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Electrophysiological Studies on the Arrest Reaction Elicited by the Brain Stem Stimulation

by

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The term "arrest reaction" was introduced by HUNTER and JASPER[8] to describe the phenomenon that a sudden arrest of movement was elicited by electrical stimulation of the intralaminar nuclei of the thalamus in unanesthetized and unrestrained cats. They reported that during the arrest reaction, the animal remained immobile as if "frozen" in position and did not respond to usually effective stimuli. Recently, KUROKI[10] has found that such a motor arrest with a reduced nocireflex can also be produced by electrical stimulation of the midline portion of the brain stem reticular formation. The arrest reactions elicited both from the thalamic stimulation (HUNTER and JASPER) and from the brain stem one (KUROKI) seem to be almost the same in appearance, although, in the latter case, higher frequency stimulation is needed to induce it and, at that time, the low voltage fast activity of EEG is revealed in most cases.

Numerous investigations have proved widespread and diverse influences of the brain stem reticular formation upon the higher brain center and the spinal cord[14]. An elicitation of the arrest reaction also speaks volumes for the complicated function of this structure. In this study, the arrest reaction induced by the brain stem stimulation was reconfirmed and analysed with acute and chronic preparations.

METHODS

Over fifty adult cats were used for this study, about the half of which were acute preparations.

Chronic preparations. Bipolar stimulating electrodes for the brain stem and the caudate nucleus were implanted through small trephine holes by means of a stereotaxic instrument and fixed to the scalp with dental cement. Screw electrodes for the EEG recording were inserted in the calvarium over anterior and posterior areas on both right and left sides. Implanted electrodes for the EMG recording were made of small silver balls and fitted intramuscularly in the foreleg. These implantations of chronic electrodes were performed with aseptic precautions under Nembutal anesthesia. The stimulating electrodes consisted of paired stainless steel wires insulated except for the tip, with diameter of about 0.3mm and with an interelectrode distance of 1.0 to 2.0mm. The coated flexible wires from both recording and stimulating electrodes were led out of the back of the neck for connecting with recording and stimulating instruments. Rectangular current pulses of various duration, frequency and intensity were used for the stimulation. The experiment was started at least two days after the implantation of electrodes.

Acute preparations. Craniectomy and laminectomy of lumbosacral segments were performed under Nembutal anesthesia. The peroneal and tibial, or the anterior tibial, sural and gastrocnemius nerves were exposed and placed on bipolar silver wire electrodes with peripheral nerve ends severed. The head was mounted in a stereotaxic instrument and the lumbosacral portion was fixed rigidly in a frame designed for the micromanipulation of recording electrode. Stimulating electrodes for the brain stem were of steel wires with diameter of about 0.3mm and insulated except for the tip and were inserted stereotaxically into the brain stem. The same repetitive rectangular current pulses as used to elicit the arrest reaction in chronic cats were given to the foci. Bilateral L6 and L7 ventral roots were sectioned and these roots of the same side were put together and placed on a pair of silver wire electrodes for recording and stimulation. An RC coupled amplifier feeding a cathode-ray oscilloscope was used for recording from the ventral roots. For recording intracellular potentials from spinal alpha motoneurons, glass micropipettes were used, whose resistance was 10-20 M Ω when filled with 2M-potassium citrate. A DC amplifier with cathode-follower imput was employed for intracellular recordings.

Histological checking. At the end of the experiment, anodal currents were passed through the stimulating electrodes in the brain and iron deposits flowing out in the tissue were stained with the method of TIRMANN-SCHMELZER. The precise location of the electrode tips was determined by making serial sections in each case.

RESULTS

1. The EEG change during the arrest reaction elicited by the brain stem reticular stimulation.

The EEG and behavioral changes were examined in unanesthetized and unrestrained cats with chronically implanted electrodes under stimulating the brain stem reticular formation. As the stimuli, repetitive rectangular current pulses were used at various frequencies of 5 to 300 per second and in durations of 0.1 to 5.0 millisecond. Concerning the frequency of stimulus, it was confirmed that high repetition rates were required, in all cases, to elicit the arrest reaction from the midbrain, pontine and bulbar reticular formations and the lowest frequency at which the arrest reaction was obviously produced was approximately 40 to 50 per second. With regard to the stimulated site, the typical arrest reaction was elicited most easily from the midline portion of the midbrain reticular formation, as described by KUROKI[10].

Recordings of EEG during the arrest reaction showed the low voltage fast activity. The desynchronized EEG was certainly not appreciably changed by the reaction, when the background activity of EEG presented the arousal pattern (Fig. 1A). When the same stimulation was applied to the animal in relaxation, drowsiness or sleep, the low voltage fast activity of EEG appeared with behavioral arousal (Fig. 1B). It is generally accepted that the low voltage fast EEG is recorded by stimulation of the brain stem reticular formation without any relation to the arrest reaction.

With lower repetition rates of the stimulation, the arrest reaction could not be observed in general, but muscle twitchings synchronous to the stimulation were elicted, extending from the face to the whole body as the intensity of stimulus was increased. Further, low frequency stimulations were less effective than high frequency ones to change the

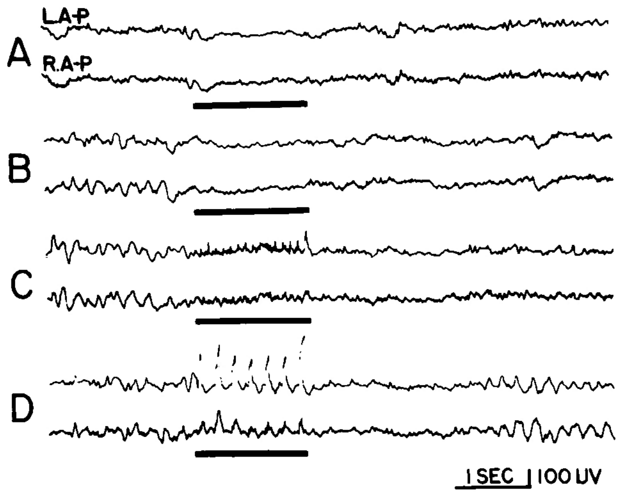

Fig. 1. Effects of the brain stem reticular stimulation upon spontaneous electroencephalographic activity. Unrestrained normal cat. Stimulating electrodes in the midline portion of the midbrain reticular formation. Bipolar EEG records from left and right (L. and R.) anterior-posterior areas (A–P).
A : the reticular stimulation with 0.2 msec, 100/sec, 0.8 V in awake state (walking). The arrest reaction was elicited by the stimulation. B : the same as A, but in drowsy state. C and D : the reticular stimulation with 1 msec, 10/sec, 2 V and 4 msec, 5/sec, 3 V in drowsiness. No behavioral arousal was induced by the stimulation. The period of stimulation is marked by a heavy line beneath the record.

background activity of EEG (Fig. 1, C and D). It is reported that a recruiting response-like pattern or synchronized cortical rhythms with behavioral signs of sleep can be induced by low frequency stimulation of the brain stem reticular formation[1,3], but none of them was obtained in this study.

2. The EMG change during the arrest reaction elicited by the brain stem reticular stimulation.

The EMG was recorded from the animal on which an elicitation of the arrest reaction by stimulation of the brain stem reticular formation was ascertained in behavioral observations. The animal was slightly anesthetized with ether and mounted on a fixing apparatus for the head. The limbs were fixed but enough to move freely and fitted with needle electrodes for EMG recordings on flexor and extensor muscles.

It was observed with the same stimulation as used to elicit the arrest reaction that the EMG change seemed to be the same in degree in all extensors and flexors on bilateral sides. There were found no reciprocal responses of the EMG's between flexor and extensor muscles and between bilateral sides of them. By the midbrain or pontine reticular stimulation of suitable strength for the arrest reaction, tonic maintained muscle discharges were considerably decreased as shown in Fig. 2, A and B, but by more intense stimulation, they were increased. The responses mentioned above were not obtained by the bulbar reticular stimulation, but an increase in the tonic activity of extensor muscles was frequently revealed (Fig. 2C).

It was found that the reticular stimulation with low repetition rates were ineffective to change the tonic maintained muscle discharges. When strength of the stimulus was

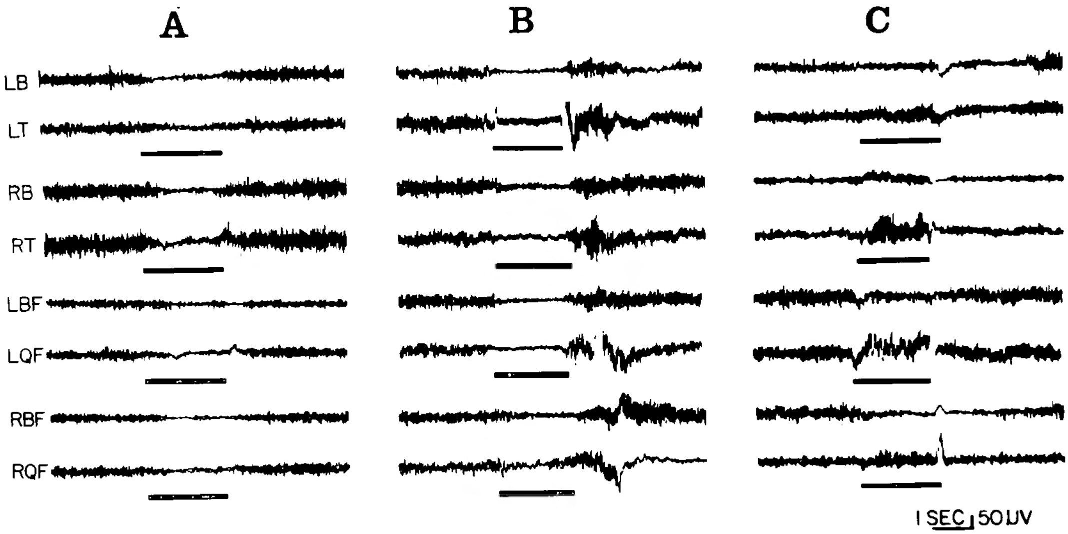

Fig. 2. Effects of the brain stem reticular stimulation upon tonic maintained electromyographic activity.
Normal cats under light anesthesia. Bipolar EMG records from left and right biceps (LB, RB), triceps (LT, RT), biceps femoris (LBF, RBF) and quadriceps femoris (LQF, RQF). Stimulation of the midline portion of the midbrain (A), pontine (B) and bulbar (C) reticular formation of three different cats with 0.2 msec, 100/sec 1 V.
Generalized nonreciprocal suppression of electromyographic activity was seen in A and B. The period of stimulation is marked by a heavy line beneath the record.

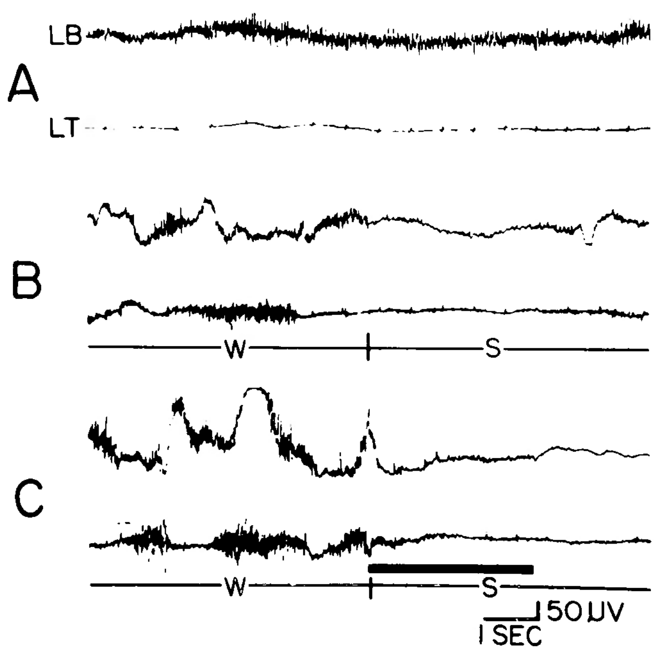

Fig. 3. EMG changes during the arrest reaction elicited by the brain stem reticular stimulation.
Unrestrained normal cat. Bipolar EMG records from left biceps and triceps (LB and LT) with implanted recording electrodes. Stimulation of the midline portion of the midbrain reticular formation with 0.2 msec, 100/sec, 1 V.
A : crouching. B : walking and natural standing. C : walking and standing during and after the arrest reaction induced by the reticular stimulation, which is marked by a heavy line beneath the record C. Fine lines marked by 'w' and 's' indicate walking and standing states.

increased, EMG changes synchronous to the stimulation were observed.

Further, the muscle activity during the arrest reaction was investigated on the EMG of unanesthetized and unrestrained cats with implanted recording electrodes. There was no marked difference between EMG's in naturally standing state and in standing one during the arrest reaction (Fig. 3). The muscle tonus enough to stand on seemed to be reserved during the reaction.

3. *Effects of the electrical coagulation of the foci eliciting the arrest reaction upon the behavior.*

The focus from which the arrest reaction could be elicited in chronic cats was electrically coagulated by direct currents through implanted stimulating electrodes. In some other cats, serial lesions at intervals of 1mm were stereotaxically made along the midline of the brain stem reticular formation, extending from the midbrain to the medulla oblongata.

After these procedures, behavioral and EEG changes were examined and followed up for several days. Scarce changes were found in behavior and EEG following such lesions in the reticular formation. At the end of the experiment, electrically destructed foci were histologically checked to be usually a size less than 1.5 mm in diameter.

4. *Effects of simultaneous stimulation of the two reticular foci located symmetrically to the midline upon the behavior.*

When a stimulated focus in the brain stem reticular formation was deviated from the midline portion and the intensity of stimulus was adequate, a movement toward the stimulated side was markedly stressed by the repetitive stimulation in chronic cats. It is a turning or rotation of the head, a circling and rolling of the whole body, as reported hitherto[6,7]. Such responses to the stimulation were not infrequently experienced also in this study, when the implantation of stimulating electrodes failed of inserting into just the midline portion. Fig. 4 shows an example of the EMG change set up by repetitive stimulation of the midbrain reticular formation on the left side in a slightly anesthetized cat. A reciprocity between muscles of the right and left sides were clearly revealed.

Repetitive stimulations were applied simultaneously through implanted electrodes to two foci, which were situated symmetrically at the distance of 2 mm from the midline in the midbrain reticular formation of unanesthetized and unrestrained cats. Though it was, strictly speaking, impossible to stimulate equally the bilateral foci, a response resembling the arrest reaction could be obtained, when a stimulating current was divided into the two foci through a variable resistor in order to make the stimulating effects upon bilateral sides equal. But the arrest reaction under such a condition was not so typical as the one elicited from the midline portion of the midbrain. The reaction was hardly observed by the symmetrical stimulation of bilateral pontine or bulbar reticular formations. Failure to obtain the arrest reaction with the bilateral pontine or bulbar reticular stimulation may partly depend upon the technical difficulty to implant stimulating electrodes exactly in symmetrical positions.

5. *Effects of the repetitive stimulation of bilateral caudate nuclei upon the behavior.*

It has been reported that high frequency stimulation of the head portion of the caudate nucleus produces, in general, a circling movement toward the contralateral side to the

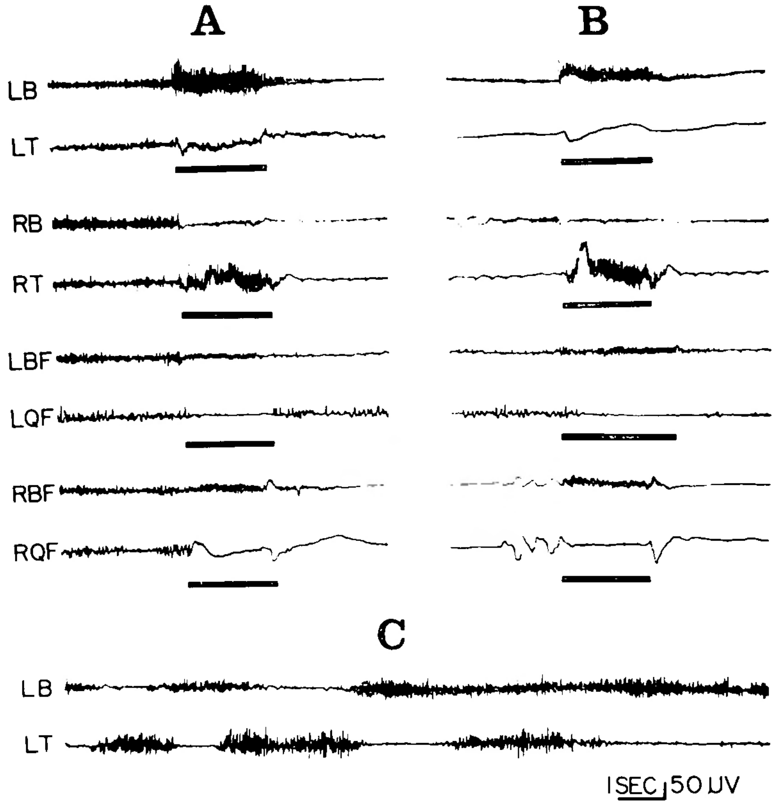

Fig. 4. Reciprocal effects of the brain stem reticular stimulation upon electromyographic activity. Normal cat under light anesthesia. Bipolar EMG records from left and right biceps (LB, RB), triceps (LT, RT), biceps femoris (LBF, RBF) and quadriceps femoris (LQF, RQF). Stimulation of the left midbrain reticular formation with 0.2 msec, 100/sec, 1 V.

A : reciprocal response elicited by the medial reticular stimulation in the tonic background activity. B : the same as A in the silent background one. C : reciprocal muscle activity of the left foreleg induced by spontaneous movements. The period of stimulation is marked by a heavy line beneath the record.

stimulation in chronic cats[2,4].

Firstly, effects of the repetitive stimulation of the nucleus on one side upon behavioral and EEG changes were examined in unanesthetized and unrestrained cats. With the caudate nucleus stimulation, higher repetition rates were needed to produce a circling movement and to change the slow background activity of EEG into the fast one. The relative value of the threshold voltage to obtain such effects by the caudate nucleus stimulation was higher than that by the reticular stimulation (Fig. 5).

Then, the repetitive stimulation was applied simultaneously to head portions of the bilateral caudate nuclei, in the same manner as in bilateral reticular stimulations, but it was confirmed that responses resembling the arrest reaction could not be obtained and the animal showed a stiff movement during the stimulation.

6. *Effects of the repetitive reticular stimulation upon the spinal reflex.*

Effects of the repetitive reticular stimulation upon the spinal reflex were examined in

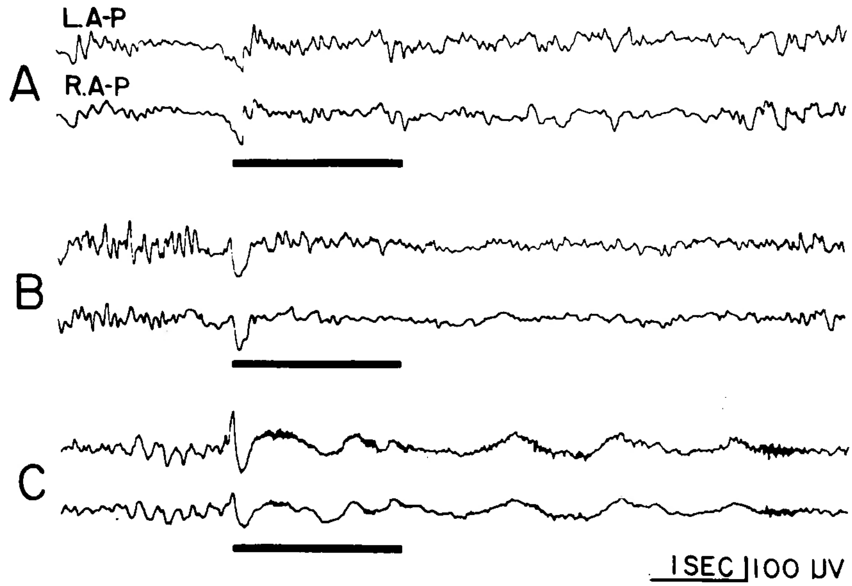

Fig. 5. Effects of stimulation of the caudate nucleus upon spontaneous electroencephalographic activity. Unrestrained normal cat. Bipolar EEG records from left and right (L. and R.) anterior-posterior areas (A-P.) Stimulation of the left caudate nucleus with 0.2 msec, 100/sec, 2 V (A), 4 V (B) and 8 V (C). By the caudate nucleus stimulation, slow EEG rhythms were unchanged or changed transiently into fast ones, but behavioral arousal was not observed (A and B). When strength of the stimulus was increased, the low voltage fast activity was induced in association with a circling movement (C). The period of stimulation is marked by a heavy line beneath the record.

slightly anesthetized cats. For obtaining the extensor and flexor monosynaptic reflexes, test stimuli in single pulses were applied respectively to the gastrocnemius and anterior tibial nerves with the intensity submaximal to group Ia fibers, while, for the polysynaptic flexor reflex, test stimuli were given to the sural nerve. These reflex discharges were recorded from the L6 and L7 ventral roots on the same side to stimulated nerves. Conditioning repetitive stimuli were delivered to the midline portion of the midbrain reticular formation, in which the arrest reaction could be most typically and easily elicited. Repetitive stimuli in this study were the same in duration, in strength and at frequency as those used in unanesthetized and unrestrained cats.

It was found that the height of both extensor and flexor monosynaptic reflexes was, on an average, scarcely changed, but the polysynaptic flexor reflex was markedly suppressed by the reticular stimulation as shown in Fig. 6. After cessation of the stimulation, such an influence upon the polysynaptic reflex disappeared in a second. Fluctuations of the background potential of the ventral roots were often slightly enhanced during the reticular stimulation.

7. *Effects of the repetitive reticular stimulation upon the intracellular potential in spinal alpha motoneurons.*

Under light anesthesia, recordings of the intracellular potential in lumbar alpha motoneurons were performed with glass micropipettes in L6 and L7 segments. Flexor or extensor motoneurons were identified by the presence of monosynaptic EPSP's elicited by

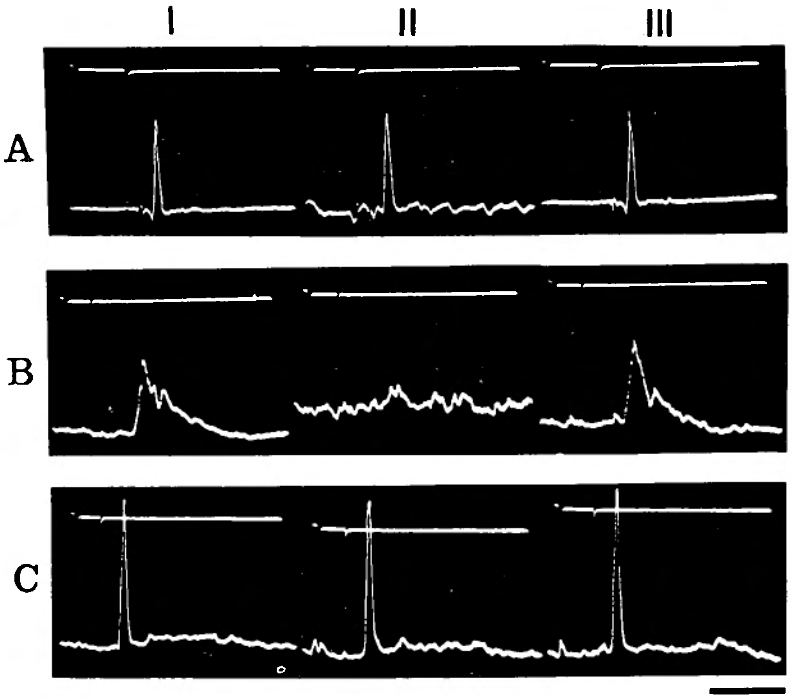

Fig. 6. Influences of repetitive stimulation of the midline portion of the midbrain reticular formation upon the spinal reflex.

A and C : flexor and extensor monosynaptic reflexes elicited by test stimuli applied to the anterior tibial and the gastrocnemius nerves. B : polysynaptic flexor reflex elicited by test stimuli given to the sural nerve. The reflexes before, during and after the conditioning reticular stimulation are shown in position I, II and III of each row from the left to the right. Upper records of each row exhibit artifacts of test stimulus.

By the reticular stimulation, the height of monosynaptic reflexes was scarcely changed (II, A and C), but the polysynaptic flexor reflex was markrdly suppressed (IIB)

Time mark : 10 msec.

afferent volleys sent from the ipsilateral peroneal or tibial nerve.

Intracellular potential records from four extensor motoneurons were presented in Fig. 7 and 8. In the motoneuron of Fig. 7, A and B, EPSP's were produced by single stimulations of the midline portion of the midbrain reticular formation. With repetitive stimulations of about 100 per second in frequency, a maintained depolarization with spike discharges took place in each motoneuron. In the motoneuron C, single reticular sitmulations set up IPSP's on the background of maintained spike discharges and the repetitive stimulation elicited a continuously maintained hyperpolarization resulting in decrease of spike discharges. In the motoneuron of Fig. 8, single stimulations brought on EPSP's and spike potentials. Whereas, by the repetitive stimulation, the membrane potential was kept nearly at the resting potential level and the number of maintained spike discharges was diminished. This may be an example of the inhibitory effect upon motoneurons without any remarkable membrane potential change[15].

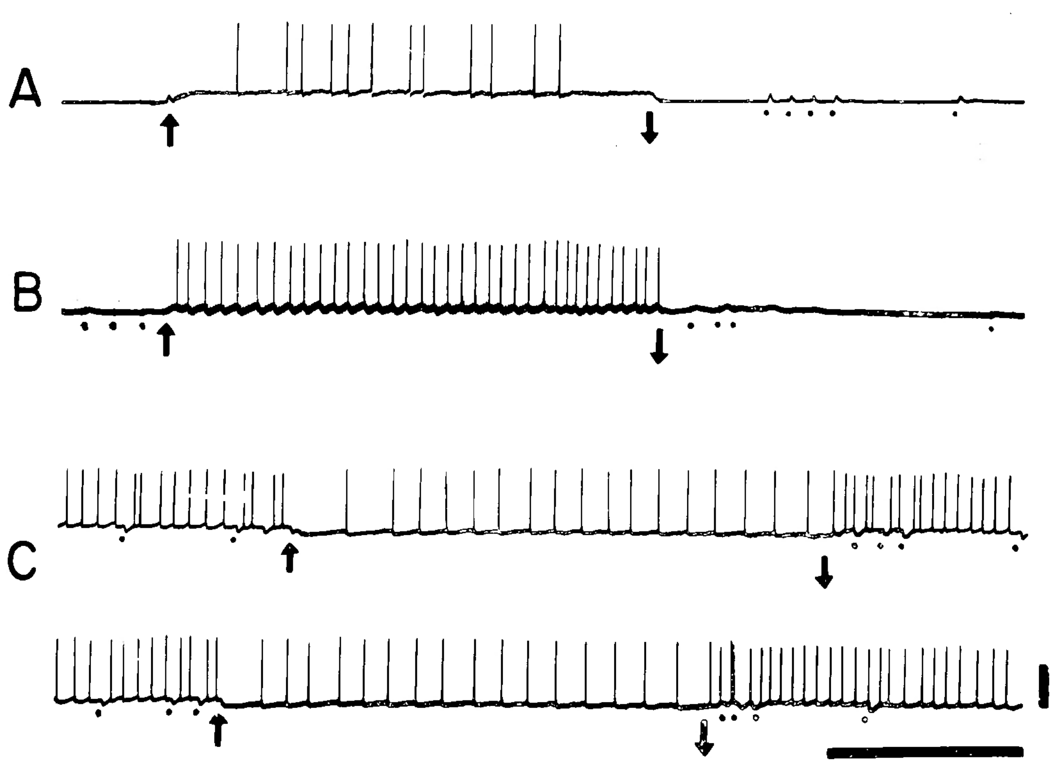

Fig. 7. Changes of membrane potential of three extensor motoneurons due to repetitive stimulation of the midline portion of the midbrain reticular formation.
A and B : EPSP's and maintained depolarization with spike discharges elicited by single stimulations (dots) and repetitive one (between arrows) at frequency of about 100 per second in silent motoneurons. C : IPSP's and maintained hyperpolarization with reduction of tonic spike discharges of the motoneuron elicited by single stimulations (dots) and repetitive one (between arrows).

Time mark : 500 msec. Voltage calibration : 50 mV.

8. *Effects of the repetitive reticular stimulation upon spinal descending tract fibers.*

Activities of single descending tract fibers were not infrequently picked up by micropipettes in the spinal cord. They showed no response to stimulation of the ventral and dorsal roots, but responded to the reticular stimulation.

In the fiber of Fig. 9A, single stimulations set up sometimes spike potentials on the silent background, but maintained spike discharges were elicited by the repetitive stimulation. In the fiber of B, responses to the reticular stimulation were more remarkably enhanced in its discharges on the tonically firing background.

These results seem to show that descending bombardents to the spinal level may be increased by the repetitive reticular stimulation.

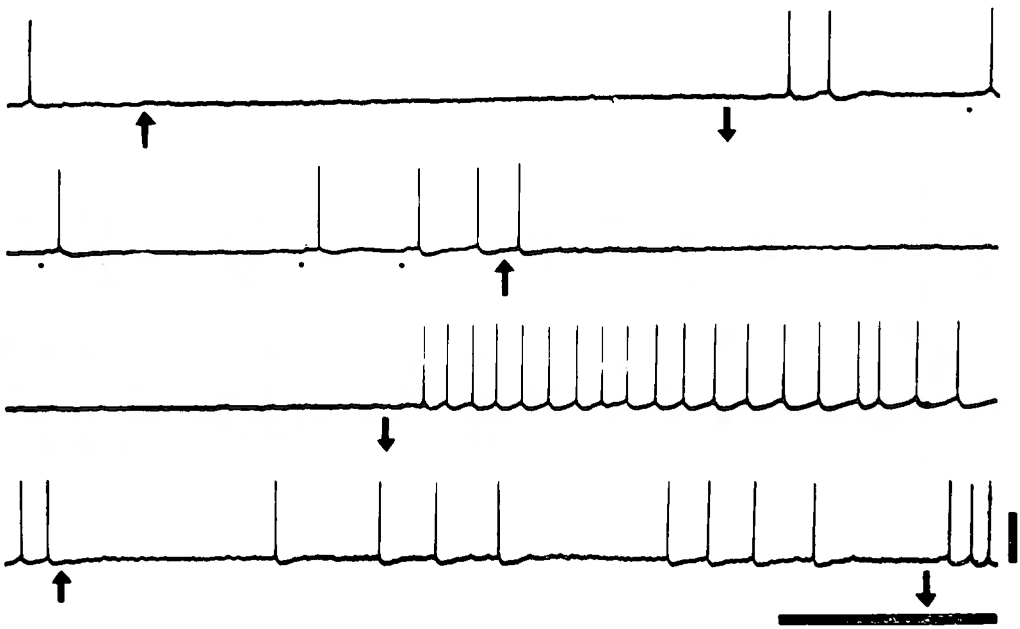

Fig. 8. Inhibition of maintained firings of the extensor motoneuron without the membrane potential change by repetitive stmulation of the midline portion of the midbrain reticular formation.
Single stimulations (dots) elicited EPSP's and spike potentials and repetitive stimulations (between arrows) at frequency of about 100 per second stopped or suppressed the maintained firings without obvious membrane potential change. The record was continued on four rows from top to bottom.
Time mark : 500 msec. Voltage calibration : 50 mV.

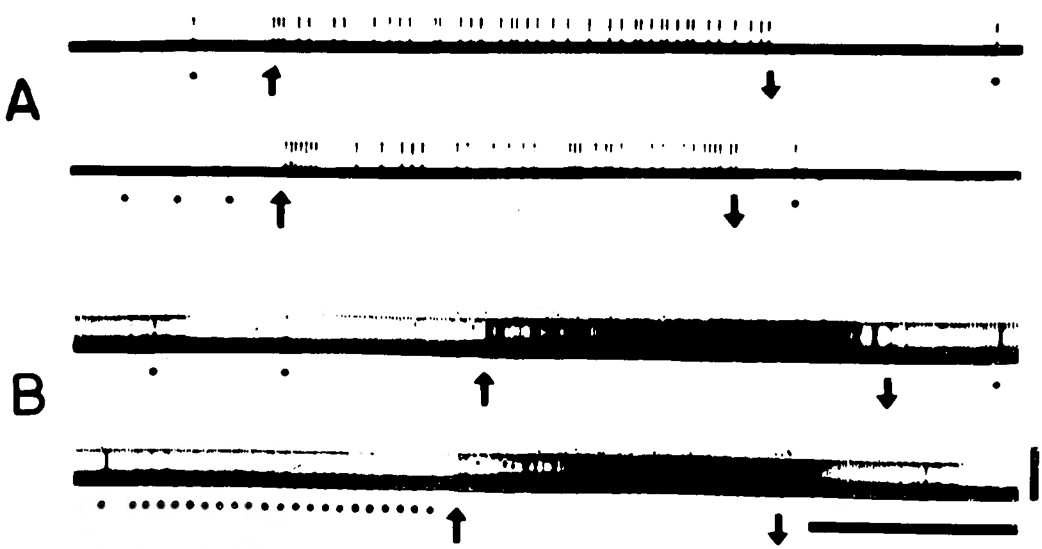

Fig. 9. Responses of two spinal descending tract fibers to stimulation of the midline portion of the midbrain reticular formation.
A : single stimulations (dots) set up sometimes spike potentials and repetitive one (between arrows) at frequency of about 100 per second elicited maintained spike discharges in a silent fiber. B : more remarkable increase of spike discharges in a tonic firing fiber.
Time mark : 500 msec. Voltage calibration : 50 mV.

DISCUSSION

The arrest reaction analysed in this study is characterized with stopping of movements and reduced responsiveness to nocistimuli. The animal under such a reaction maintains usually the posture just before the electrical stimulation, though it crouches slightly in some cases. The animal does not seem to be in fear or fright, since it never skips away after cessation of the stimulation, continuing the interrupted movements further on.

In order to elicit the arrest reaction, the repetitive stimulation with a certain strength and at a frequency has to be applied to an appropriate portion in the brain stem. In this study, as reported by KUROKI[10], the most effective focus for eliciting the arrest reaction was checked to lie in the midline portion of the midbrain. The stimulation of the midline portion of the pons and medulla oblongata also could produce the arrest-like reaction but hardly maintain a "frozen" posture through the whole course of stimulation. As regards the frequency of stimulation, high repetition rates more than about 50 per second were needed to elicit obviously the arrest reaction. When the reaction was produced by the brain stem stimulation, the low voltage fast activity of EEG was always revealed in all cases. The EEG change is quite different from that in the arrest reaction elicited from the thalamic stimulation[8]. On the EMG, there was found no marked difference between the muscle activities of legs in naturally standing state and in standing one during the arrest reaction.

The repetitive stimulation of bilateral caudate nuclei could not produce a response resembling the arrest reaction. The nucleus stimulation on one side elicited a circling movement, but it was less effective to change the EEG activity than the reticular stimulation. On the other hand, the arrest reaction could be obtained by the symmetrical stimulation of bilateral midbrain reticular formations. It has been reported that electrical stimulation of the brain stem reticular formation at high repetition rates induces the low voltage fast activity of EEG[12]. These facts suggest that the ascending reticular activation may be necessary to elicit the arrest reaction, but only an offset effect of bilateral motor control upon the spinal function may not bring about the reaction. However, the excitation spread widely to the upper brain center will in any way come down to 'final common pathways'. Such a circumstance seems to correspond to that of the speech arrest induced by electrical stimulation of the motor cortex.

Recently, the reciprocal effect from the brain stem reticular formation upon the spinal function has been emphasized[5,16]. It was experienced also in this study that, when the stimulated focus was deviated from the midline of the brain stem reticular formation, a movement toward the stimulated side was revealed and this seemed to be the same as that of the "tegmental response" reported formerly[6,7]. Such a movement was composed of the ipsilateral flexion and contralateral extension of forelegs to the stimulated side, but movements of hindlegs were rather various. On the other hand, it was confirmed in this study that EMG changes elicited by the stimulation of the midline portion of the midbrain and pons were not in the reciprocal manner but were usually generalized diffuse activities of bilateral extensor and flexor muscles. If a neutralization of the reciprocal movements of the bilateral legs would result in the motor arrest, such a generally suppressed

EMG as seen in Fig. 2 could not be observed but an increase in the tonic activity of the leg muscles should be revealed on the EMG in association with the stimulation. The EMG findings presented in this study seem to suggest that the portion, from which the arrest reaction may be elicited, must give rise to some generalized effect upon the spinal motoneurons.

With the spinal reflex test, it was observed that both extensor and flexor monosynaptic reflexes were, in most cases, scarcely changed, but the polysynaptic flexor reflex was markedly suppressed by the stimulation. These results seem just to correspond to the fact that the animal can keep a standing posture with a reduced nocireflex during the arrest reaction. The scarce influence upon the monosynaptic reflex may indicate indirectly that the membrane potential of motoneurons on an average may not be changed so markedly, being near the resting potential level. Consequently, suppression of the polysynaptic flexor reflex by the stimulation should be due to some special inhibitory mechanism acting on the pathway of the reflex. Recently, supraspinal inhibition affecting specially upon the flexor reflex, elicited by cutaneous nerve stimulations of hindlegs, was found by stimulating the cerebellar nucleus of cats (T. TANAKA, unpublished observation).

Effects of the same midbrain stimulation as mentioned above upon the intracellular potential of spinal motoneurons were investigated in very slightly anesthetized cats in order to examine more exactly the spinal mechanism of the arrest reaction. In some motoneurons, a maintained depolarization or hyperpolarization of the membrane potential was revealed during the stimulation. The maintained potential change seems to be resulted from a temporal summation of individual EPSP's and IPSP's elicited successively by each single pulse of the repetitive stimulation. In some other motoneurons, the membrane potential was seemingly kept near the resting potential level during the stimulation. In this case, since suppression of maintained firings of motoneurons can be often observed without remarkable change of membrane potential, it is probably assumed that diffuse random volleys, which imply both facilitatory and inhibitory components just in balancing amounts, are bombarding to the motoneurons during the stimulation[15]

With unitary recordings from the spinal descending tract fibers, a remarkable enhancement in spike discharges was revealed in many cases in association with the stimulation. Consequently, it is reasonably assumed that impingements converging to the spinal motoneurons may be increased by the stimulation when compared with those before the stimulation, but the increased impingements may be balanced in the effect upon the motoneurons and unorganized in the pattern determining the animal movements.

Such an unspecific and unorganized activity may be obtainable from stimulation of the midline portion of the brain stem reticular formation, probably due to a symmetrical spread of stimulated effects to both sides and also due to functional features of the brain stem reticular formation eliciting the extensive excitation over the whole brain. With the anatomical investigation, it has been reported that the descending reticular neurons do not originate from the midbrain[17] while the ascending projections to the basal ganglia seem to arise from the rostral midbrain[13]. Furthermore, the cerebellofugal fibers pass through and relay at the midbrain, decussating especially at the midline. From these facts, the descending influences from the midbrain upon the spinal cord are seen to be far more indirect than those from the pons and medulla oblongata, consequently the unspecific and diffuse activity mentioned above may be expected to be elicited more easily from the midbrain.

The midbrain destruction performed in this study may be too restricted to reduce the outflow volleys from the midbrain to upper and lower centers, so no change in behavior and EEG could be found in the animal[9,11].

In concluding, a hypothetical interpretation of the arrest reaction may be delivered as follows.

An excitation spread widely to the brain elicited by the brain stem stimulation may derange and eliminate highly organized patterns of the activity, which may have been flowing down from upper brain centers to the spinal cord just before the stimulation, and consequently may induce an unspecific and unorganized diffuse pattern of descending activities. Such an unorganized pattern of descending activities may give rise the tonic influence upon the motoneurons, which is possible to maintain the posture but not enough to elicit newly a movement due to their balancing and unspecific pattern. Under such circumstances, the nocireflex is specifically inhibited by the descending influences.

SUMMARY

1. The arrest reaction elicited by electrical stimulation of the brain stem was reconfirmed in chronic cats. The most effective focus for eliciting the arrest reaction was checked to lie in the midline portion of the midbrain. With regard to the frequency of stimulation, high repetition rates more than 50 per second were needed to induce obviously the reaction. During the reaction, the low voltage fast activity of EEG was revealed in all cases and on the EMG, the muscle activity of the legs in a standing state during the arrest reaction was unchanged as compared with that in a naturally standing one. Under light anesthesia, the same reticular stimulation as used to produce the arrest reaction elicited nonreciprocal suppression of tonic maintained muscle discharges of the legs.

2. Scarce change was found in behavior and EEG following the electrical coagulation of the foci eliciting the arrest reaction.

3. The simultaneous repetitive stimulation of the two reticular foci located symmetrically in the midbrain produced a response resembling the arrest reaction, but such a response was hardly observed by the symmetrical stimulation of the bilateral pontine or bulbar reticular formations.

4. The repetitive stimulation of the bilateral caudate nuclei, with the same manner as in the bilateral reticular stimulations, could not elicit a response resembling the arrest reaction.

5. With the repetitive stimulation of the midline portion of the midbrain reticular formation in light anesthesia, the heights of both extensor and flexor monosynaptic reflexes were in most cases scarcely changed, but the polysynaptic flexor reflex was markedly suppressed.

6. The repetitive stimulation of the midbrain as mentioned above set up various effects on the intracellular potential of lumbar alpha motoneurons. In some motoneurons, a main-

tained depolarization or hyperpolarization of the membrane potential was revealed during the stimulation. In some other motoneurons, the membrane potential was seemingly maintained near the resting potential level and, at that time, suppression of tonic firings of the motoneurons was often observed.

7. With unitary recordings from the spinal descending tract fibers, a remarkable enhancement in spike discharges was in many cases observed in association with the reticular stimulation.

8. Based on these findings, a hypothetical interpretation of the arrest reaction elicited by the brain stem stimulation was delivered.

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脳幹性アレスト反応の電気生理学的研究

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視床髄板内核に適当な条件の電気刺激を加えると，無麻酔無拘束猫に運動の停止が起り，その際通常では有効と思われる刺激に応じなくなる状態が惹起されることを Hunter 及び Jasper (1949) が見付け，arrest reactionと名付けた．その後，黒木(1958)により，これと同じ反応が視床のみならず，中脳から延髄にいたる脳幹網様体の中心線上の点の刺激によつても惹起されることが見出された．本研究はこの脳幹性アレスト反応の発現機構の解析を試みたものである．

1) 脳幹性アレスト反応は黒木の指摘した如く，中脳網様体の中心線上の点の頻回電気刺激で最も容易に典型的なものが惹起され，刺激頻度としては少くとも毎秒約50回以上のものを要し，その際脳波は低電圧速波を示す．また筋電図上はアレスト反応による歩行停止時と，自然の歩行停止時との差異は殆んど認められなかつた．かかる慢性動物を軽度麻酔下において，無拘束時にアレストを起させるのと同条件で刺激すると，緊張性筋放電は非相反的全般的抑制を受けることを示した．

2) アレスト反応を惹起した点に対して，1点またはそれらの点をつらねて電気凝固を加えたが，動物の態度及び脳波上特別な変化は見られなかつた．

3) 中脳網様体中で中心線に対して対称的な位置を占める2点を選び，同時に頻回刺激を加えると，アレスト反応に似た反応を起し得るが，橋部延髄部では起し難い．

4) 電気刺激による運動効果誘発が比較的判然としていて，背景脳波活動を変えるに要する閾値が脳幹網様体に比して高いと思われる尾状核を選び，その頭部を同様の方法で両側同時に刺激したがアレスト反応とみられるものは起し得なかつた．

5) 更に軽麻酔下の急性実験において，アレスト反応を惹起するのと同一条件の中脳網様体刺激を用いて脊髄反射活動を調べたが，単シナップ反射はほぼ不変であるに反し，多シナップス屈曲反射は著明な抑制を受けた．

6) また脊髄α運動細胞の細胞内電位記録では，この頻回網様体刺激で一様に持続した脱分極性ないし過分極性電位が現われるものの他，静止膜電位に近づいて固定されるものも見出された．脊髄下行路と思われるものからは，網様体刺激に一致してスパイク発射の著明な増加が認められた．

以上の実験的事実より，脳幹性アレスト反応の発現機構を推論すると次の如くなる．即ち脳幹網様体の頻回刺激により，脳内に広範に拡がつて惹起された興奮が，刺激直前まで上位脳より脊髄に下行していた高度に organizeされたインパルス・パターンを攪乱し，その結果 organize されていない非特異的な無統制のパターンがこれに代り下行する．脊髄運動細胞に対して，これは tonic な影響を与えることになり，姿勢の維持は出来るが新たな運動を惹起することは不可能となるのであろう．一種の abortive な tonic 全身痙攣とでもいうべきか．尚アレスト反応中の侵害反射障害については，多シナップス屈曲反射の著明な抑制が，網様体刺激で認められたことで或る程度裏付けられるであろう．中脳網様体刺激でアレスト反応を惹起し易いのは，この部の何等かの特異的な解剖学的関係から説明されるべきものではなかろうか．