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SOMATOSENSORY EVOKED POTENTIAL IN MAN: FAR FIELD POTENTIALS *

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In ear reference recordings, the first event in the complex scalp-recorded somatosensory evoked potential to median nerve stimulation in normal adults consists of a small positive potential with a peak latency of 13–17 msec (Goff et al. 1962, 1969; Broughton 1969; Cracco 1972). This potential is distributed widely over the scalp. Its maximal potential is around the vertex and at parasagittal recording locations contralateral to the stimulated median nerve (Cracco 1972). The scalp distribution, positive polarity and short latency of this potential are consistent with a response arising in subcortical regions. Recently, two positive potentials preceding this component have been observed in scalp referential recordings where the reference electrode was placed on the dorsum of the hand or antecubital fossae contralateral to the side of stimulation (Cracco, in press).

In this study further observations on these short latency potentials were made. Additionally, ear and hand reference recordings of the median nerve evoked response recorded over the cervical spine were obtained and compared.

Methods and materials

Observations were made on 11 normal adult volunteers (4 females, 7 males) ranging in age from 17 to 30 years. Subjects relaxed in a comfortable reclining chair in a quiet room. Stimulating electrodes were attached over the right median nerve just proximal to the wrist. These consisted of tin discs (7 mm in diameter) attached to the skin with collodion and filled with conductive jelly. The cathode was placed 3 cm proximal to the anode. Stimulation pulses (duration 0.2 msec) were generated at rates of 9–10/sec. The stimulus intensity was adjusted to produce a small twitch of the thumb.

Recordings were made from tin disc electrodes (7 mm in diameter) attached with collodion to the nose, inion, left and right ear (A_1 and A_2) and vertex (C_z) (International 10–20 system) and filled with conductive jelly. Recording electrodes were also placed on the dorsum of the left hand or styloid process of the left wrist contralateral to the stimulated right median nerve. Electrode impedance was maintained between 1500 and 3000 Ω. Hand or wrist reference recordings were obtained from C_z, A_1, A_2, nose and inion. C_z–A_1 and C_z–A_2 recordings were also performed. Recording electrodes were also placed over the stimulated right median nerve in the forearm and 2 cm proximal to the axilla and over the right branchial plexus at Erb's Point. Bipolar recordings (interelectrode distance 3 cm) and left hand, wrist or knee reference recordings were performed. Additionally, recording electrodes were placed over the fifth and second cervical spines and referential recordings in which the left or right ear or left hand or wrist served as the reference electrode were obtained and compared. In 2 subjects scalp, ear and cervical spine referential recordings were performed where the left knee served as the reference site. In both these subjects left hand–left knee recordings were also obtained.

Input from the recording electrodes was led to differential amplifiers and the output was summated by a computer and then recorded by an X–Y plotter *. The frequency response of the recording apparatus was 10–2500 c/sec (–3 dB). Analysis times of 20 msec were used and 1024, 2048 or 4096 responses were summated. The computer horizontal resolution was 80 µsec per point with 256 points per channel. Two or three summated recordings were superimposed to differentiate time-locked from random components. In all recordings relative negativity in grid 1 resulted in an upward deflection.

The onset and peak latencies of potentials recorded from the scalp, ear, nose and cervical spine were measured and compared. In recordings over the stimulated median nerve and brachial plexus, the onset of the negative potential served as the latency indicator since this is thought to signal the approximate time at which the first impulses contributing to the response pass under the recording electrode in referential leads or the recording electrode nearest the approaching volley in bipolar leads (Gilliatt et al. 1965).

Results

Scalp recordings

In vertex–ear recordings a positive potential peaking at 14.0–16.5 msec was consistently recorded (Fig. 1 and 2). This component was often preceded by inconstant or poorly defined fluctuations. In recordings from the vertex, both ears, inion and nose where the reference electrode was placed on the hand dorsum or wrist, three positive potentials were recorded. In vertex–hand recordings the onset latencies

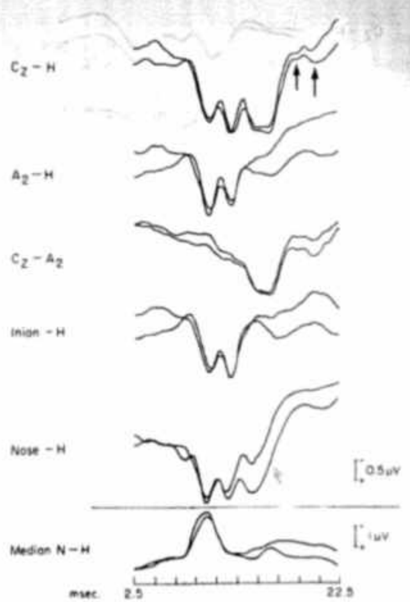

Fig. 1. Evoked potentials to right median nerve stimulation recorded from the vertex (C_z), right ear (A_2), inion, nose and over the median nerve just proximal to the axilla (median N) in reference recordings where reference electrode was placed on the dorsum of the left hand (H) or right ear (A_2). In each recording 1024 or 2048 responses were summated. Two recordings are superimposed in each trace. The analysis time is 20 msec. There is a delay of 2.5 msec between the shock and the sweep onset. Relative negativity in grid 1 results in an upward deflection. Calibration is 1.0 µV for the bottom trace and 0.5 µV for the top 5 traces, as indicated. In hand reference recordings, the response at the vertex consists of three positive potentials with peak latencies of 9.9, 12.0 and 15.5 msec. These potentials are followed by a poorly defined bilobed positive component with peaks at about 18.5 and 20 msec (arrows). In hand reference recordings, the first two positive potentials are similar in amplitude at the vertex, right ear, inion and nose. They are not clearly defined in the vertex–ear lead. In hand reference recordings, the third positive potential is greatest in amplitude at the vertex, smaller at the nose and not clearly evident at the ear or inion. It is well defined in the vertex–ear lead. The latency of onset of the first positive potential recorded from the scalp, nose and ear is similar to that of the negative potential recorded over the stimulated median nerve 2 cm proximal to the axilla (bottom trace) (Subject 6).

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* Details of the instrumentation used can be obtained by writing to the author.

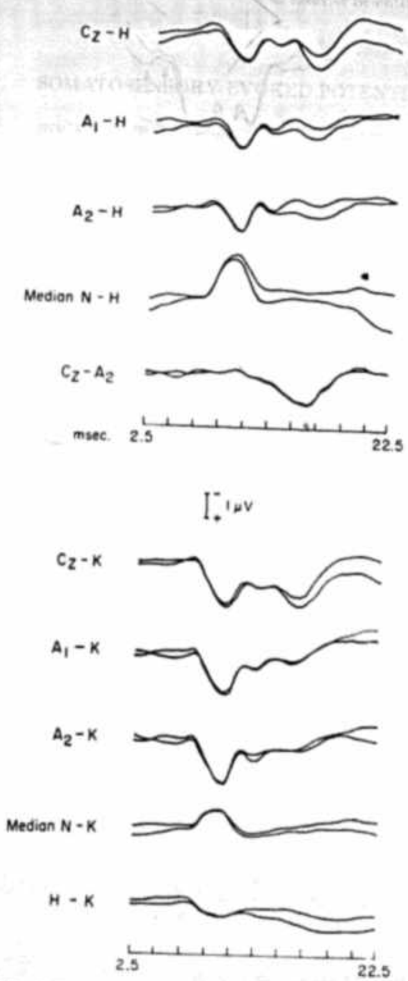

Fig. 2. Evoked potentials to right median nerve stimulation. 2048 or 4096 responses were summated in each recording and two recordings are superimposed in each trace. Three positive potentials are recorded from the vertex and ears in leads where the reference electrode was placed over the dorsum of the left hand (top 3 traces, top set) and left knee (top 3 traces, bottom set). The first two potentials are similar in amplitude at the vertex and ears and are not apparent in the vertex—ear lead (bottom trace, top set). The onset latency of the negative potential recorded over the median nerve 2 cm proximal to the axilla (fourth trace, top and bottom sets) is similar to that of the first positive potential recorded from the vertex and ears. A positive potential is recorded in the hand—knee lead contralateral to the side of stimulation (bottom trace, bottom set) which is similar in onset latency to the first positive potential recorded from the vertex and ears and to the onset latency of the negative potential recorded over the stimulated median nerve just proximal to the axilla (Subject 3).

of these components ranged between 6.5—9.0, 10.0—12.4 and 12.0—14.4 msec, respectively. Their peak latencies were 9.0—11.4, 10.7—13.4, and 14.0—16.5 msec. Differences in onset latency between the first and second and second and third positive potentials were 2.5—4.0 and 1.5—3.1 msec. Differences between their peak latencies ranged between 1.7—2.6 and 2.0—4.0 msec.

In hand or wrist reference recordings, the first two positive potentials were similar in amplitude at the vertex, inion, both ears and nose (Fig. 1 and 2). They were partially fused in some subjects. They were poorly defined or absent in vertex—ear recordings (Fig. 1 and 2). In hand or wrist reference recordings, the third positive potential was consistently greater in amplitude at the vertex than at the inion, nose or ears (Fig. 1 and 2). In some subjects it was poorly defined or absent in recordings from the inion or ears (Fig. 1). It was consistently recorded in vertex—ear leads (Fig. 1 and 2). This component was bilobed in 5 subjects.

A fourth positive potential which was small and often poorly defined was recorded from the vertex in ear and hand reference recordings in 5 subjects. It was bilobed in 4 subjects (Fig. 1). The peak latency of this component was about 19 msec.

Similar results were obtained when the left knee was substituted for the left hand or wrist.

as the reference site in the 2 subjects in whom these studies were performed (Fig. 2). Additionally, in both these subjects, a positive potential of similar onset latency to the first of the positive potentials recorded from scalp, ear and nose in hand reference recordings was recorded in hand—knee leads (Fig. 2).

The onset latency of the first of the positive potentials recorded from the scalp, ears and nose was greater than that of the negative potential recorded over the stimulated median nerve in the forearm, similar to that of the response recorded over the median nerve just proximal to the axilla and less than that of the median nerve evoked response over the brachial plexus at Erb's Point (Fig. 1, 2 and 3).

Recordings over the cervical spine

Cervical—hand or wrist reference recordings yielded an initially positive diphasic or triphasic potential in 6 of the 11 subjects (Fig. 3). Cervical—ear recordings in these subjects were characterized by small upward deflections followed by large broader upward deflections which were bilobed in some subjects (Fig. 3). The latency of the first upward deflection was similar to that of the first positive potential recorded in cervical—hand leads and was also time-locked to the first of the three early positive potentials recorded in ear—hand leads. This suggests that the first upward deflection recorded in cervical—ear leads is a positive potential which is recorded as an upward deflection because the ear (grid 2) is more positive than the cervical region (grid 1) at this time (Fig. 3). In cervical—ear recordings, the beginning of the second upward potential was similar in latency to the second positive potential recorded in ear—hand leads (Fig. 3). The entire second upward potential in cervical—ear leads was also similar in latency to the negative potential recorded in cervical—hand leads (Fig. 3). This suggests that the second upward potential recorded in cervical—ear leads is due to activity recorded by both the cervical electrode (negative potential) and ear electrode (positive potential).

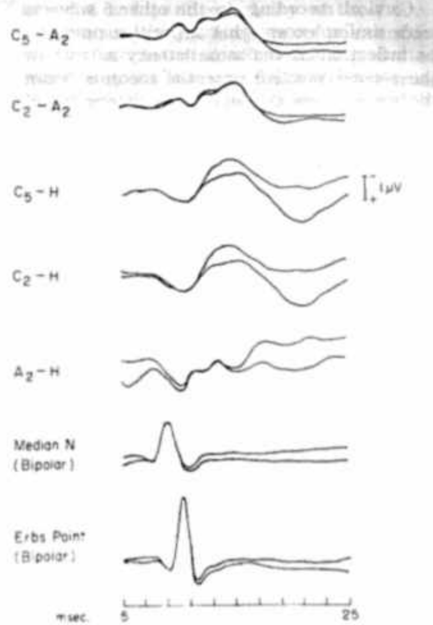

Fig. 3. Right median nerve evoked potentials recorded over the fifth and second cervical spines in ear and hand dorsum reference recordings. 1024 or 2048 responses were summated in each recording. Two recordings are superimposed in each trace. In hand reference recordings the cervical response consists of an initially positive triphasic potential. In cervical—ear leads it consists of a small upward deflection followed by a larger upward deflection which is bilobed. The first upward deflection is similar in latency to the first positive potentials recorded from the ear and cervical spine in hand reference leads. The initial portion of the second upward deflection recorded in cervical—ear leads is similar in latency to the second positive potential recorded from the ear in the hand reference lead. The entire second upward deflection is similar in latency to the negative potential recorded in cervical—hand leads. The latency of onset of the first positive potential recorded from the ear is similar to that of the negative potential recorded over the stimulated median nerve just proximal to the axilla (second trace from bottom) and less than that of the negative potential recorded over the brachial plexus at Erb's Point (bottom trace) (Subject 7).

Cervical recordings in the other 5 subjects were similar except that a positive potential or inflection of the same latency as that of the second positive potential recorded from the vertex, ears and inion was superimposed on the diphasic or triphasic potential recorded in cervical—hand leads. This suggests that this positive potential can be detected by cervical recording electrodes in some subjects. This potential was always more prominent in recordings over the second cervical spine than in recordings over the fifth cervical spine.

Discussion

In vertex, inion, ear and nose referential recordings where the hand dorsum, wrist or knee served as the reference site, three short latency positive potentials were recorded. In some subjects a fourth positive potential was observed. The first two positive potentials were similar in amplitude at the scalp, nose and ear. Therefore they were not well defined in vertex—ear leads because of a cancellation effect. The third positive potential was more prominent at the vertex than at the ear and was consistently recorded in vertex—ear leads.

The short latencies, distribution and positive polarity of these components are consistent with responses arising in subcortical regions. The first scalp recorded evoked potential to median nerve stimulation thought to arise in cerebral elements is a negative potential which has a peak latency of 17—22 msec (Broughton 1969; Allison et al., in press). This latency is greater than that of the first three positive potentials and similar to that of the fourth.

The observation that the onset latency of the first of these positive potentials was similar to that of the evoked response recorded over the stimulated median nerve just proximal to the axilla and less than that of the response recorded over the brachial plexus at Erb's Point suggests that the first positive potential is a volume conducted response arising largely in peripheral nerve fibers. The spinal cord cervical dorsal column may also contribute to it. The observation that a positive potential of similar latency was recorded in hand—knee leads contralateral to the stimulated median nerve demonstrates that far field potentials can be recorded at considerable distances from their generator sources in man using computer averaging techniques.

It seems probable that the second and third positive potentials, which were consistently recorded in all subjects, and the fourth positive potential, which was recorded in some subjects, arise in the brain stem, cerebellum or diencephalon. Since the cuneate and lateral cuneate nuclei, the medial lemniscus, thalamus and the cerebellum are known to receive considerable somatosensory input (Ranson and Clark 1959), it is possible that these potentials reflect, at least in part, activity in some of these structures. Synaptic and post-synaptic activity in the cuneate nuclei and medial lemniscus may be the primary sources for the second positive potential. Similarly, synaptic and post-synaptic activity in the thalamus and thalamocortical radiation may be largely responsible for the third. The fourth potential may arise in the cerebellum or in cerebellar connections. The observations that the second positive potential was similar in amplitude at the ear, nose and scalp and was sometimes recorded from the cervical spine whereas the third potential was more prominent at the scalp than at the nose or ear could be consistent with sources in the brain stem and diencephalon, respectively. The observation that the third positive potential was bilobed in some subjects suggests that this potential has more than one generator source. Potentials evoked by median nerve stimulation which have a latency similar to that of the third positive potential have been recorded in the human thalamus (Ervin and Mark 1964; Albe-Fessard and Liebeskind 1966; Mathews et al. 1970). A cerebellar source may also contribute to this potential. Similar positive potentials, thought to reflect activity arising in brain stem have been recorded from skull overlying

cerebral somatosensory area following forepaw stimulation in rats and cats (Iragui-Madoz and Wiederholt 1976a,b).

Jewett et al. (1970) have recorded multiple positive peaks superimposed on the initial positive potential of the human scalp recorded auditory evoked response. They concluded that these peaks arise in brain stem and auditory structures. There is evidence which suggests that the recording of these auditory evoked potentials in patients with brain stem dysfunction may have diagnostic usefulness (Starr and Achor 1975). Similarly, it is possible that evoked somatosensory far field potentials will also have diagnostic utility.

Evoked responses to peroneal nerve stimulation arising in the cauda equina and spinal cord have been recorded from surface electrodes placed over the lumbar, thoracic and cervical spine of man (Cracco 1973). Similar responses have been recorded from the spinal dura (Ertekin 1973; Cracco et al., in press). Median nerve evoked potentials have also been recorded from the surface and dura over the cervical spinal cord (Cracco 1973; Ertekin 1973; Allison et al., in press; Cracco et al., in press). However, this study provides evidence which suggests that uncontaminated spinal cord evoked responses to median nerve stimulation cannot be recorded from the surface in cervical referential leads where the reference electrodes are placed on the scalp, nose or ear since these sites will record the far field potentials described in the preceding paragraphs whose latencies are similar to those of the cervical spinal response. A far field potential was also recorded from the cervical spine in hand reference leads in some subjects.

Summary

Three short latency positive potentials evoked by median nerve stimulation were recorded from the scalp, nose and ear of 11 normal adult subjects in leads where the hand or knee contralateral to the side of stimulation was used as the reference site. The short latencies and positive polarity of these components suggest that they are volume conducted far field potentials. Evidence is presented which suggests that the first potential arises in peripheral nerve fibers. Brain stem and diencephalic structures are suggested as possible sources for the second and third potentials.

The configuration of the response to median nerve stimulation recorded over the cervical spine in ear and hand reference recordings was different. Evidence is presented which suggests that this occurs because the electrode placed on the ear records the far field potentials described in the above paragraph. A far field potential was also recorded in hand—knee leads contralateral to the stimulated median nerve.

Résumé

Potentiel évoqué somato-sensitif chez l'homme: potentiels transmis à distance

Trois potentiels positifs à courte latence, évoqués par stimulation du nerf médian, ont été enregistrés au niveau du scalp, du nez et de l'oreille chez 11 sujets adultes normaux sur des dérivations où la main ou le genou controlatéraux au côté de la stimulation étaient utilisés comme point de référence. Les latences courtes et la polarité positive de ces composantes suggèrent qu'il s'agit de potentiels transmis à distance par le volume conducteur. Les données présentées suggèrent que le premier potentiel provient des fibres nerveuses périphériques. Il est possible que les structures du tronc cérébral et du diencéphale soient à l'origine des second et troisième potentiels.

La configuration de la réponse à la stimulation du nerf médian enregistrée sur la colonne cervicale en référence à l'oreille et à la main est différente. Les données présentées suggèrent que ceci se produit en raison du fait que l'électrode placée sur l'orielle enregistre les potentiels transmis à distance décrits dans le paragraphe ci-dessus. Un potentiel transmis à distance est également enregistré dans des