ELECTROPHYSIOLOGICAL CHARACTERISTICS OF CONVERGENCE OF TRANSCALLOSAL AND SOMATOSENSORY EXCITATION IN THE RABBIT SOMATOSENSORY CORTEX

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Acute experiments were carried out on rabbits anesthetized with pentobarbital. During interaction between transcallosal and somatosensory excitation an effect of summation, occlusion, and facilitation was observed. These effects indicate convergence of excitation on the same central neurons. The structures on which these two forms of excitation converge may evidently be the apical dendrites of the pyramidal cells in layers III-IV of the cortex.

Since a preceding transcallosal response blocks the negative component of the evoked potential to clicks in the auditory cortex of cats anesthetized with pentobarbital, Chang [2] considers that it cannot be assumed that these two stimuli excited two different groups of neurons without involving common elements. The blocking suggests that common elements are implicated in both groups of responding neurons and that pyramidal cells of cortical layers III-IV and their apical dendrites are predominant among these elements [2].

Bremer [1] simultaneously recorded responses to clicks in the middle and posterior ectosylvian gyri in experiments on anesthetized cats and showed that the response of both zones can not only be blocked, but also considerably facilitated by the preceding transcallosal response. The possibility of convergence of transcallosal and peripheral excitation has also been demonstrated recently on single neurons.

More than half the cells which discharged during stimulation of the homologous point of the opposite hemisphere responded in the same way to other types of stimulation, so that transcallosal and other types of stimulation can converge on the same cells [4]. The number of cells exhibiting convergence was a maximum at the depth of 600-900 μ which, according to Sholl [5], corresponds to cortical layers III-IV, in which the pyramidal neurons are located.

Nearly all investigations studying interaction between transcallosal and other types of excitation have been conducted on cats.

This paper describes an attempt to demonstrate the possibility of interaction between transcallosal excitation and excitation traveling along the specific pathway from the sciatic nerve in the rabbit somatosensory cortex. The evoked potential was used as indicator for the study of this interaction.

EXPERIMENTAL METHOD

Acute experiments were carried out on 46 adult rabbits under pentobarbital anesthesia. The sciatic nerve was stimulated by buried electrodes with an interelectrode distance of 3 mm. Square pulses (3-5 V, 0.1 msec) were applied from a "Fiziovar" stimulator. The evoked response was recorded at the focus of maximal activity by a silver ball electrode directly from the pia mater.

The surface layers of the cortex were stimulated at the exactly symmetrical point of the opposite hemisphere by bipolar electrodes in glass insulation (interelectrode distance 0.5-1 mm). Single pulses

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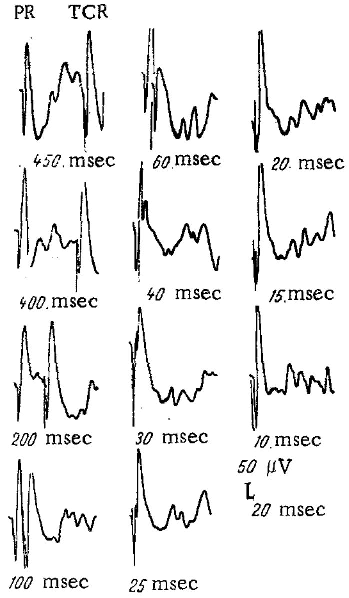

Fig. 1

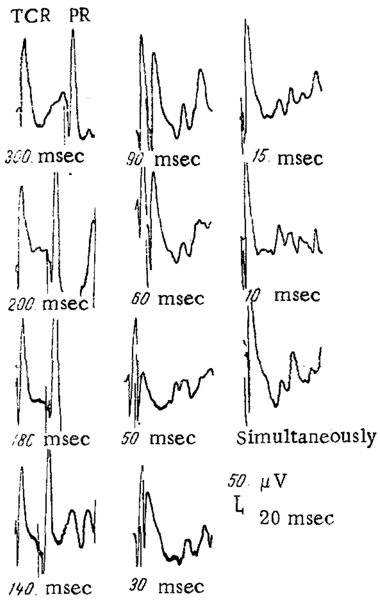

Fig. 2

Fig. 1. Effect of primary somatosensory response on transcallosal response with different intervals between stimulations. Intervals between stimuli applied to sciatic nerve and to callosal neurons shown beneath each record. First stimulus was synchronized with the beginning of the sweep. Application of second stimulus marked by a vertical line.

Fig. 2. Effect of transcallosal response on primary somatosensory response with different intervals between stimuli. Legend as in Fig. 1.

(0.1 msec, 10-15 V) from the "Fiziovar" stimulator were applied to the cortex at intervals of 0-1 sec. There were two variants of the experiments. In the first variant stimuli were applied to the sciatic nerve and then, after various intervals of time, the callosal neurons were stimulated. In the second variant, the callosal neurons were stimulated first. Depending on the interval between these two forms of stimulation, the final effect, consisting of changes in the evoked potential, varied.

EXPERIMENTAL RESULTS AND DISCUSSION

With intervals of between 1 sec and 400 msec, regardless of the order of stimulation, no visible changes took place in the evoked potentials. All the changes began to appear if the intervals were shorter and accordingly intervals of 400 msec or less were used in these experiments.

If the somatosensory response preceded the transcallosal with long intervals (400-100 msec) between stimuli the transcallosal response was independent of the preceding somatosensory one. In addition, a decrease in the transcallosal response was observed on account of a decrease in its negative component, sometimes amounting to the complete suppression of the negative component of the response. The same picture was observed with intervals of between 100 and 30 msec between stimuli. Finally, with intervals of between 20 and 0 msec the amplitude of the evoked response increased again, as before because of an increase in the amplitude of the negative component of the response (Fig. 1).

If, on the other hand, the somatosensory response was preceded by the transcallosal stimulation with intervals of 400 msec or more the evoked response was independent of the preceding transcallosal stimulus. With intervals of 300-150 msec, a facilitatory effect was observed, and if the stimuli were closer together still (between 80 and 30 msec) the somatosensory response began to be inhibited by the preceding transcallosal stimulus. With short intervals (from 10 to 5 msec), and also if the two stimuli were applied simultaneously, the somatosensory response again was facilitated. All the changes affected mainly the negative component of the response (Fig. 2). In response to stimulation, and also with intervals of 20-5 msec between them, as a rule the negative component of the response was increased. Under the experimental conditions used, it was impossible to differentiate and to identify the potential to which the negative wave belonged. The amplitude of the increased negative component was always greater than the amplitude of the negative wave of the somatosensory response and the negative wave of the transcallosal response. With short intervals between stimuli, such an increase could take place only by summation of these two negative components. It is characteristic, however, that, notwithstanding this summation, the complete sum was never obtained, i.e., the negative component was always 25-30% less in its amplitude than the sum of the amplitudes of the two negative components. Most probably this effect can be explained by the occlusion taking place in this region. If common elements did not participate in the formation of these two components, simple algebraic summation would have taken place without mutual blocking. Since Sherrington's time occlusion has been, and still is, the classical indicator of convergence of excitation on the same elements. The most probable site of this occlusion is the apical dendrites, since the formation of the negative component both of the somatosensory and of the transcallosal response takes place on account of these elements.

With a further increase in the intervals between stimuli (30-80 msec) the negative component of the second testing response was sharply inhibited, regardless of the order of the responses, and in some cases the negative component was completely suppressed. Presumably, like peripheral nerves or other excitable tissues, the neurons of the central nervous system as a whole pass through a cycle of changes in excitability after its activation. Analysis of interaction between transcallosal excitation and excitation traveling along the specific pathway from the sciatic nerve indicates a change in excitability only in the end point where the volley of these afferent impulses enters, for elsewhere there can be no interaction between these two afferent streams. On which actual cortical elements can this interaction take place? Both the negative component of the transcallosal response and the negative component of the somatosensory response are effected principally on the apical dendrites of the pyramidal cells of cortical layers III-IV [3]. Consequently, suppression and reduction of the negative component of the second testing response takes place because the apical dendrites are in a state of subnormal excitability at this time.

Whereas the summation effects and the effects of depression of the negative wave of the second response observed in these experiments are independent of the order of stimulation, the facilitation effects with long intervals are observed only when the transcallosal stimulus is applied first. This phenomenon was first studied in detail by Bremer [1], who pointed out that it is observed only in the absence of barbiturate anesthesia. However, in the present experiments, carried out on rabbits anesthetized with pentobarbital, a facilitatory effect was very clearly seen when the stimuli were separated by long intervals. Results similar to these were described earlier by Zhang Gin-Gu [6]. The mechanism of this prolonged facilitatory effect of transcallosal excitation is not yet clearly understood.

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