

Current Comment

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A Method for Recording Electroencephalograms During Electrical Anesthesia

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This report describes a method for recording simultaneously the electroencephalographic (EEG) changes which occur in dogs during the passage of alternating electrical currents through the brain. The electrical currents are similar to those which have been used to produce electrical anesthesia in animals and man.^{1, 2, 3} Electrical interferences thwarted earlier attempts to use the EEG to monitor changes in brain waves while current passed through the brain. Smith *et al.*⁴ studied the EEG of dogs immediately following electrical anesthesia produced by a combination of direct and alternating current and found the amplitude decreased by 20 per cent while the frequency averaged an increase of about 4 waves per second. However, no determination has been made of alterations which occur in brain waves while electrical current is passing through the brain.

METHOD

To record the EEG while electrical currents flowed through the brain we developed a low pass filter† which passed brain wave frequencies of 0–90 cycles per second (c.p.s.) and rejected electrical anesthesia frequencies of 400 c.p.s. and above (95 decibels attenuation at 825 c.p.s.). A circuit at the input of the filter provided a 100 microvolt signal in series with the input. The filter was placed between stainless steel, chronically implanted electrodes and the EEG (fig. 1). Modifying slightly the method of Faulconer,⁵ we placed two EEG electrodes on the cortex of the brain through holes drilled in the skull, one 2 cm.

posterior to the right eye, the other 2 cm. anterior to the inion. Both electrodes were 3 cm. to the right of the midline. The inter-electrode distance was 4.5 cm. A needle electrode which served as a ground rested on bone between the eyes. A Sanborn 350–1500 low level pre-amplifier coupled to an ECG pre-amplifier and recorder (Sanborn 150) made the EEG tracings. At maximal gain of the amplifier the maximal noise was 2 microvolts peak to peak, referred to the input of the recorder. From a fully blocked condition the overload recovery of the amplifier was one second. The paper speed was 25 mm. per second. An electrical anesthesia apparatus,† consisting of a battery-powered, constant-current amplifier driven by a battery-powered oscillator (Hewlett-Packard 204B), generated an alternating current of 825 c.p.s., of variable amperage. A vernier dial on the oscillator adjusted the frequency, thereby reducing harmonic beats in the EEG. An a-c current probe (Hewlett-Packard 456A), coupled with an a-c voltmeter, measured anesthesia currents continuously without a direct connection. The electrical current was applied to the top of the head through two silver electrodes, 3 cm. in diameter, placed 8–10 cm. apart, one on each side of the head, midway between the ears and eyes. Contact with the skin was made with a glycerin sodium chloride paste.

Since previous experiments² demonstrated that atropine sulfate prevents severe bradycardias and cardiac irregularities during the passage of electrical currents, all dogs received atropine sulfate 0.2 mg. intravenously. At the same time gallamine triethiodide 20–40 mg. was administered intravenously to permit endotracheal intubation and to eliminate muscle

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† Supplied by Medtronic, Incorporated, Minneapolis, Minnesota.

artifacts from tracings. Atropine sulfate, in man, causes a decrease in voltage of all brain waves, followed by bursts of regular, high voltage waves with a frequency of 10 c.p.s.⁶ Gallamine triethiodide causes little or no change in the EEG of the cat.⁷ After endotracheal intubation with a cuffed tube, the dogs were connected to a Takaoka respirator which administered intermittent positive pressure respiration with room air at a rate of 16 times per minute.

RESULTS

In experiments with a dead dog receiving a current of 15 milliamperes (root mean square) (fig. 2A) and with a calibration of 100 microvolts per centimeter the average noise level was 0.5 mm. In fig. 2B is shown the level of noise when a current of 35 milliamperes was applied to the same dead dog at the same calibration. This current gave an average noise level of about 0.7 mm., and when the current was turned off the average noise level decreased to 0.5 mm. The noise was primarily due to 60 cycle a-c interference.

The EEG tracing obtained from a normal, paralyzed dog before electrical current was applied (fig. 2C) was a mixture of 5 and 10 per second activity and superimposed low voltage fast with a few isolated 1½ to 2 per second waves. When a current of 5 milliamperes was applied to this dog, the tracing (fig. 2D) remained essentially unchanged while the current passed through the dog. Also, no essential change occurred when the 5-milliampere current was turned off. With a 15-milliampere current flowing through the dog (fig. 2E) the tracing showed a mild decrease in amplitude and a decrease in slow activity. When a 35-milliampere current passed through the dog (fig. 2F) the tracing showed suppression of fast activity and a predominance of 4-6 per second frequencies. A current of 50 milliamperes (fig. 2G) produced a definite decrease in amplitude and a predominant activity of 10 per second mixed with low voltage fast. Calibrations made during the times when these various currents flowed through the dog showed no decrease in amplification. When a current of 50 milliamperes was turned off (fig. 2H) the tracing continued to show a persistence of 5-10 per second ac-

tivity with moderate to low voltage and some faster frequencies at lower voltage superimposed. The segment of tracing shown encompasses a period ten to twenty seconds after cessation of the current. Eighty seconds after the 50 milliampere current was turned off (fig. 2I) the tracing had returned to the pre-current pattern of figure 2C.

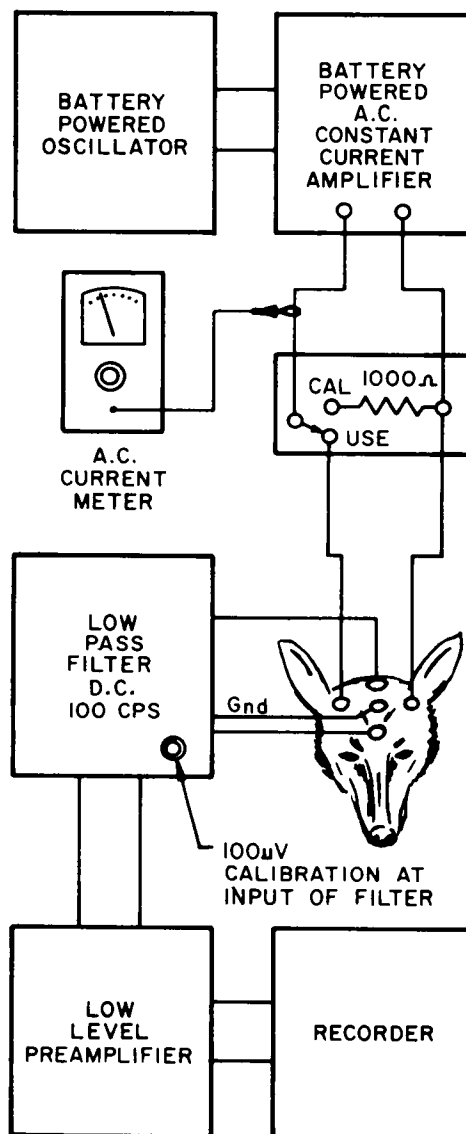


FIG. 1. Diagram of the electronic apparatus used to record simultaneously electroencephalograms during the application of electrical current to the brain.

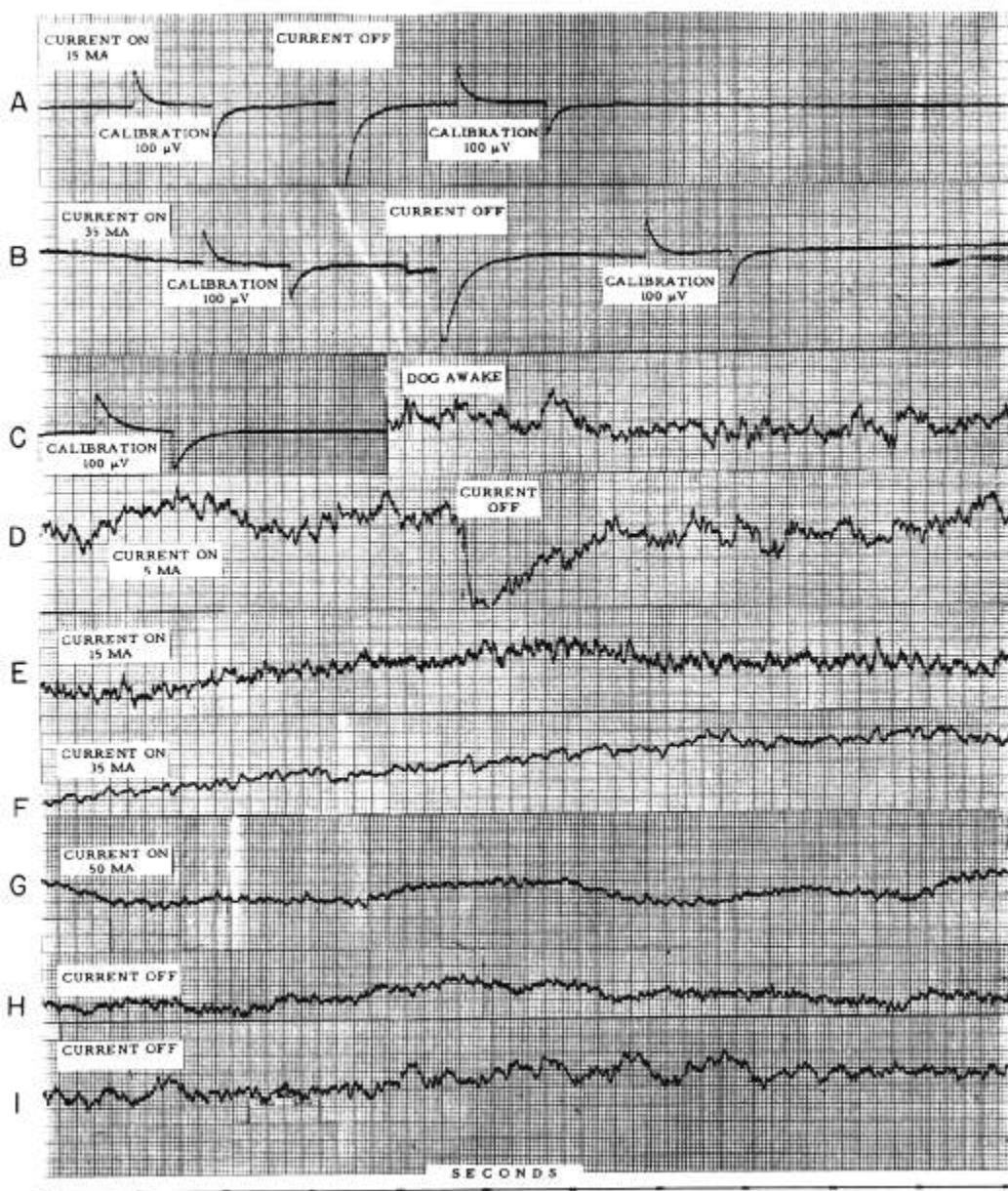


FIG. 2. Electroencephalograms of dogs when, A, a dead dog received an alternating current of 15 milliamperes, 825 cycles per second, through the head. Calibrations of 100 microvolts per centimeter were made before and after the current was turned off; B, a dead dog received a current of 35 milliamperes which was later turned off; C, after calibration of 100 microvolts per cm., the spontaneous EEG of an alive, paralyzed dog was obtained from chronically implanted electrodes. (The rest of the tracings were from the same live dog); D, a current of 5 milliamperes flowed through the dog and was later turned off; E, a current of 15 milliamperes flowed; F, a current of 35 milliamperes flowed; G, a current of 50 milliamperes flowed; H, a current of 50 milliamperes had been turned off for a period of 10–20 seconds; I, a current of 50 milliamperes had been turned off for a period of 80–90 seconds. The paper speed was 25 mm. per second.

This method has proven satisfactory when applied to nineteen dogs. All of the dogs showed changes in the EEG during the passage of electrical currents through the brain.

DISCUSSION

The tracings shown in figures 2C through 2I represent EEG's of the dog. They do not appear to be artifacts caused by the action of electrical current on the recording electrodes because, first, only slight changes appear in the dead dog tracings (figs. 2A and B) even when high electrical currents pass through the head; secondly, the changes seen in figure 2G, obtained while current is flowing, continue in Fig. 2H when the current has been off for a period of 10 to 20 seconds; thirdly, we have observed in the tracings of many dogs receiving low currents (15-20 milliamperes) the EEG return gradually to the pre-current tracing even while current continues to flow. Neither is it evident that these tracings are caused by "noise" in our apparatus, since we have measured carefully all noise by calibration and by using dead dogs as controls. The very slow baseline shifts in figures 2E, F, G, and H are caused by a beat between the electrical anesthesia apparatus and the second harmonic of the chopper in the Sanborn 350-1500 EEG pre-amplifier. These shifts may be reduced by adjusting the oscillator.

Although it appears from the tracings in figure 2 that a certain progression of decreasing amplitude with increasing current occurs, this phenomenon was not observed in all dogs studied. Some dogs showed persistence of a tracing similar to figure 2E in spite of the application of increasing currents. Also, pre-current tracings differed greatly from one dog to another. In other words, in these nineteen dogs we have been unable to distinguish a consistent pattern of EEG changes occurring with various electrical currents.

It is not the intention of this paper to suggest that these EEG tracings show the dogs are

either "anesthetized" or "asleep" or "alerted" under the currents herein reported. In earlier experiments on dogs and human beings² we were able to obtain a rigid, unresponsive state with similar currents; but to correlate levels of consciousness with these EEG tracings would require conditioned animals or humans. We have not yet attempted this, but have merely developed a method which offers assistance in further studies of electrical anesthesia.

SUMMARY

Construction of an electronic filter and a battery-powered electrical anesthesia apparatus permitted the simultaneous recording of electroencephalograms while electrical currents passed through the brains of dogs. The brain waves changed in voltage and frequency during the passage of electrical currents.

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