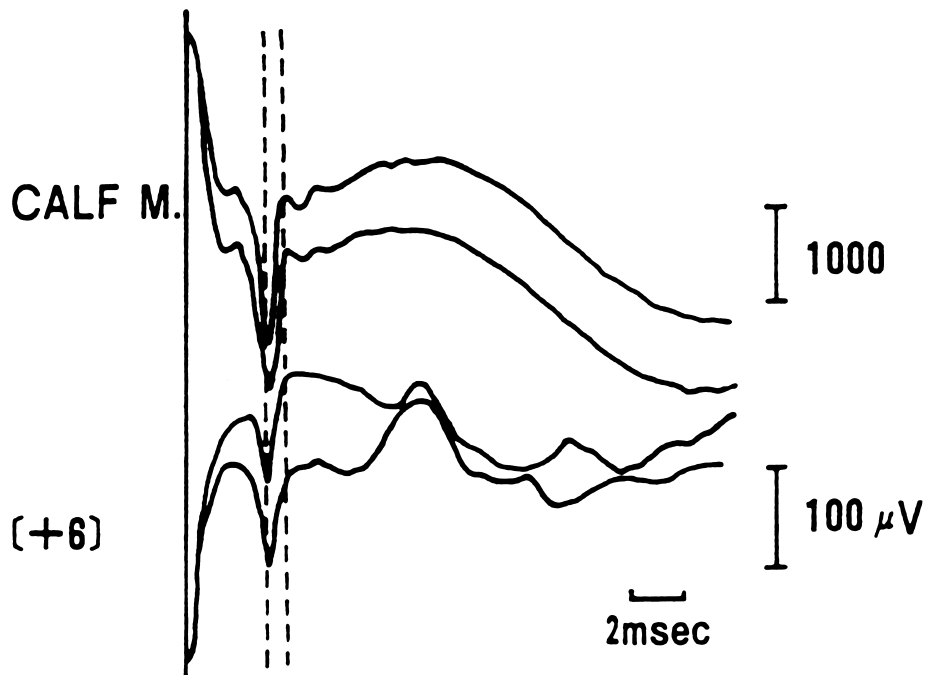


Fig. 5. In referential derivation, the stationary potential was observed at the skull by direct calf muscle electrical stimulation. This potential didn't change in shape or amplitude irrespective of transection of the tibial nerve.

rabbits. The potentials were obtained on the head ([+6] or [+7]) in all the subjects. The peak latency of the potential ranged from 3.78 msec to 5.04 msec with the average of 4.32 msec (Table 1). Bipolar derivation was carried out in eight out of ten rabbits. In bipolar derivations, the upper limits of observation of the stationary waves were from [+2] through [+6]. The peak latency ranged from 2.35 msec to 5.46 msec with the average of 4.12 msec (Table 1). The CMAPs of the calf muscles and the stationary potential at the recording site disappeared after severing the tibial nerve distal to the stimulating site while no change occurred by cutting the nerve proximal to stimulation (Figs. 2, 3).

The shapes of the stationary potential as well as of the CMAPs recorded over the calf muscle changed by compressing the calf muscle (Fig. 4).

In referential derivation, the stationary potential was observed at the skull by direct calf muscle electrical stimulation. This potential didn't change in shape and amplitude irrespective of severing the tibial nerve (Fig. 5).

DISCUSSION

In order to record evoked potentials, it is necessary to derive the electric physiology phenomenon generated in the sensory neuron in vivo with electrodes on the surface or inside the body. The living body organization, which lies between an electrode and electric source, is called volume conductor. Volume conduction can be spread from a potential source through a conducting medium, such as the body tissues. On the other hand, evoked potential with latency, which does not change even if the stimulation condition and the deriving condition are changed, is called a stationary potential. The stationary potentials are widely distributed in volume conductors, the shape of which is not changed even if the sites of electrodes are changed, and can be recorded far away from the source of potential and is named far field potential (5, 6, 7). The complex waveform of far-field potentials seems to result from a combination of different physiologic mechanisms that are uniquely dependent on the physical relationship between the nerve and volume conductor (8). There are varying opinions about the mechanisms of generation of far field potential. It occurs when an action potential transverses one of the following:

① a region where the shape of the volume conductor changes (9,10,11,12); ② a bent segment of an axon (13,14); ③ a region in a volume where the resistance changes suddenly (15).

The present experiment reveals that compound muscle action potentials far away from the ordinary recording spots can be recorded as stationary potentials which have the same peak latency through the volume conductor.

Deriving to the head was especially possible for referential derivation in all subjects. A latency difference between the CMAP and the stationary peak suggests that there is a time lag of occurrence of stationary potentials accumulated in the volume conductor. The study on the optimal position of recording electrodes for CMAPs

has been carried out (16, 17). However, there have been no reports that reproducible stationary waves originated from CMAPs can be recorded even away from the stimulated muscles. Neither has the description of the recording method of these stationary potentials. This research shows that it is possible to record CMAPs from a part far away from the source as far field potentials which have constant latency.

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