Electrophysiological aspects of sensory conduction velocity in healthy adults

2 Ratio between the amplitude of sensory evoked potentials at the wrist on stimulating different fingers in both hands

A. CRUZ MARTÍNEZ, M. BARRIO, M. C. PÉREZ CONDE,
AND M. T. FERRER

From Servicio de Neurofisiología Clínica, Ciudad Sanitaria de la Seguridad Social La Paz, Madrid, Spain

SUMMARY The normal ratio between the amplitude of the sensory evoked potential (SEP) at the wrist on stimulating digits 1, 2, 3, and 5 was determined in 44 healthy adult subjects. The first digit had the larger amplitude, and the fifth digit the smallest SEP. The amplitude expresses the density of sensory innervation in each finger. The ratio between the amplitude of different fingers varied according to the age of the subject. The amplitude of the SEP from a digit innervated by the median nerve decreased in the elderly more than the SEP amplitude of the digit innervated by the ulnar nerve, probably because of a chronic compression in the carpal tunnel. The changes in the normal amplitude ratio can be applied to the topographic diagnosis of radicular and brachial plexus lesions if a fixed segmental sensory innervation of the hand is accepted. In 44 right handed subjects the amplitude of the sensory evoked potentials at the wrist was significantly larger in the left hand. This asymmetry of sensory innervation between hands could be physiological, and suggests a greater density of sensory innervation in the left hand of right handed subjects.

Normal values of the sensory conduction velocity (SCV) and amplitude of the sensory evoked potential (SEP) are applied habitually in the diagnosis of peripheral nerve diseases and entrapment syndromes but the amplitude of the SEP is rarely used to diagnose radicular lesions. Some authors (Bonney and Gilliatt, 1958; Kliney *et al.*, 1969; Gilliatt *et al.*, 1970) have used this criterion to differentiate pre- and post-ganglionic root avulsions. Consequently, the amplitude of the SEP in each finger and, more exactly, the ratio between the amplitude of the SEP for each finger, can be used to locate post-ganglionic avulsions of roots from plexus lesions. It has been necessary to assume a fixed sensory segmental innervation of the hands, and to calculate the normal ratio in amplitude between the different fingers. This ratio can change according to the age of the subject (Dreschler, 1975).

Unfortunately, there is little published information about these questions (Gilliatt *et al.*, 1970; Monserrat *et al.*, 1974; Cruz Martínez *et al.*, 1975). In this paper we attempt to determine the normal values of the ratio between the amplitude of the SEP at the wrist on stimulating different fingers in both hands, and the effect of aging; we also examine whether the amplitude of the SEP, assumed to be an index of the sensory innervation density, is the same in both hands. An asymmetry of the sensory innervation between both hands has previously been suggested in adults (Monserrat *et al.*, 1974) and infants (Cruz Martínez *et al.*, 1975).

Subjects and methods

The series explored is the same as that in Cruz Martínez *et al.* (1978b)—47 healthy subjects aged from 21 to 77 years.

The maximum SCV from the digit to wrist segment, and the duration and amplitude of the SEP

Address for reprint requests: Dr A. Cruz Martínez, C/Toledo, 144C.D, Madrid 5, Spain.

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at the wrist were determined stimulating digits 1–5 in both hands. The ratios between the SEP amplitudes of digits 2 : 1, 3 : 1, 5 : 1, 5 : 2, and 5 : 3 were established in both hands, separately, in all subjects.

In 44 of the subjects, all of them right handed, the amplitudes of the SEP in both hands were compared.

The technical details on stimulation and recording are the same as in Cruz Martínez *et al.*, (1978b). The preparation and skin temperature were the same in both hands. There were no significant differences between hands in the circumference of fingers and wrist.

Results

The maximum SCV from digit to wrist was the same for digits 2, 3, and 5 but 19% lower for the digit 1–wrist segment (Table 1). No significant differences were found between hands. Changes in the SCV according to age have been described previously (Cruz Martínez *et al.*, 1978a, b).

The duration of the SEP at the wrist was moderately shorter for first digit than for the others

(Table 1). No significant differences were found between hands. The duration increased with age, as shown previously (Cruz Martínez *et al.*, 1978a, b) (Table 1).

Comparative study of the amplitude of the SEP showed that the first digit had the largest amplitude, followed by digits 3 and 2 and, eventually, by digit 5 which had the least one (Fig. 1). The ratios between the amplitude of the different fingers (2 : 1, 3 : 1, 5 : 1, 5 : 2, and 5 : 3) are shown in Table 2. The results were similar in both hands of right handed subjects (Table 2).

The ratio in amplitude changed according to the age. The ratios 2 : 1, 3 : 1, 5 : 1, 5 : 2, and 5 : 3 increased in elderly subjects (Table 2). The ratios in amplitude 3 : 1 and 5 : 3 as a linear function of age are shown in Fig. 2. According to these results, the amplitude of the SEP of the digits innervated by the median nerve decreased more than in the digits innervated by the ulnar nerve. The reduction of the amplitude of SEP in the digits innervated by the median nerve was different for each finger. The amplitude of the SEP of digit 1 decreased in elderly subjects more than the SEP amplitude of digits 2 and 3.

Table 1 Sensory conduction velocity (SCV) digit to wrist, amplitude, and duration of the sensory evoked potential at the wrist, stimulating digits 1, 2, 3, and 5 in 47 healthy adults. Mean±standard error; SD=standard deviation

Digit	Age (yr)	SCV (m/s)	SD	Amplitude (μV)	SD	Duration (ms)	SD
1	< 30	44.2 ± 0.84	3.28	40.3 ± 2.42	9.30	0.94 ± 0.03	0.10
	31–49	43.5 ± 0.86	3.24	33.7 ± 3.28	11.20	0.96 ± 0.02	0.09
	≥ 50	41.2 ± 0.93	3.63	19.8 ± 1.11	4.30	1.04 ± 0.02	0.10
2	< 30	54.6 ± 1.05	4.10	16.3 ± 1.15	4.40	1.06 ± 0.02	0.07
	31–49	54.2 ± 0.97	3.66	13.7 ± 0.93	3.40	1.07 ± 0.02	0.08
	≥ 50	52.5 ± 1.00	3.90	10.1 ± 0.44	1.70	1.12 ± 0.03	0.12
3	< 30	53.4 ± 0.77	3.00	22.2 ± 1.89	7.30	1.05 ± 0.02	0.10
	31–49	53.6 ± 0.79	2.97	18.0 ± 1.54	5.70	1.05 ± 0.02	0.09
	≥ 50	51.5 ± 0.77	2.99	12.0 ± 0.63	2.50	1.12 ± 0.03	0.12
5	< 30	53.1 ± 0.60	2.36	11.5 ± 0.69	2.68	1.01 ± 0.02	0.08
	31–49	53.8 ± 1.23	4.61	11.0 ± 0.68	2.58	1.02 ± 0.01	0.07
	≥ 50	51.4 ± 0.98	3.80	7.5 ± 0.62	2.42	1.13 ± 0.03	0.13

Fig. 1 Sensory evoked potentials at the wrist stimulating digits 1, 2, 3, and 5 in the right hand of a normal man aged 25 years.

Table 2 Ratio between the amplitude of the SEP at the wrist stimulating digits 1, 2, 3, and 5 in both hands. Mean± standard deviation

Age (yr)	Right hand					Left hand				
	2:1	3:1	5:1	5:2	5:3	2:1	3:1	5:1	5:2	5:3
Total series	0.42 ± 0.10	0.55 ± 0.15	0.31 ± 0.09	0.75 ± 0.15	0.57 ± 0.17	0.41 ± 0.09	0.57 ± 0.11	0.29 ± 0.07	0.71 ± 0.18	0.51 ± 0.13
< 30	0.41 ± 0.08	0.55 ± 0.17	0.28 ± 0.09	0.69 ± 0.18	0.51 ± 0.16	0.40 ± 0.09	0.55 ± 0.12	0.27 ± 0.08	0.68 ± 0.21	0.50 ± 0.13
30-49	0.39 ± 0.08	0.51 ± 0.09	0.32 ± 0.08	0.81 ± 0.13	0.62 ± 0.13	0.41 ± 0.06	0.66 ± 0.12	0.30 ± 0.06	0.74 ± 0.17	0.46 ± 0.15
≥ 50	0.51 ± 0.08	0.61 ± 0.16	0.38 ± 0.08	0.75 ± 0.16	0.62 ± 0.19	0.45 ± 0.10	0.56 ± 0.12	0.33 ± 0.05	0.72 ± 0.15	0.58 ± 0.13

Fig. 2 Ratios in amplitude of SEP from digits 3:1 and 5:3 in the right hands of 44 healthy adults as a function of age. Solid line=regression line; dashed lines =95% confidence limits; R=correlation coefficient.

In the 44 right handed subjects in this series the amplitude of the SEP was compared in both hands. The SCV and duration of the SEP were the same in each hand, whereas the amplitude of the SEP at the wrist was larger in the left hand than in the right one, especially for digits 3, 1, and 2 (Fig. 3). The amplitude at the wrist was 30.4% (digit 1), 28.1% (digit 2), 33.3% (digit 3), and 21.1% (digit 5) higher in the left hand than in the right. Statistical differences of the mean values were more significant for digits 1, 2, and 3 ($P<0.01$) than for digit 5 ($P<0.05$) (Fig. 4). The circumference of the fingers and wrist, the skin temperature, and the distance between stimulating and recording points did not show significant differences between hands.

Discussion

The absolute values of the SEP amplitude have been applied in order to differentiate between pre- and post-ganglionic root avulsions (Bonney and Gilliatt, 1958; Kliney *et al.*, 1969). However, analysis of the ratio between the amplitude of the SEP that corresponds to each finger can be more exact than the study of the absolute values of the amplitude. This method permits a more precise and earlier topographic localisation in radicular or brachial plexus lesions.

Fig. 3 Sensory evoked potentials at the right (R) and left (L) wrist in a healthy right handed adult aged 45 years. Bilateral stimulation of digits 1, 2, and 3.

The ratio between the amplitude of the SEP of the ulnar (digit 5) and median (digit 2) nerves can provide additional information for the diagnosis of the carpal tunnel syndrome (Loong and Seah,

Fig. 4 Mean values of the amplitude of the sensory evoked potentials at the wrist are significantly larger ($P<0.01$ – $P<0.05$) in the left (L) than in the right (R) hand, in 44 right handed adult subjects. Percentage larger amplitude in the left hand $\pm$ standard deviation is also marked.

1971). Gilliat *et al.* (1970) described reduction in amplitude of the SEP on stimulating digit 5 in entrapments of the brachial plexus by a cervical rib.

Using these methods, we have been able to determine the post-ganglionic involvement of the C6 segment in some cases of brachial neuritis (relative reduction in amplitude of the SEP of digit 1), and we have had some help in localising the topographic distribution of the lesions in traction injuries of the brachial plexus. It is obviously necessary to know first the normal segmental sensory innervation of each finger. However, one of the problems consists in the individual variations of the sensory innervation of the hand. According to Sunderland (1968) and Williams and Warwick (1975) the hand is innervated by C6 to C8 cord segments: digit 1 connects to C6; digit 2 connects to C6 and C7; digits 3 and 4 connect to C7 and digit 5 connects to C8 segment. Recently, Inouye and Buchthal (1977) have concluded that the cutaneous areas of digits 1 and 2 connect as often to C6 as to C7, whereas the cutaneous fibres of digit 5 seemed to connect to C8 or to C7 and C8 spinal nerves. According to this segmental sensory innervation, the variations of the SEP of each finger provide information about which spinal nerve is damaged.

Thus, it is necessary to determine the normal ratio in amplitude between SEP on stimulating the different fingers. Assuming that the SEP ampli-

tude is a function of the number of fibres activated by electrical stimuli (Buchthal and Rosenfalck, 1966), it can indicate the density of the sensory innervation of each finger. According to this idea, the largest sensory innervation corresponds to digit 1, and the least one corresponds to digit 5. Propagated activity from the radial nerve, and the short distance between stimulating and recording points, can contribute partially to the large amplitude of the SEP of the thumb (Buchthal and Rosenfalck, 1966). However, the propagated activity and the distances involved are not the cause of the observed differences in amplitude, since the distances for digits 2 and 3 are the same, whereas the SEP amplitude is larger in digit 3 than in digit 2. Likewise, the distance in digit 5 is shorter than in digits 2 and 3, whereas the SEP amplitude is smaller for the fifth digit. Otherwise, the amplitude of the SEP for each finger compares well with their cortical representation, according to Penfield's homunculus. Consequently, we think that the differences in amplitude of the SEP from the different fingers are physiological, and the amplitude expresses the density of the sensory innervation in each finger.

The ratio in amplitudes calculated by us is not essentially different from the results published by Loong and Seah (1971) and by Monserrat *et al.* (1974). There were only some slight differences from ratios calculated from the values published by Buchthal and Rosenfalck (1966). In infancy (Cruz Martínez *et al.*, to be published) the ratios are different, and the differences between SEP amplitude of the thumb and amplitudes of the other fingers are less marked. Thus, the ratio in amplitude varies according to the age. In healthy adults the reduction in amplitude is more marked in digits innervated by the median than by the ulnar nerve, and the ratio between digits 5:3 increases in elderly subjects. These results agree with those of Dreschler (1975), and the preferential involvement of the median nerve in the elderly could be explained by a chronic compression in the carpal tunnel, and by a higher sensitivity to anoxia of the median nerve of the limbs of older people (Dreschler, 1975). These results also agree with the conclusions of Cruz Martínez *et al.* (1978b), and suggest that age causes changes particularly in the points where the nerves are more frequently compressed.

The amplitude of the SEP was significantly larger in the left hand of right handed subjects, especially for digits 1, 2, and 3. Stimulation and recording, temperature, conduction distances, circumferences of the fingers and wrist, and other technical data were the same in each hand. Thus,

an artefact of the technique is not the explanation for these results, which are the same as those previously published by Monserrat *et al.* (1974). An axonal neuropathy with loss of large myelinated nerve fibres in the dominant hand might be the explanation in adults, but this hypothesis must be rejected since in right handed infants the amplitude of the SEP is also larger in the left hand than in the right one (Cruz Martínez *et al.*, to be published). Hence, the asymmetry between hands could be physiological, with a greater sensory innervation in the left hand of right handed subjects. In some left handed adults (unpublished data) the amplitude of the SEP at the wrist was larger in the right hand. This finding agrees with the hypothesis of a physiological asymmetry of sensory innervation. However, we think that more detailed studies are necessary for complete explanation.

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