SURAL NERVE CONDUCTION STUDIES USING ULTRASOUND-GUIDED NEEDLE POSITIONING: INFLUENCE OF AGE AND RECORDING LOCATION

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Sural NCS using USNP

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ABSTRACT

Introduction: The aim of this study was to compare orthodromic sural nerve conduction study (NCS) results using ultrasound-guided needle positioning (USNP) to surface electrode recordings.

Methods: 51 healthy subjects aged 24 – 80 years, divided into 5 age groups, were examined. Electrical stimuli were applied behind the lateral malleolus. Sensory nerve action potentials (SNAPs) were recorded 8 and 15 cm proximally with surface and needle electrodes.

Results: Mean SNAP amplitudes in μV (surface / needle electrodes) averaged 12.7 (SD 7.6) / 40.6 (SD 20.8), $P<0.001$, for subjects aged 20-29 years, and 5.0 (SD 2.4) / 19.8 (SD 9.8), $P<0.01$, for subjects aged > 60 years. SNAP amplitudes were smaller at the proximal recording location.

Discussion: NCS using USNP yield higher amplitude responses than surface electrodes in all age groups at all recording sites. SNAP amplitudes are smaller at proximal recording locations due to sural nerve branching.

Keywords: Sensory nerve conduction studies, sural nerve, ultrasound-guided needle positioning, normative data, healthy volunteers, nerve branching

INTRODUCTION

The pure sensory sural nerve is widely used for sensory nerve conduction studies (NCS). It is formed by the medial cutaneous sural nerve branch from the tibial nerve and the lateral cutaneous sural nerve branch from the common fibular nerve. Its distal part is well suited for NCS due to its location close beneath the skin surface in the dorsolateral aspect of the distal lower leg, embedded in a fat pad lateral to the Achilles tendon.

Orthodromic NCS of the sural nerve are easily performed using surface stimulation behind the lateral malleolus with recording 80 to 150 mm proximally using surface or needle electrodes.

In 2 previous studies, we demonstrated that ultrasound-guided needle positioning (USNP) yields higher sensory nerve action potential (SNAP) amplitudes in NCS of the sural nerve compared to “conventional” needle electrode placement without the use of ultrasound [1], and that NCS using USNP are as reproducible as NCS using surface electrodes [2]. However, for detection of nerve conduction disorders, the age-dependent variation of NCS results in healthy subjects should be known. The aim of this study was to analyze the age-dependent distribution of NCS results comparing surface electrodes and USNP and to analyze the influence of the location of the recording site with respect to the branching of the sural nerve into the medial and lateral cutaneous sural nerves.

MATERIALS AND METHODS

Subjects. Thirty-one healthy volunteers were enrolled in the study. They had no prior history of neuropathy, trauma, surgery on the investigated leg, inflammatory or metabolic diseases (especially no cardiovascular risk factors), or current medication use, as assessed by through a structured history with a study questionnaire. A physical examination was not performed. The study was approved by our local ethics committee, and written informed consent was obtained from all subjects prior to the study. Additional data from 20 healthy volunteers previously published [2] have been added to increase the number of healthy volunteers to 51 for the reporting of the normative data.

Neurographic recordings. For the neurographic recordings, a Viking Select EMG apparatus (Nicolet Biomedical, Madison, WI, USA) was used with bandpass filtering from 10 Hz to 10 kHz. For needle recordings, disposable sensory needle electrodes were used, which were insulated except for the tip (recording electrode: Medtronic, Denmark, REF 9013R0223 30 x 0.7 mm, 22 G, recording area 5.0 mm2; reference electrode: Medtronic, Denmark, REF 9013R0213, 15 x 0.7 mm, 22 G, recording area 8.0 mm2). For surface recordings, paired disc surface electrodes (Medtronic, Denmark, REF 9013S0401, HUSH DiscTM electrodes, 10 mm diameter) with electrode gel were used.

Ultrasound imaging. For ultrasound imaging, a Philips iU22 ultrasound system was used, with a L17-5 high resolution linear array 17 MHz transducer (Philips Ultrasound, Bothwell, WA, USA). The sural nerve and needle electrode were visualized at the level of needle insertion, and the distance between the tip of the needle and the center of the nerve was measured (termed nerve–needle distance, in mm).

Protocol. Orthodromic NCS were performed while subjects lay prone in a comfortable position with the investigated left leg resting on a cushion to allow a relaxed foot position. The skin surface was kept above 34°C using foot baths prior to examination and overhead heating devices.
The sural nerve of the left leg was stimulated along its anatomical course between the lateral malleolus and the Achilles tendon. Paired fixed surface electrodes (cathode-anode distance 20 mm) were used to apply a rectangular pulse of 0.2 ms duration, and the stimulation intensity was adjusted to yield maximal responses. A ground electrode was placed between the stimulating and recording electrodes.
Nerve conduction studies were performed first with 2 pairs of surface electrodes, then 2 pairs of needle electrodes. The first recording surface electrode was placed 8 cm proximal to the stimulation site, slightly lateral to the Achilles tendon, the second another 7 cm further proximal. Both recording surface electrodes were positioned along the anatomical course of the sural nerve. Both reference surface electrodes were placed 3 cm medial to the recording electrodes at the

same distance along the proximal-distal axis. The recording electrode position was optimized by moving the electrode slightly to the medial and lateral sides of the anatomical course of the sural nerve until maximum SNAP amplitude was achieved. The EMG apparatus allowed for simultaneous recording of both electrode pairs. The first NCS was performed, and the SNAPs were averaged until no change in amplitude, area, latency, and configuration of the SNAP was noticed. Surface electrodes were then removed. The recording needle electrodes were inserted at the locations of the recording surface electrodes. The tips of the needles were placed as closely as possible to the sural nerve, using USNP. The reference needle electrodes were placed approximately 3 cm medial to the reference electrode [1]. The second NCS was then performed the same way as with the surface recordings.

Statistical analysis. According to the Lilliefors test, some of the data were not distributed normally. Therefore, the Wilcoxon signed rank test was used to test the differences between the means of the dependent groups (needle versus surface electrodes, proximal versus distal recording site). For descriptive statistics of the normative data, means and standard deviations (SD) are reported, unless stated otherwise. Significance was set at the 5% level. Since the same NCS techniques and a similar protocol were used in our previous study [2] (the only difference being that the distance between stimulating and recording sites was 8 vs 10 cm), data from an additional 20 healthy volunteers coule be used for pooled analysis in the present study to increase the number of subjects in the respective age groups for reporting of normative values.

RESULTS

All 31 volunteers, 13 men and 18 women, completed both NCS using surface and needle electrodes. The mean age was 53.1 years (range 24 – 80). Subjects were distributed according to age groups as follows: 4 (20-39 years), 5 (40-49 years), 13 (50-59 years), 9 (60-80 years). Average BMI was 24.3 kg/m2 (SD 3.4).

In all volunteers, the sural nerve and the needle-nerve distance could be visualized using ultrasound imaging at both proximal and distal recording sites. The approximate time for positioning the needle tip near the nerve using ultrasound imaging by an experienced neurophysiologist was less than 2 minutes. The average distance between stimulation and recording site was 7.9 cm (SD 0.9) for the distal surface electrode, 15.1 cm (SD 1.5) for the proximal surface electrode, 7.8 cm (SD 0.8) for the distal needle electrode, and 14.8 cm (SD 2.0) for the proximal needle electrode.

The average distance between the needle tip and the nerve was 1.3 mm (SD 0.6) for the distal needle electrode, and 1.3 mm (SD 0.6) for the proximal needle electrode. The average distance between the nerve and the body surface underneath the surface electrode was 4.8 mm (SD 1.6) for the proximal surface electrode, and 5.5 mm (SD 2.4) for the distal surface electrode.

Average SNAP amplitudes at the proximal and distal recording sites for surface and needle electrodes are summarized for the 31 volunteers in Figure 1. The coefficients of variation of SNAP amplitude for surface electrodes were 0.68, and 0.56 for needle electrodes, respectively. Mean duration of the SNAP using surface electrodes was 1.70 ms (SD 1.53) at the distal recording site, and 1.75 ms (SD 0.79) at the proximal recording site (not significant). The mean duration of the SNAP using needle electrodes was 1.50 ms (SD 0.95) at the distal recording site, and 1.81 ms (SD 0.88) at the proximal recording site (not significant).

The pooled results from this study and from the healthy volunteers of our previous study[2] are summarized in Table 1. The total number of volunteer subjects was thus 51 (24 men, 27 women, age range 20 – 80 years). Significant differences of means between age groups were observed for surface electrodes for SNAP amplitude (20-29 and >60; 40-49 and >60; $P<0.05$) and velocity (20-29 and >60, $P<0.05$), and for needle electrodes for SNAP amplitude (40-49 and >60, $P<0.05$). The branching point of the sural nerve was always proximal to the recording site in our previous study [2] and proximal to the distal recording site in this study, as determined by ultrasound imaging.

DISCUSSION

In 2 previous studies, we demonstrated the usefulness of USNP for sensory NCS of the sural nerve, yielding larger SNAPs with good test-retest reproducibility compared to established techniques [1,2]. In this study, we report on the sensory NCS results of the sural nerve using USNP in respect to age and the influence of recording site location in healthy volunteers.

Amplitudes of the SNAP were always greater in all age groups using USNP compared to surface electrodes. This confirms the findings of our previous studies, and expands recordings to age groups from 20 to > 60 years. A reduction of SNAP amplitudes was noticed, particularly in the age group of >60, for both USNP and surface electrodes. As a limitation, optimization of the placement of needle electrodes using USNP was based on visualization of the sural nerve and hence on structural information on its anatomy, whereas positioning of surface electrodes was performed without prior knowledge of sural nerve anatomy and solely based on electrophysiological parameters. However, NCS using surface electrodes are less prone to variation due to slight differences in electrode position near or over the nerve compared to needle electrodes [1,3].

The reduction of SNAP amplitudes with increasing age in healthy volunteers as seen in our results has been described previously [4]. Some authors have stated that an absent sural SNAP could be considered normal in subjects > 60 years [5]. In this study, sural nerve SNAPs were obtained in all 9 of our older subjects, but possibly absent SNAPs would have occurred had we investigated a greater number of older subjects. Nevertheless, our data suggest that a missing SNAP may be an indicator of abnormality, even in the elderly. The cause of the age-dependent amplitude drop is uncertain. In particular, it is not clear this reflects a normal age-dependent loss of axons [6] or the higher prevalence of unrecognized polyneuropathy in elderly subjects[7]. Since USNP has an increased sensitivity to detect small responses, the age-range of subjects that can be assessed using sural NCS can be expanded to higher ages. This study provides normative data from a cohort of healthy subjects using USNP (Table 1). However, discriminative SNAP amplitudes between healthy subjects and those with neuropathy cannot be provided using our results, as we only studied healthy volunteers.

These data permit analysis of the effect of recording site location on NCS results. In all subjects, sural SNAPs were smaller at the proximal recording site (15 cm) compared to the distal recording site (8 cm) with both recording techniques. We could rule out temporal dispersion as an explanation for the smaller SNAP amplitude at the proximal recording site. Anatomically, the distal sural nerve is an anastomosis of fibers contributed from the lateral and medial cutaneous sural nerves, which unite during their course in the lower leg. Previous cadaver and ultrasound studies have shown that the junction site of the 2 branches is highly variable between subjects, ranging from the popliteal fossa to the ankle [8–10]. During our study, sural nerve branching was noticed in all subjects, mostly between the 2 recording sites (Figure 2). The reduced amplitude of the proximal recording site is due to placement of the recording surface electrode over just 1 sural nerve branch or close to it, hence reducing the number of nerve fibers below the electrode. Therefore, NCS of the sural nerve, especially in longitudinal examinations, should be performed using the same distance between recording and stimulating electrode. Additionally, we suggest choosing a recording site as distal as possible to ensure recording from the unbranched portion of the sural nerve. At the same time, care should be taken to ensure a sufficiently long distance between stimulating and recording electrodes to permit an accurate distance measurement for calculation of NCV.

In a previous study [2] we demonstrated that sural NCS using needle electrodes and USNP have good test-retest reliability as assessed by similar variances of the SNAP amplitude changes in repeated examination compared to NCS using surface electrodes. In line with our previous results, the coefficient of variation of SNAP amplitude using surface electrodes (0.68) and needle electrodes with USNP (0.58) were similar in this study.

In conclusion, NCS of the sural nerve using USNP provide consistently higher amplitude SNAPs than using surface electrodes, across different age ranges up to > 60 years, even proximal to the branching site. Together with our previous studies, we have shown that USNP is superior to NCS using surface electrodes or other techniques of near-nerve needle placement, has a similar test-retest reproducibility, and can be performed successfully in elderly people. A consistent recording site location is recommended for follow-up studies.

Abbreviations: NCS, nerve conduction studies; NCV, nerve conduction velocity; SD, standard deviation; SNAP, sensory nerve action potential; USNP, ultrasound-guided needle positioning; n.s. not significant.

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Table 1. Nerve conduction pooled results (n=51) from this study and our previous study[2] for the distal recording site using surface electrodes and needle electrodes with USNP[2].

Age	n	Surface electrodes mean (SD)		Needle electrodes & USNP mean (SD)		Significances comparing surface and needle electrodes	
		Amplitude [µV]	NCV [m/s]	Amplitude [µV]	NCV [m/s]	*P* (Amp.)	*P* (NCV)
20-29	16	12.7 (7.6)	55.0 (4.2)	40.6 (20.8)	50.1 (4.7)	<0.001	<0.01
30-39	7	13.3 (5.4)	53.8 (3.5)	36.8 (21.4)	50.0 (3.0)	<0.05	<0.05
40-49	6	15.9 (9.3)	54.6 (6.9)	59.0 (49.1)	50.9 (3.7)	<0.05	n.s.
50-59	13	12.3 (5.0)	50.3 (4.1)	45.3 (15.8)	47.3 (4.3)	<0.001	n.s.
>60	9	5.0 (2.4)	48.4 (5.4)	19.8 (9.8)	48.1 (6.7)	<0.01	n.s.

Amp., amplitude; n, number of subjects; NCV, nerve conduction velocity; n.s., not significant; USNP, ultrasound-guided needle positioning.

Figure 1. SNAP amplitude using surface (top row) and needle (bottom row) electrodes with USNP for various age ranges and recording locations for 31 volunteers. Lines within boxes = median; box edges = 25th and 75th percentile; bars = SD; cross = outliers.

Figure 2. Branching of the sural nerve visualized by ultrasound during USNP. Transducer location at proximal (**A**) and distal (**B**) recording sites. * medial cutaneous sural nerve; < lateral cutaneous sural nerve; << sural nerve.

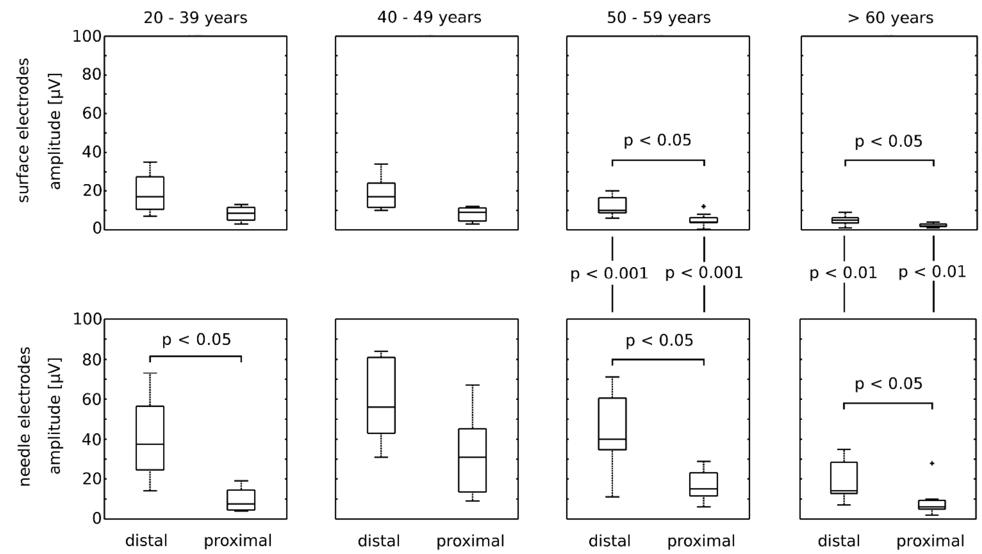

Figure 1. SNAP amplitude using surface (top row) and needle (bottom row) electrodes with USNP in dependence on age range and recording location for our 31 volunteers. Lines within boxes = median; box edges = 25th and 75th percentile; bars = SD; cross = outliers.
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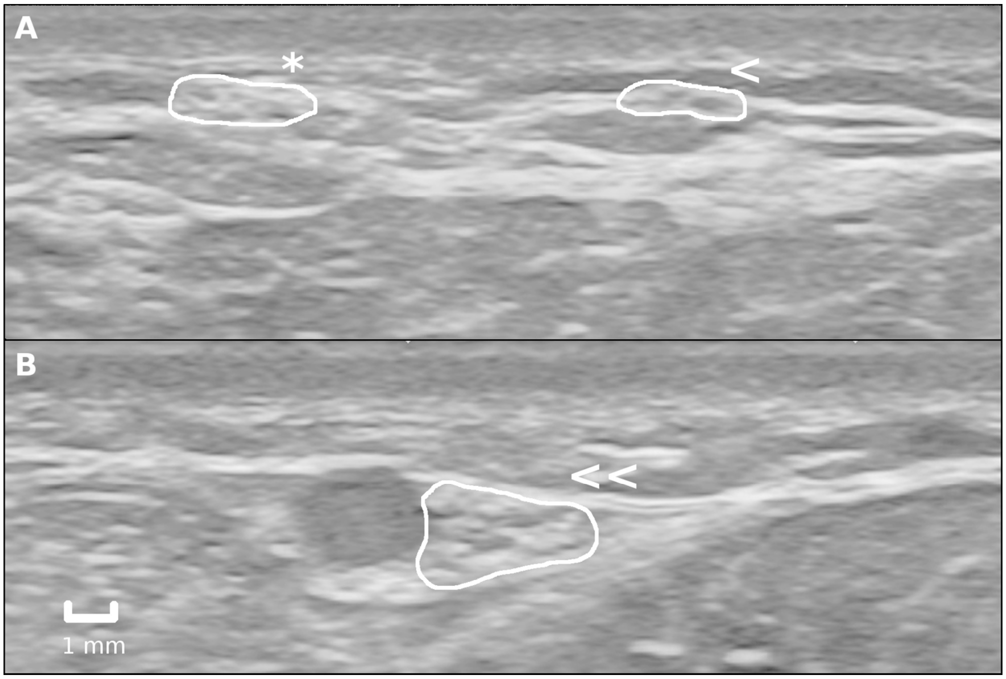

Figure 2. Branching of the sural nerve visualized by ultrasound during USNP. Transducer location at proximal (A) and distal (B) recording site. * medial cutaneus sural nerve; < lateral cutaneus sural nerve; << sural nerve.
152x102mm (300 x 300 DPI)