Polarity reversal of N20 and P23 somatosensory evoked potentials between scalp and depth recordings

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Summary From depth and scalp electrodes, we recorded MN-SSEPs of a 33-year-old man with right parietal dysfunction and refractory right temporal seizures. A depth lead with 8 electrodes was implanted deep in each parietal-temporal region. Stimulation and recording parameters followed American EEG Society guidelines. Scalp recordings had well-defined P9, P13-14, N18, N20, and P23 potentials with normal conduction times bilaterally. Depth recordings showed potentials of greater number, voltage, and coherence. P13-14 and N18 were recorded at all depth sites with latencies similar to those at the scalp. N18 had markedly greater voltage and duration near the thalamus, with multiple fast components on its ascending phase. In the deep parietal region there was a positivity corresponding to the scalp N20 and a negative potential equal in latency to scalp P23. These findings support an origin of P13-14 caudal to the thalamus, multiple thalamic and possibly rostral brain-stem generators for N18, and generation of N20 and P23 in sensory cortex or subjacent white matter.

Key words: Somatosensory evoked potentials; Median nerve; Depth recording; Generator sources: N20; P23

Despite the clinical utility of short-latency median nerve somatosensory evoked potentials (MN-SSEPs), their generator sources are incompletely understood. The origin of even the N20 potential, one of the principal SSEP components measured in clinical applications, remains controversial after numerous investigations. The N20 is the earliest localized scalp negativity and is restricted to the parietal region contralateral to stimulation, features that suggest an origin in the somatosensory cortex. But some clinico-pathologic correlations (Chiappa et al. 1979; Goldie et al. 1981) imply an N20 generator at the level of the thalamus.

During evaluation of a candidate for epilepsy surgery, we recorded MN-SSEPs from depth electrodes in the parietal and temporal lobes and compared them to the corresponding scalp activity. We found a polarity reversal of the scalp N20 and P23 at deep parietal electrodes, consistent with a cortical rather than thalamic origin of these components.

Methods and material

The subject was a 33-year-old right-handed man undergoing presurgical evaluation of refractory partial seizures of right temporal lobe origin. Seizures began at age 7 years without known etiology. Neurological examination showed right parietal dysfunction, including constructional apraxia, left inferior quadrantanopsia, impaired discriminative sensation on the left side, and decreased alternating motion rate of the left hand. Brain CT showed mild right hemispheric atrophy. Positron emission tomography demonstrated focal hypometabolism in the right temporal-parietal region. A multi-electrode multiple conductor depth lead was implanted stereotaxically in each parietal-temporal region for depth electroencephalography (Fig. 1). Each lead was constructed of polyurethane tubing with 8 stainless steel electrodes connected by means of fine Teflon-coated stainless steel wire to independent pins mounted in the connector at the lead’s proximal end. The electrodes were 2.5 mm in length and separated by 2.5 mm of polyurethane tubing.

MN-SSEPs were recorded from the depth electrodes 3 days following their implantation. Four-channel re-
cordings were obtained on a Grass Model 10 system. Amplifier gain was 24,000, and amplifier bandpass was 30–3000 Hz (−3 dB) with filter roll-off slopes of 12 dB/octave. The analysis time was 51.2 msec with 1024 data points/channel, giving a dwell time of 50 μsec. Amplitude resolution of A/D conversion was 8 bits.

Each average consisted of 1024 samples, repeated at least once for each derivation to assure coherence. Depth electrodes were designated 1 through 8 in sequential order from the distal tip of each depth lead, and referenced to a disk electrode affixed with collodion to the shoulder opposite the stimulated side. MN-SSEPs were

Fig. 1. A: lateral skull film shows position of the depth leads in the parietal and temporal lobes along a dorsoposterior to ventroanterior axis. The 8 electrodes on each lead are discretely visible on plain X-ray but not distinguishable from other lead components on CT. B: axial CT at the level of the ventral thalamus, showing depth leads in cross-section at the left no. 4 and right no. 5 electrodes. CT is without contrast infusion, and right hemisphere is displayed on left side. C: axial CT at the level of the dorsal thalamus, in the highest plane where depth electrodes (left no. 7 and right no. 8) are situated bilaterally.
also recorded from scalp, cervical, and Erb's point (EP) electrodes attached with collodion, using the same technique and instrumentation as for depth studies, and in accordance with American EEG Society guidelines (1984). Electrode impedances were maintained below 5000 $\Omega$.

The stimulus was a 200 $\mu$sec square wave generated by a constant current stimulator at a rate of 5.1 Hz. Each wrist was stimulated independently at an intensity sufficient to produce a vigorous thumb twitch. Stimulating electrodes were standard EEG disks with impedances below 10 k$\Omega$, placed with the cathode 2 cm proximal to the anode. The ground was a plate electrode on the volar forearm.

Results

Scalp recordings demonstrated good definition and coherence of all potentials on stimulation of either median nerve (Fig. 2). All peak latencies and conduction times were within normal limits (Table I).

Depth recordings showed potentials of greater voltage and complexity with a high degree of reproducibility (Fig. 3). Potentials similar in latency and polarity to the scalp-recorded P13–14 and N18 were present in all 16 depth derivations. N18 had markedly greater voltage, duration, and complexity at electrodes closest to the thalamus (electrodes 5 and 6). Numerous fast components appeared on the ascending phase of N18 in these derivations. The most dorsal electrodes (left no. 6, and nos. 7 and 8 bilaterally) were situated in or near the deep parietal region on each side. In these derivations, there were 2 potentials that immediately followed N18 and were equal in latency but opposite in polarity to the scalp-recorded N20 and P23 (Fig. 4). Voltage and distribution of these ‘P20–N23’ depth potentials were greater in the left parietal recordings. In right hemisphere depth and scalp recordings, the wave forms following N18 corresponded less clearly, although polarity reversal of the N20 potential was discernible. The apparent attenuation of ‘P20’ and ‘N23’ potentials in right parietal depth recordings may be due to asymmetric placement of the leads. However, the patient’s right parietal dysfunction does suggest the possibility that this interhemispheric asymmetry in the depth recordings represents an abnormality that is not detectable in scalp recordings.

![Fig. 2. Scalp SSEP recordings on right (A) and left (B) median nerve stimulation.](image-url)
TABLE I

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<thead>
<tr>
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<th>Peak latency (msec)</th>
<th>Conduction time (msec)</th>
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<tr>
<td></td>
<td>Left</td>
<td>Right</td>
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<tr>
<td>EP</td>
<td>10.9</td>
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<tr>
<td>N13</td>
<td>14.6</td>
<td>16.1</td>
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<tr>
<td>N20</td>
<td>20.2</td>
<td>21.6</td>
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<tr>
<td>P23</td>
<td>22.2</td>
<td>24.3</td>
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Discussion

With non-cephalic reference, in the first 18 msec following median nerve stimulation at the wrist in normal adults, similar wave forms are recorded from electrodes placed widely over the scalp (Desmedt and Cheron 1981b; Emerson and Pedley 1984). These consist of P9, P11, P13–14, and N18. Two wave forms, N20 and P23, can only be recorded from the parietal area contralateral to the stimulated side.

The onset of P9 precedes the potential recorded at Erb's point and represents a stationary far-field potential arising as the afferent volley reaches a site under the lateral part of the clavicle (Cracco and Cracco 1976; Desmedt et al. 1983). The P11 latency corresponds to that of N11 recorded over the posterior aspect of the
Fig. 4. Comparison of post-N18 components of scalp and depth SSEPs. Left cerebral hemisphere recordings during right median nerve stimulation.

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