ELECTRICAL CORTICAL ACTIVITY IN NEWBORN INFANTS UNDER VARIOUS CONDITIONS

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We here report a study of the cortical electrical activity in physiologically mature newborn infants; it was made during the first 8-9 days of life, and at various phases of the sleep and waking cycle, and the effects of various stimuli were investigated.

Present reports of the electrical activity in newborn children are very contradictory. It is however generally agreed that in the electroencephalogram (EEG) slow irregular waves preponderate. They have frequently been reported as lying within the range 0.5-2 per second [7, 8, 11, 14, 18, 19], but others have claimed that the frequency is 3-4 or even 5-6 cycles per second [3, 4, 9, 12, 13, 16]. Together with the slow waves there is also a higher frequency of 7-10 cycles [3, 11, 13, 19], and in newborn children there may also be dominant rhythms of from 10-14 to 35 cycles per second [3, 4, 10, 12, 16, 17]. However, in the references given, there is no indication of the sleeping or waking condition corresponding to any of these frequencies.

Recently several papers have appeared in which the condition of sleeping or waking has been taken into account. According to some authors, changes in the electrical activity which are typical of those of adults can be found in children from $1\frac{1}{2}$ months [7, 8] and even at 3 months [17]. Other workers have found [5, 12, 15, 16, 18, 19] that, just as in adults, there are more or less marked though somewhat variable changes in the EEG which occur during the first days of life at the onset or cessation of sleep.

It has also been suggested that stimuli such as light and sound do not effect the standard response characteristic of adults. In newborn infants, in response to the stimuli, the slow potentials may be either depressed, or enhanced and then depressed [7, 8, 11, 12].

METHOD

EEG recordings were made from fronto-occipital leads using silver-plate electrodes 8 mm in diameter fixed to the head by rubber bands. Contact between the electrode and skin was made by gauze soaked in 2% NaCl. The frequency response of the apparatus was from 1 to 10 cycles. The sensitivity for all observations was 6 mm per 20 μv. Recording was made by an ink writer. An electric bell and a 6 w electric lamp with reflector were used as stimuli.

We made 90 observations on 77 physiologically mature children aged from 8 to 9 days.

RESULTS

EEG recordings were made for various waking states, as follows: during natural sleep following immediately after feeding at the regular time; dressed, lying as still as possible with the eyes open; and during the period of expectancy immediately before the regular feeding time.

It was found that three types of EEG corresponded to the three conditions.

After a meal (when the child was asleep and showed no active sucking movements when given the bottle), slow irregular waves at various frequencies were produced. The most typical were those at a frequency of 2-3 cycles, having an irregular shape and an amplitude of from 10 to 30 μv. Besides the slow waves, there were small waves at a higher frequency. The frequency varied with different children, most commonly it was 6-10, and occasionally 20 cycles (Fig. 1, a).

During the increased wakefulness associated with the excitation of the feeding center at feeding time, there was a definite change in the electrical activity, and low voltage waves having a frequency of 30-40 cycles appeared. In adults, this activity is usually called a β-rhythm. Oscillations at a frequency less than 30 per second occur irregularly, and are not dominant; the commonest frequency in this range is one of 20 cycles. The amplitude does not exceed 10-15 μv (Fig. 1, b). It must be noted that this high frequency activity occurred during excitation of the

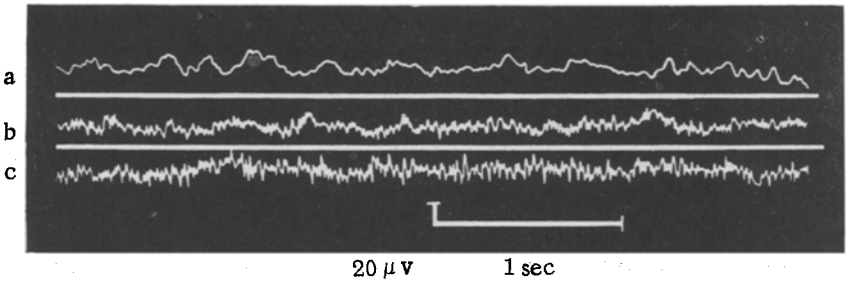

Fig. 1. Electroencephalogram of the child K., 5 days old. a) Asleep; b) just before feeding; c) while taking milk from the bottle.

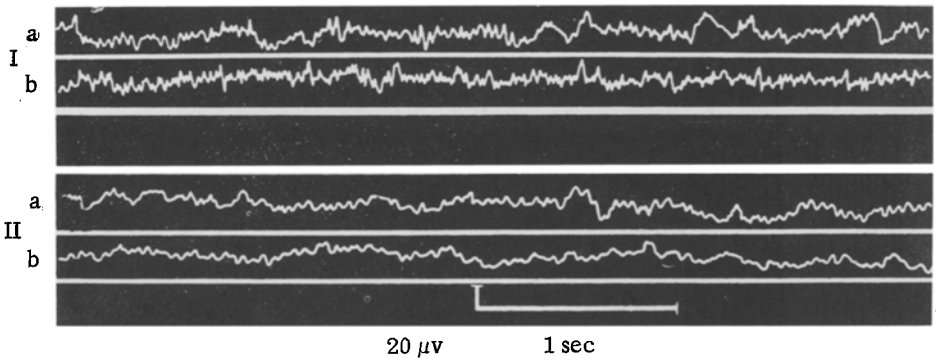

Fig. 2. Electroencephalogram of the child N., 8 days old (I) and of the child P., 4 days old (II). a and a_1) In resting condition; b and b_1) when given the bottle while in this condition.

feeding center, but when there are no searching or sucking movements. If the bottle was given at this time, active sucking movements occurred and high frequency electrical activity was recorded, and in some children there might be some increase in amplitude (Fig. 1, c). Figure 1 shows EEGs taken under the conditions described above in one child during a single observation.

We also observed comparatively short periods lasting from 5 to 20 minutes, when the infant lay quietly with its eyes open. However, the EEG of the infant is different from that of the adult in a corresponding condition. In the infant, the EEGs recorded might resemble those recorded during sleep or those evoked by excitation of the feeding center. However, in the latter case there might be slow waves of the order of 6 to 10 oscillations per second (or more really of 4 cycles) while in the EEG taken during sleep, there were small amplitude waves at a frequency of 25-35 per second. It was found that the high frequency waves were usually recorded from children shortly before feeding. Then, if the bottle was given, it produced active sucking movements, and the high frequency waves became more marked (Fig. 2, a, b).

The results obtained suggest that the extent to which the high frequency waves in newborn children are shown may depend on the degree to which the feeding center is excited. Because of its importance, the natural step was to confirm this discovery that the EEG recorded did in fact reflect the state of excitation of the feeding center, and did not result from potentials originating in the facial musculature. Because of the difficulties of recording action potentials from the facial muscles in newborn children, other observations were made on a large number of infants, which served as a reliable control.

Thus, EEGs recorded during resting condition and showing lower frequency waves were recorded in children after a full meal; the children were woken by the placement of the electrodes, and usually fell asleep very soon afterwards. In most cases, when they were given the bottle no active sucking movements were observed. When sucking movements were produced, the high frequency rhythm in the EEG did not appear (see Fig. 2, a, and b). This set of observations eliminated any connection between the high frequency rate discovered and any tension or contraction of the facial musculature. Also, as was pointed out above, the high frequency waves appeared in the quietly resting child as little as 10-15 minutes before it was due to be awakened, when there were still no sign of any facial movements.

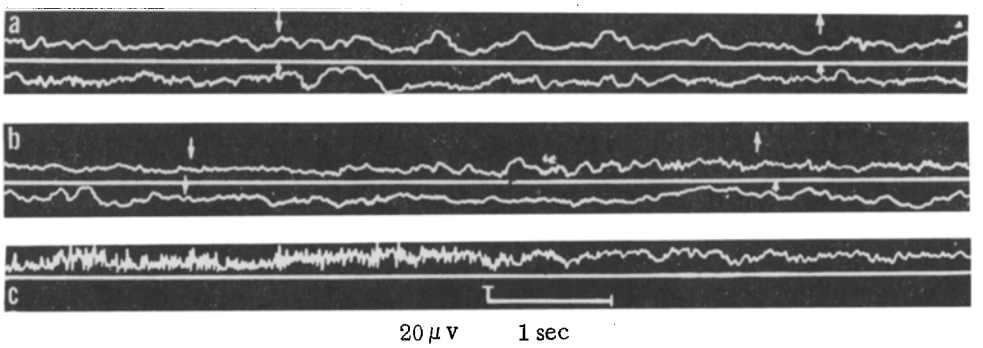

Fig. 3. Different responses of the EEG in 6- and 7-day old infants. a) To light; b) to sound stimulus; c) change in electroencephalogram induced by the heel reflex in a 7-day old infant.

We may therefore conclude that in newborn infants, the appearance of high frequency waves in the EEG (which is usually taken as a sign of activation) is associated with excitation of the feeding center. In this connection, observations made on children when first given the breast 12-16 hours after birth are interesting. Before ever being put on the breast, high frequency waves were present, despite the fact that food searching movements by the facial muscles cease 1-2 hours after birth. They are then in a condition which in our laboratory is referred to as one of unnatural, unphysiological, parabiotic sleep [1].

From the EEG records, three conditions may be distinguished in 8-9 day old children: there may be a condition of active sleep following a full meal, or an active waking state associated with the regular time for excitation of the feeding center, or there may be a resting condition. In newborn infants, unlike adults, the latter condition shows no constant type of rhythm. The frequency depends on the state of excitation of the feeding center. We have referred to the resting condition, during which the EEG is made up of comparatively low frequency waves, as a state of restful wakefulness without feeding excitation.

The next step was to investigate changes in electrical activity induced by exteroceptive stimuli such as a bell or light stimulus, which in adult subjects caused the same changes in the EEG as are caused in newborn infants by feeding activity; i.e. they produce a generalized activation.

When the child is asleep or in a condition of resting wakefulness, apart from food stimuli exteroceptive stimuli do not cause the normal adult response. Artifacts may arise through movements, such as trembling at the bell, or blinks caused by a light signal; when they were avoided, presentation of stimuli caused either some depression or else an exaltation of the previously recorded slow waves. Figure 3 shows EEGs which illustrate the different types of response to (a) a light and (b) a sound stimulus.

Under the conditions described, we did not observe the activation reaction in the EEG which is characteristic of adults. It is important to note that when a sound stimulus, or especially when a light stimulus induces contraction of the facial musculature in a child it is not reflected in the high frequency component of the EEG in the same way as is excitation of the feeding center, where the effect is particularly marked when food is taken from a bottle. The appearance of high frequency waves was observed only when the stimulus induced excitation a short time before feeding was due.

The short bursts of high frequency waves in the EEG were evoked by the heel reflex described by I. A. Arshavskii [2]. In the heel reflex, a light pressure on the heel causes a motor response and a crying grimace, and is used to diagnose the state of maturity or immaturity of a newborn infant.

During sleep, the response is of very short duration, and usually does not wake the child. At first there are artifacts in the EEG due to movements, but subsequently they are replaced by a trace of high frequency waves which very rapidly changes over to the original low frequency pattern. In Fig. 3, c we show a record of the electrical activity induced by the heel reflex. The duration of the response depends upon the depth of sleep and in deep sleep it lasts from 5 to 10 seconds. Shortly before the normal feeding time, it is prolonged to 15-20 seconds, and sometimes causes the infant to wake.

It has been previously shown in our laboratory [1, 6] that in newborn infants the rhythm during changeover from sleep to wakefulness is associated with excitation of the feeding center. When the stomach has been filled with milk, the gastric receptors are stimulated, the feeding center is inhibited, and sleep ensues.

The EEGs also show that the condition of wakefulness, which is accompanied by the typical β-rhythm, is closely associated with feeding excitation, and can be revealed in children on a full diet only at periods preceding the normal feeding time. The records show that on the first day there was a marked difference in the traces obtained during sleep and wakefulness when the waking state was one of feeding excitation. Confirmation was supplied by the fact that the same high-frequency activity was observed when the child was feeding from the bottle. Further, we never observed high-frequency waves during the condition of peaceful wakefulness, when there was no feeding excitation, or during the action of exteroceptive stimuli. We infer that activation in the EEG in newborn children may occur from the first day onwards, but that it is basically and characteristically associated with feeding excitation. The reaction may be elicited transitorily by means of the heel reflex.

SUMMARY

EEG records were obtained from infants aged 8 to 9 days in varying conditions of sleep and wakefulness. Records were made from the fronto-occipital lead. During the natural sleep following breast feeding, slow waves occurred having frequencies of 2-3, 6-10, or rarely 20 cycles. During excitation of the feeding center (state of active wakefulness) the waves at a frequency of 30-40 cycles became dominant. During quiet waking, comparatively low frequency oscillations were recorded and according to the condition of nutritional excitation which varied with the period between feeds, the frequency resembled either those recorded during sleep or during wakefulness.

It was only during a condition of nutritional excitation that high-frequency waves, representing generalized activation of the EEG typical of adult persons in the active waking state were recorded. In no cases did light or sound provoke the characteristic adult EEG response.

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