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THE EFFECT OF LATERAL HYPOTHALAMIC LESIONS ON SPONTANEOUS EEG PATTERN IN RATS

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Abstract. Neocortical and hippocampal EEG was recorded in ten rats subjected to bilateral lesions of the lateral hypothalamus at different levels of its rostro-caudal axis. In nine rats the damage evoked a marked increase of waking time with a simultaneous reduction of the percentage of large amplitude irregular activity related to slow wave sleep in the first eight postlesion days. There was also a decrease in the amount of paradoxical sleep. Enhanced waking coexisted with behavioral somnolence. The most extensive hypothalamic lesions produced qualitative changes of EEG concerning mainly the frequency of hippocampal theta rhythm. Control lesions within the subthalamic region did not influence either qualitative or quantitative EEG pattern. It is concluded that limited lesions of the lateral hypothalamus did not destroy a sufficient number of reticular activating fibers to disturb a cortical desynchronizing reaction. The increased amount of waking pattern may be due to serotonergic deafferentation of the neocortex. Dissociation of behavioral and EEG indices of the level of arousal imply the existence of separate neuronal systems for both aspects of "activation".

INTRODUCTION

Bilateral destruction of the lateral hypothalamus (LH), particularly in its middle portion produces a set of severe abnormalities known as "the lateral hypothalamic syndrome". The animals, both rats and cats, display, among others, profound

impairments in food and water intake (1, 32), deficits in sensorimotor integration (16), somnolence, akinesia and catalepsy (14). Most of these symptoms are transient and after a period of time the animals eventually recover if they are artificially fed and watered during the acute stage of the syndrome.

From the anatomical point of view the lateral hypothalamus is an extremely complex structure. It contains about 50 ascending and descending axonal components (for review see Nieuwenhuys et al. (25)) which interlink various nuclei of the midbrain, pons and the medulla with prosencephalic and diencephalic structures, as well as a number of neurons (path neurons) scattered among the fibers of the medial forebrain bundle (19). Up to now there has been considerable uncertainty as to which of the so-called „lateral hypothalamic symptoms" may be attributed to the destruction of the hypothalamic neurons and which are the result of damage to the fiber systems passing through LH.

There is strong evidence (38) that the main lateral hypothalamic deficits, particularly somnolence and akinesia, but also to some extent aphagia and adipsia may be related to the loss of endogenous activation caused by damage to the reticular activating system which was reported to run through LH (7, 24, 28, 37). As was found by Wolgin et al. (38), cats which show profound somnolence and lack of spontaneous voluntary activity after LH lesions may be aroused to aggressive behavior or vigorous eating by highly activating stimuli or by stimulant drugs.

Deficits in arousal are even more striking after destruction of the posterior hypothalamus. Large electrolytic lesions of the posterior hypothalamic area produce severe somnolence and akinesia (9, 17, 23, 27, 38) accompanied by a period of aphagia and adipsia (38). Posterior hypothalamic somnolence can also be reversed by activating external stimuli (27, 38) even more easily than in the lateral hypothalamic animals (38).

Gross malfunctions of the reticular activating system which are believed to manifest themselves in somnolence and lack of spontaneity after extensive hypothalamic damage should affect EEG pattern. Indeed, large destruction of the lateral hypothalamus (5, 8, 11) and massive lesions of the caudal diencephalon including the posterior hypothalamic area (9, 17, 27) were reported to result in a predominance of a sleep-like EEG pattern characterized by large amplitude irregular activity in the neocortex. They also abolished hippocampal theta rhythm associated with voluntary movements (5, 11, 27).

The above cited experiments were performed using very large hypothalamic lesions involving parts of adjacent structures. In the present paper we made relatively limited lesions of LH at different levels of its rostro-caudal axis with the hope of correlating possible changes of EEG with localization of the lesions and with behavioral deficits evoked by the damage. We tried to establish exact quantitative relations between waking and quiescent phases of EEG activity of LH rats in one hour samples of EEG taken from the light part of day.

MATERIAL AND METHOD

The experiment was carried out on 15 male albino rats of the Wistar strain weighing about 250–400 g at the day of surgery. The animals were kept in individual home cages with food and water ad lib., in an artificially maintained 12 : 12 hours light/dark cycle.

Each rat was implanted, under Nembutal anesthesia, with chronic electrodes for lesions, bilaterally in the region of the lateral hypothalamus (experimental group; $n = 10$) or above the hypothalamus (control group; $n = 5$). All animals were also implanted with recording electrodes in the left dorsal hippocampus and over the right occipital cortex.

Lesion electrodes were made of stainless-steel wire 0.3 mm dia., insulated with Orex on the entire length with the exception of the flat-cut tip. Bipolar, concentric electrode for hippocampal EEG recording consisted of stainless-steel wire 0.1 mm dia. inserted into a stainless-steel cannula 0.5 mm o. d., both poles insulated from each other by a thin glass coat. The outside surface of the cannula was additionally coated by Orex. Unisolated tip of the inner wire was 0.3 mm longer than the cannula, the end of which was also bare at the distance of 0.3 mm. A watch screw driven in a skull bone served as a neocortical recording electrode. An earth screw electrode and reference electrode made of a silver wire 0.3 mm dia. and rolled up into a flat crosier were also implanted. Silver wire loops were sutured into the neck muscles for recording EMG activity. The offtakes of the electrodes were soldered with a subminiature male connector and attached to the skull with Duracryl.

Stereotaxic coordinates for the experimental group were chosen so that the damage would involve lateral hypothalamic — medial forebrain bundle area at various levels of the rostro-caudal axis, and were as follows: 1.5–2.8 mm posterior to the bregma, 1.5–1.8 mm lateral to the midline and 8.9–9.0 mm below the surface of the skull (lambda 1 mm below the bregma). In the control group lesions were centered at the subthalamic region (respective coordinates: 1.7 mm, 1.7 mm and 7.0–7.5 mm). Stereotaxic coordinates for the recording electrode in the dorsal hippocampus were: 2.5–2.8 mm posterior to the bregma, 2.5 mm lateral to the midline, and 2.5–3.5 mm below the skull surface. Neocortical recording electrode was screwed 10 mm posterior to the bregma and 3 mm lateral to the midline at a depth of 1 mm below the skull surface.

EEG recording began after 10 days of recovery period, during which the rats were adapted to the experimental conditions. The recording was carried out in an illuminated, sound attenuating chamber for 1 hour daily (11.00–12.00 a. m.) with the use of 16 canals Medicor polygraph (passband 0.53–50 Hz). The animals were continuously observed by the experimenter through a camera connected to a monitoring system and their behavior (walking, rearing, grooming, probable sleep etc.) was noted concomitant with EEG records. Normal EEG pattern was recorded for

at least 3 days. Then the rats were subjected, under light ether anesthesia, to electrolytic lesions made by passing 1.5–2.0 mA anodal current for 15–20 s through previously implanted electrodes.

Starting from the day following the brain damage the EEG pattern was recorded for 8 conseccutive days and then on 11th and 14th postlesion day according to the same procedure as before the lesion.

The rats were also observed for the occurence of somnolence and disturbances in food and water intake resulting from the brain damage. Somnolence was rated as "++" when the rat did not move spontaneously, sat in the cage with semi-closed eyes and did not react to handling, taking out of the cage and placing on the floor. As "+" was rated the state when the rat responded with a brief orienting reaction to handling and placement in the new environment, and as "±" — the state when the animal was nearly normal but still less reactive than intact rats.

During the first few days after the lesion daily food and water intake and body weight were measured. The intensity of ingestive impairments was evaluated on the basis of the maximal loss of body weight expressed in grams and in a percentage of body weight on the day of the lesion as well as on the basis of total aphagia and adipsia (in days). As food and water intake were measured for at least 3 days before the lesion it was also possible to establish a degree of hypophagia and hypodipsia. The rats which were aphagic and adipsic or extremely hypophagic and hypodipsic for more than 2 days were artificially fed and watered by means of a gastric tube.

After completion of the experiment the rats were treated with an overdose of ether anesthesia, the brains were removed from the skull and placed in 10% Formalin. After fixation brain sections of 30 μm thick were cut using a frozen tissue technique. The sections were stained with the cresyl violet for cell bodies.

All EEG records were visually analyzed and counted for the amount of waking, slow wave sleep and paradoxical sleep. A number of episodes of the particular types of EEG activity and a duration of a single episode were measured in each experimental session. The records were also inspected for possible qualitative abnormalities.

The results were statistically analyzed with the use of the Student's t-test (percentage distribution of waking, slow wave sleep and paradoxical sleep) and the Mann–Whithney U test (number and duration of episodes of particular types of EEG activity).

RESULTS

Normal EEG pattern. In the prelesion records four main types of EEG pattern were distinguished: (i) low voltage fast activity in the neocortex accompanied by fast activity in the hippocampus when an awake animal remains motionless or engages in automatic movements such as grooming (desynchronization with hippo-

campal fast activity, marked on Tables I and II as D/FA), (ii) desynchronization in the neocortex accompanied by hippocampal rhythmical activity (theta rhythm) when an animal explores the cage (desynchronization with hippocampal theta rhythm, marked on Tables I and II as D/Te), (iii) large amplitude irregular activity in the neocortex and hippocampus characteristic for slow wave sleep (SWS), and (iv) generalized theta rhythm in the neocortex and hippocampus accompanied by the neck muscle atonia which characterize paradoxical sleep in the rat (PS). The above types of rat's EEG activity have already been described by other authors (33, 35, 36).

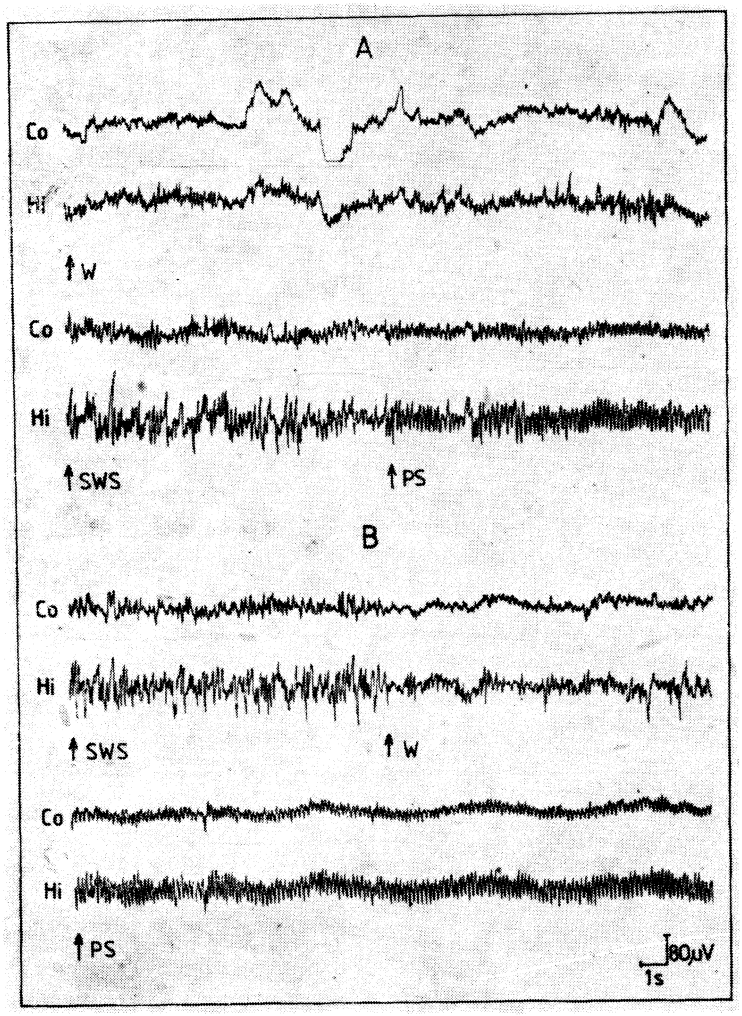

Fig. 1. Examples of EEG records before LH damage (A) and on the first postlesion day (B). Co, cortex; Hi, hippocampus; W, waking; SWS, slow wave sleep; PS, paradoxical sleep

TABLE I

Effect of LH lesions (Group A) on quantitative aspect of EEG pattern. The records of the last prelesion day (-1) were taken as a baseline

Postlesion day	Waking state					Slow wave sleep			Paradoxical sleep		
		D/FA		*D/Te*							
	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)	Median number of episodes	Median duration of a single episode (s)	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)
1	33.7± 4.2	32.0	13.3	13.5	17.0	53.3±3.9	32.5	35.8	13.2±1.2	8.0	37.0
1	65.4± 7.3***	50.0**	20.0**	20.0	17.0	30.2±5.9***	24.0	22.0	4.3±1.8****	1.0****	56.5
2	59.6± 6.8***	54.0**	18.5	14.0	14.0	34.9±5.4**	28.0	21.0	5.7±1.6***	3.0****	22.0
3	62.1± 7.9***	55.0**	18.5	21.0	13.0	30.0±5.2***	25.0	21.0	7.9±2.2	4.0*	36.5
4	58.9± 8.0****	57.0****	18.0	37.0	11.5	34.3±6.1*	34.0	20.0***	6.9±2.9	3.0***	80.0
5	62.5± 9.8****	54.0****	19.5**	37.0	13.5	29.9±7.8**	35.0	22.3	7.7±2.3	4.0*	52.0
6	48.0± 5.1*	52.0***	16.0	20.0	15.0	41.2±4.0*	35.0	30.5	10.8±1.4	5.0	86.5*
7	57.9± 5.7**	60.0****	18.5	34.0***	12.5	35.5±5.6*	34.0	19.0	6.6±2.1**	3.0***	52.0
8	51.2±10.5	34.0	16.5	16.0	11.0	40.9±8.8	24.0	24.0	8.0±2.5	5.0***	85.8
11	38.0± 3.4	35.5	14.0	17.0	11.0	49.6±5.7	29.5	39.5	12.4±2.3	6.5	52.5
14	49.2±12.5	44.0**	16.0	19.0	17.5	41.4±8.3	29.0	34.0	9.3±4.7	3.0***	97.0

The level of significant difference from the baseline: $*P \leqslant 0.05$; $**P \leqslant 0.02$; $***P \leqslant 0.01$; $****P \leqslant 0.001$.

TABLE II

Quantitative EEG pattern unchanged by control lesions (Group B). Postlesion records were not significantly different from prelesion baseline

Postlesion day	Waking state					Slow wave sleep			Paradoxical sleep		
		D/FA		*D/Te*							
	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)	Median number of episodes	Median duration of a single episode (s)	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)	Mean±*SE*% of total recording time	Median number of episodes	Median duration of a single episode (s)
−1	41.0± 4.1	45.0	18.5	18.5	19.0	48.3± 3.3	32.5	46.0	9.1±2.0	4.5	62.8
1	41.8± 2.8	39.0	15.0	19.0	15.5	47.5± 4.8	32.0	27.0	10.7±3.0	6.0	52.5
2	47.8± 9.4	41.5	16.5	28.5	19.8	42.8± 6.8	33.5	28.0	9.4±3.0	4.5	47.3
3	41.2± 7.1	34.5	17.5	23.0	14.8	47.9± 5.1	34.5	29.8	10.9±2.4	5.0	70.0
4	47.5± 8.7	38.0	16.0	36.0	10.0	42.1± 7.1	36.0	33.5	10.3±2.4	5.0	47.0
5	57.2±12.6	53.5	19.0	20.5	16.8	33.4±10.4	39.0	25.0	9.4±3.7	4.5	45.5
6	42.4±11.0	46.5	17.8	22.5	17.5	45.6± 7.6	34.0	31.8	12.0±3.8	7.5	51.0
7	57.3± 9.3	42.0	18.0	18.0	13.0	32.3± 7.5	34.0	25.0	8.3±2.9	5.0	36.0
8	42.5±10.3	41.0	15.8	18.5	13.8	44.3± 7.1	36.5	33.5	13.2±5.4	11.5	67.5
11	46.2± 3.6	51.0	18.0	16.0	13.0	46.7± 4.9	39.0	25.0	7.2±1.8	3.0	29.0
14	40.3± 5.7	42.5	17.3	17.5	14.3	48.7± 4.6	29.0	36.5	11.0±2.3	6.0	52.0

Quantitative distribution of waking, slow wave sleep and paradoxical sleep was expressed as a percentage of the total recording time. Activities D/FA and D/Te were added up to obtain total amount of waking.

Before the lesion the rats spent 36.5±2.1% (mean ± SE, average data for all rats in all prelesion days) of the total recording time awake, slow wave sleep took 52.6±1.8% and paradoxical sleep — 11.0±0.7%. These data are within the limits of sleep-waking distribution in the albino rat analyzed by Clancy et al. (4) for a 12 h daytime cycle.

EEG pattern after brain damage. After the brain damage the qualitative EEG pattern was essentially similar to that recorded before the lesion (Fig. 1.), although in some animals, especially those with most extent damage there was a reduction of frequency of hippocampal theta rhythm from 6.5–7.8 Hz to 5.3–5.7 Hz. The same changes in hippocampal activity after hypothalamic lesions have already been described by other authors (5, 11, 27).

Out of 15 rats used in this experiment quantitative disturbances in EEG pattern were found in 9 subjects (group A). The remaining 6 rats maintained their prelesion relations between waking, slow wave sleep and paradoxical sleep.

Table I shows percentage distribution of waking, SWS and PS in group A rats. As is seen, lateral hypothalamic damage produced in these animals a significant increase of waking time in comparison to the prelesion baseline with a simultaneous reduction of the percentage of slow wave sleep. The amount of waking was almost doubled in the early postlesion period, whereas SWS was reduced by about 40%. There was also a decrease in paradoxical sleep, significant however only on the first two postlesion days. In some animals, during the early period after LH damage complete loss of PS was observed. Changes in waking and SWS were most pronounced and significant in the first eight days after the lesion and then gradually decreased approaching preoperative level.

For a more detailed analysis we counted the number of episodes of the particular types of EEG activity as well as the duration of singular episodes to find out which of the two was in fact influenced by LH damage. However the results obtained (Table I) were equivocal. The most consistent changes were found in a number of episodes of neocortical desynchronization accompanied by hippocampal fast activity (D/FA) which was significantly higher in the first seven days after the lesion as compared to the prelesion baseline. Also a number of episodes of paradoxical sleep was significantly influenced by the brain damage and depressed in the majority of postlesion days. We were not able to find significant changes in both the number and duration of episodes of slow wave sleep, although the median duration of a single episode was in fact reduced in the first eight days after the lesion. The main cause of this discrepancy seems to be a great inter- and intraindividual variability of this parameter (range from 5 to 811 s). The same is true for the duration of episodes of paradoxical sleep (range from 5 to 269 s).

Table II shows the results of group B rats in which EEG pattern both qualitative and quantitative was not influenced by the brain damage. This group contains 5 rats with lesions situated above the hypothalamic region (control group) as well as one animal from the lateral hypothalamus-lesioned group.

It would seem that the rats from group A were less active in the prelesion period in comparison to those from group B. Mean ± SD (averaged data in 3 prelesion days) percentage of waking was 32.8±14.4 in group A and 41.3±11.7 in group B. Respective values of SWS were 55.8±11.6 and 48.2±9.9. PS took 11.4±5.1% in group A and 10.5±2.0% in group B. However a statistical analysis did not reveal any significant difference between the groups in their baseline distribution of waking, SWS and PS.

Behavioral disturbances. In the majority of animals from group A the lateral hypothalamic lesions evoked disturbances in food and water intake of different intensity. Five of them were also somnolent. Table III shows behavioral effects of

TABLE III

Behavioral effects of LH damage in group A

Rat	Loss of body Weight		Days of aphagia	Days of adipsia	Days of somnolence
	[g]	[%]			
4	20.0	6.6	1	1	1
5	8.0	2.4	0	0	0
7	0	0	0	0	0
8	7.0	2.5	0	0	0
9	43.0	14.9	3	2	4
24	61.0	15.6	1	4	4
26	102.0	30.4	7	6	5
28	65.0	22.8	7	7	0
29	24.0	8.8	1	1	1

the brain damage in the particular subjects from group A. Total aphagia and total adipsia, both lasting from 1 to 7 days were found in 6 rats. In 2 animals the lesions evoked transient hypophagia and hypodipsia resulting in a decrease of body weight, and in one animal there were no behavioral deficits after the brain damage. Despite differences in behavioral disturbances all rats showed the same type of EEG changes after the lesion.

The most interesting aspect of these results is a lack of correlation between electroencephalographic and behavioral signs of the level of arousal. Somnolence assessed on the basis of animal behavior was accompanied by a significant elevation of the electroencephalographic waking pattern but not by EEG synchronization as one might expect. Figure 2 shows the dissociation of behavioral and EEG indi-

ces of the state of vigilance in one rat with well pronounced somnolence. As is seen the greatest elevation of the amount of waking pattern is convergent with the most intense signs of behavioral somnolence.

Anatomical verification of the lesion placements. All rats from group A had lesions situated within the region of the lateral hypothalamus-medial forebrain

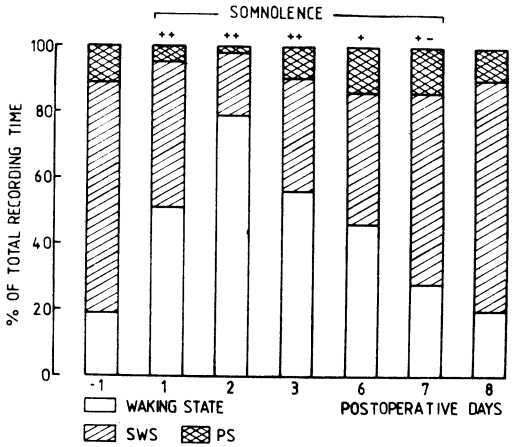

Fig. 2. Percentages of sleep and waking patterns on consecutive days after LH damage in relation to behavioral somnolence (rat no 9).

bundle in the proximity of the medial border of the internal capsula, and/or cerebral peduncle. In regard to the rostro-caudal extention of the lesions three main types of damage may be distinguished. In 3 animals the lesions extended throughout the whole length of the lateral hypothalamic area from the level of the anterior hypothalamic nucleus to the posterior and mamillary region (Fig. 3*A*). Four animals had destructions beginning at the level of the ventro-medial nucleus and spreading up to the posterior and mamillary area (Fig. 3B). In two rats lesions involved the most caudal portion of the lateral hypothalamus and encroached on the anterior midbrain just medially to the substantia nigra (Fig. 3*C*).

Although centered in the lateral hypothalamic — medial forebrain bundle area the lesions frequently involved parts of the internal capsula, and sometimes slightly encroached upon the zona incerta and H_1, H_2 fields of Forel.

The most intense behavioral deficits resulted from the most extensive hypothalamic damage involving either the whole length of the lateral hypothalamus or at least its middle and posterior portions. Hypophagia and hypodipsia without signs of somnolence accompanied lesions situated most caudally. In one animal of group A which did not show behavioral disturbances the lesions were asymmetrical and unilateral destruction involved only the most dorsal part of the lateral hypothalamus and neighboring tissue of the zona incerta.

In 5 rats of group B lesions were centered within the zona incerta encroaching partially on the ventral thalamus (Fig. 4*A*). In one animal damage involved the most ventral part of the lateral hypothalamus approaching the base of the brain at the level of the ventro-medial nucleus (Fig. 4*B*).

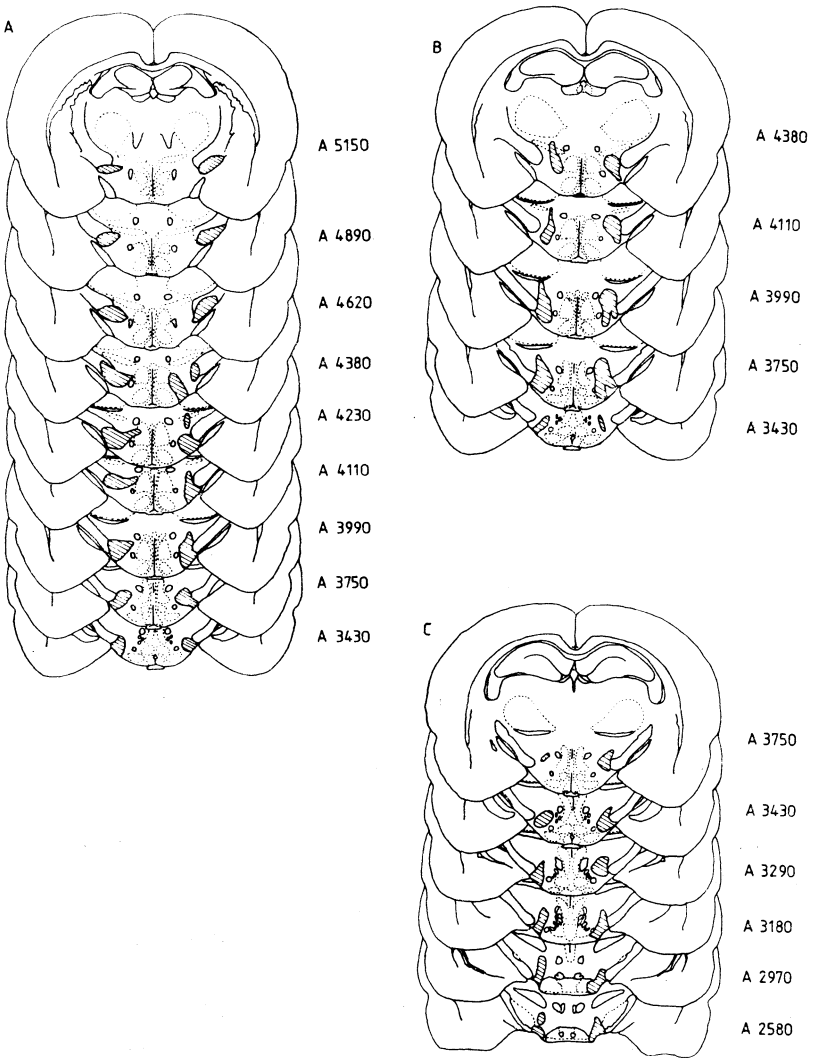

Fig. 3. Example lesions (shaded areas) of three rats (no 26, 9 and 8) from group A. Each rat represents different rostro-caudal extention of the lesion: a whole length of LH (A); middle to posterior LH (B), and the most posterior part of LH (C). Reconstruction of the lesions are superimposed on plates taken from the atlas by König and Klippel (12).

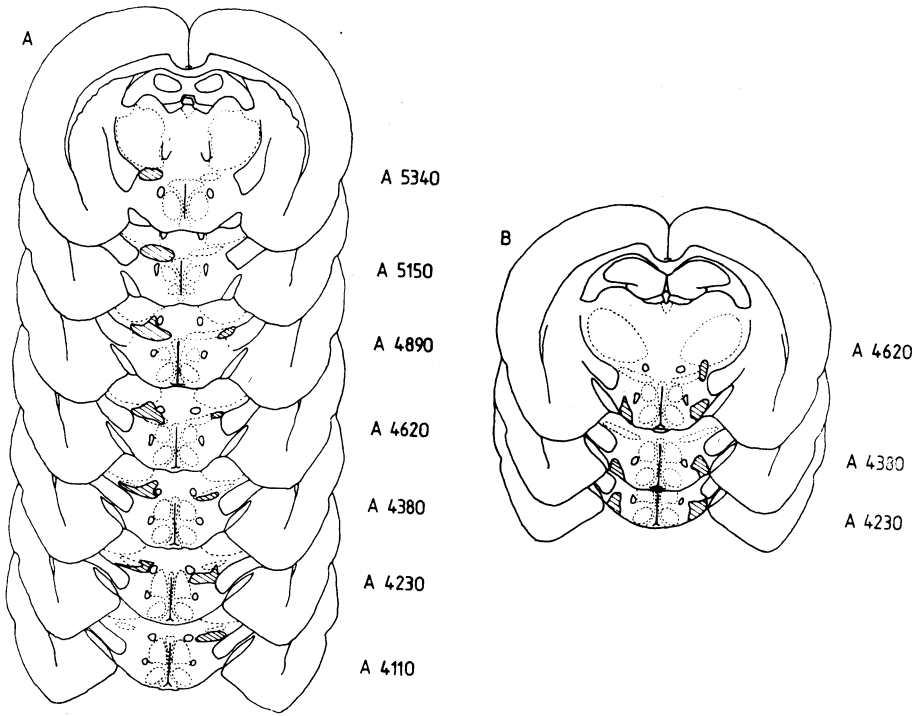

Fig. 4. Example lesions (shaded areas) of two rats (no 21 and 16) *A*, subthalamic lesion; *B*, LH lesion which did not evoke disturbances in EEG pattern. Reconstructions of the lesions are superimposed on plates taken from the atlas by König and Klippel (12).

DISCUSSION

The main purpose of this study was to establish whether damage to the lateral hypothalamic area will result in changes of EEG pattern, as may be inferred from previous reports (7, 24, 28, 37) on the anatomical connections of LH as well as from behavioral deficits evoked by its destruction. We did not intend to study details of either waking state or sleep cycle but rather to find gross, if any, abnormalities in the level of arousal. Therefore we took 1 h samples of EEG and compared them with the analogous prelesion records.

Large destructions of the lateral hypothalamus were found to cause an impairment of neocortical desynchronizing reaction and as a consequence a continuous sleep-like pattern of EEG, accompanied by behavioral somnolence (5,11). Therefore we expected that in our experiment LH lesions would abolish arousal EEG pattern and increase the percentage of large amplitude irregular activity in a similar way. As our lesions differed slightly in size and location and accordingly the rats differed in the intensity of behavioral deficits, we hoped that we might be able to

correlate EEG changes with behavioral impairments after LH damage, especially with the degree of somnolence.

The results obtained were opposite to what we had expected. Almost all LH rats, despite variations in the localization of the lesion and in behavioral deficits, showed a marked increase of percentage of waking EEG pattern with a simultaneous decrease of percentage of large amplitude irregular activity related to slow wave sleep, and to some extent also reduction of the amount of paradoxical sleep.

In searching for an explanation of our results we found it necessary to analyze the exact localization of the reticular activating fibers within the lateral hypothalamus to establish the degree of damage to these fibers caused by our lesions. The unspecific activating impulses are transmitted from the midbrain (7,30) and rhombencephalic (24,28) reticular formation to the neocortex by two routes. The main stream of impulses follows the dorsal branch of fibers which enter the midline-intralaminar thalamic nuclei at the level of the medial portion of the caudal diencephalon. The smaller, ventral or extrathalamic branch of fibers runs through the subthalamic region, the capsula interna, the posterior hypothalamic area and the most dorsal part of the lateral hypothalamus. Our LH lesions located within the lateral hypothalamic-medial forebrain bundle area in the proximity of the medial border of the capsula interna undoubtedly destroyed part of the extrathalamic pathway however the majority of reticular, corticopetal fibers namely those passing through the thalamus and subthalamus were spared by the damage. As a consequence the neocortex retained its ability to desynchronize. Partial destruction of the zona incerta in the control group did not abolish neocortical desynchronization either. In the electrophysiological experiments a loss of low voltage fast activity in the neocortex was found after large lesions involving almost the whole body of the capsula interna, the lateral portion of the zona incerta together with neighbouring tissue of the dorsolateral hypothalamus, and parts of the ventral thalamus from the level of the anterior to the posterior diencephalon (29). We think therefore that only large lesions of LH involving substantial portions of the adjacent structures, especially those lying dorsally and laterally to the lateral hypothalamus proper may evoke constant synchronization in the neocortex.

The damage to the posterior hypothalamus which produced coma and constantly synchronized EEG (9, 17, 27) were also very large and destroyed almost the entire ventral diencephalon. In our experiment limited lesions situated laterally in the posterior hypothalamus evoked opposite EEG changes, namely an enhanced desynchronizing activity.

As concerns hippocampal activity, the hypothalamic fiber systems were found to carry impulses from the rhombencephalic reticular nuclei for both hippocampal theta and low voltage fast activity (2, 15, 34). Torii (34) proposed that the fast wave system ascends through the hypothalamus via the medial forebrain bundle and the theta rhythm involves the dorsal fasciculus of Schütz. This was subsequently supported by electrophysiological and lesion experiments (2). In our study we

found in some animals, mainly those with the most extensive LH lesions, a reduction of frequency of theta rhythm similar to that reported earlier in the lateral hypothalamic (5, 8, 11), and posterior hypothalamic (27) rats. Why disturbances in theta rhythm result from damage to the lateral hypothalamus in one group of studies (11, and present results) whereas in other experiments (2) they appear exclusively after medial hypothalamic lesions is not certain. Some suggestions to solve this problem were put foreward by Robinson and Whishaw (27).

As concerns quantitative relations between arousal and quiescent phases of EEG we believe that the discrepancy between our results and those of other authors (5, 8, 11) depend on the differences in the size of lesions, but we have no definite explanation for the predominance of desynchronized EEG pattern after LH lesions in the present study. Extreme elevation of waking time up to complete suppression of sleep accompanied by behavioral restlessness was reported by McGinty and Sterman (18) after extensive preoptic-basal forebrain damage. However, our lesions were situated more caudally and we observed rather somnolence and decrease of the locomotory drive. Kolb and Whishaw (11) although pointing to predominance of synchronous EEG activity in the majority of their LH rats mentioned a few animals which showed constant desynchronization. However these authors did not analyze this phenomenon. In experiment of McGinty (17) massive lesions of the caudal diencephalon evoked a few days acute somnolence accompanied by synchronization of the neocortex followed by long lasting hyposomnia and elevation of waking pattern in daily records. In some animals increase of waking was observed already on the third postlesion day. All these facts indicate that we were facing a real phenomenon connected anatomically with the hypothalamus which up to our knowledge has not been analyzed till now.

According to classical neurophysiology the structures implicated in cortical synchronization are: the nucleus of the solitary tract and the raphe nuclei in the lower brainstem, recruiting system of the thalamus, the basal forebrain-preoptic region together with certain parts of the frontal cortex (see 10 and 22), and some nuclei of the amygdaloid body (13). On the basis of our material it is difficult to relate the present results to those obtained after experimental manipulations of all the above listed structures, however it is well established that the majority of them have direct anatomical connections with the lateral hypothalamus (3, 20, 26).

There is a bulk of literature (for review see 6, 10, 21) which strongly suggests the essential role of the serotonergic systems deriving from the raphe complex in generation of synchronous neocortical activity and SWS. Comparing our lesions with the topography of ascending serotonine fibers within the lateral hypothalamus as described by Moore et al. (20), we found that in all LH rats these fibers were at least partially destroyed. This may suggest that serotonergic deafferentation of the neocortex is responsible for increased desynchronizing activity after LH lesions. With such an assumption we can not however explain the case of one rat from

LH group with most ventral location of the lesion which did not show EEG changes although parts of serotonine fibers should have been damaged in this animal too. The main difference between this rat and the other LH animals is that the lesions did not approach the capsula interna. Having only one such rat we are not able to discuss this problem at present.

The intriguing aspect of our results is dissociation of the behavioral and electroencephalographic indices of the level of arousal. Behavioral "depression" was accompanied by increased amount of waking pattern in EEG records. The very same EEG pattern was also seen in animals with no obvious behavioral impairments. This finding may suggest that anatomical substrate of behavioral "arousal" and cortical "activation" are separate and they may be dissociated by certain brain damage. The same view has already been put foreward by Feldman and Waller (9) on the basis of EEG effect of the posterior hypothalamic lesions. As we discussed earlier, the lateral hypothalamus contains a relatively small portion of reticular activating fibers so its destruction does not depress tonic cortical activity unless very large lesions involving substantial parts of the adjacent structures are applied. On the other hand it carries fibers of the nigro-striatal and other monoaminergic pathways which have now been suggested (31) to be responsible for unspecific activation of the behavioral systems. It is possible that limited lesions preferentially destroy catecholaminergic systems leaving a tonic activating influx to the neocortex relatively intact. Simultaneous destruction of the serotonergic fibers may predispose the neocortex to a desynchronizing reaction.

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