CHARACTERISTICS OF SLEEP AND WAKING ELECTROENCEPHALOGRAMS IN DOGS OF DIFFERENT AGES

I. I. Gokhblit

Laboratory of Age Physiology and Pathology (Director – Professor I. A. Arshavskii), Institute of Normal and Pathological Physiology (Director – Active Member AMN SSSR V. N. Chernigovskii), Academy of Medical Sciences USSR, Moscow

(Received January 2, 1958. Presented by Active Member AMN SSSR V. N. Chernigovskii)

The question of the special features of the electroencephalogram (EEG) at early ages has not yet been solved exhaustively, despite the fact that there is a number of investigations dealing with the characteristics of cerebral cortical activity both in animals of different ages [3, 5, 6, 10] and in children of different ages.

Two points of view have emerged in connection with the special EEG features in children.

One view, postulated by D. Lindsley [16] regards the whole frequency spectrum from 3 to 13 cps, as recorded from children of different ages, as an expression of gradual establishment and reorganization of the same electrical activity, viz., the alpha-rhythm. The latter appears in children at the age of about 3 months at a frequency of 3-4 cps and only attains the frequency of 10-12 cps by the age of 13-16 years. This viewpoint is shared by a number of authors [15, 18].

The other view is represented by L. Cornil [14] and his collaborators. These authors consider that the transition of electrical activity from 3-4 cps in very young children to the adult alpha-rhythm as noted by Lindsley is spurious. Cornil et al. suggest that the various rhythms (subdelta, delta, theta and alpha) in children's EEG exist simultaneously but their preponderance varies depending on the age.

In the USSR this point of view appears to be subscribed to by A. B. Kogan and N. V. Shteinbukh [7].

The present work is concerned with obtaining the chracteristics of natural sleep and waking electroencephalograms recorded from dogs from the first days of life to adult age.

EXPERIMENTAL METHOD

Experiments were performed on dogs of various ages. The animals were not fixed in the stand and were free to assume natural postures. Newborn pups were subjected to experiments immediately after breast-feeding, older pups were given additional food just before the experiment.

Electroencephalograms were recorded by the bipolar method, using needle electrodes inserted into the cranial bone in the frontal or parietal regions. The interelectrode distances was 1-1.5 cm. Simultaneous EEG and electrocardiogram (ECG) records were made on a two-channel ink-writing electroencephalograph.

The amplifier range band was 1 to 100 cps. Extension of this to include lower frequencies (0.5-0.2 cps) complicates EEG recording from a nonfixed animal. Amplification 1 cm = 50 μv.

Repeat EEG recording from the same pup at a very early age presented the difficulty that insertion of needle electrodes into the cranial bone could only be done episodically. Special observations showed that the use of such electrodes daily or even every other day caused the appearance of chronic inflammation in the cranial bones. On the other hand, it is impossible to apply the in-dwelling electrode technique to pups only a few hours or a few days

old. Therefore we made use of single or episodic insertion of needle electrodes in most of our experiments.

A total of 160 pups of various ages was subjected to investigation under different experimental conditions.

EXPERIMENTAL RESULTS

The investigations permit the conclusion that the waking state and natural sleep have their chracteristic EEG features at various ages.

In adult dogs and pups aged over 3 months the dominant activity in the waking state is of low voltage (20--25 μv) with a frequency of 45 cps. The lower limit of frequency is 35-40 cps, the upper 50-60 cps. This rhythm can naturally be described as corresponding to β-rhythm. On transition to sleep the background activity disappears, "spindle" activity (10-12 cps) appears during drowsiness and so-called "sleep" potentials (slow waves at 3-4 cps and up to 100 μv in amplitude) appear in deep sleep. Similar electroencephalographic events have been described during sleep and waking by many authors, both Soviet and foreign [4, 9, 11, 12, 17].

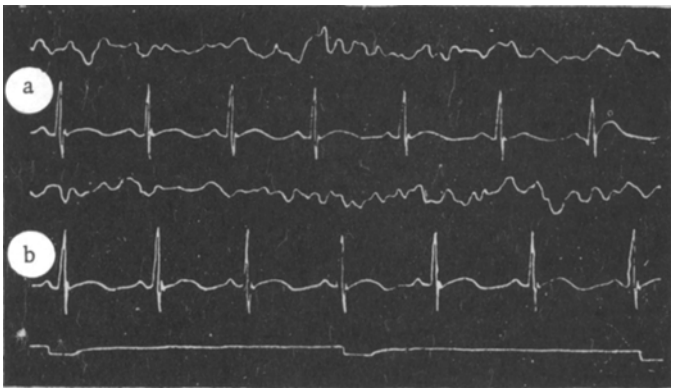

Fig. 1. Electroencephalogram and electrocardiogram of a 7-day-old pup.
a) Waking state; b) during natural sleep.

Investigations carried out on very young pups indicate that the frequency and amplitude characteristics found in the EEG of adult animals during waking and natural sleep, as well as those changes observed during transition from one to the other, are absent during the early stages of postnatal ontogenesis. Pups aged up to 16-18 days show bioelectric cortical activity in the waking state which consists of more or less regular, and in a number of cases dominant, activity at 10-14 cps and amplitude which rarely exceeds 15μv. The lower limit of this activity may be 6-8 cps. Unlike this, slow activity at 3-4 cps and of unstable amplitude (10-50 μv) is less constant and may even be episodic. At the same time this slow rhythm is characteristic for EEG of young animals in the waking state (Fig. 1, a).

It is known that in the newborn the periods of sleep greatly exceed those of waking, which only occur during feeding. Observations made in our laboratory have shown that each succeeding waking results from excitation of the feeding center by the "fasting" composition of the blood.

Allowing the newborn to take milk in the amount equal to the capacity of his stomach elicits reflex inhibition of the feeding center with transition to general sleep [1, 8].

EEG recorded from very young pups during deep natural sleep revealed no appreciable change in the frequency of the bioelectric activity (Fig. 1, b) . In some cases a drop in frequency of 1-2 cps can be seen and decrease in amplitude is noted somewhat more commonly, but these changes are not regular and consistent and may occur both on transition from sleep to wakefulness and vice versa. Both in the very young pups and at later stages the transition to a stage of sleep is accompanied by some decrease in the rate of cardiac contractions (Fig. 1, a and b).

The significant finding is the absence in the very young age group of a difference between the electrical activity of the cerebral cortex during wakefulness and in sleep.

The more or less regular and rhythmic activity at 10-14 cps described above must be formally designated

as activity of alpha-rhythm type. But, unlike the alpha-rhythm of adult animals, this activity is not desynchronized on transition to the waking state. Further analysis of the evolution of this activity suggests rather that it corresponds to the future beta-rhythm of adult animals. Thus, beginning from the 18th-20th day of life, the main and predominant waking activity is a rhythm at 16-18 cps; by the age of one month such activity is at 20-22 cps. Slow activity at this age is exceptional during wakefulness (Fig. 2, a).

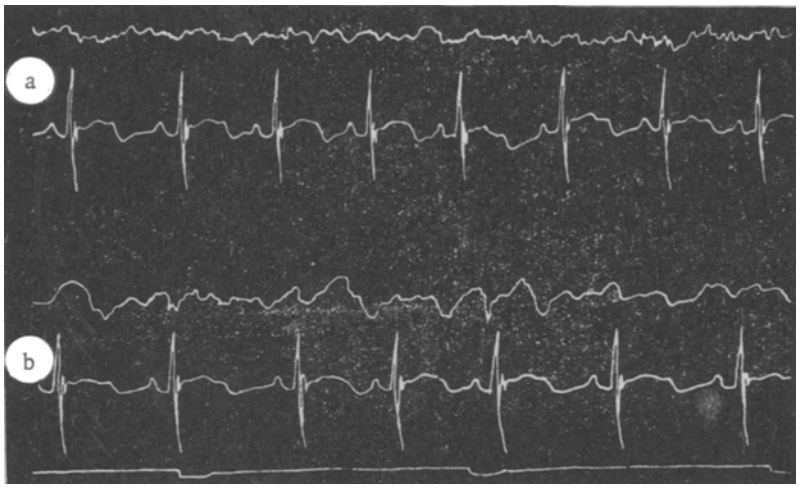

Fig. 2. Electroencephalogram and electrocardiogram of 18-day-old pup.
a) In the waking state; b) during natural sleep.

The dominant activity mentioned above increases in frequency with age and by the age of 3 months reaches frequencies of the β range as observed in adult animals in the waking state (Fig. 3, a). Concurrently, beginning with the age of 18-20 days, the transition to sleep is accompanied by the appearance of slow "sleep" potentials with frequencies of 4-5 cps and of considerable amplitude (Fig. 2, b). Slow "sleep" potentials become more prominent with age and by the age of 3 months approach those of adult animals in amplitude and frequency (Fig. 3, b and c).

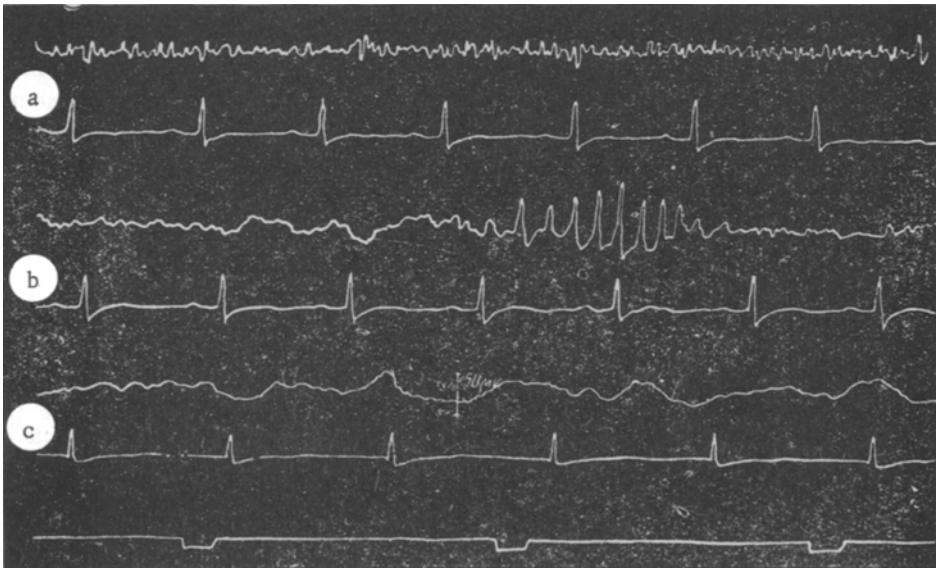

Fig. 3. Electroencephalogram and electrocardiogram of 3-month -old pup.
a) In the waking state; b) during drowsiness; c) during natural sleep.

According to the data obtained in our laboratory the onset of sleep is associated with the development of the second catelectrotonic parabiotic process in the nuclei of the thalamic region which play the part of an intermediate link with respect to afferent impulses passing to the cerebral cortex [2].

In modern interpretation such an intermediate link is constituted by the nonspecific nuclei of the thalamic reticular system. The pessimal state with signs of negativity and depolarization developing in these nuclei on the one hand blocks those constant influences which pass, during wakefulness, from these nuclei to the cortex, and on the other hand elicits a state of heightened polarization, i.e., electropositivity, in the cortical cells; this occurs through perielectrotonic contrast. Such a concept of the mechanism of the onset of sleep approaches in some aspects only to the corresponding views of F. Bremer [13].

I. A. Arshavskii considers that the nonspecific nuclei of the thalamic reticular system play the same role of intermediate link with respect to the cerebral cortical cells as the sinoauricular node with respect to myocardial elements or the neuromuscular junction with respect to the skeletal muscle elements.

The data presented suggest that the absence of difference in the special features of the cerebral cortical electric activity during wakefulness and sleep in very young pups is naturally explicable by the absence of functional, and evidently structural, maturation of the appropriate nuclei of the thalamic reticular system, viz., its ascending part. The first signs of such maturation are detected in pups beginning with the 18th-20th day of life. This serves to explain why it is at this very age that the electrical activity shows an appreciable drop in frequency during sleep. This is also associated with a rise in the upper limit of frequency of the cerebral cortical electrical activity during wakefulness.

SUMMARY

Every age-period is characterized by definite frequency and amplitude indices of EEG, depending on the state of the animal.

In young animals the basic electrical activity, when the animal is awake, is characterized by a rhythm of 10-14 cycles per second. It corresponds to the future rhythm of β-type. Commencing from the age of 18 days the rhythm increase to 16-18 per second while at 3 months it equals 35-45 per second.

Sleep does not cause any significant changes in the bioelectric activity of young puppies. The first signs of change of EEG in sleep (as compared to that while the dog is awake) commence from the 18-20th day of the dog's life and are manifested by the appearance of slow oscillations of large amplitude. When the puppies are 3 months old the typical changes in the EEG, characteristic of adult animals, appear in sleep.

LITERATURE CITED

[1] I. A. Arshavskii, Uchen. Zap. Leningr. Univ. Ser. Biol. No. 164, 32, 126-135 (1954).

[2] I. A. Arshavskii, Uspekhi Sovremennoi Biol. 41, No. 2, 193-216 (1956).

[3] A. A. Volokhov and N. N. Davydova, In the book: Transactions of the 1st Scientific Conference on the Problems of Age Morphology and Physiology,* Moscow, 1954, pp.49-56.

[4] G. V. Gershuni and A. V. Tonkikh, In the book: Transactions of the Pavlov Institute of Physiology,* 1949, Vol. 3, pp.11-31.

[5] I. V. Danilov, In the book: Texts and Abstracts of Communications Presented at the Conference on Problems of the Physiologic Evolution of the Nervous System,* Leningrad, 1956, pp.52-54.

[6] V. E. Delov, In the book: Transactions of the Bekhterev Brain Institute,* 1947, Vol. 18, pp. 66-67.

[7] A. B. Kogan and N. V. Shteinbukh, Zhur. Nevropatol. i Psikhiat., No. 1, 41-48 (1950).

[8] P. S. Kravitskaia, Fiziol. Zhur. SSSR No. 1, 47-51 (1951).

[9] R. N. Lur'e and L. G. Trofimov, Fiziol. Zhur. SSSR 42, No. 4, 349-356 (1956).

[10] A. S. Pentsik, Biull. Eksptl. Biol. i Med. 21, No. 4, 47-51 (1946).

* In Russian.

[11] G. T. Sakhiulina, Doklady Akad. Nauk SSSR 104, No. 1, 153-156 (1955).

[12] F. Bremer, Bull. Acad. Roy. Med. Belg. (1937), 2, p. 68-86.

[13] F. Bremer, in the book: Brain Mechanisms and Consciousness. A Symposium. Paris, 1956, p. 137.

[14] L. Cornil and J. Corriol, Semaine hop. Paris, 1949, 25, p. 2964-2967.

[15] C. E. Henry, Electroencephalograms of Normal Children. Washington, 1944.

[16] D. B. Lindsley, Science, 1936, 84, p. 354.

[17] H. W. Magoun, Physiol. Rev. 30, p. 459-474, (1950).

[18] J. R. Smith, J. Psychol. v. 11, p. 177-198 (1941).