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Source

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Abstract

Somatosensory evoked potentials (SEPs) to **median nerve** stimulation were investigated in normal controls and patients with cervical lesions. Attention was paid primarily to the N13 and P13 components in the posterior and anterior cervical records with non-cephalic references. In normal subjects the CV2 and CV6 electrodes registered N13 with almost the same amplitude. Dissociation between N13 at the CV2 electrode (ucN13) and N13 at the CV6 electrode (lcN13) was observed in the patients. In 4 patients with cervical dorsal column lesions, lcN13 was preserved but ucN13 was almost completely absent. Anterior cervical P13 (acP13) was preserved. In a patient with syringomyelia, lcN13 and acP13 were greatly attenuated while ucN13 was relatively well preserved. These results suggested that the origins of ucN13 and lcN13 are different. The generator of lcN13-acP13 was assumed to be the postsynaptic potential of the dorsal horn interneurons. Upon comparison with previous animal studies and intraoperative studies, it was concluded that the generator of ucN13 is the postsynaptic potential of the cuneate nucleus.

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Posterior cervical N13 in median nerve SEP has two components

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Summary Somatosensory evoked potentials (SEPs) to median nerve stimulation were investigated in normal controls and patients with cervical lesions. Attention was paid primarily to the N13 and P13 components in the posterior and anterior cervical records with non-cephalic references. In normal subjects the CV2 and CV6 electrodes registered N13 with almost the same amplitude. Dissociation between N13 at the CV2 electrode (ucN13) and N13 at the CV6 electrode (lcN13) was observed in the patients. In 4 patients with cervical dorsal column lesions, lcN13 was preserved but ucN13 was almost completely absent. Anterior cervical P13 (acP13) was preserved. In a patient with syringomyelia, lcN13 and acP13 were greatly attenuated while ucN13 was relatively well preserved. These results suggested that the origins of ucN13 and lcN13 are different. The generator of lcN13-acP13 was assumed to be the postsynaptic potential of the dorsal horn interneurons. Upon comparison with previous animal studies and intraoperative studies, it was concluded that the generator of ucN13 is the postsynaptic potential of the cuneate nucleus.

Key words: Somatosensory evoked potential; Median nerve; N13; Cuneate nucleus

Short-latency somatosensory evoked potentials (SEPs) to median nerve stimulation are now widely used in clinical practice. However, not all the generators of individual components have been identified. In particular, there has been much debate about the origin of the so-called 'N13' component of the cervical-scalp recording. The dorsal horn of the cervical spinal cord (Jones 1977), the dorsal column (Cracco 1972, 1973; Lesser et al. 1981) and the cuneate nucleus (Jones 1977; Hume and Cant 1978; Leandri et al. 1981; Favale et al. 1982) were all postulated as the generator of N13 in cervical-scalp records.

Cracco and Cracco (1976) first recorded SEPs with a non-cephalic reference. They noted that the scalp electrodes which had been used as reference in previous studies, such as the frontal electrode, were also active when recorded with a non-cephalic reference. A negative potential (N13) was recorded at the cervical electrode with a non-cephalic reference, while a positive potential (named P13, P13–14 or P14 by various authors) is recorded simultaneously at scalp electrodes. At first, cervical N13 and scalp P13–14 were thought to be generated by the same generator (Jones 1977; Yamada et al. 1980).

Using esophageal recording, Desmedt and Cheron (1981) found a prevertebral P13 which represented phase reversal of N13 at the posterior cervical electrodes. They interpreted this N13–P13 dipole to be the postsynaptic potential of the dorsal horn interneurons and argued that it should be differentiated from the scalp P14 which originates in the medial lemniscus. Later they found that the prevertebral P13 can also be recorded from the skin surface of the anterior neck region (Desmedt and Huy 1984).

Although their opinion is now widely accepted, an animal study pointed out the dual origin of the posterior cervical N13, that is, one part from the interneurons of the dorsal horn and the other

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from the cuneate nucleus (Allison and H
However, these authors used a fronta
and this point has not been clarified
with a non-cephalic reference. The a
study is to investigate the dual nat
posterior cervical N13 with a non-cep
ence in clinical cases where a dissoci
the two components was expected fr
and MRI (magnetic resonance imaging

Subjects

We studied 17 normal volunteers
tory of neurological disease and 5
patients. Informed consent was obtai
subjects. Normal subjects were divi
groups according to age: the young
men and 3 women) had a mean age
(23–32 years) and the older group (r
and 3 women) had a mean age of
(65–81 years).

Patients were divided into 2 grou
to the site of the lesion. Table I pres
the clinical details of the patients.

Cases 1–4 had cervical dorsal co
above the entry zone of the median n

TABLE I

Case no.	Age	Sex	Diagno
1	62	F	cervica
2	66	F	rheum atlant disloca
3	19	M	myelit
4	29	F	multi
5	40	M	postt syring

placed over the index finger and the antidromic SNAP was shown on an oscilloscope. Then, the stimulus intensity was further regulated so that the amplitude of the SNAP would exceed at least half of the maximal amplitude. It was confirmed in some normal subjects that stronger stimulation would produce little change in the amplitude of the posterior cervical N13. The stimulus which produced the SNAP with the maximal amplitude was rather painful.

Disk electrodes were placed at the following sites. The CV6 electrode was placed over the spinous process of the CV6. The 'CV2' electrode was placed at the midpoint of the inion and the CV6 electrode taking into consideration that the spinous process of the CV2 was hardly felt in some subjects. The anterior cervical electrode (AC) was placed contralateral to the stimulated side 5 cm from the midline at the midpoint of the rostro-caudal length of the neck. This deviation was employed because the root spike (which continues from N9) interferes considerably with the midline electrode (Desmedt and Huy 1984). Other electrodes included Fz, contralateral hand sensory area (named 'HS') and inion. The non-cephalic reference electrode (NC) was placed on the contralateral shoulder.

Evoked potentials were amplified and filtered between 5.3 and 1500 Hz (− 3 dB). Averaging was performed on 2000–3500 responses over an analysis time of 50 msec, using a sampling rate of 10,000 Hz. Two averages were superimposed. Samples showing excessive artifact were rejected on-line from the average. As a rule, bipolar montages were obtained directly by measuring potential difference between two electrodes, although off-line subtraction between two waves of non-cephalic reference was substituted in some cases.

Results

Normal subjects

Left median nerve stimulation was performed in all subjects. Right median nerve stimulation was performed in 6 subjects. Because the latter response was generally of poor quality due to ECG artifact, we considered primarily the records to left median nerve stimulation.

An example of wave forms in a normal subject is shown in Fig. 1. Both in CV2 and CV6 leads with non-cephalic reference, P9 far-field potential and subsequent negativity were noted in all sub-

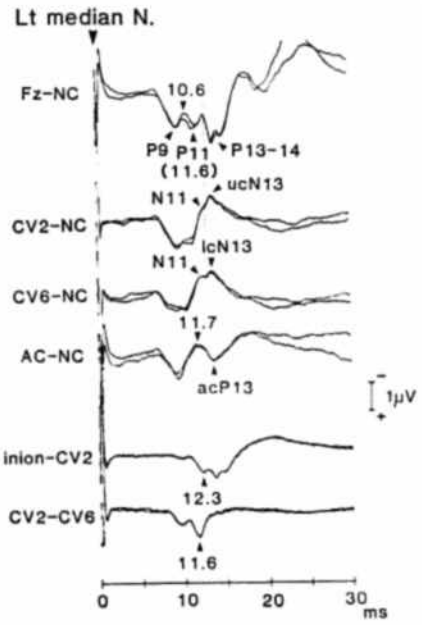

Fig. 1. A normal control (25-year-old male). The upper 4 traces are recorded with non-cephalic reference. The lower two traces are bipolar records. Both the CV2 and CV6 electrodes register N13 potentials and preceding N11 potentials. N13 at the CV2 electrode is named ucN13 and N13 at the CV6 electrode is named lcN13. The amplitude of ucN13 is almost the same as or slightly larger than that of lcN13. P13 is present at the anterior cervical (AC) electrode, which is named acP13. A scalp electrode (Fz) registers 3 far-field potentials: P9, P11 and P13–14. The onset of P11 is earlier than that of acP13. Two bipolar leads show peaks traveling caudo-rostrally which correspond to scalp P11. The termination of the scalp P11 coincides with the termination of N11 at posterior cervical electrodes (dashed line). Figures represent latencies expressed in milliseconds.

jects. This negative potential was a composite of N11 and N13, althc could not be discerned in some sub as is discussed later, N13 was co termine the main configuration of especially its peak and descend named N13 in the CV2 lead 'ucN1 cal N13) and N13 in the CV6 lead cervical N13).

In the anterior cervical (AC) le were identified in all subjects. The cal P13 was named 'acP13' (anteri in order to distinguish it from th far-field potential. In scalp lead P13–14 far-field potentials were n We discerned the following two c P11, which were employed as the presence of P11 in clinical cases. of P11 invariably preceded the Second, bipolar derivations from inion-CV2 showed the traveling sponding to P11, which was sup ascending dorsal column volley Cheron 1980; Favale et al. 1982).

In order to quantify the abno we tried to evaluate its amplitud and N13 overlapped in the poste ords, we could only measure the tudes of N11 + N13. This, howev a rough estimate of the amplitude the dominant component. The m ing the N11 + N13 amplitude is 2. The results are shown in Fi subjects, the amplitude of N11 + the same in the CV2 and CV6 greater in the former. Although o significantly smaller amplitude. ratio of the amplitude of N11 + constant irrespective of age.

Patients

In each of the 4 patients with lesion (Figs. 4A, 5A, 6A and 7A), electrode (ucN13) was almost c while the CV6 electrode registere negative potential which was tho lcN13 (later discussed). Both N1 could definitely be identified in

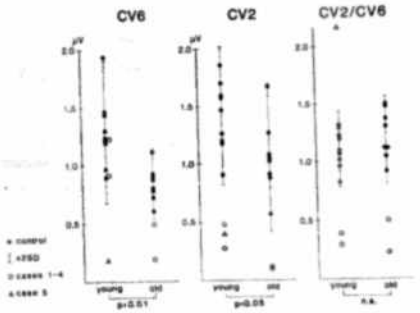

Fig. 3. The amplitude of N11+N13 at the CV6 and CV2 electrodes and the CV2/CV6 ratio of the amplitude of N11+N13 are shown. Closed circles represent normal subjects. Young and old subjects are considered separately. Old subjects have significantly smaller amplitudes at both the CV6 and CV2 electrodes, but the amplitude ratio is constant irrespective of age. Open circles represent patients with a dorsal column lesion (cases 1–4). They clearly have small amplitude ratios. Open triangles represent case 5. He has a large amplitude ratio. Case 5, who is 40 years old, is included in the young group.

In 3 other cases (Figs. 5A, 6A and 7A), definite P11 scalp far-field potentials with earlier onset than that of acP13 were present. As for the later components, delayed P13–14 was noted in case 4 (Fig. 7A) and delayed N20 potentials were noted in cases 2 and 4 (Figs. 5A and 7A).

In case 4, a patient with long-standing multiple sclerosis, who had a clear but delayed P13–14 at the scalp electrodes, a rather flat negativity, probably intercalated by P13–14, was noted at the CV2 electrode, which was assumed to be a delayed ucN13 (Fig. 7A).

In a patient with a cervical grey matter lesion (case 5, Fig. 8A), both acP13 and lcN13 had very small amplitudes. It was judged that the negative potential at the CV2 electrode mainly represented ucN13 and not N11 since its peak was behind the termination of the scalp P11 (see the following section). The ucN13 was also attenuated but was relatively well preserved in comparison with lcN13. The CV2/CV6 ratio of the amplitude of N11+N13 was therefore higher than in normal subjects (Fig. 3). Scalp far-field potentials were normal in this patient.

Discussion

Some remarks on wave identification

As is mentioned above, the posterior cervical negative wave with non-cephalic reference is thought to be composed of N11 and N13. In order to discuss N13 at all, one must be able to identify N11 and N13 separately.

N11 is thought to be generated by the near-field potential of the ascending dorsal column volley (Desmedt and Cheron 1980). Therefore, the duration of N11 must be relatively short, reflecting the time for the impulses to go up the dorsal column. In normal subjects where two peaks of N11 and N13 could be clearly distinguished, termination of N11 coincided with the termination of scalp P11 (Fig. 1), which supports the theory that the scalp P11 sees the approaching front of depolarization of the dorsal column volley (Desmedt and Cheron 1980). The peak of N13, which usually represented the major peak of the overall negativity, existed behind the termination of N11 and scalp P11 (Fig. 1). In subjects where the two peaks could not be discerned, the peak of the overall negativity was also behind the termination of scalp P11.

From these findings, the authors concluded that the peak and the gentle descending slope of the posterior cervical negative potential are free from the influence of N11 and represent principally N13. N11 was thus estimated as a rather small potential located on the ascending limb of N13. This opinion agrees with Desmedt and Cheron (1980) and is also supported by the findings with epidural recording (Berić et al. 1986). On this ground, N13 was judged to be lost when the characteristic broad descending slope was lost, such as in the CV2 electrodes in present cases 1–4. Conversely, N13 was most probably preserved when the broad descending slope was preserved, although of small amplitude, such as at the CV6 electrodes in cases 1 and 2. It seems unlikely that N11, which was originally a small steep potential analogous to a sensory nerve action potential, would assume such a clear prolonged shape even if it was metamorphosed. Moreover, if the negative potential is interpreted as N11, it is difficult to explain the fact that acP13, which is thought to be the counterpart of the posterior cervical N13

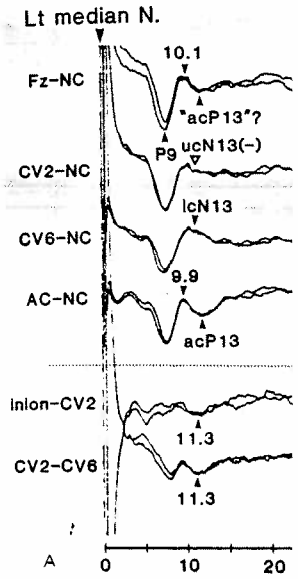

Fig. 4. Case 1. A 62-year-old woman with amplitude. N13 at CV2 (ucN13) is absent, which resembles acP13. This is not though bipolar leads do not show traveling of the

(Desmedt and Cheron 1981), is pre cases.

Two generators of N13

The present study revealed that at CV2 and CV6 electrodes are of a size in normal subjects. However, trode is far from the level of the entry where Desmedt and Cheron strated that prevertebral P13 has i plitude. In the present clinical cas between N13 potentials in the hig terior cervical electrodes was ob patients with cervical dorsal colur at the CV6 electrode (lcN13) wa though N13 at the CV2 electroc

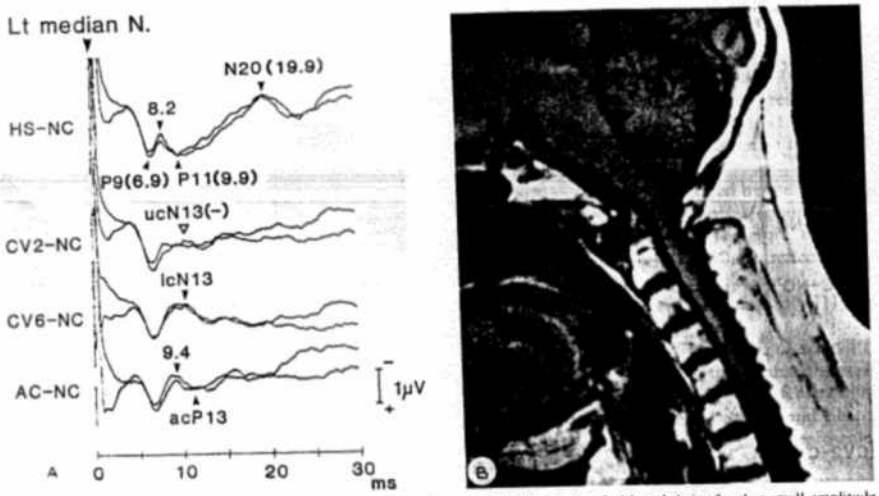

Fig. 5. Case 2. A 66-year-old woman with atlanto-axial dislocation. A: lcN13 is preserved although it is of rather small amplitude. ucN13 is absent. acP13 is preserved. The electrode at the contralateral hand sensory area (HS) registers P11 and N20. P13–14 is absent. P11 has a rather broad configuration. Its onset precedes the onset of acP13. N20 is delayed in this short-stature patient since P9-N20 interpeak latency is clearly prolonged (13.0 msec. Average and standard deviation of normal subjects; 10.36 ± 0.65 msec, n = 17). B: sagittal section of MRI showing posterior compression of the spinal cord at the C1–2 level due to the displaced posterior arch of the atlas.

possibility to explain the above results is that a subclinical partial disturbance of each generator is present in such cases.

It seems clear that the generator of lcN13–acP13 is the postsynaptic potential of the dorsal horn interneurons which was studied by Desmedt and Cheron (1981). The generator of ucN13 is assumed to be located more rostrally. Its location should be at or above the C1–2 level since it was lost in cases 2, 3 and 4 with lesions at the C1–2 level. In normal subjects, the latency of ucN13 is the same or just less than that of the scalp P13–14, the main generator of which is now accepted to be the medial lemniscus. Therefore, its generator should be caudal to the medial lemniscus since it is supposed that no sensory impulses ascend more rapidly than in the dorsal column-lemniscal system. Considering these two facts, the location of the ucN13 generator must be between the C1–2 level and the medial lemniscus. The most conspicuous anatomical structure of the sensory system near there is the cuneate nucleus. The authors therefore considered the cuneate nucleus as the first candidate for the ucN13 generator.

The potential generated by the cuneate nucleus — review of the literature

Therman (1941) first described in cats a negative-positive biphasic potential at the dorsal aspect of the cuneate nucleus when the peripheral nerve was electrically stimulated. Andersen et al. (1964) recorded a similar potential and studied it in detail. The slow negative potential was shown to have its maximal amplitude precisely over the dorsal aspect of the cuneate nucleus. The results of depth recording led them to conclude that the negative potential reflects the EPSP of the neurons of the cuneate nucleus produced by the dorsal

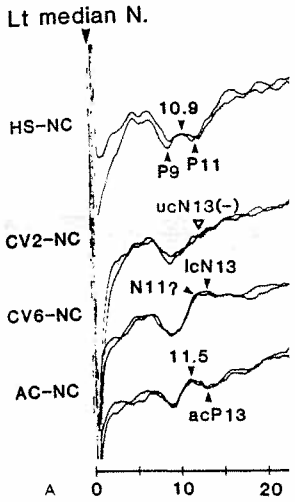

Fig. 6. Case 3. A 19-year-old man with myo
steep N11 peak and subsequent lcN13. ac
sagittal section of MRI (T_2 intensified im
intensified imag

column afferent impulses. Allis
(1981) and Kaji et al. (1986)
similar potential. Kaji et al. (19
electrical dipole around the c
dorso-caudally negative and vent
tive.

Allison and Hume (1981) a

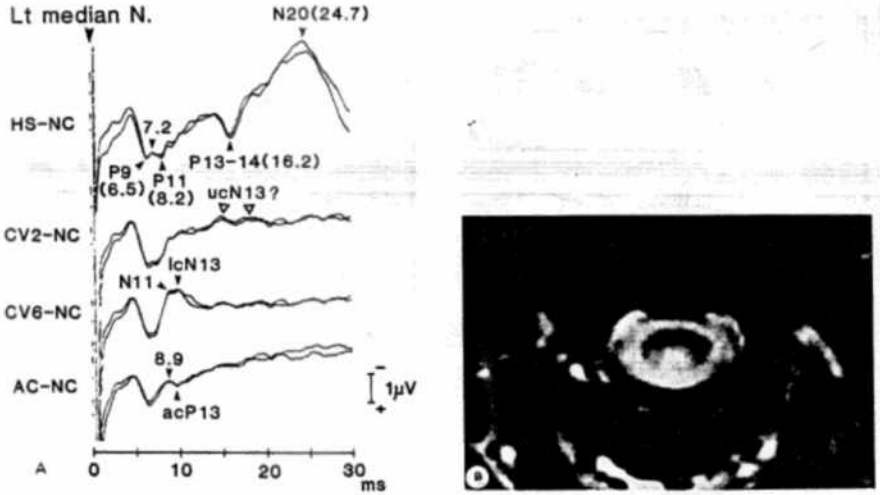

Fig. 7. Case 4. A 29-year-old woman with multiple sclerosis. A: lcN13 and acP13 are preserved. The HS electrode registers P9, P11 and delayed but clear P13–14 and N20. In the CV2 electrode, a broad and rather flat negativity probably intercalated by P13–14 is noted long after lcN13, which is thought to be a delayed ucN13. B: horizontal section of MRI (T_2 intensified image) at the C2 level. A high intensity region which mainly affects the dorsal column is noted.

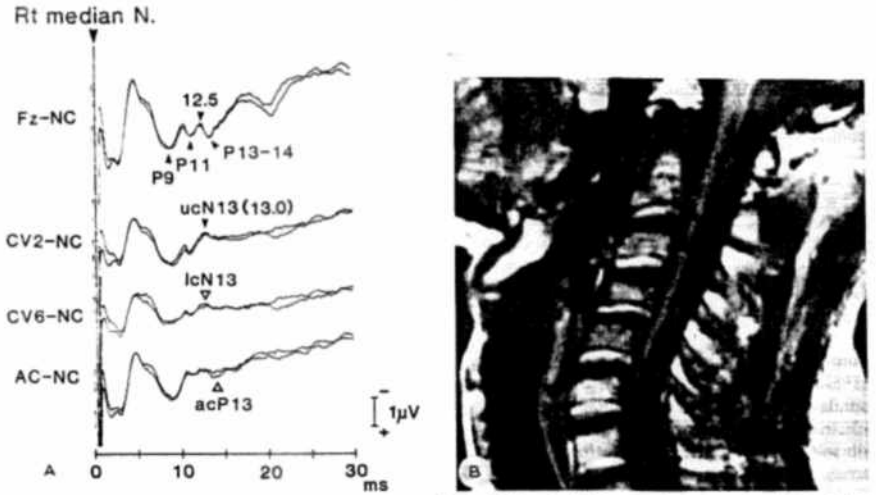

Fig. 8. Case 5. A 40-year-old man with posttraumatic syringomyelia. A: lcN13 and acP13 are greatly attenuated. ucN13 in CV2 is relatively well preserved. Its peak lies behind the termination of scalp P11. Scalp far-field potentials are normal. B: sagittal section of MRI. Syrinx is noted from the foramen magnum level to the thoracic spine.

Similar negative waves at the
were recorded intraoperatively in
by several authors (Lesser et al. 19
Mayanagi 1984; Urasaki et al. 19
1985; Møller et al. 1986; Jacobson
although they were interpreted as
activity of cuneate nucleus only
(Suzuki and Mayanagi 1984; Uras
Lesser et al. (1981) and Yasue et
preted their origin to be the presyn
the dorsal column.

In clinical studies, the dissociati
nal N13–P13 and scalp P13–14
several authors (Mauguière and
Emerson and Pedley 1986; Uras
Neither study, however, paid atter
cervical N13. Using bipolar reco
Sumner (1987) distinguished betw
dipole (their N13a) and an axia
and showed that each was selecti
intramedullary (N13a) and high
lesions, respectively. They attribut
N13b to the caudal medial lem
cuneate nucleus. However, becaus
bipolar leads (corresponding to
derivation), their N13b is assumed
tion of N13 at the high cervical e
scalp P13–14 already present at
the inion. High cervical N13 prop
arately identified in their study.

The broad configuration of ucl
ent study resembles the negative
dorsal aspect of the cuneate nu
animal studies and intraoperativ
was suggested by Andersen et al.
postsynaptic potential of the
cuneate nucleus. On these ground
that the most probable generator
postsynaptic potential of the cune
hypothesis of the generators of th
is illustrated in Fig. 9.

The generators of the scalp P13–1

The present study made some
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tial in humans. Electroenceph. clin. Neurophysiol., 1986, 65: 94–101.
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Origin o
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Summary To identify the origin of scalp median nerve stimulation (designated N18), dir and 3 posterior fossa operations.

In the thalamus a negative potential with a was a large positive potential in the VC nucleu stimulation was given to the median nerve, in high frequency stimulus.

Direct recordings made through the medul latency. Above the upper pons, there was stati and N18 is shown by their having the same late by high frequency stimulus.

Our data suggest that scalp N18 comes fro thalamus.

Key words: Somatosensory evoked potentials;

The early phase of short-latency so evoked potentials (SSEPs) elicited by r stimulation generally consists of 3 p negative components that precede potentials. Their respective peak about 9 msec (P9), 11 msec (P11), (P14), and 16–18 msec (N18) after r stimulation. Since Cracco (1972a) f subcortical potentials from the scalp been many reports on the origin o their clinical uses. The recent consens 3 positive components are generated i

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