REPRESENTATION OF THE INTERNAL ORGANS IN THE CAT AND THE DOG CEREBRAL AND CEREBELLAR CORTEX

III. REPRESENTATION OF THE PUDENDAL NERVES IN THE CAT CEREBRAL CORTEX

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By recording primary responses in the cerebral cortex resulting from stimulation of the central ends of the pelvic nerves we have shown that in the cat the area onto which the nerves project lies within the region in which the hind limbs are represented. The focus of maximal activity (FMA) of the first zone, i.e., the area within which primary responses can be found which have maximal amplitude and minimum latent period lies usually on the gyrus cruciatus posterior, near the central part of the cruciate sulcus. The FMA of the second zone lies on the anterior ectosylvian gyrus in the middle part of the ectosylvian sulcus [2, 3]. It is known however that afferent fibers of many of the internal organs such as the urethra, urinary bladder, and vagina run not only in the pelvic but also in the pudendal nerves. Since the cortical representation of the latter has not yet been worked out, we have attempted to determine it. Our experiments on 24 cats have shown that this nerve also has its area of cortical representation which overlaps that of the pelvic nerves. Nevertheless, their FMA do not coincide, and for each nerve there is a small territory within the common area in which responses from both nerves can be obtained, where the response from one nerve has a maximum value.

METHOD

The experiment was performed as follows: Recordings were made of the response to stimulation of a single nerve, and then without moving the leading-off electrode, recordings were also made on stimulating the other. Next the electrode was transferred to an adjacent portion of cortex and the whole operation again repeated. In studying the representation of the two nerves in parallel in this way, particular attention was paid to maintaining equal time intervals between separate stimuli applied alternately to one nerve and to the other. The time interval chosen was selected empirically so that the reaction resulting from stimulation of one nerve did not fall in the period of the after-effect of the preceding stimulus applied to the other. Usually an interval of at least one minute was left between stimuli.

RESULTS

Figure 1 shows the results obtained in one such experiment. Comparison of the responses recorded from five points on the anterior ectosylvian gyrus shows that stimulation of the pudendal nerves produces a response having a minimum latent period and maximum amplitude when the recording is made from point 2. On stimulating the pelvic nerve, the response with minimum latent period and maximum amplitude is recorded from point 4. Thus points 2 and 4 are the FMA of the two nerves.

The results of this and many other experiments show that in a single preparation the areas of representation of the pudendal nerves are less extensive than those of the pelvic nerves and lie mostly within the field of the latter. Accordingly, the FMA of the pelvic nerve is somewhat more extensive. By comparing the responses obtained from the two nerves it is clear that stimulation of the pelvic nerve causes responses which have a rather greater amplitude and somewhat smaller latent period than those caused by stimulation of the pudendal nerve (see Fig. 1).

This greater activity of the pelvic nerve takes place both in the first and second zones common to it and the pudendal nerve.

Control experiments. In this electrophysiological method, control experiments are of particular importance as helping to determine correctly the reason for any particular electrical response occurring.

We have several times observed that under light anesthesia the application of a single electrical stimulus to the central end of the pelvic or pudendal nerves may cause reflex contraction of the adductor muscles of the thigh. These contractions may occur as short twitches also in the muscles of the base of the pelvis, and when stronger stimuli are used, more distant muscle groups may also contract strongly. It was necessary to determine any possible relationship between these contractions and the electrical recordings which we made.

The control experiments were performed as follows. A bipolar electrode having an interelectrode distance of 4 mm was inserted into the contracting muscle. The potentials from it were displayed on one of the two beams of a cathode-ray oscillograph. The other beam showed the electrical responses in one of the cortical areas of the nerves concerned. Records were made before and after immobilizing the animal. Immobilization was secured by using a Russian preparation named diplacin. It was chosen because when injected intravenously in doses sufficient to cause paralysis it had no noticeable effect on the cortical potentials recorded, as was also found by G. D. Smirnov [4] for the "reactive potentials" of the visual cortex.

Figure 2, traces 1 and 2 shows the results of one such experiment. Trace 1 was obtained before and trace 2 after injecting 0.5 cm^3/kg of a 2% solution of diplacin. Comparison of the two traces shows that the primary response in the cerebral cortex results from stimulation of the afferent fibers of the pelvic nerve and not from the associated reflex contraction of the muscles, because otherwise there would be no response in the complete absence of any muscular contraction (trace 2).

Concerning the action of diplacin, it must be noted that with the dose we used the effect on the electrical responses depended to some extent on the depth of anesthesia. With light anesthesia the injection of diplacin had no effect on the potentials evoked. But if the animal was deeply anesthetized, injection of diplacin reduced the amplitude of the primary response somewhat and increased the latent period (compare traces 1 and 2, Fig. 2). However, increasing the intensity of the stimulus caused a return of the response to the previous amplitude and to the previous value of the latent period.

It remains to describe the effect of the reflex muscular contractions on the electrical cortical response following stimulation of an afferent nerve. Amassyan found that reflex contaction of the lower intercostal muscles caused by stimulating the splanchnic nerve in cats caused a third early wave to occur in the first representational area. The injection of d-tubocurarine eliminated this wave [5]. In the experiment shown in Fig. 2, traces 1-2, injection of diplacin caused some change in the wave form of the response: the second negative wave which occurs in trace 1, is much smaller in trace 2. We never found that diplacin caused any

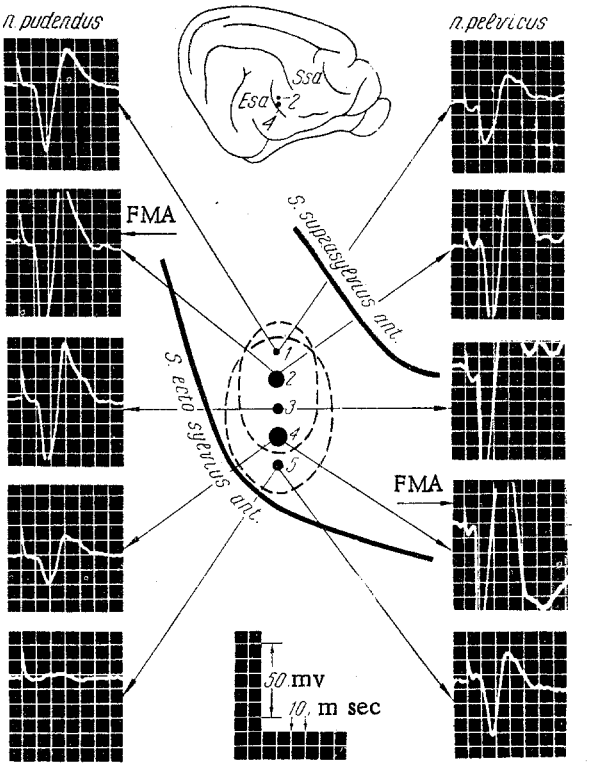

Fig. 1. Comparison of the areas of representation of the pelvic and pudendal nerves in the second contralateral area. Cat No. 162; experiment performed January 18, 1957. Deep anesthesia with a mixture of chloralose and nembutal. Animal immobilized with diplacin. Artificial respiration. Stimulating voltage 7.5 v. Pulse length 0.2 msec; Ssa--S. suprasylvius ant.; Esa--S. ectosylvius ant. Potential in microvolts, time in microseconds.

more definite changes in the shape or size of the different components of the response.

In most experiments, the injection of diplacin caused no noticeable change in the cortical response.

Although muscular contraction caused little effects on the primary response, we were nevertheless careful to immobilize the animal. This was done in order to eliminate completely any artifact, and also because the artificial respiration applied to the paralyzed animal guaranteed a more constant level of oxygenation of the blood than would be obtained during an experiment lasting several hours under normal conditions.

It remains to suggest one further possibility. It might be thought that the responses we recorded occurred through the excitation of other nerves by escape of current. To exclude the possibility we produced a cold block proximal to the stimulating electrodes. When this was done, despite the stimulation of the nerve, no primary responses were obtained. Figure 2 gives the results of one such experiment (traces A-F). Trace A shows the primary response in the first contralateral cortical area due to stimulation of the pelvic nerve. Trace B was obtained two minutes after the onset of cooling the nerve. It can be seen that with the same strength of stimulating cur-

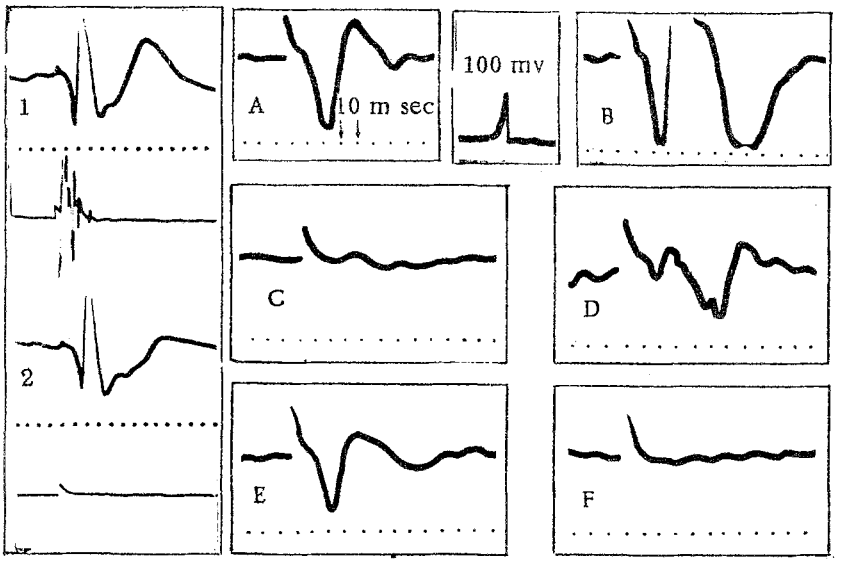

Fig. 2. Traces 1-2. Independence of electrical response from first area of cortical representation of pelvic nerve from reflex contraction of muscles. Cat No. 171; experiment performed January 31, 1957. 1) Before, 2) after injecting diplacin. First and fourth curves) cortical response; second and fifth curves) time marker (10 msec); third and sixth curves) electromyogram of adductor muscles of thigh. Artificial respiration. Chloralose anesthesia. Stimulus strength 5.5 v; duration 0.2 msec. Traces A-F. Cold block and pressure on afferent nerve prevent the development of the cortical response. Cat No. 74; experiment performed October 23, 1955. Deep chloralose anesthesia. Stimulus pulse duration 0.2 msec, amplitude 1.6 v. A, B, C) cortical responses (first area of cortical respresentation of pelvic nerve) developing on stimulation of the cooled pelvic nerve; D, E) record from the same cortical point when the nerve was heated: F) pressure applied to the nerve above the stimulating electrodes—cortical response eliminated.

rent, the amplitudes of the primary response have increased, and a secondary response is also present. The changes in the primary response are evidently due to the cooling of the nerve, which passes through a stage of heightened excitability (N. E. Wedensky, 1901). Trace B obtained four minutes after cooling shows that the cold block in the pelvic nerve prevents the primary response occurring. Trace D was obtained some time after cooling had ceased. Now stimulation of the nerve with a single shock of the previous intensity is once more followed by a cortical response. Ten minutes after cooling had ceased, excitation had returned to the original level, and the cortical response (trace E) shows little difference from that which was recorded before the cold block was applied (see trace A). At the end of the experiment the nerve was crushed proximal to the stimulating electrodes. This caused an irreversible block of all cortical response (see trace F, Fig. 2).

In our opinion, the results obtained show that the cortical responses obtained depend on excitation occurring in the fibers of the nerves stimulated.

SUMMARY

By recording primary responses in two cortical areas of the pudendal nerve, afferent fibers have been shown to run to the cortex of each cerebral hemisphere. The focus of maximal activity (FMA) of the first zone, i.e., the cortical area within which the primary responses occur at maximum amplitude and minimum latent period is usually located on the posterior cruciate gyrus. The FMA of the second zone is located on the anterior ectosylvian gyrus. Both zones lie in the area representing the hindlimb. The cortical areas of the pudendal and pelvic nerves discovered previously by the present author overlap each other widely, though their FMA do not coincide. This signifies that for each of the nerves, within the boundaries of the common area in which primary responses occur, there is a small area in which maximum values are obtained.

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