Changes in Somatosensory Evoked Potentials and Reflectory Reactions of Human Hand Muscles to Nociceptive Stimulation of Index Finger before and during Ischemia

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Somatosensory evoked potentials and reflectory reaction of *m. thenar* to nociceptive electrical stimulation of the index finger before and during its ischemia were studied in healthy volunteers. The amplitude of early components of the somatosensory evoked potentials N23-P31 and N50-P120 correlated with stimulus intensity, while the amplitude of N140-P200 did not depend on both stimulus intensity and pain. The nociceptive RIII reflex recorded from *m. thenar* was the most reliable index of pain caused by electrical stimulation of the finger.

Key Words *pain sensation; somatosensory evoked potentials; RIII nociceptive reflex*

For the past two decades somatosensory evoked potentials (SSEP) are used to measure clinical and experimental pain in humans [4,5,8,10]. Abundant data on this problem were summarized in a number of review articles [2,6,9,13]. It was found that the early SSEP components (N65-P120) reflect the intensity of physical nociceptive stimulus, while the amplitude of late components (N140-P260) correlates with subjective pain perception [9,14]. Late SSEP components depend on numerous factors associated with cognitive activity, such as memory, attention, and emotions [3, 15]. Hence, pain feeling does not directly depend on stimulus intensity. In this study we investigated changes in the amplitude and temporal characteristics of early and late components of SSEP and nociceptive reactions of hand muscles to electrical stimulation of increasing intensity applied to the distal phalanx of the index finger before and during its ischemia.

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MATERIALS AND METHODS

The study involved 9 healthy male volunteers aged from 36 to 54 years. During the recording session the subjects sat comfortably in an arm-chair with their eyes closed. Surface bipolar electrodes (3 mm in diameter, 5 mm between tips) were placed on distal phalanxes of the index finger. Stimulation was performed with 0.2-msec square pulses. Stimulus intensity was controlled by stimulus amplitude and subjective pain sensation scored using a visual-analog scale (VAS). The currents for painless stimulation ranged from 5 to 7 mA, pain thresholds varied from 10 to 15 mA, and 40-50-mA current caused strong pain (7-8 points VAS score). Ischemic deafferentation was performed by placing a rubber tourniquet on the proximal phalanx of the index finger. Changes in tactile and pain sensitivity, SSEP, muscle reactions, and pain sensation were studied for 40 min after deafferentation.

Nihon Kohden needle electrodes were used to record SSEP. Bilateral active electrodes were placed 7-8 cm laterally to the head middle line along the line connecting the point 1-2 cm caudal to the vertex with the external acoustic meatus. This area corresponds to

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somatosensory projection of the hand (C4" and C3"). A reference electrode was placed in Fz area.

Simultaneously, we recorded orthodromic evoked potentials from the median nerve (OEPMN) with bipolar electrodes (3 cm between tips) placed on the wrist (skin projection of *n. medianus*), and EMG from *m. thenar*.

To isolate SSEP and reflectory muscle response, the EEG and EMG signals were input to a TIESY-VIII amplifiers (Toennies) through 20-2000 Hz and 20-20,000 Hz filters, respectively. Then the signals were processed with a personal computer using a 0.4 msec sampling rate, 300-msec epoch of analysis, 500-1000 averagings for each record. The data were analyzed statistically using the Student *t* test.

RESULTS

Finger electrical stimulation evoked SSEP similar to those induced by stimulation of the distal part of the median nerve [8]. Painless stimulation induced ipsi- and contralateral SSEP consisting of stable early (N23, P31, N39) and variable late (N58-77, P100-119) components (Fig. 1, *1*). When stimulus intensity attained pain threshold (Fig. 1, *2*), the amplitude of early components increased in parallel with OEPMN enhancement. The late (diffuse) negative-positive component N58-77-P120 observed during painless stimulation also increased in amplitude and slope and was followed by two additional positive-negative waves (P98-120-N142-154 and P186-196-N232-242). Further increase in stimulus intensity (Fig. 1, *3-5*) caused no significant enhancement of the early and late components, despite the fact that all subjects reported increasing intensity of nociceptive stimulation. The amplitudes of *m. thenar* reflectory reactions more closely correlated with the increase in stimulus and pain intensity (Fig. 1, *3-5*). As shown previously [1], the reflectory EMG-discharges evoked by nociceptive stimulation of hand fingers are analogs of a nociceptive flexor response (RIII-reflex) [7,12] and can be used as a measure of pain intensity.

Nociceptive stimuli applied 8-15 min after fixing the tourniquet on the finger induced significantly smaller OEPMN (Fig. 2, *2, 3*), which indicated the blockade of conductivity along afferent A-fibers. Simultaneously, the subjects noted the impairment of tactile epicritic sensibility, while epicritic nociception (needle prick), pain appreciation, and the amplitudes of SSEP components and RIII-response remained unchanged. The tactile and epicritic nociceptive sensitivity completely disappeared after 20-25-min ischemia. Pain appreciation was preserved but significantly decreased (to 4-5 points). The disappearance of epicritic nociception was accompanied by a pronounced reduction of the first negative-positive SSEP wave N23-P31

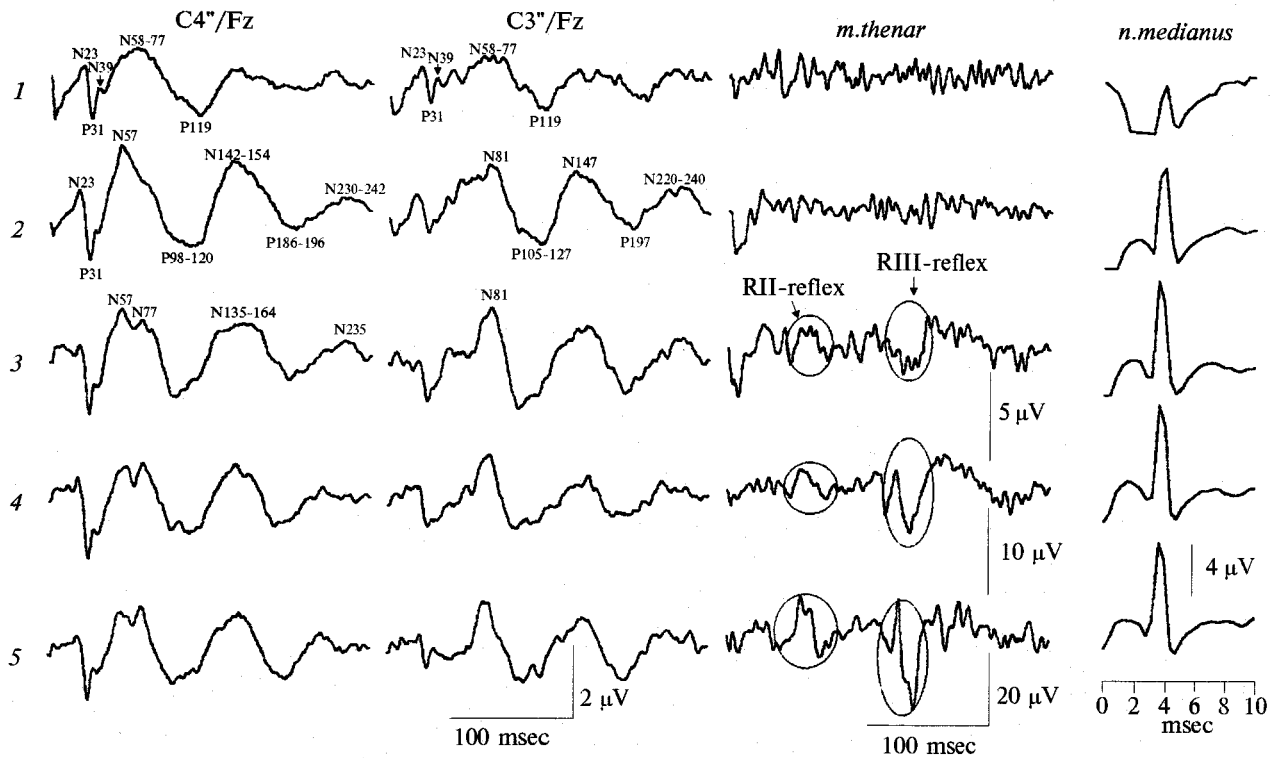

Fig. 1. Somatosensory (S4"/Fz and S3"/Fz), electromyographic (*m. thenar*) and neurographic (*n. medianus*) potentials evoked by electrical stimulation of distal phalanx of the left index finger of increasing intensity. Electrostimulation: *1)* painless; *2)* threshold; *3,4,5)* painful, corresponding to 2, 4, and 7 VAS scores, respectively. Here and in Fig. 2: latency of SSEP components is indicated by inscriptions.

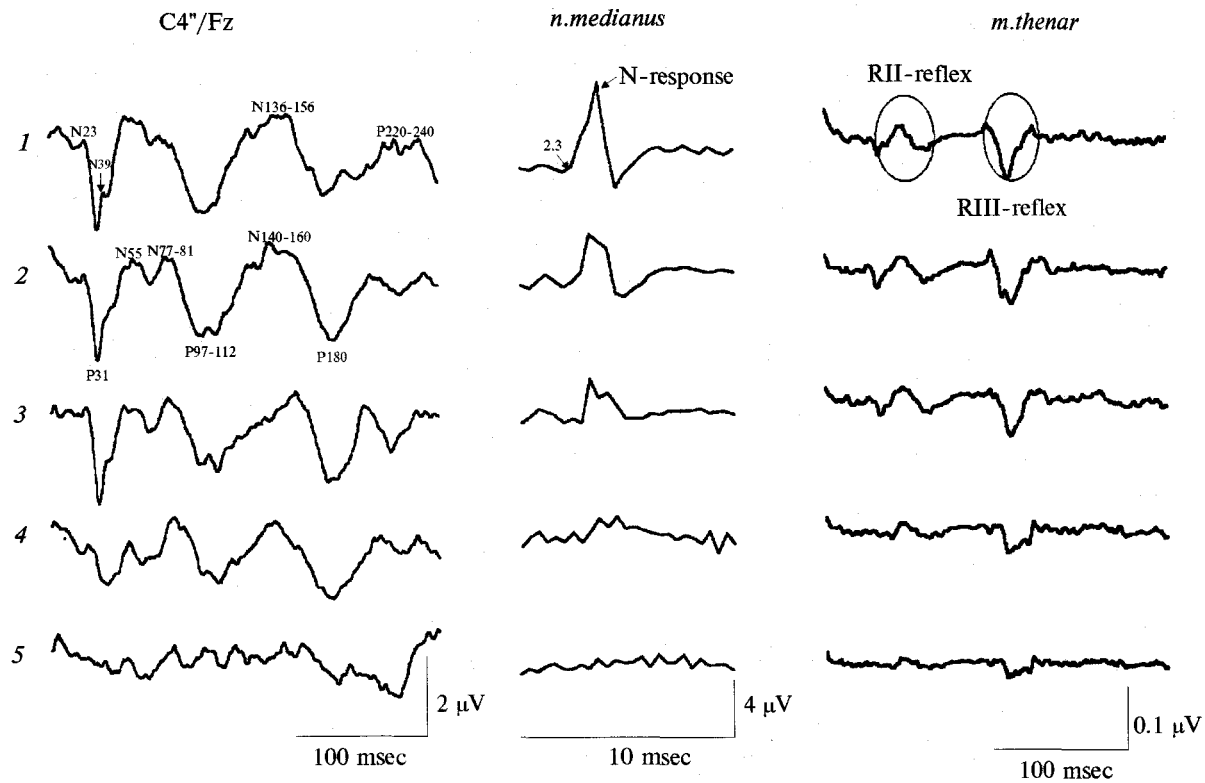

Fig. 2. Changes in somatosensory (S4"/Fz), neurographic (*n. medianus*), and electromyographic (*m. thenar*) potentials evoked by nociceptive stimulation of the index finger after its ischemia. *1*, responses before ischemia; *2*, after 8-min; *3*, after 15-min, *4*, after 15- min, *5*, after 40-min ischemia.

(sometimes, it was completely eliminated) and a significant ($p<0.05$) decrease in the amplitude of N60-P120 component (Fig. 2, *4*). The amplitude of late SSEP components (N140-P200) tended to decrease, but the difference with corresponding SSEP components before ischemia was insignificant). There was no orthodromic response from *n. medianus* and the amplitude of RIII-response was significantly ($p<0.01$) reduced. After 30-40-min ischemia, finger stimulation induced no pain sensation and no electrophysiological responses (Fig. 2, *5*).

These results suggest that early SSEP components N23-P31 and N50-P120 originate from activation of A-β and A-δ afferents which participate in the formation of tactile sensitivity and epicritic nociception [9, 11,15]. This is evidenced by higher amplitudes of early component elicited by more intense stimulation and by the elimination of these components after disappearance of epicritic nociception during finger ischemia. This conclusion agrees with previous reports [6, 8,10] showing that the amplitude of early SSEP components is determined by afferent flow in myelinated high-conductance fibers. The amplitude of late components did not correlate with subjective perception of pain induced by stimulation of increasing intensity and the amplitude of N140-P200 component remained practically the same until the 25th min of ischemia despite a two-fold decrease in the pain VAS scores. Therefore, the subjective pain perception is rather independent of N140-P200 amplitude, which put into doubt the possibility of controlling the intensity of pain by this parameter. The amplitude of nociceptive RIII-reflex, which positively correlated with the intensity of pain sensation in our study, remains the most reliable index for evaluation of pain intensity.

REFERENCES

1. A. V. Gnezdilov, A. V. Syrovegin, M. L. Kukushkin, *et al.*, *Byull. Eksp. Biol. Med.*, **126,** No. 9, 278-282 (1998).
2. L. R. Zenkov and M. A. Ronkin, *Functional Dyagnostics of Nervous Diseases* [in Russian], Moscow (1981).
3. E. A. Kostandov and N. N. Zakharova, *Zh. Vyssh. Nervn. Deyat.*, **42,** No. 3, 477-490 (1992).
4. A. V. Livshits, A. A. Sokolova, and N. A. Demina, *Zh. Nevropatol. Psikhiatr.*, **88,** No. 5, 30-34 (1998).
5. V. K. Reshetnyak, M. L. Kukushkin, A. M. Ovechkin, *et al.*, *Anest. Reanimatol.*, No. 4, 4-7 (1996).
6. B. Bromm, *Advances in Pain Research and Therapy*, New York (1985), Vol. 9, pp. 305-329.
7. C. W. Y. Chan and H. H. Y. Tsang, *Ibid.*, pp. 361-370.
8. C. R. Chapman, A. C. N. Chen, and S. W. Harkins, *Ibid.*, (1979), Vol. 3, pp. 791-803.
9. A. C. N. Chen, *Pain,* **54,** No. 2, 115-132 (1993).
10. A. C. N. Chen, C. R. Chapman, and S. W. Harkins, *Ibid.*, **6,** No. 3, 365-374 (1979).

11. R. Dowman, *Ibid.*, **45,** No. 2, 269-291 (1991).
12. M. Hugon, *New Development in Electromyography and Clinical Neurophysiology,* Ed. J. E. Desmendt, Basel (1973), Vol. 3, pp. 713-729.
13. L. L. Serra and C. Serra, *Acta Neurol.,* **12,** 429-439 (1990).
14. R. D. Treede, S. Kief, T. Holzer, and B. Bromm, *Electroencephalogr. Clin. Neurophysiol.,* **70,** 429-441 (1998).
15. R. Zaslahsky, E. Sprecher, C. E. Tenke, *et al., Pain,* **66,** No. 1, 39-49 (1996).