Clinical Neurophysiology 128 (2017) 1214–1219

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

A new technique for dorsal sural nerve conduction study with surface strip electrodes

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ARTICLE INFO

Article history:
Accepted 2 April 2017
Available online 19 April 2017

Keywords:
Anatomical variants
Dorsal sural nerve
Nerve conduction study
Sensory nerve action potential
Standard bipolar stimulator
Surface strip electrodes

HIGHLIGHTS

- Our method with surface strip electrodes (SSEs) yielded larger SNAP amplitudes in the dorsal sural nerve (DSN) than did the conventional method.
- All branches of the DSN could be stimulated at the same time by SSEs.
- SSEs enable DSN sensory nerve action potentials to be obtained easily even in elderly people.

ABSTRACT

Objective: To obtain higher amplitude of dorsal sural sensory nerve action potentials (SNAPs), we used a new method for dorsal sural nerve conduction study with surface strip electrodes (SSEs).
Methods: Dorsal sural SNAPs were recorded orthodromically. The recording electrodes were placed behind the lateral malleolus. SSEs were attached to the laterodorsal aspect of the foot for stimulation of the dorsal sural nerve (DSN). We also used a conventional method with a standard bipolar stimulator and compared the findings.
Results: Dorsal sural SNAPs were recordable bilaterally from 49 healthy volunteers. Mean peak-to-peak amplitude for SNAPs was 12.9 ± 6.3 μV, and mean nerve conduction velocity was 44.8 ± 5.5 m/s. The mean amplitude of SNAPs obtained by our method was 118.6% higher than that of SNAPs obtained by the conventional method (12.9 μV vs. 5.9 μV; $P < 0.001$).
Conclusions: The highest amplitude of dorsal sural SNAPs was constantly obtained by SSEs since SNAPs arising from whole digital branches of the DSN could be elicited by placement of SSEs.
Significance: When the DSN supplies more cutaneous branches to the lateral half of the foot, SSEs gives higher amplitude of dorsal sural SNAPs than that of the standard innervation type.

1. Introduction

For recording sensory nerve action potentials (SNAPs) of the sural nerve, surface recording electrodes are placed behind the lateral malleolus, and a bipolar stimulator is placed on the lateral posterior aspect of the mid-calf (Oh, 2003). This antidromic method was accepted as a standard method for sural nerve conduction study (NCS) and has been used routinely for diagnosis of length-dependent neuropathy (LDN), but its diagnostic value is limited due to its more proximal location above the ankle. In LDN, sural NCS may show normal findings by the method for a "proximal segment". Since the innervation of the feet is most commonly affected in LDN, a reliable sural NCS of a more distal location is needed for early detection. We therefore selected a method for a "distal segment" in this study.

The dorsal sural nerve (DSN) is the terminal branch of the sural nerve innervating the lateral dorsal aspect of the foot (Oh, 2003).

Abbreviations: CoV, coefficient of variation; IDCN, intermediate dorsal cutaneous nerve; LDN, length-dependent neuropathy; MDCN, medial dorsal cutaneous nerve; NCS, nerve conduction study; NCV, nerve conduction velocity; SD, standard deviation; SNAP, sensory nerve action potential; SSEs, surface strip electrodes.

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http://dx.doi.org/10.1016/j.clinph.2017.04.004
1388-2457/

Although dorsal sural NCS is suitable for detecting LDN due to its more distal location (Dias and Carneiro, 2000; Killian and Foreman, 2001), the small amplitude evoked response has limited the routine use of dorsal sural NCS. According to previous reports, the SNAP amplitude of the DSN was 50–73% lower than that of the sural nerve by the method for a "proximal segment" (Dias and Carneiro, 2000; Killian and Foreman, 2001; Balci et al., 2005), and to make matters worse, dorsal sural SNAPs were frequently absent even in healthy subjects (Burke et al., 1974; Killian and Foreman, 2001). Oh et al. (2001) established an orthodromic method for dorsal sural NCS and reported that the mean peak-to-peak amplitude for SNAPs was 7.26 ± 6.2 μV. In Oh's method, a bipolar stimulator was placed on the laterodorsal aspect of the foot for stimulation of the DSN. We hypothesized that the standard bipolar stimulator might have stimulated only a part of the cutaneous branches of the DSN, thus causing the small SNAP amplitude.

To solve the problem, a comprehensive knowledge of the anatomical variations of the DSN is very important. The medial dorsal cutaneous nerve (MDCN) and the intermediate dorsal cutaneous nerve (IDCN) are distal branches of the superficial fibular sensory nerve. Our previous study showed that variant innervations were more frequent in the IDCN than in the MDCN due to the anatomical relationship of the IDCN with the DSN (Hemmi et al., 2017). In 93.5% of the feet, the IDCN was partially or totally absent and its place was taken by the DSN. A cadaveric dissection study showed that the IDCN was absent or did not innervate any toe in 35% of cases and that the DSN supplied cutaneous branches to the lateral half of the foot and toes instead of the IDCN in 40% of cases (Solomon et al., 2001). Similar results were also reported by Kosinski (1926). According to his report, there were 12 patterns of termination of the dorsal nerves of the foot and the IDCN was totally absent in 25.3% of cases.

Due to the anomalous innervation of the DSN to the IDCN territory, it is thought that a far-reaching strip electrode is needed for obtaining higher dorsal sural SNAP amplitude. Therefore, in this study, we examined the usefulness of dorsal sural NCS with surface strip electrodes (SSEs), which are usually used as disposable digital ring electrodes. We also conducted conventional dorsal sural NCS using the standard bipolar stimulator method established by Oh et al. (2001) on the same nerves and compared the findings.

2. Methods

2.1. Subjects

The study subjects were 49 healthy volunteers. Individuals with a previous history of lumbar laminectomy, foot trauma, peripheral neuropathy, diabetes mellitus, or alcoholism were excluded. All subjects signed an informed consent form prior to evaluation. The Ethics Committee of Kawasaki Medical School and Hospital approved this study.

2.2. New technique, dorsal sural NCS with SSEs

All NCSs were performed bilaterally with an electromyography machine (Neuropack MEB-2216; Nihon Kohden, Tokyo, Japan). The bandpass filter was set at 20 Hz–2 kHz. Subjects lay in a lateral decubitus position with a relaxed foot position. Skin temperature was measured at the plantar surface and was maintained at ≥32 °C. The skin of the feet was cleaned with alcohol to decrease impedance.

Dorsal sural SNAPs were recorded orthodromically (Fig. 1). Ag-AgCl cup electrodes were used for recording. The active recording electrode was placed at the ankle just behind the lateral malleolus, and the reference recording electrode was placed 3 cm proximal to it. For stimulation of the DSN, we used disposable ring electrodes (disposable pre-gelled, Ag-AgCl ring electrodes, contact area of 8 mm × 95 mm, Natus Neurology, USA) as SSEs. Since the SSEs were a little long, they were truncated to 65 mm before use. We attached the SSE as the stimulating cathode on the lateral dorsal aspect of the foot 10 cm distal to the active recording electrode. The stimulating anode was placed parallel to the stimulating cathode. A ground electrode was placed over the dorsum of the foot between the stimulating and recording electrodes. Stimuli were rectangular electrical pulses of 0.1 ms in duration delivered at 1 Hz. Supramaximal stimulation was assured by increasing the stimulus intensity by 25–30% beyond the intensity at which a SNAP increased continuously up to the maximum. The SNAPs were averaged at least 20 times until no further change in amplitude, latency, and duration occurred. To assure reproducibility, at least 2 recordings for each SNAP were made. When the conduction parameters were completely matched, the SNAPs were chosen for analysis.

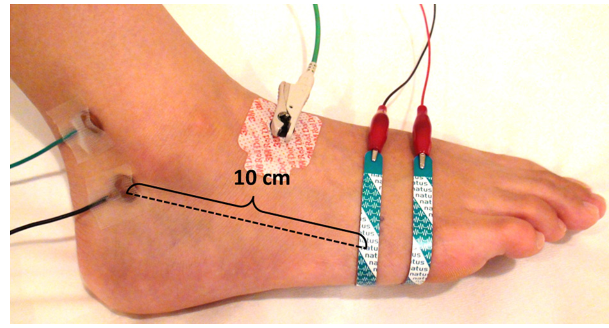

Fig. 1. Technique for dorsal sural NCS with SSEs.

Conduction parameters, including onset latency, peak latency, peak-to-peak amplitude, maximum nerve conduction velocity (NCV), negative peak NCV, duration of SNAPs, and side-to-side difference in amplitude, were measured. The conduction parameters from the left and right sides were combined for analysis. Because of the significantly skewed distribution of conduction parameters, the means and standard deviations (SD) of log-transformed data were calculated and then converted back to original units to be used as limits of normal values (Robinson et al., 1991). The value of SNAP amplitude and NCV corresponding to the mean minus 2 SD was considered to be the lower limit of normal, and the latency and SNAP durations corresponding to the mean plus 2 SD were considered to be the upper limit of normal.

2.3. Conventional technique, dorsal sural NCS with a standard bipolar stimulator

We performed conventional dorsal sural NCS on the same nerves (Oh et al., 2001). Dorsal sural SNAPs were recorded orthodromically with surface electrodes. The active recording electrode was placed at the ankle just behind the lateral malleolus, and the reference recording electrode was placed 3 cm proximal to the active recording electrode. For stimulation of the dorsal sural nerve, the conventional bipolar stimulator was placed on the lateral dorsal aspect of the foot 10 cm distal to the active recording electrode.

2.4. Statistical analysis

Statistical analysis using the Wilcoxon signed rank test was carried out to compare values obtained by the different methods (dorsal sural NCS with SSEs vs. dorsal sural NCS with a standard bipolar