Effect of Technique Variation on Sensory Nerve Conduction Characteristics

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The impact of technique variation on the wave-form characteristics of the evoked sensory potential was determined from the median and ulnar nerves of healthy subjects. The conduction characteristics of latency, amplitude, and duration were determined for orthodromic and antidromic techniques of stimulation as measured under each of three recording modes: 1) single evoked response, 2) superimposition, and 3) electronic averaging. Variation in the technique of stimulation significantly affected each of the three wave-form characteristics. Peak latency and duration of the evoked sensory potential were longer in antidromic stimulation. The amplitude of the sensory potential varied significantly with both recording and stimulating techniques. The amplitude of the sensory response was larger in antidromic stimulation than in orthodromic stimulation and also was found to be smaller with electronic averaging than with the other recording modes in both antidromic and orthodromic conduction techniques. This degree of variation requires that standardized techniques of methodology be established with the development of normal values for the particular laboratory.

Key Words: *Electric stimulation, Nervous system.*

The application of techniques in nerve conduction evaluation to sensory nerve was first demonstrated by Dawson and Scott in 1949.[1] Gilliatt and Sears, among other investigators, demonstrated the use of nerve conduction studies in the assessment of patients with peripheral nerve lesions.[2]

With appropriate technique and instrumentation, an individual may stimulate sensory axons at one point along the nerve trunk and record the resultant wave of depolarization at other sites along the same nerve trunk. When the resultant wave of depolarization is recorded proximal to the point of stimulation, the direction of conduction is termed orthodromic. A wave of depolarization recorded at a point distal to the one of stimulation is referred to as antidromic conduction.

These basic sensory conduction techniques have been used in contemporary clinical assessment for a number of sensory nerve distributions in the upper and lower extremities. The wave-form characteristics of the evoked sensory potential—low amplitude and short duration—require a relatively high amplification of the bioelectric signal. This degree of signal amplification increases the recording of extraneous electrical activity, which may preclude the visualization of the evoked sensory potential. The use of a variable frequency filter provides a degree of filtering out of extraneous electrical noise with minimal disruption of the desired evoked sensory response.

Even with the filter adjustment, the amplitude of the evoked sensory potential may still approach the noise level of the instrumentation. Techniques are available to improve the display of these small signals through either superimposition or electronic averaging. Superimposition involves the recording of a number of consecutive evoked sensory responses on a storage oscilloscope, a single exposure of photographic film, or a paper printout. The evoked sensory response, which will be fixed in time and direction of the wave-form deflection, will stand out from the background electrical noise, which will be random in character. A signal averager will accomplish the same goal through the electronic averaging of a number of successive evoked responses.

An additional, early modification in latency measurement or the time between the stimulus and the response was to measure that characteristic to the peak of the evoked response, rather than to the initial deflection, as is generally done in motor conduction studies. With modern instrumentation, sensory latencies may be readily measured to the initial deflection of the evoked response.

The purposes of this study were to develop normal data for the characteristics of the evoked sensory potential (latency, amplitude, and duration) for the median and ulnar nerves and to assess the impact of technique variation on these characteristics.

METHOD

Subjects

Twenty-six subjects (14 men and 12 women) were included in the study. The age range was 20 to 39 years with a mean age of 30 years. All subjects had been screened for symptoms and signs of neuropathy and were healthy. All subjects signed informed consent forms. The study was approved by the local clinical investigations committee.

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Instrumentation

A TECA TE 4 electromyograph* with a fiber optic paper recorder and electronic signal averager was used for all determinations. Sweep velocity was set at 2 msec/division and the amplitude gain varied between 10 and 50 μV/division. The frequency band pass was 32 Hz to 3.2 kHz. A supramaximal direct current stimulus of 0.1 msec duration was delivered at a rate of 1 Hz for all recordings.

Room temperature was maintained between 26° and 28°C (78.8° to 82.4°F). I determined skin temperatures over the volar pads of the distal interphalangeal joints of the second and fifth digits and over the volar wrist crease with a thermistor† before testing. Skin temperatures were randomly monitored during testing. Standard skin and electrode preparation consisted of cleaning with alcohol swabs. I periodically calibrated the electromyograph for time and amplitude measurements by applying a test signal of known wave-form characteristics.

I used paired digital ring electrodes to record or stimulate over the distal interphalangeal and metacarpophalangeal joints of the second and fifth digits with the negative pole at the proximal joint. Plastic-mounted, surface disk electrodes with an interelectrode distance of 3 cm were used for orthodromic recording at the wrist. A ground electrode was placed over the dorsum of the hand. Proximal stimulating and recording points on nerve trunk were at the level of the wrist. Nerve segment lengths were not premeasured, but an attempt was made to maintain electrode placement at the wrist anatomically consistent with the volar wrist creases.

Procedures

I determined conduction characteristics for antidromic and orthodromic techniques of stimulation under each of three recording modes: 1) single evoked response, 2) superimposition of 10 successive evoked responses, and 3) electronic averaging of 16 consecutive evoked responses. Antidromic conduction was performed before orthodromic conduction first for the ulnar nerve and then for the median nerve. Additionally, the amplitude of the evoked sensory potential for the median nerve was compared under each of 6 different electronic sweep averages from 4 to 128 sweeps. All data were printed on fiber optic recording paper with a time calibration wave to permit direct measurement of the conduction characteristics.

I measured sensory latencies to the initial and negative peak deflections of the evoked response. Amplitude of the evoked potential was measured peak to peak, and duration was measured from the initial deflection to the peak of the positive deflection for the sensory response.

Data Analysis

Data were analyzed by an analysis of variance—repeated measures design with Neuman-Keuls *post hoc* test for significance of difference.

* TECA Corp, 3 Campus Dr, Pleasantville, NY 10570.

† YSI Model 44, Yellow Springs Instrument Co, Box 279, Yellow Springs, OH 45387.

TABLE 1
Mean Latency (msec) of Single Evoked Response

Stimulation Technique	Nerve					
	Ulnar			Median		
	$\bar{X}$	*s*	Range	$\bar{X}$	*s*	Range
Antidromic						
initial	2.49	.27	(1.8–3.0)	2.73	.29	(2.3–3.5)
peak	3.04	.34	(2.4–3.8)	3.28	.38	(2.7–4.2)
Orthodromic						
initial	2.43	.28	(1.7–3.0)	2.69	.32	(2.3–3.6)
peak	2.91	.33	(2.1–3.7)	3.20	.34	(2.7–4.0)

TABLE 2
Peak Latency (msec) as a Function of Stimulation and Recording Techniques

Nerve	Recording Technique					
	Single		Superimposed		Averaged	
	$\bar{X}$	*s*	$\bar{X}$	*s*	$\bar{X}$	*s*
Ulnar						
antidromic	3.04	.34	3.02	.35	3.04	.34
orthodromic	2.91	.33	2.90	.32	2.90	.31
Median						
antidromic	3.28	.38	3.29	.38	3.31	.57
orthodromic	3.20	.34	3.19	.34	3.20	.36

RESULTS

Skin Temperature

Digital skin temperatures demonstrated a wide range of variability from 22.8° to 35.6°C (73.04° to 96.08°F) with mean values of 31.9°C and 31.7°C (89.42°F and 89.06°F) for the second and fifth digits, respectively. Volar wrist temperature was warmer with a mean value of 32.8°C (91.04°F) and demonstrated less variability among subjects. Seven subjects had digital temperatures under 30°C (86°F), and two additional subjects had a 5°C (41°F) drop in digital skin temperature during the testing period.

Latency

Latency measurements are a direct function of the nerve segment length between the recording and stimulating points. The mean segment length for the median nerve was 14.0 cm with a range from 13 to 15.5 cm; the corresponding mean values for the ulnar nerve were 12.5 cm with a range from 10 to 14 cm.

Latency measurements of the single evoked response for antidromic and orthodromic techniques averaged approximately 0.25 msec (initial peak deflection measurement) and 0.27 msec (negative peak deflection measurement) longer for the median nerve than for the ulnar nerve.

Negative peak deflection latencies for the two nerves under the two techniques of conduction exceeded the latencies measured to the initial deflection of the evoked response by an average of 0.52 msec (Tab. 1).

TABLE 3A
Analysis of Variance for Ulnar Latency (msec)

Source	*df*	SS	MS	*F*
Stimulation (A)	1	.6156	.6156	42.24[a]
Record (B)	2	.0036	.0018	NS
Stim.-rec. inter. (AB)	2	.0005	.0003	NS
Within-subject (S)	25	16.6000	.6640	
Stim.-subj. inter. (AS)	25	.3644	.0146	
Rec.-subj. inter. (BS)	50	.1064	.0021	
Stim.-rec.-subj. inter. (ABS)	50	.0695	.0014	
TOTAL	155	17.7600		

[a] Significant at the .01 level of confidence.

TABLE 3B
Analysis of Variance for Median Latency (msec)

Source	*df*	SS	MS	*F*
Stimulation (A)	1	.3800	.3800	29.24[a]
Record (B)	2	.0073	.0037	NS
Stim.-rec. inter. (AB)	2	.0101	.0051	NS
Within-subject (S)	25	19.8800	.7952	
Stim.-subj. inter. (AS)	25	.3249	.0130	
Rec.-subj. inter. (BS)	50	.1227	.0025	
Stim.-rec.-subj. inter. (ABS)	50	.0799	.0016	
TOTAL	155	20.8049		

[a] Significant at the .01 level of confidence.

The measurement of peak latency values for the two nerves under both antidromic and orthodromic techniques did not vary significantly with the type of recording technique (Tab. 2).

In the comparison of latency measurement between antidromic and orthodromic techniques, there was no significant difference in latency measured to the initial deflection for the two nerves. Peak latencies in orthodromic conduction, however, were significantly shorter than the comparable measurements over the same nerve segment lengths in antidromic conduction at the .01 level of confidence (Tabs. 2, 3A, and 3B). Mean orthodromic peak latencies were 3.20 msec and 2.91 msec compared with 3.28 msec and 3.04 msec in antidromic conduction for the median and ulnar nerves, respectively (Tab. 2).

Amplitude

Peak to peak amplitudes of the evoked sensory potential varied significantly (at the .01 level of confidence) as a function of both stimulating and recording techniques. The mean amplitude of the single evoked antidromic response was 59.9 μV and 44.5 μV, compared with the orthodromic values of 21.9 μV and 19.2 μV for the median and ulnar nerves, respectively (Tab. 4). The electronically averaged amplitude was significantly smaller (at the .01 level of confidence) than either the single or superimposed amplitudes for both antidromic and orthodromic evoked responses of the two nerve distributions (Tabs. 4, 5A, and 5B). The mean percent decrease in amplitude was 10 and 7 percent for the median and ulnar nerve orthdromic potentials and approximately 2 percent for both nerves in antidromic conduction. There was no significant difference in amplitude of the evoked response between the single and superimposed sensory potentials.

With electronic averaging of the evoked response, the number of sweeps averaged had no significant effect on the measurement of amplitude for the median nerve.

Duration

The duration of the evoked sensory potential did not vary significantly with the recording technique but did vary significantly with the technique of stimulation at the .01 level of confidence (Tabs. 6, 7A, and 7B). The duration of the antidromic evoked potential averaged approximately 0.5 msec longer than the orthodromic evoked response. The duration of the antidromic evoked response was 1.85 msec and 1.74 msec compared with the orthodromic values of 1.32 msec and 1.26 msec for the median and ulnar nerves, respectively (Tab. 6).

TABLE 4
Amplitude (μV) as a Function of Stimulation and Recording Technique

Nerve	Recording Technique					
	Single		Superimposed		Averaged	
	$\bar{X}$	*s*	$\bar{X}$	*s*	$\bar{X}$	*s*
Ulnar						
antidromic	44.5	17.2	45.2	17.8	43.4	19.5
orthodromic	19.2	6.5	19.2	6.5	17.6	6.3
Median						
antidromic	59.9	20.9	61.0	20.9	58.6	21.0
orthodromic	21.9	8.1	22.0	8.0	19.8	7.7

TABLE 5A
Summary of Analysis of Variance and Newman-Keuls Test of Ulnar Amplitude (μV)

I. Analysis of Variance

Source	*df*	SS	MS	*F*
Stimulation (A)	1	25743.69	25743.69	57.66[a]
Record (B)	2	85.24	42.62	7.53[a]
Stim.-rec. inter. (AB)	2	3.04	1.52	NS
Within-subject (S)	25	17224.64	688.99	
Stim.-subj. inter. (AS)	25	11161.31	446.45	
Rec.-subj. inter. (BS)	50	283.09	5.66	
Stim.-rec-subj. inter. (ABS)	50	321.96	6.44	
TOTAL	155	54822.97		

[a] Significant at the .01 level of confidence.

II. Newman-Keuls *post-hoc* test

	Averaged	Single	Superimposed
$\sum x$	1585	1658	1689

Table of Differences of $\sum x$

	Averaged	Single	Superimposed
Averaged	—	73[a]	104[a]
Single	—	—	31[b]
Superimposed	—	—	—

[a] Significant at the .01 level of confidence.
[b] Nonsignificant.

TABLE 5B
Summary of Analysis of Variance and Newman-Keuls Test of Median Amplitude (μV)

I. Analysis of Variance

Source	*df*	SS	MS	*F*
Stimulation (A)	1	58116.16	58116.16	99.20[a]
Record (B)	2	155.17	77.58	9.43[a]
Stim.-rec. inter. (AB)	2	7.32	3.66	NS
Within-subject (S)	25	23720.67	948.82	
Stim.-subj. inter. (AS)	25	14646.67	585.87	
Rec.-stim. inter. (BS)	50	411.50	8.23	
Stim.-rec.-subj. inter. (ABS)	50	319.35	6.39	
TOTAL	155	97376.84		

[a] Significant at the .01 level of confidence.

II. Newman-Keuls *post-hoc* test

	Averaged	Single	Superimposed
$\sum x$	2037	2126	2160

Table of Differences of $\sum x$

	Averaged	Single	Superimposed
Averaged	—	89[a]	123[a]
Single	—	—	34[b]
Superimposed	—	—	—

[a] Significant at the .01 level of confidence.
[b] Nonsignificant.

TABLE 6
Duration (msec) as a Function of Stimulation and Recording Technique

Nerve	Recording Technique					
	Single		Superimposed		Averaged	
	$\bar{X}$	*s*	$\bar{X}$	*s*	$\bar{X}$	*s*
Ulnar						
antidromic	1.74	.32	1.72	.30	1.74	.32
orthodromic	1.26	.16	1.25	.13	1.26	.13
Median						
antidromic	1.85	.30	1.88	.30	1.88	.30
orthodromic	1.32	.24	1.32	.22	1.32	.23

DISCUSSION

Direct comparison of the results of this study with previously reported results is difficult because of the wide range of technique variation among different investigators. Additionally, some studies fail to identify specific conditions under which normal sensory conduction values were determined. Despite these limitations, the results of the present study fall within an area of general agreement with the published data and identify some considerations not previously noted in the literature.

The difference in latency values between the initial and peak negative deflection ranged between 0.4 and 0.8 msec. Other investigators have reported similar values.[3–5] In developing normal data, values should be determined for either or both methods of latency measurement, but normative data for one technique of latency measurement should not be used with the other technique.

Relatively few reports in the literature give latency values as a function of nerve segment length. Segment lengths, when reported, have varied between 11 and 15 cm. Felsenthal has suggested a 0.2 msec/cm correction factor for sensory latencies over unequal nerve segment lengths based on an average conduction velocity of 50 m/sec.[3] This correction factor applied over a segment-length difference of 2 cm could account for a 0.4 msec difference in latency. The range of sensory latencies in the present study can be attributed, in part, to the variable segment lengths. The application of this correction formula to the mean values for the median and ulnar nerves would result in approximately equal values of latency for these two nerve distributions. Melvin et al have determined that no difference exists in latency between the median and ulnar nerves over the same nerve segment distance.[6] Consequently, consideration needs to be given to the impact of segment-length variation on latency measurements, particularly in comparative studies between different nerves in the same subject or the same nerve in opposite extremities, as well as among different subjects.

Few authors have reported either skin or perineural temperatures in the determination of normal data. Buchthal and Rosenfalck have suggested a correction factor of 2 m/sec per 1°C change in temperature in the temperature range of 26° to 36°C.[7] Of particular interest in the present study is the demonstration of sensory latencies at the extreme upper range by two of the three subjects with digital skin temperatures below 27°C. These relatively longer latencies are in all probability related to the decreased skin temperatures. Using the correction factor over the mean segment distances in the present study could account for a 0.1 msec increase in latency for every 1°C drop in skin temperature. Skin temperatures should be measured before testing and modified by preheating or

TABLE 7A
Analysis of Variance for Ulnar Duration (msec)

Source	*df*	SS	MS	*F*
Stimulation (A)	1	8.919	8.9190	78.98[a]
Record (B)	2	.005	.0025	NS
Stim.-rec. inter. (AB)	2	.001	.0005	NS
Within-subject (S)	25	6.050	.2420	
Stim.-subj. inter. (AS)	25	2.823	.1129	
Rec.-subj. inter. (BS)	50	.185	.0037	
Stim.-rec.-subj. inter. (ABS)	50	.162	.0032	
TOTAL	155	18.145		

[a] Significant at the .01 level of confidence.

TABLE 7B
Analysis of Variance for Median Duration (msec)

Source	*df*	SS	MS	*F*
Stimulation (A)	1	11.743	11.743	80.12[a]
Record (B)	2	.007	.0035	NS
Stim.-rec. inter. (AB)	2	.007	.0035	NS
Within-subject (S)	25	7.179	.2872	
Stim.-subj. inter. (AS)	25	3.664	.1466	
Rec.-subj. inter. (BS)	50	.083	.0017	
Stim.-rec.-subj. inter. (ABS)	50	.077	.0015	
TOTAL	155	22.760		

[a] Significant at the .01 level of confidence.

controlled through the application of a correction formula. Two additional subjects in this study demonstrated a marked drop in digital skin temperature of 5°C during the period of testing, although their latency values remained in the mid portion of the normal range of variation. I presumed that this rapid decrement in digital skin temperatures was related to a vasoconstriction in digital blood flow resulting from the anxiety of the testing environment. Monitoring of skin temperature during the period of testing by touch or thermistor would facilitate the recognition of this potentially complicating autonomic variable.

Peak sensory latency, but not latency to the initial deflection, was found to vary significantly with the technique of stimulation in the present study. Several previous studies have suggested equality of latencies measured orthodromically and antidromically.[8-10] Separate studies by Felsenthal,[3] Melvin et al,[6] and Murai and Sanderson[5] indicated shorter latencies for orthodromic conduction. The latter study demonstrated that peak latency was directly related to the recording interelectrode distance. When the interelectrode distance was 1 cm, peak latency for antidromic conduction was equal to that for orthodromic conduction. Felsenthal suggests the effect on peak latency to be on the order of 0.1 msec/cm.[3] In the present study, the recording interelectrode distance in antidromic stimulation varied with the distance between the metacarpophalangeal and distal interphalangeal joints. In all cases, this distance exceeded the orthodromic recording interelectrode distance of 3 cm with the fixed, plastic-mounted electrodes. The difference in peak latency with the technique of stimulation may thus be a function of the relative difference in recording interelectrode distance between antidromic and orthodromic techniques. Consequently, when using peak latency measurements, recording interelectrode distance should be kept constant.

The amplitude of the evoked sensory potentials were two to three times larger in antidromic conduction than in orthodromic conduction for the two nerve distributions. I attributed this difference to both anatomical and technical considerations. The greater proximity of the nerve to the surface recording electrode in antidromic conduction compared with orthodromic conduction results in less attenuation of the voltage change recorded at the skin surface. Additionally, with antidromic conduction, a volume conducted, evoked muscle-action potential may contribute to the positive phase of the evoked sensory potential and thereby increase the apparent peak to peak amplitude of the sensory response.

Amplitude was the only wave-form characteristic to be affected by the recording mode. The amplitude of the evoked sensory potential was significantly smaller with electronic averaging. The decrement in amplitude with electronic averaging ranged from a 20 to 40 percent decrease in individual cases and was more pronounced in orthodromic conduction. The explanation for this decrement remains unclear. The measured amplitude of the evoked sensory response is composed of the bioelectric signal and random electrical noise. With electronic averaging, random electrical noise is more completely eliminated from the evoked sensory response than with the other two recording modes. Consequently, some of the amplitude decrement with electronic averaging may result from the more effective noise elimination in this technique. Conversely, the process of electronic averaging might diminish the bioelectric signal, as well as the electrical noise, as an inherent part of machine design or, perhaps, as a consequence of a malfunction of the particular averager used in this study. Further evaluation of this possible explanation is needed. Other possible explanations for this amplitude decrement relate to technique factors such as stimulus strength and adequacy of electrode contact with the skin surface, although considerable effort was made to control these variables in the study.

The duration of the antidromic sensory potential was noted to be 0.5 msec longer than for the orthodromic sensory potential. Buchthal and Rosenfalck have demonstrated that duration is a direct function of recording interelectrode distance.[11] As was true for peak latency, the difference in duration is a reflection of the variable recording interelectrode distances between the two techniques of stimulation in this study.

The wave-form characteristics of the evoked sensory potential have been found to vary significantly with variation in measurement, recording, and stimulating techniques. Any laboratory performing nerve conduction studies must understand the impact of these variables in technique on the measured wave-form characteristics of the evoked sensory response. Equally important is the need to adopt a consistent and standardized technique to sensory nerve conduction testing and to develop normal data for the particular methodology chosen.

SUMMARY

The sensory conduction characteristics of latency, amplitude, and duration varied significantly with change in recording, stimulating, and measurement techniques. Amplitude was the only characteristic to be affected by the technique of recording. Electronic averaging of the evoked sensory response resulted in a smaller recorded amplitude in both orthodromic and antidromic techniques of conduction. Variation in the number of sweeps electronically averaged had no effect on the amplitude measurement. Variation in the technique of stimulation affected all three characteristics. Peak latency was longer in the antidromic technique compared with orthodromic conduction over the same nerve segment length. Duration of the evoked potential was also greater under antidromic conduction than with orthodromic conduction. The increased peak latency and duration values were related to variation in recording interelectrode distance between antidromic and orthodromic techniques. Amplitude of the sensory potential was greater in antidromic conduction than in orthodromic conduction. Peak latency exceeded latency measured to the initial deflection by an average of 0.52 msec.

The need to monitor and correct for variation in nerve segment length and skin temperature was discussed. A rapid decrement in skin temperature during the period of testing was noted to occur in some subjects.

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