

EVOKED POTENTIALS ELICITED BY STIMULATION OF THE CAUDATE NUCLEUS AND INTERNAL CAPSULE WITH MULTILEAD ELECTRODE

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ABSTRACT

By stimulation of serial points of the caudate nucleus and internal capsule in cat with multilead electrode, pericruciate responses are elicited easily by internal capsule stimulation but responses by caudate nucleus stimulation are due to the current spread to the internal capsule.

A part of the diffuse thalamic projection system has been inferred to pass through the internal capsule.

It was confirmed electrophysiologically that the head of the caudate nucleus has some close fiber connections with the nucleus niger and globus pallidus.

INTRODUCTION

This experiment was carried out in order to confirm electrophysiologically the fiber connections which originate from the head of the caudate nucleus and reach the cortex, globus pallidus and the nucleus niger.

In this respect, many investigators have reported various anatomical and physiological findings and opinions.

Connections between the caudate nucleus and cortex. Anatomical

Wilson¹⁾ reported in his physiological study of monkey brains that he found no direct connections between the corpus striatum and the cortex. This report has been supported by some investigators (Riese²⁾, Kodama³⁾, Voneida⁴⁾, Burandt, French and Akert⁵⁾), while the existence of direct fibers from corpus striatum to cortex has been supported by other investigators (Mettler, Grundfest and Hovde⁶⁾, Harman, Tankard, Hovde and Mettler⁷⁾, Tankard and Harman⁸⁾). On the other hand, indirect pathways from caudate nucleus to cortex via globus pallidus and nucleus ventralis anterior and lateralis of the thalamus have been proved by still other investigators (Woodburne, Crosby and McCotter⁹⁾, Johnson and Clemente¹⁰⁾, Nauta and Mehler¹¹⁾, Szabo¹²⁾).

Physiological

Repetitive stimulation of the caudate nucleus decreases the amplitude and

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increases the frequency of the electrocorticogram (Morison, Dempsey and Morison¹³), Shimamoto and Verzeano¹⁴), Tokizane, Kawakami and Gellhorn¹⁵). Starzl, Taylor and Magoun¹⁶) reported that the internal capsule, rather than the basal ganglia, appeared to be the excitable focus. Purpura, Housepian and Grundfest¹⁷) believed the existence of direct caudatocortical fiber connection, as the cortical response which appeared by stimulation of the caudate nucleus was not due to spread of the stimulation current to the internal capsule. Electrocortical activation elicited from the caudate nucleus was considered due to spread of current to the thalamus (Demetrescu and Demetrescu¹⁸)).

Laursen¹⁹) reported, by using a 14-lead multilead electrode, as follows: 1) A potential elicited in the caudate by stimulation of the caudate was spread to the cortex by volume conduction. 2) Potentials arising in the cortex in response to single shock stimulation of the caudate were not found. 3) Cortical recruiting responses were only elicited from the internal capsule and the thalamus and from a fringe of tissue of the head of the caudate bordering these structures.

Goldring²⁰) *et al.* reported: the segment of the internal capsule which carries axons relating to the sensory motor cortex does not so closely adjoin the caudate in the monkey as it does in the cat. Therefore, the caudate-induced cortical responses can be obtained without stimulating the adjoining internal capsule. In the monkey, caudate stimulation never produced cortical responses, and only internal capsule stimulation evoked the potential complex which had been attributed to caudate nucleus stimulation in the cat.

Connections between the caudate nucleus—internal capsule border zone and thalamus

When the border zone between the caudate nucleus and internal capsule was destroyed, the degeneration of nerve cells appeared in the nucleus VA, VL, CM, CP, and N. Retic. of the thalamus. These findings show that the fibers originated from these nuclei pass through the border zone and reach to the ipsilateral pericruciate cortex (Nashold, Hanbery and Olszewski²¹)).

Connections between the caudate nucleus and nucleus niger

Regarding the fibers from corpus striatum to nucleus niger, the fibers from the caudate nucleus or putamen have been confirmed to pass through the internal capsule and basis pedunculi and end in the zona reticulata of the nucleus niger in cat and monkey (Voneida⁴), Johnson²²), Nauta and Mehler²³)).

Pallidonigral connections were reported in cat (Johnson and Clemente¹⁰), Nauta and Mehler¹¹)). Direct putaminofugal fiber connection to nucleus niger was reported in man and monkey (Papet²⁴), Verhaart²⁵), Nauta and Mehler¹¹), Szabo¹²) but some investigators denied it (Ranson, Ranson and Ranson²⁶), Johnson and Clemente¹⁰)).

With stimulation of the caudate nucleus, biphasic waves were recorded

after a latency of about 6 msec in the nucleus niger (Shimamoto and Verzeano¹⁴). Stimulation of the caudate nucleus or putamen evoked short latency spikes and/or large amplitude activity lasting up to 100 msec in the nucleus niger. Frigyesy²⁷ and Purpura, applying intracellular recording from neurons of the nucleus niger, have disclosed 3-4 msec latency EPSPs and succeeding IPSPs in response to ipsilateral stimulation of the head of the caudate nucleus. Nigral neurons activated by caudate nucleus stimulation are found in the rostral portion of the nucleus whereas more caudal regions in the nigra contain elements responsive to stimulation of medial pallidal-entopeduncular outflow pathways.

METHODS

About 50 cats weighing from 2.5 to 3.5 kg were used for these experiments. They were anesthetized throughout the surgical period with Fluothane. The trachea and saphenous vein were cannulated. The head was clamped in a stereotaxic instrument and the dorsal aspect of bilateral hemispheres was exposed. After completion of surgery the cats were immobilized with succinylcholine chloride and Mylaxen and given artificial respiration. All wound margins and stereotaxic pressure points were then sufficiently infiltrated with 1% Xylocain.

Multilead electrode described by Buchthal²⁸ and by Laursen¹⁹ was used for stimulation, as was shown in Fig. 1. It contained 14 enamel covered copper leads each 0.1 mm in diameter distributed along 5.2 mm of a stainless steel cannula with an external diameter of 1 mm. The distance between the centers of adjacent lead was 0.4 mm. Concentric electrode of 0.7 mm in diameter was used for thalamic stimulation and for recording from subcortical structures. A doublet string electrode of which two tips were apart 1 mm from each other was used to record from the nucleus niger and pedunculus. Further, a needle electrode of 100 μ of tip diameter was used to record from subcortical structures. In addition to the above, the silver ball electrode was used to record from the cortex, and the distance between these centers were 2 mm.

The multilead electrode was stereotaxically inserted into the brain. In order to diminish the damage of the brain by inserting the electrode, it was kept in a location and never moved any more until the examinations were over. Stimuli were applied through different paires of adjacent leads. Two

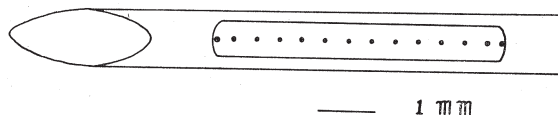


FIG. 1. Multilead electrode. It contains 14 enamel covered copper leads each 0.1 mm in diameter in the stainless steel cannula of an external diameter of 1 mm. The distance between every adjacent stimulating point was 0.4 mm.

stimulators with isolators were employed for delayed double shock. The common indifferent electrode was set on the bone of the frontal sinus or on the temporal muscle. At the beginning of the experiments, the indifferent electrode was tested against a silver needle in the temporal muscle to confirm that it did not record responses. Recording from the cortex was carried out from ipsilateral or from two symmetrical points on both hemispheres through silver ball electrode set on the pia. The electrocorticogram was recorded with an electroencephalograph.

In order to confirm the site of the electrode, the tips of the electrode were marked by passing a current between the tips of the electrode and a large electrode placed in the rectum, and the brain of cat was perfused with 5% formalin solution, leaving the electrode in situ as it was. After fixation the brain was sliced parallel to the axis of the electrode. The brain was prepared for histological examination so that each of stimulation and recording points might be affirmed.

RESULTS

1. Response from ipsilateral anterior sigmoid gyrus by the stimulation of the head of the caudate nucleus or internal capsule

a) Single shock stimulation

Multilead electrode was inserted in the head of the caudate nucleus and internal capsule. Stimulating frequency was 0.5 cps. Weak stimulation, if effective, elicited quatriphasic waves (two waves). The first phase was a small positive, hardly detected, and a large negative wave (short latency response) and the second large negative wave (Fig. 2, 3). The conspicuous amplitude of the waves was caused by stimulation of the internal capsule and its border zone up to the caudate nucleus, and the more the stimulation focus apart from the border zone into the caudate nucleus, the less became the evoked potential. When the intensity of the stimulation was five times as strong as that of the weak stimulation, the amplitude of the waves increased and the difference became more marked between the effects of the stimulation of internal capsule and caudate nucleus. The first wave (short latency response) was stably recorded, but the second wave was unstable.

The stimulus to peak time of the evoked potential elicited from the medial part stimulation of the caudate nucleus differed from that of the lateral part of the caudate nucleus or of internal capsule, as was reported by Laursen. The evoked potential elicited from the medial part of the caudate was without positive deflection but with two negative waves. The height of negative deflection was remarkably varied depending on each stimulation. But the variability of the height of negative deflection by stimulation of the caudate nucleus was lesser than that by stimulation of internal capsule.

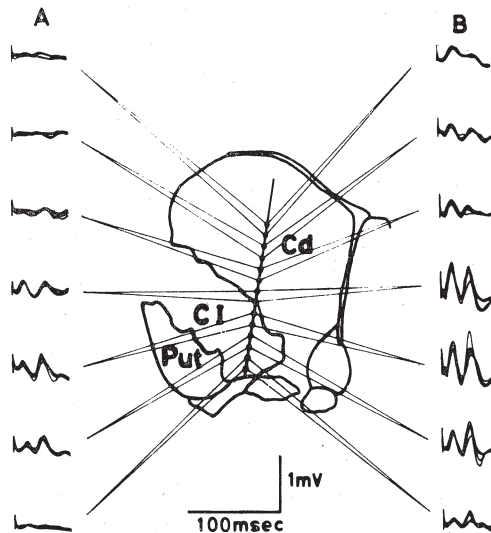


FIG. 2. Cortical responses to stimulation of the head of the caudate nucleus and internal capsule of unanesthetized and unmobilized cat with succinylcholine chloride and Mylaxen. Recording superimposed five times from the anterior sigmoid gyrus of the cortex on the ipsilateral side to the stimulation. Column A shows responses to the slightly supraliminal single shock of 0.2 msec duration. Column B shows responses to the stimulation five times stronger than that in A. The stimulating points are shown by 14 dots on the straight line representing the multilead electrode. Cd Caudate nucleus. CI internal capsule. Put Putamen. In this and all other figures positivity is signalled by the downward deflection.

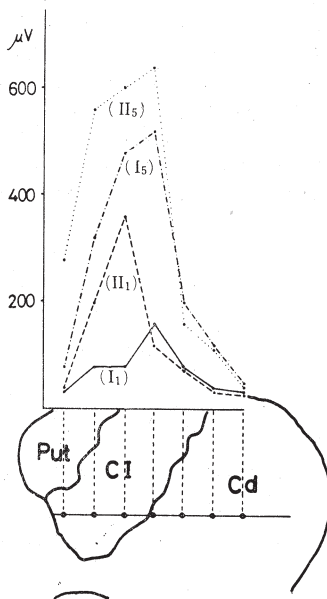


FIG. 3. The amplitude of the evoked cortical potentials is represented by the first ($I_5 I_1$) and second ($II_5 II_1$) negative peaks of the waves. The recorded waves varied according to the stimulating points as well as the strength of stimulation. The sizes of the both first and second peaks were plotted against the stimulating points which are shown on the straight line drawn under the abscissa. In $I_5 II_5$ the stimulation intensity was applied five times greater than in $I_1 II_1$.

b) Repetitive stimulation at the rate of 5 to 10 cps

As was stated above, by stimulation of the caudate nucleus, the evoked cortical potentials were small and there were observed no conspicuous changes in the amplitude even when the repetition of stimulation was applied. But when the internal capsule was stimulated repetitively at 8 cps, the amplitude of the first negative wave became a little smaller, while the second negative wave showed "waxing and waning" and the maximum amplitude of the responses was more than two times as large as that by single shock (Fig. 4).

The recruiting response was never evoked by repetitive stimulation in the medial part of the head of the caudate nucleus nor in the limited lateral part of the internal capsule; This shows that the diffuse thalamic projection system does not spread into the medial part of the head of the caudate nucleus, and the lateral part of the internal capsule has little relation with the diffuse thalamic projection system (Enomoto²⁹), Jasper³⁰), Stoupe³¹), Marco³²). By stimulation of the lateral part of the caudate, the recruiting response could be caused, but this was interpreted to be due to current spread of the stimulus to the medial part of the internal capsule.

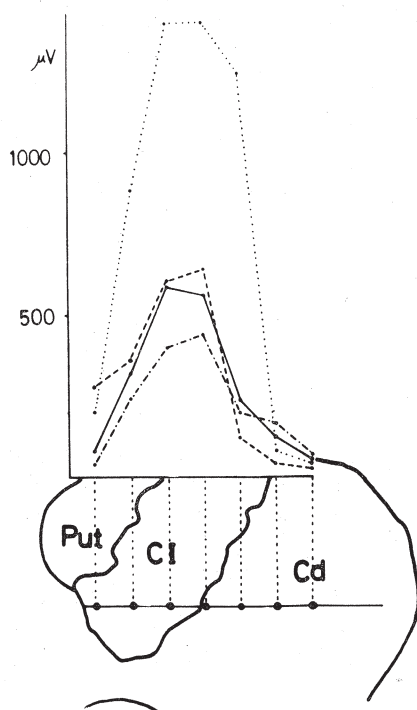


FIG. 4. The differences between cortical responses elicited by single shock (0.5 cps) or repeated (8 cps) stimulation. Recordings from the ipsilateral anterior sigmoid gyrus. Solid line; The first peak of the evoked potentials elicited by single shock. Dash line; The second peak, single shock. Chain line; The first peak, repeated stimulation. Dotted line; The second peak, repeated stimulation.

c) Comparison of the amplitudes of the evoked potentials by single stimulation at several places on the cortex

On the internal capsule stimulation, the amplitude of the first negative

wave recorded from the ipsilateral anterior sigmoid gyrus was about five times larger than that from the posterior one. While the amplitude of the second negative wave from the former was about two times larger than that from the latter. By stimulation of the medial part of the head of the caudate nucleus, however, the amplitude was small and almost of the same size in both recordings from the anterior and posterior sigmoid gyri (Fig. 5). Responses in the other part of the cortex, except in the anterior and posterior sigmoid gyrus, were very small or obscure.

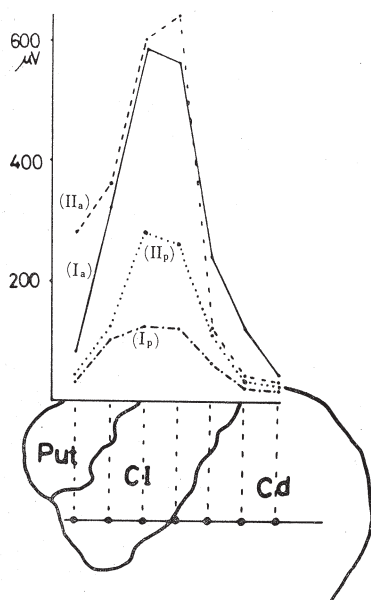


FIG. 5. The amplitude of the evoked potentials observed in the anterior sigmoid gyrus ($I_a II_a$) are compared with those obtained in the posterior sigmoid gyrus ($I_p II_p$). Other explanation abbreviations are the same as in Fig. 3.

2) Interaction between the caudate nucleus or internal capsule and the nuclei of the thalamus

The amplitude of the evoked potential in the ipsilateral anterior sigmoid gyrus elicited by the caudate nucleus or internal capsule stimulation was inhibited by high frequency (200 cps) stimulation of the nucleus centrum medianum of the thalamus (CM), as reported by Krauthamer, but on the contrary, the cortical response elicited by low frequency stimulation of CM was not inhibited by stimulation of the caudate-internal capsule at 200 cps. This may suggest that CM high frequency stimulation caused changing of the cortical excitability and revealing of desynchronization, because CM belongs to the diffuse thalamic projection system (Moruzzi and Magoun³⁴), Jasper, Naquet and King³⁵), Jasper and Ajmon-Marsen³⁶). On the contrary the caudate-internal capsule stimulation caused the cortical excitability to change only in a small area of the pericruciate cortex, so the above stated reversal evidences

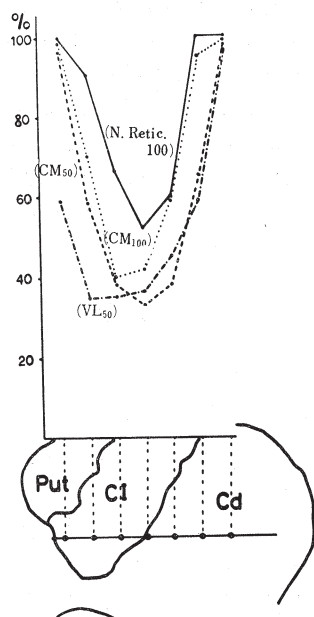


FIG. 6. Interaction between the caudate nucleus or internal capsule and the nuclei of the thalamus. The conditioning stimuli were given to the caudate or internal capsule. The test stimuli were given to the nuclei of the thalamus. Ordinate is amplitude of the evoked potential observed at the ipsilateral anterior sigmoid gyrus elicited by test stimuli. 100% shows amplitude of the test response without conditioning stimuli. The black dots show stimulating points of the conditioning stimuli. Dash line (CM₅₀). Amplitude of the responses elicited by test stimuli applied after the interval of 50 msec to CM. Dotted line (CM₁₀₀). Stimulation interval was 100 msec. Chain line (VL₅₀). Test stimuli are to VL after the interval of 50 msec. Solid line (N. Retic. 100). Test stimuli to the nucleus reticularis of the thalamus, after the interval of 100 msec.

may be due to the spatial difference of the synaptic junction. Conditioning stimuli were given to the caudate nucleus and internal capsule, and testing stimuli to the CM with delay time 50 and 100 msec. After the conditioning stimuli of the medial part of the internal capsule and lateral part of the caudate nucleus, the evoked potential evoked by the CM stimulation was inhibited, but not inhibited after the conditioning stimuli were applied to the lateral part of the internal capsule or the medial part of the caudate nucleus. The evoked potential elicited by the VA stimulation, with its delay time of 50 msec, was inhibited, but when the delay time was 100 msec, the inhibition was little. Evoked potential by the stimulation of the nucleus reticularis with the delay time 100 msec was inhibited too (Fig. 6).

3) Responses of the bilateral gyri to the stimulation of the head of the caudate nucleus or internal capsule

In unanesthetized cats, the evoked potential of the contralateral anterior sigmoid gyrus showed no evident response with single shock to the caudate nucleus or internal capsule. But on repetitive stimulation of the internal capsule and lateral part of the caudate nucleus at 4 to 15 cps, recruiting response could be recognized, though the height was smaller and its latency of response was a little longer than that of ipsilateral. By cortical surface anesthesia with 4% Xylocaine, those responses of the bilateral almost disappeared. The obvious mirror image, as reported by Laursen, between bilaterally recorded cortical responses could not be proved in this experiment which was

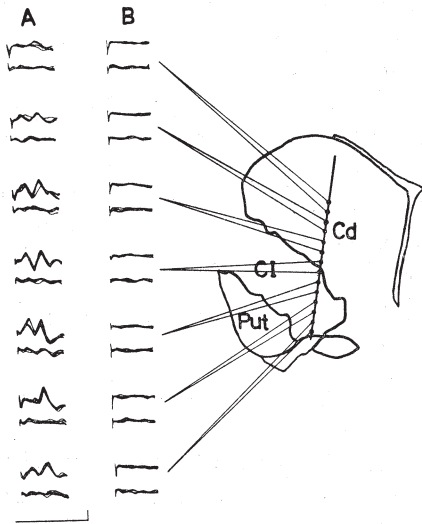


FIG. 7. Influence of Xylocaine anesthesia of the cortical surface upon the responses to stimulation of the head of the caudate nucleus and internal capsule. Column A, without Xylocaine. Column B, anesthetized with Xylocaine. The upper traces of the each pair were recorded ipsilateral, the lower contralateral to the side of stimulation. Five superimposed sweeps. Cal: 100 msec; 100 μ V.

carried out both with cat, anesthetized or unanesthetized (Fig. 7).

4) Responses of the globus pallidus in comparing with cortical responses

By caudate nucleus stimulation, either single or repetitive, there appeared the positive-negative wave with about 5 msec latency in the record from the pallidum, and the stimulus to peak time was 22 msec, but this was hardly recognized by internal capsule stimulation. On the stimulation of the caudate

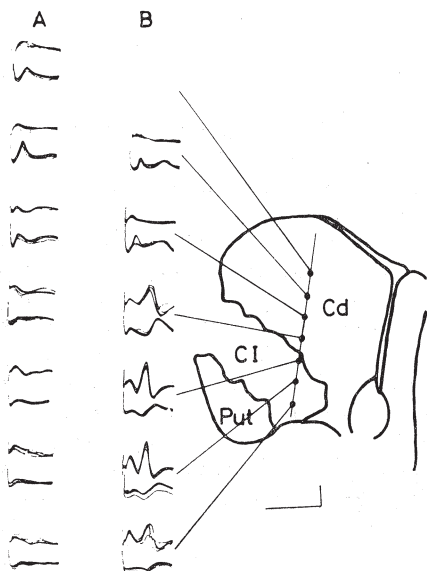


FIG. 8. Records are obtained from the ipsilateral anterior sigmoid gyrus and globus pallidus. Upper traces show recording from ipsilateral anterior sigmoid gyrus, lower traces from ipsilateral globus pallidus. Column A 0.5 cps stimulation. Column B 8 cps. Cal: 100 msec 100 μ V.

nucleus, the response was elicited in the pallidum with such weak strength as could not evoke response at the pericruciate cortex (Fig. 8, column A). In column B, the stimulus intensity was the same as in A, but when the stimulation was repetitive, there appeared the recruiting response clearly in the cortex. With repetitive stimulation of the internal capsule and border zone of the caudate nucleus and internal capsule, the later appearing positive-negative wave with the peak latency of about 30 msec was elicited. This long latency wave may be related to the recruiting response, since this wave did not appear with single shock. The second positive-negative wave from the pallidum appeared in good accordance with the occurrence of the cortical second wave.

5) *Responses of the pedunculus, the nucleus niger and the head of the caudate nucleus*

A part of fibers which originate from the head of the caudate nucleus reaches the rostral part of the nucleus niger (Szabo¹², Verhaart²⁵, Voneida⁴). In order to record the response from the pedunculus and nucleus niger, the pasted doublet string electrode was used. The distance between the tips of the electrode was 1 mm. When the tip of the longer electrode was inserted in the cerebral pedunculus and the ipsilateral motor cortex was stimulated, this electrode recorded the pyramidal responses (Patton and Amassian³⁷). In this situation the short electrode tip did not lead the pyramidal response but led the electrical activity in the nucleus niger (Fig. 9, 10, 11). This method should be used at the place where the thickness of the nucleus niger is more than 1 mm. In recording from the pedunculus, the internal capsule stimula-

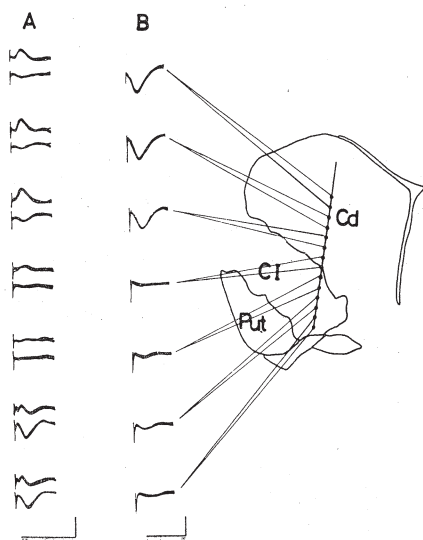


FIG. 9. Records are from the nucleus niger, pedunculus and the head of the caudate nucleus. Upper traces of the column A show recordings from the ipsilateral nucleus niger. Lower traces from pedunculus. Column B shows the responses of the head of the ipsilateral caudate nucleus which was elicited by the stimulation of the caudate nucleus or internal capsule. In the caudate stimulation, the response shows manifest positive deflection, and those stimulus to peak time were 25 msec. On the other hand, the stimulation of the internal capsule or its border zone did not elicit clear response.

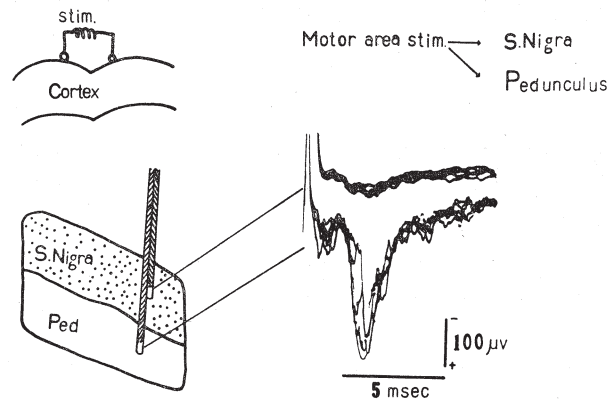


FIG. 10. Cortical stimulation and recordings from the ipsilateral nucleus niger and pedunculus. Weak stimulation of the cortical motor area evoked the pyramidal response with D and I waves in the ipsilateral pedunculus but there was no obvious response in the nucleus niger.

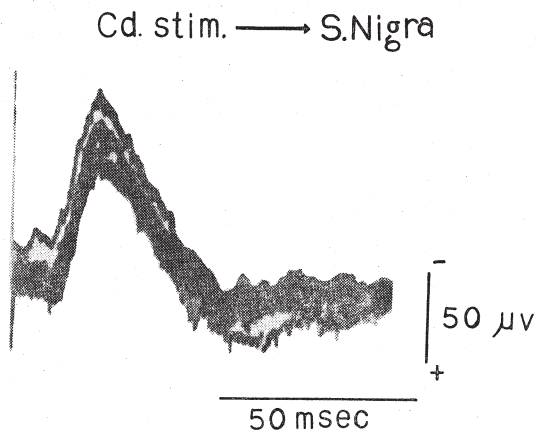


FIG. 11. Evoked potentials from the nucleus niger elicited by single shock stimulation to the head of the caudate nucleus.

tion elicited positive-negative and positive deflections and, at the same time, recording from the nucleus niger showed a doublet of small negative and a positive response. Both stimulus to peak times of the negative responses were measured about 4 and 11 msec respectively. When the border zone between the caudate nucleus and internal capsule was stimulated, clear response did not appear in both longer and shorter electrode recordings. When the caudate nucleus was stimulated, the recording from the rostral part of the nucleus niger showed a large negative wave of which latency was about 8 msec and the stimulus to peak time was about 18 msec. The pedunculus recording

showed a slight positive deflection. This result differs from those of Shimamoto and Verzeano¹⁴⁾, Frigyesi and Purpura²⁷⁾.

DISCUSSION

Merits of the multilead electrode are, as Laursen¹⁹⁾ indicated, that the distance between the stimulating points are constant and once the electrode is fixed stereotaxically in the brain, we can stimulate any time the same points without an excess injury of brain tissue. The concentric electrode was used too, but the response elicited with this electrode was the same as that elicited with the multilead electrode.

By single shock stimulation of the caudate nucleus or internal capsule, the response of the symmetrical location of the contralateral cortex was very small.

Laursen¹⁹⁾, however, described that a mirror image appeared between the bilateral cortical responses by stimulation of the caudate nucleus, which was not altered in any respect by local cortical anesthesia or ablation. He suggested that the mirror image of the response elicited by caudate stimulation was caused by volume conduction originated from excitation of this nucleus.

In this experiment, the mirror image of the responses could not be found between the bilateral cortices. In the cortical surface anesthetized locally with 4% Xylocaine, the response to the Cd-CI stimulation was almost disappeared, while in the Laursen's experiment, the response was conserved against the local anesthesia of the cortices. Further, Laursen anesthetized the animal with chloralose but this experiment was carried out in wakefulness. Though there was found the similar appearance in the electrical activity, both responses should be considered to be different from each other.

The first positive-negative cortical response (short latency response) was not elicited by stimulation of the medial part of the caudate nucleus, so the existence of the direct cortical afferent fiber from the medial part of the caudate nucleus can be hardly verified. This seems to contradict the existence hypothesis. The cortical responses elicited by the caudate nucleus stimulation may have been caused via other nuclei, for instance the globus pallidus or nuclei of the thalamus. The short latency response elicited by strong caudate stimulation is considered perhaps to be elicited by current spread to the internal capsule, as was reported by Laursen.

In contralateral recordings, the recruiting responses appeared clearly with repetition of stimulation of the internal capsule, but its latency is a little longer than that of ipsilateral. This indicates that the diffuse projection system near the internal capsule has close relation with bilaterality, but Enomoto described that the recruiting response elicited by internal capsule stimulation appeared only on the ipsilateral cortex. The recruiting response was also observed by stimulation of the lateral part of the caudate nucleus as

was mentioned in papers (Jasper³⁰⁾³⁸), Stoupel, and Terzuolo³¹), Marco and Brown³²), but its amplitude was considerably smaller than that elicited by internal capsule stimulation. This discrete decrease in amplitude indicates to be due to current spread from the stimulating site to the internal capsule rather than to activity in the caudate nucleus.

The fiber connections between the medial part of the internal capsule or the lateral part of the caudate nucleus and many nuclei of the thalamus, for example, VA, MD, VM, CM, VL, Pc etc. have been reported by many authors (Nauta and Whitlock³⁹), Nashold, Hanbery and Olszewski²¹). On this anatomical ground of the relationship between Cd-CI and nuclei of the thalamus, the electrophysiological examination was carried out. It became clear from this experiment that the evoked potentials by single or repetitive test stimulation at low frequency of CM, VL, VA and N. Reticularis were inhibited by conditioning stimulation of the medial part of the internal capsule or lateral part of the caudate nucleus, which preceded 30 to 100 msec. to the test stimuli. As shown in Fig. 6, the effect of the inhibition upon the cortical response was obtained by the stimulation of the relating area extending from the medial part of the internal capsule to the lateral part of the caudate nucleus. This fact indicates that the fiber connections through the lateral part of the caudate nucleus and the medial part of the internal capsule to the sensori-motor cortex have close relations with CM, VA, VL, Cp and N. Reticularis, corresponding to the anatomical findings. The maximum effect was obtained on stimulation at the medial part of the internal capsule, which shows that the fiber connections pass through the medial part of the internal capsule, while considerable effects were detected on stimulation at the lateral part of the caudate nucleus, but this fact does not verify that the fiber connections pass through the lateral part of the caudate nucleus because the current spread cannot be excluded completely.

By using 1. the multilead electrode for stimulation and 2. the concentric electrode for recording—this being situated within 3 mm from the stimulation point in the head of the caudate nucleus—the short latency positive wave with stimulus to peak time about 25 msec could be recorded. The obtained record coincided fairly well with the reports of Umbach⁴⁰) and Wieck, Kuhn and Kohlman⁴¹), but differed from the report of Laursen⁴²). The disagreement with the result of Laursen's has been considered to owe to the difference of the recording methods.

The response of the nucleus niger was recorded by stimulation of the medial part of the caudate nucleus. A small positive, large negative response with about 8 msec latency was elicited in the nucleus niger by caudate nucleus stimulation, but there was no response to the stimulation of the CI-Cd border zone. By stimulation of the internal capsule, a doublet wave of short latency could be recorded. The latency of the second wave was about 6 msec and

this response resembles that of Shimamoto's¹⁴⁾. Shimamoto did not compare the responses elicited by the caudate nucleus stimulation with that by internal capsule stimulation, and left the stimulus current spread to the internal capsule out of consideration. Purpura²⁷⁾ recorded the response with latency of about 4 msec in the nucleus niger by caudate stimulation. This response corresponds to the first wave of the internal capsule stimulation in this experiment. By stimulation of the internal capsule, short and long latency positive waves were recorded in the pedunculus, but it cannot be clearly asserted whether these waves correspond to the D and I waves of the pyramidal response or not. In the pedunculus recording, positive deflection which was elicited by caudate stimulation was obscure. This shows, as reported by Verhaart⁴³⁾, that the fibers from the head of the caudate do not pass through the pedunculus directly.

SUMMARY

Caudatofugal fiber connections were investigated electrophysiologically in the cat by using a multilead electrode for stimulation of the caudate nucleus and internal capsule. The animal was immobilized with succinylcholine chloride and maintained awake.

(1) The response to stimulation of the internal capsule was obtained manifestly at the pericruciate gyrus, but obscure at other areas. They were recorded as two waves: the first short latency response and the second delayed one. By caudate nucleus stimulation, the similar response was obtainable with strong stimuli. This shows that the direct cortical afferent fibers do not originate from the head of the caudate nucleus, and the short latency response elicited by caudate stimulation was considered to be caused by current spread to the internal capsule.

(2) The so-called mirror image (Laursen¹⁹⁾) between bilateral cortical responses elicited by caudate stimulation was not obtained.

(3) The recruiting response was never evoked by repetitive stimulation of the medial part of the head of the caudate nucleus, nor by that of the limited lateral part of the internal capsule, so the diffuse thalamic projection system did not seem to reach the head of the caudate nucleus, and the lateral part of the internal capsule has no connection with the diffuse thalamic projection system.

(4) The responses which showed "waxing and waning" elicited by stimulation of the thalamus and of the internal capsule were compared and after giving conditioning stimuli to the internal capsule and testing stimuli to the thalamus, it was inferred that the fibers connecting CM, VA, CP, VL, and N. Retic. to the cortex pass partially through the medial part of the internal capsule.

(5) There appeared the positive-negative waves in the globus pallidus by

stimulation of the caudate nucleus, with about 5 msec latency and the stimulus to peak time of 22 msec.

(6) In order to record the response of the nucleus niger and cerebral pedunculus, a doublet string electrode was used, and by stimulation of the caudate nucleus, a diphasic wave of small positive and large negative deflections was obtained at the rostral part of the nucleus niger in particular, after the latency of about 8 msec and with stimulus to peak time of about 18 msec.

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