Nociceptive Muscle Reflex Responses in Human Forearms

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In healthy volunteers, 5-min noxious stimulation with rectangular electrical pulses applied transcutaneously to the phalanges enhanced tonic activity in the palmar and finger flexor muscles resulting in a specific electromyographic pattern consisting of two successive bursts of activity which appeared after a period of inhibition. In patients with chronic pain in the arm, significantly lower thresholds for the first and the second waves of reflex activity have been found. This electromyographic pattern of the forearm muscle reflex responses is supposed to be similar to the nociceptive flexor reflex in the leg. It can be useful for objective assessment of the effectiveness of analgesia and pain syndrome therapy in patients with cervical spinal cord injury.

Key words: *electromyogram; nociceptive flexor reflex; pain; inhibition; excitability*

Methods of the reflex excitability estimation in the different parts of the neuromotor apparatus are now widely used for the pain syndrome diagnosis, choosing of appropriate analgesia treatment, and control of its effectiveness. The nociceptive flexor reflex (RIII reflex) recordings are most frequently used in clinical studies [8] aimed at evaluating hyperalgesia which results from tissue damage [4-6] and to determine an analgetic effectiveness[3]. However, this method allows one only to explore the excitability of nociceptive neurons from the lumbosacral segments of the spinal cord [9,10].

We attempted to find the nociceptive reflex responses in the forearm muscles induced by noxious transcutaneous electrical stimulation similar to RIII-reflexes in the shank and tibial muscles.

MATERIALS AND METHODS

Nine healthy male volunteers (age range 35-50 years) and eight patients (4 males and 4 females, aged 28-58 years) with pain irradiating from the shoulder blade to the arm and to the forearm, sometimes accompanied by finger paresthesia were included in the study. Pain originated from the compression lesions in cervical segments of the spinal cord in men and after mastectomy in women and casted from 3 months to 2 years. Electromyograms (EMGs) were recorded via bipolar surface electrodes from the following muscles: *m. thenar, m. extensor pollicis brevis, m. extensor carpi radialis, m. extensor digiti communis*, anterior head of *m. deltoideus,* and *m. extensor carpi ulnaris.* Circular electrodes (5 mm in diameter) were fixed to a muscle belly a 2 cm distance between them. The EMG was amplified in a TIESY electrophysiological system in the frequency band of 20-2000 Hz and recorded in the digital form with a sampling rate of 5 kHz. Electrical stimuli were applied to the I, II, IV, or V finger via surface electrodes attached to the 1st and the 2nd phalanges. The stimulus was a train of constant current rectangular pulses (0.2 msec) delivered at the rate of 0.2-1 Hz. A threshold current (5-10 mA) was determined individually by subjectively reported tactile sensation (electrical shock), which was not painful or unpleasant. At suprathreshold intensities (30-40 mA), the stimulus produced moderate bear-

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able pain sensation. In some experiments, the constancy of the electric current was controlled by the combined action potential amplitude recorded from the median nerve at the wrist region.

Fast Fourrier transform of EMG signals was computed to obtain tonic activity spectra. The EMG signal was averaged in two ways: simple averaging of myograms and averaging by the module of integral activity (epoch window 128-500 msec, sample duration 0.2-0.8 msec, n=150-200).

The subjects rested comfortably in an armchair during EMG recordings. The EMG recording was started when the muscles under investigation were completely relaxed (EMG amplitude was as low as the noise of amplifier — 6 μV), or when the tonic activity in the muscles was about 40 μV.

RESULTS

Reflex responses in different muscles of the arm were registered during stimulation of various skin areas. It was found that the nociceptive flexor reflex in the forearm muscles in response to transcutaneous electrical stimulation of the phalanx was the most stable.

Electrical pulses (30-40 mA) applied to phalanges caused a pin-prick pain sensation in subjects and activated motor units in relaxed muscles. Started from several single potentials, this activity then transformed into asynchronous EMG bursting activity, which is characteristic of increased muscle tonus (Fig. 1, *a*). In tonically active muscles, 3-5-min noxious stimulation markedly increased the EMG activity (Fig. 1, *b, c*). If the stimulation was not painful, such EMG responses were absent.

Further analysis showed some organization of EMGs with bursts and periods of inhibition followed the noxious stimulation. The averaged responses demonstrate that the specific EMG pattern consists of two successive bursts of activity separated by two inhibition periods T1 and T2 (Fig. 2). As in the investigations on the nociceptive withdrawal reflex mechanisms in the leg muscles [8,9], we consider the early wave of activity in the EMG as RII reflex and the late one as RIII reflex.

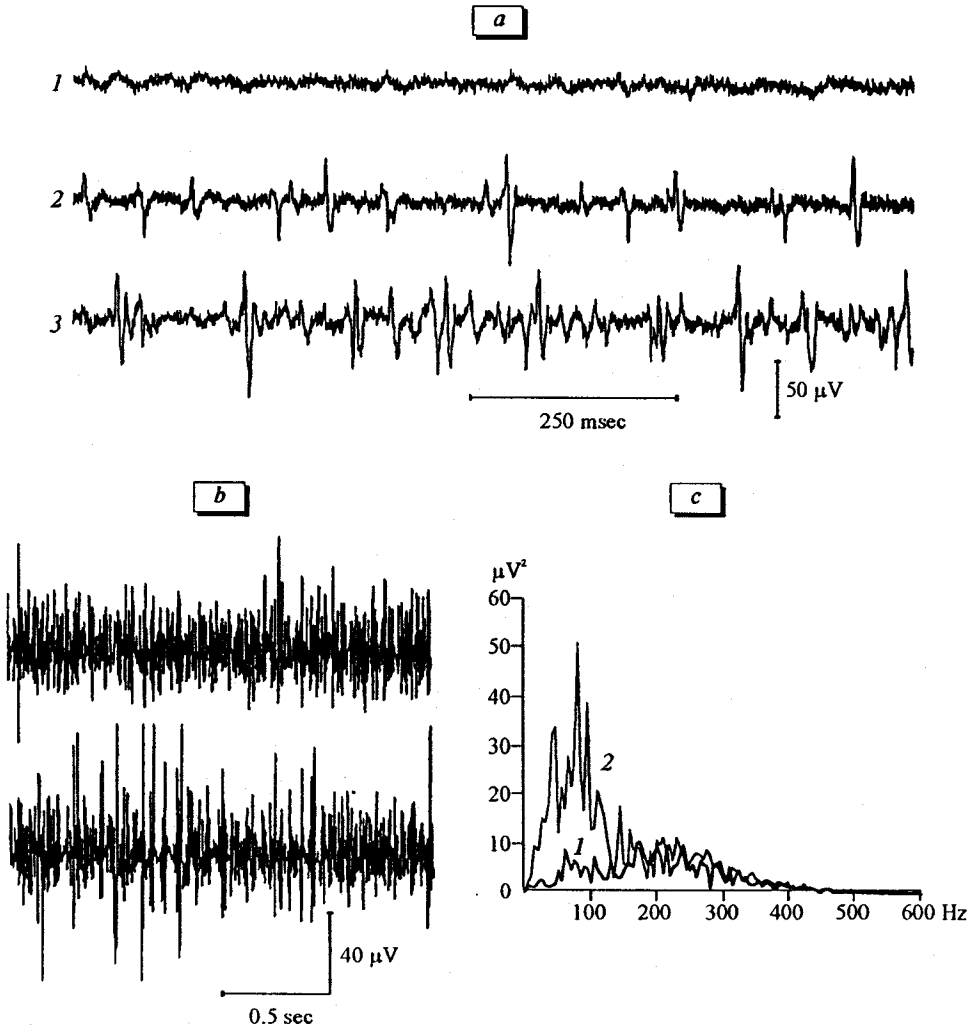

Fig. 1. Electromyographic (EMG) records showing tonic activity in *m. extensor carpi radialis* (*a*) and *m. extensor digitorum communis* (*b, c*) evoked by noxious transcutaneous electrical stimulation (0.3 Hz) of the index finger. (*a*) first (*1*), third (*2*) and fifth (*3*) minute of noxious stimulation, initially tonic activity is absent; (*b*) tonic activity before stimulation (the upper record) and after 3 min of noxious stimulation (the lower EMG-record); (*c*) power spectrum of the tonic EMG before stimulation (*1*) and during noxious stimulation (2).

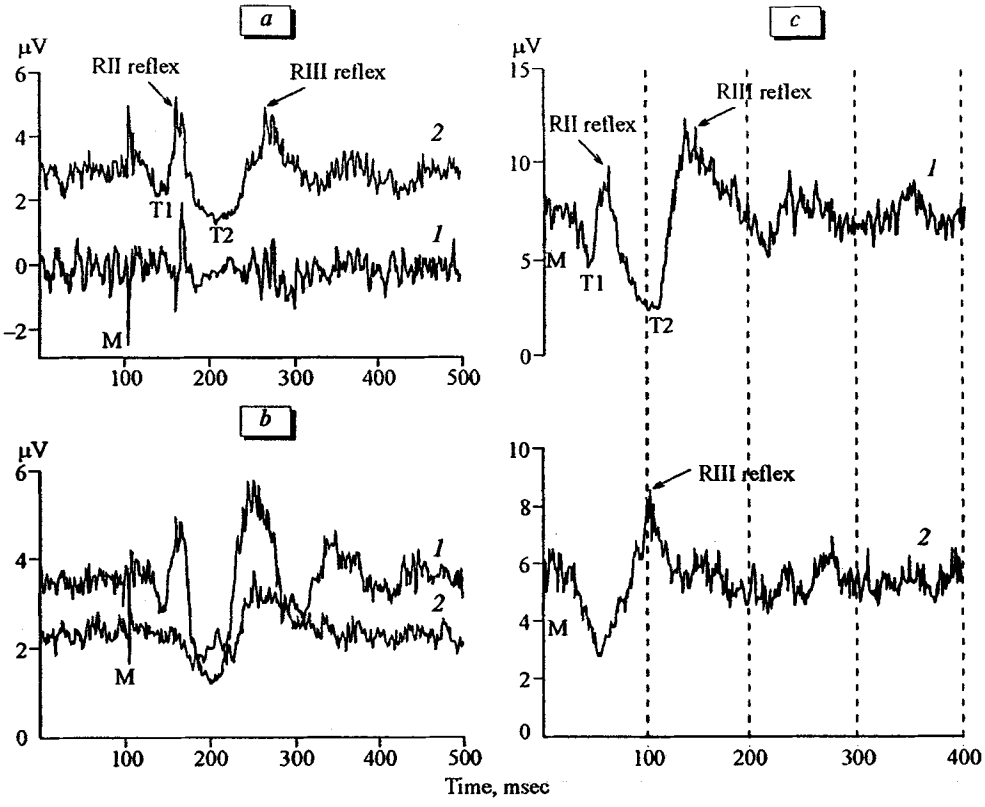

Fig. 2. Avaraged electromyographic reflex responses (n=150) in palmar and finger extensor muscles evoked by noxious transcutaneous electrical stimulation of the medical finger phalanges in healthy subjects. (*a*) evoked potentials in *m. extensor digiti communis ipsilateralis*, obtained with usual (*1*) and with averaging by modulus (*2*); (*b*) evoked potentials in *m. extensor carpi radialis ipsilateralis* (*1*) and *contralateralis* (*2*) averaged by modules; (*c*) evoked potentials in *m. extensor digiti communis ipsilateralis ipsilateralis* (*1*) and *m. deltoideus ipsilateralis* (*2*) averaged by modules; *M*: the beginning of noxious electrical stimulation; *T1* and *T2*: periods of inhibition.

The RII reflex was recorded only in the muscles from the stimulated arm, while RIII reflex appeared in the muscles that were both ipsi- and contralateral with respect of the stimulated arm (Fig. 2, *b*). The mean values of temporal and amplitude parameters of the EMG major response components in the common extensor of the fingers to noxious stimulation of the ring finger phalanges are summarized in Table 1.

In some healthy subjects, a low-amplitude early response corresponding to the RII reflex appeared in the EMG averaged in a typical way.

This response was irregular and was evoked only by noxious stimulus. By contrast, in patients with chronic pains in the arms, the early responses were induced by nonpainful electrical stimulation (Fig. 3). Therefore, this reflex depends on the excitability and reactivity of the dorsal horn neurons.

These results suggest that noxious electrical stimuli applied transcutaneously to the fingers evoke nociceptive reflex EMG responses in flexor muscles of the forearm associated with the withdrawal defense reaction. This assumption is confirmed by the fact that the pattern of the EMG reflex in the flexors of the fingers and of the hand is similar to the pattern in the leg flexor muscles registered in response to noxious electrical stimulation of the *n. suralis* [9,10]. Activation of the dorsal horn nociceptive neurons and, in particular, of the wide-dynamic-range (WDR) neurons is considered to be responsible for the nociceptive flexor reflex [3-5]. The excitability and reactivity of WDR-neurons are regulated by two pathophysiological mechanisms. The first mechanism is the sensitization of nociceptors in the area of injury or inflammation [8].

TABLE 1. EMG Components of Reflex Responses in *M. Extensor Digiti Communis* during Noxious Stimulation (33-40 mA, 0.5 Hz) of the Medical Finger in Healthy Subjects ($M \pm m$)

EMG Components	Latency	Time of maximum, msec	Amplitude of maximum, μV	Duration, msec	Area, μV×msec
T1	30.9±2.4	40.4±5.7	0.7±0.5	16.6±4.9	9.1±8.0
RII reflex	46.6±5.9	59.1±5.5	3.1±2.1	26.1±8.0	53.9±48.1
T2	73.1±6.3	98.2±6.6	2.4±1.5	50.8±9.0	75.1±42.2
RIII reflex	124.6±8.7	150.0±12.4	2.5±1.1	57.9±12.9	66.3±38.9

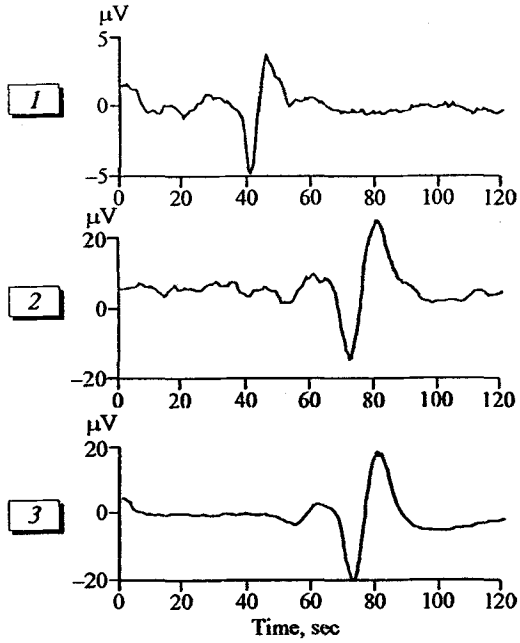

Fig. 3. Averaged electromyographic potentials in the distal part of the arm evoked by non-noxious electrical stimulation of the index finger phalanges in patient with chronic arm pains. Reflex response in *m. extensor carpi radialis* (*1*), *m. extensor pollicis brevis* (*2*), and *m. thenar* (*3*).

The second mechanism relates to the formation of neuronal group in the dorsal horn, which became hyperactive, virtually insensitive to inhibitory control, and capable of abnormally firing for a long time [1,2,7]. Both processes facilitate WDR-neuron activation to the extent that they begin to respond to the tactile stimulus, leading to hyperalgesia, allodynia, or chronic pain [2,3,7,8]. Our findings that in patients with chronic pains in the arm the EMG reflexes are evoked by the nonpainful electrical stimulation of the fingers confirmed this hypothesis.

Thus, recording of EMG activity during forearm flexor reflex evoked by noxious transcutaneous electrical stimulation of the finger phalanges can be used as a method of evaluating the effects of analgesia and pain therapy in patients with chronic pain in the arm.

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