

P9 in median nerve SEPs is a junctional potential generated by the change of the volume conductor size between trunk and neck

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Abstract

Objectives: We aimed to investigate the origin of P9 in median SEPs by applying the junctional potential theory.

Methods: We studied the distribution over the body surface with contralateral shoulder reference in 4 normal subjects.

Results: A stationary potential field P9/tN9 (=truncal N9) was recorded: P9 over head and neck (the smaller part), tN9 over trunk (the larger part), the boundary being located between trunk and neck. This polarity agreed with that expected from simulation studies.

Conclusions: P9 is a junctional potential generated by the change of the volume conductor size between trunk and neck. © 1998 Elsevier Science Ireland Ltd. All rights reserved

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1. Introduction

P9 is the first component of the far-field potentials of somatosensory evoked potentials (SEPs) following median nerve stimulation. There remains substantial controversy regarding its origin. Because it appears slightly earlier than N9, a near-field recording of the nerve action potentials at Erb's point, P9 has been thought to be generated near the brachial plexus (Cracco and Cracco, 1976; Desmedt and Cheron, 1980). Some investigators have suggested that P9 arises due to a change of direction of propagating nerve impulse (Desmedt et al., 1983; Nakanishi et al., 1986). Others have suggested that P9 is generated by a certain change of volume conductor surrounding the nerve trunk (Yamada et al., 1985; Cunningham et al., 1986; Eisen et al., 1986). However, the evidence proposed by these studies seems insufficient. In the present study, we extensively investigated the distribution of P9 over the body surface

and analyzed its origin by precisely applying the theory of the junctional potential.

2. Subjects and methods

We studied P9 distribution in 4 healthy volunteers without neurological abnormalities. Informed consent was obtained from all subjects. The left median nerve was stimulated at the wrist at a rate of 5 Hz. The potentials were picked up by EEG disc electrodes and amplified and filtered between 5 and 1500 Hz (–3 dB). Two thousand responses were averaged, over an analysis time of 50 ms, using a signal processor DP1100 (NEC Sanei). Two averages were superimposed. Multiple recording electrodes were placed over the wide area of the body such as head (Cz), neck (C2S and C6S), trunk and leg (Kc and Ki, knee electrodes contralateral and ipsilateral to the stimulation). Truncal electrodes were placed at the following two levels: BKc, BKm and BKi electrodes were placed over the contralateral, midline and ipsilateral back surface at the level of the inferior angle of the scapula. ICc, L4S and ICi electrodes were

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placed at the level of the iliac crest, contralaterally, midline and ipsilaterally, respectively. A common reference electrode was placed over the shoulder contralateral to the stimulation.

3. Results

A typical distribution in a subject is shown in Fig. 1. The Cz electrode over the scalp registered 3 positive far-field potentials, P9, P11 and P13/14. P9s were recorded at Cz, posterior neck (C2S and C6S) and EPc (contralateral Erb's point) electrodes. The amplitude of the P9 potentials was almost equal for Cz and C2S electrodes, whereas it was slightly smaller at C6S. Trunk and leg electrodes registered negative potentials of the same peak latency as P9, which was labeled as tN9 (truncal N9) in order to distinguish it from N9 at Erb's point. The amplitude of tN9 was equal for electrodes at the iliac crest level (ICc, L4S and ICi) and for bilateral knee electrodes. BKi electrode registered a larger tN9, which was thought to be due to spread of the near-field potential of the nerve volley at axilla.

In summary, a dipolar potential distribution, P9/tN9 was formed over the body surface. The boundary between two polarities seemed to run between neck and trunk.

4. Discussion

P9 in median nerve SEPs is a typical far-field potential, in the sense that it is generated when both active and reference electrodes are located far away from the traveling action potentials. In general, far-field potentials are thought to be generated either by postsynaptic potentials or by the mechanism of the junctional potential (Kimura et al., 1986). We can easily deny the possibility that P9 is generated by postsynaptic potentials, because there are no synapses around the brachial plexus, the assumed origin of P9.

Previous investigators have proposed following 4 situations as the generating mechanism of the junctional potential: (1) an abrupt change of the size of the volume conductor surrounding the nerve trunk (Kimura et al., 1983, 1986), (2) a change of the conductivity of the volume conductor (Nakanishi, 1982), (3) a change of the direction of the nerve propagation (Desmedt et al., 1983; Nakanishi et al., 1986) and (4) the termination of the action potential propagation (Dumitru and Jewett, 1993). A number of simulation studies gave a theoretical basis to the above hypotheses and further clarified the characteristics of the junctional potential (Stegeman et al., 1987; Dumitru and Jewett, 1993). It is important to make use of these achievements when discussing the origin of P9, which is supposed to be a junctional potential, as we did when we demonstrated that P15 in tibial nerve SEPs is a junctional potential (Sonoo et al., 1992).

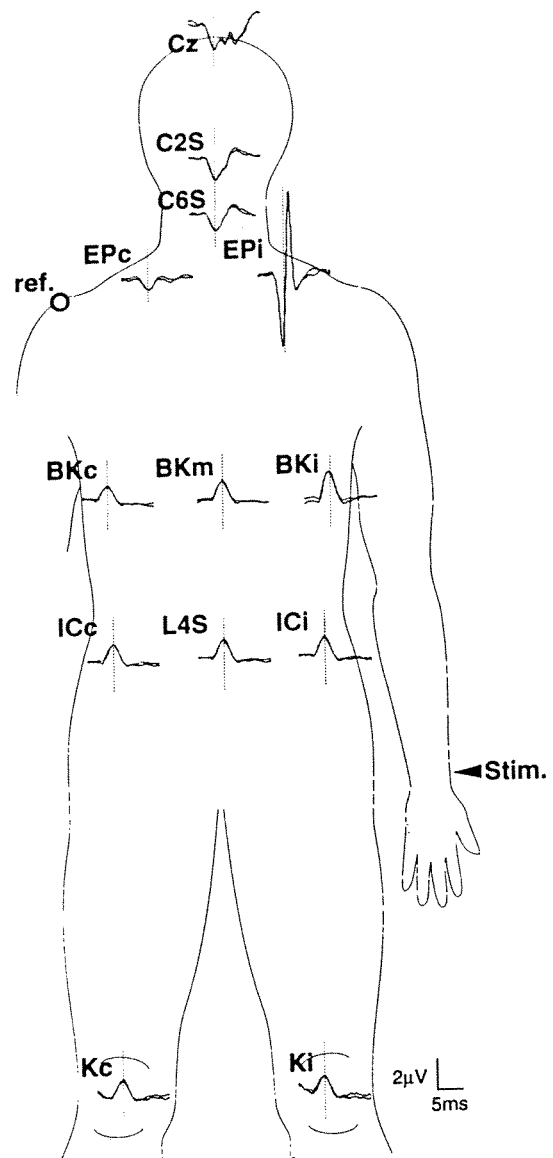


Fig. 1. Distribution of P9/tN9 over the body surface in a normal subject. Left median nerve was stimulated at the wrist. A common reference electrode was placed at the contralateral shoulder. P9 was distributed over the head and neck. tN9 was distributed over the trunk. The boundary between two polarities ran between trunk and neck. The peak latencies of P9 and tN9 (vertical dotted line) were the same. The amplitude of the P9 potentials were almost the same for Cz and C2S electrodes, whereas that at C6S was slightly smaller. The amplitude of tN9 was the same for electrodes at the iliac crest level (ICc, L4S and ICi) and for bilateral knee electrodes, whereas BKc electrode registered a slightly smaller tN9. BKi electrode registered a larger tN9, which was thought to be due to a spread of the near-field potential of the nerve volleys at the axilla. The amplitude of the P9 potentials were almost the same for Cz and C2S electrodes, whereas that at C6S was slightly smaller. EPI, ipsilateral Erb's point; EPc, contralateral Erb's point; BKc, back contralateral to the stimulation; BKm, back in the midline; BKi, back ipsilateral to the stimulation (these electrodes were placed at the level of the inferior angle of the scapula.). ICc, contralateral iliac crest; ICi, ipsilateral iliac crest; Kc, knee contralateral to the stimulation; Ki, knee ipsilateral to the stimulation.

There have already been a number of attempts to interpret P9 as a junctional potential. One major opinion has been that P9 is generated due to a change of the volume conductor

size between arm and trunk (Yamada et al., 1985; Cunningham et al., 1986; Eisen et al., 1986). However, this hypothesis is not supported by the result of the simulation study (Stegeman et al., 1987). That is, when the traveling action potentials enter from the arm, having a smaller size, into the trunk, having a larger size, the arm should become positive while the trunk should become negative. As the boundary regarding this junctional potential exists between arm and trunk, head/neck/truncal electrodes all belong to the same truncal compartment and, hence, should have the same potential (Kimura et al., 1986). However, this deduction completely disagrees with our observation that head and neck electrodes register P9 whereas truncal electrodes register tN9. In this way, we can deny the hypothesis that P9/tN9 is formed by the change of the volume conductor size between arm and trunk.

Frith et al. (1986) are the only investigators who expressed an opinion that P9 is generated due to a change of the volume conductor size between trunk and neck. They came to this conclusion by comparing the latency of P9 with those of traveling nerve volleys. We agree with their opinion based on our present study which revealed the following 4 facts.

First, P9/tN9 had a constant latency irrespective of the electrode position, which means that they represent a standing potential. A standing potential should be either a junctional potential or a postsynaptic potential and not a conducting potential having shifting latencies depending on the electrode position (Kimura et al., 1986). P9 must be a junctional potential, because it cannot be a postsynaptic potential as already mentioned.

Secondly, P9/tN9 showed a dipolar distribution over the body surface. The boundary between two polarities seemed to run along the border between neck and trunk. That is, the body was divided into two compartments, head/neck part and truncal part, regarding this dipolar potential, which is a well-known characteristic of the junctional potential (Kimura et al., 1986; Stegeman et al., 1987).

Thirdly, far-distant knee electrodes registered tN9 potentials as large as those at rostrally-situated truncal electrodes. That is, these electrodes belonging to the same compartment of the trunk were iso-potential. This is also a characteristic of the junctional potential (Kimura et al., 1986). Dumitru and Jewett (1993) showed that a junctional potential field is distributed uniformly within a columnar compartment as long as the distance from the boundary exceeds 1.9 radii of the column. This agrees well with our observation that knee electrodes and electrodes at the iliac crest level were iso-potential whereas the BKc electrode, an electrode least contaminated by the axillary near-field potential among 3 electrodes at this level, registered a slightly smaller tN9 potential, considering that the line of 1.9 radii from the boundary between trunk and neck is supposed to run between BKc at the level of inferior angle of scapula and iliac crest.

Lastly, the polarity of P9/tN9 agreed with that expected

from simulation studies regarding the junctional potential generated by the change of the volume conductor size. That is, the smaller part (head and neck) should become positive compared to the larger part (trunk) (Stegeman et al., 1987).

All these facts are sufficient evidence for our opinion that P9 is a junctional potential generated by the change of the volume conductor size between trunk and neck.

Finally, we must mention the study of Hashimoto et al. (1992) who gave a quite different explanation for the mechanism of P9 generation. They investigated the potential field distribution over the body using a reference electrode placed on the contralateral knee and found that an electrode near axilla showed a negative potential, truncal electrodes zero, and head and neck electrodes positive. They suggested that these potentials are generated, as a near-field potential, by the electrical current derived from the conducting potentials just entering into the trunk. We indeed recorded the most negative potential at BKi electrode near axilla and interpreted that this is due to a contamination of the nerve volleys at axilla. However, their theory can never explain the observed fact that head electrodes which are far distant from the positive source of the current dipole are more positive than neck electrodes, such as C6S, even though it can explain equal potentials between head and neck electrodes as they did.

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