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Muscle afferent contributions to tibial nerve somatosensory evoked potentials investigated using knee stimulations

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Abstract

Objective: To investigate the contribution of muscle afferents to tibial nerve somatosensory evoked potentials (SEPs).
Methods: The left tibial nerve was stimulated at the knee and ankle in eight normal subjects. We tried to selectively stimulate Ia fibers from the calf muscles at the popliteal fossa by subtly changing the stimulation site while monitoring the H-waves of the calf muscles and sensory events.
Results: Selective or predominant Ia stimulation at the knee was achieved in seven subjects, and evoked a significantly smaller first cortical component (labeled as P38 for both ankle and knee stimulations) than that evoked by ankle stimulation or by mixed stimulation of the foot branch and muscle afferents at the knee. The P38 following mixed stimulation at the knee was smaller than that following ankle stimulation in six out of eight subjects, which must be due to a partial gating mechanism and also indicates that calf Ia afferent SEPs are not extremely large.
Conclusions: Physiologically important muscle afferents from the large calf muscles evoked rather small cortical components.
Significance: It seems reasonable to infer that the contribution of muscle afferents from the small intrinsic foot muscles to routine tibial nerve SEPs following ankle stimulation is even smaller.
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Keywords: Cutaneous afferents; H-wave; Muscle afferents; Somatosensory evoked potential; Tibial nerve

1. Introduction

It remains controversial as to whether tibial nerve somatosensory evoked potentials (SEPs) are generated by cutaneous or muscle afferents. Arguments from both sides have been presented, but no consensus has been reached (Burke et al., 1981, 1982; Jones et al., 1982; Kakigi and Jones, 1986; Macefield et al., 1989; Naka et al., 1998). In order to resolve this issue, we investigated tibial nerve SEPs when the stimulation site was minutely changed at the popliteal fossa. The calf muscle branches and the sensorimotor branch to the foot are separated at the knee (Sunderland, 1953; Urushidani, 1974). Therefore, the selective stimulation of each branch must provide clues regarding the origin of the tibial nerve SEPs.

2. Methods

The subjects consisted of eight healthy volunteers (four men and four women, aged 29–38) with no neurological abnormalities. We examined more than 10 additional subjects but selective or predominant Ia stimulating conditions (explained later) were not achieved for these subjects, and therefore we did not investigate them further. These

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subjects were not included within the present series. Informed consent was obtained from each subject. One to three Hertz square-wave pulses of 0.2–1.0 ms duration were delivered to each site using a surface-stimulating electrode. The stimulus frequency was adjusted considering the pain of the subject, but a constant frequency was employed throughout an experiment of a given subject. Evoked potentials were amplified and filtered between 5 and 1500 or 2000 Hz (−3 dB). A total of 200–800 responses were averaged and two or more averages were superimposed.

The left tibial nerve was stimulated at the ankle or at the knee (popliteal fossa), with the cathode being placed proximally. Cortical SEPs were recorded in the Cz′–Cc lead (Cz′: 2 cm posterior to Cz, Cc: contralateral central electrode in a 10–20 EEG electrode system), which we previously employed as the standard derivation to record cortical components in tibial nerve SEPs (Miura et al., 2003). We mainly evaluated the first positive cortical potential, labeled as P38 for both ankle and knee stimulations. In six out of eight subjects, electrodes were placed at four different locations (Fz, Ci: ipsilateral central electrode, Cc, Cz′) with the right earlobe as a reference (Ac), to investigate the scalp distribution of the cortical components.

Simultaneous to SEP recordings, we monitored surface-recorded compound muscle action potentials (CMAPs) of lateral and medial heads of the gastrocnemius (LGC and MGC), soleus (SOL) and abductor hallucis (AH) for knee stimulations, and only the AH for the ankle stimulation. The H-waves of the calf muscles were used as a sign that indicated the activation of muscle afferents from these muscles. We also monitored sensory events evoked by the stimulus by asking the subject about the region of skin over which he or she felt radiating sensations, and recorded the threshold at which the sensations began. We considered the M-wave of the AH and radiating sensations to the sole or toes as a sign indicating activation of the sensorimotor branch to the foot.

For knee stimulations, we tried to stimulate muscle afferents from the calf muscles or the sensorimotor branch to the foot as separately as possible. The stimulating electrode was firmly fixed at each explored site, and the threshold intensities for the radiating sensation to each skin area, H-waves, and M-waves were determined at each stimulus site. Then, the stimulus intensity was increased in a stepwise fashion, and the SEPs were recorded together with CMAPs.

When we managed to evoke H-waves of calf muscles without any sensory events radiating distally or the AH CMAP, we judged that we had successfully stimulated muscle afferents from the calf muscles selectively and labeled this condition as "selective Ia stimulation" at the knee. In other situations, the stimulus evoked H-waves of calf muscles and slight radiating sensations to the skin over the calf area, but accompanied neither by the AH CMAP nor radiating sensations to the sole, toes or the sural nerve area. We labeled this condition as "predominant Ia stimulation". As explained later, the selective stimulation of the sensorimotor branch to the foot was impossible for every subject.

When we were able to give the subject a strong stimulus that elicited sufficiently large M-waves from calf muscles and AH, and that was well over the threshold for radiating sensations to the sole and toes, we assumed that both calf muscle afferents and the sensorimotor foot branch were almost fully activated. We labeled this condition as a "mixed stimulation" at the knee. This stimulation mode was usually achieved where the threshold for the sensorimotor foot branch was the lowest in order to minimize the pain of stimulation, because this threshold was usually highest among those for several constituent branches of the tibial nerve at the knee.

For ankle stimulation, we looked for a stimulation site where both contraction of the intrinsic foot muscles and radiating sensations to the sole and toes were elicited at a low threshold. The stimulus intensity was then adjusted to exceed twice the threshold for the radiating sensations and 50% over the motor threshold (Miura et al., 2003).

We measured the onset-to-peak amplitude and the onset-to-peak interval of the P38 component, and compared each parameter between different stimulation modes using paired t tests. The amplitude parameter was evaluated after it was converted to a logarithmic scale.

In three subjects for whom selective or predominant Ia stimulations were achieved, we performed the following additional double stimulation experiment. First we measured the approximate onset latency of the action potentials evoked by the ankle stimulation recorded at the knee stimulation site (5–7 ms). Then we gave a selective or predominant Ia stimulation at the knee, delayed by the above interval after the ordinary ankle stimulation. Namely, we gave the stimulation approximately at the very timing when the nerve volley following ankle stimulation passed through the knee stimulation site. In this way, we added the selective or predominant Ia stimulation at the knee to the ankle stimulation, and simulated the mixed knee stimulation, except that the sensory branches from sural nerve area or other proximal skin areas (in selective Ia stimulation) were not activated. Burke et al. (1982) suggested that muscle afferents first arriving at the cortex suppress components evoked by the later-coming skin afferents. We expected that we could estimate this gating effect by the above-described double stimulation experiment.

3. Results

3.1. Achieved stimulus conditions

Selective Ia stimulations were achieved in four of eight subjects. Predominant Ia stimulations were achieved in three more subjects, and hence selective or predominant Ia stimulations were achieved in seven of the eight subjects. In the remaining one subject, only a mixed stimulation was recorded other than the ankle stimulation.

Selective stimulation of the sensorimotor branch to the foot was impossible in all of the subjects. The threshold of the M-wave of AH was always higher than that for

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