

Electrocardiographic Studies During Electronarcosis

David Gowing, M.D., Rex J. Underwood, M.D., Frederick P. Haugen, M.D.

One of the problems encountered in experimental electronarcosis has been the difficulty of obtaining electrophysiological data while the current is on. A method of monitoring the electrocardiogram during electronarcosis is described. The signal that interferes with the ECG is a square wave, 1–2 milliseconds wide, with a repetition rate of 100 per second and an amplitude of at least several volts. A balanced input to the recording amplifier reduces the magnitude of the artifact considerably. Clipping diodes are then used to reject any portion of the artifact which exceeds 1 millivolt. Then, cancellation of the remaining square wave is accomplished by means of an equal and opposite signal. Finally, the oscilloscope beam is blanked to remove any transients still present.

In a preliminary series of eight experiments on atropinized dogs, no abnormalities other than rare extrasystoles were seen on the precordial electrocardiograms.

ALTHOUGH electronarcosis has been a subject of some interest for nearly a century, systematic and determined investigations have been relatively recent. The method employed in this study is essentially that of Smith.¹⁻⁴ This technique involves the use of a square wave of 1–2 milliseconds' duration with a repetition rate of 100 per second, superimposed on a continuous direct current of the same polarity so as to prevent the square wave from returning to the baseline.

One constant problem has been the difficulty of obtaining electrophysiological data of any sort, due to the interference caused by the electronarcosis signal. Sances, Larson, and Jacobs,⁵ using a computer of average transients and a filter which cut out frequencies above 25 c.p.s., felt that the technique of Smith did result in some degree of blocking action on the transmission of sensory stimuli. Still more

recently, Knutson,⁶ using implanted cortical electrodes, an electronarcosis frequency of 825 c.p.s. and a filter which cut out frequencies above 90 c.p.s., demonstrated that electric current did indeed produce rapidly-reversible EEG changes. Since electrical recording techniques can yield information not otherwise readily obtainable from animals, we have devoted most of our efforts to further such studies.

Method

In these experiments, a series of mongrel dogs weighing 25–35 pounds was used. About one third of these animals were fairly resistant to electronarcosis, and were used twice, then returned to the stock pool. The remaining animals were used from four to eight times, then held for up to two months for observation. The animals were anesthetized with 200–250 mg. of thiopental mixed with 0.6 mg. of atropine sulfate given intravenously. A cuffed endotracheal tube was inserted and connected to a gas machine set to deliver nitrous oxide-oxygen in equal proportions, together with ½–1 per cent halothane. After the head had been shaved, an electrode covering the scalp from ear to ear and from external occipital protuberance to supra-orbital ridge was placed. The other electrode was inserted into the mouth in contact with the hard palate. Full power (5–20 ma. d.c. and 4–12 ma. a.c.) was abruptly applied, and pure oxygen at a high flow rate substituted for the anesthetic mixture. The square wave used was 1–2 msec. wide, recurring at a rate of 100/second. Gallamine, in a dosage of ⅔ mg. per pound, was then given intramuscularly. This dose caused minimal decrease in tidal volume, as observed with a Roswell Park Ventimeter, and the dog could still struggle feebly if the electronarcosis were for any reason discontinued. Small reinforcing doses of gallamine, usually one-third the initial dose, were administered whenever fasciculations in

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the muscles of the scalp and neck became marked. These supplemental doses were generally required every 90 minutes. The animal was intermittently stimulated by pinching the nasal septum, ears, skin of the flank, and full thickness of the tail with a large Kocher clamp. If the animal reacted, the current was increased slightly, with the d.c. and peak a.c. voltages being kept equal. Blood pressure readings were taken on some of the animals by means of a small blood pressure cuff applied to the upper forelimb. In some of these, the point of earliest deflection of the manometer needle was taken as the systolic blood pressure, in others, an impedance plethysmograph was used to provide a more reliable criterion. Pulse, respiratory rate, and respiratory minute volume were also observed. When the recording technique had been developed, precordial electrocardiograms were taken. After a period of from one to several hours after induction, the gallamine was antagonized with neostigmine and atropine intravenously, rectal temperature was taken, and a final series of painful stimuli administered to see if the animal still showed no reaction. The ties securing the endotracheal tube were loosened, and the current abruptly turned off. Within five seconds, all animals lifted their heads and would then extubate themselves unless this were done for them. Within a minute or two, all animals could walk and appeared fully oriented. Most of the animals would eat hungrily when offered meat at this time.

Apparatus. ELECTRODES: Electrodes were fitted individually for each dog. The backing was made from Kerr's (dental) Impression Compound. The conductive surfaces were made from Ash's Soft Metal No. 4, which is extremely malleable and does not become tarnished easily. This was cemented to the backing. EKG Sol (Burton, Parsons, & Co.) was used as the electrode paste because it is non-irritating and remains wet for about six hours.

GENERATOR: The electronarcosis generator was modified from that of Smith. The direct-current portion of the apparatus was a conventional power supply with a vernier-driven potentiometer. The square wave generator was a high-powered cathode follower amplifier driven by a Tektronix Type 161 Pulse Genera-

tor driven in turn by a Type 162 Waveform Generator. The apparatus was capable of delivering 40 ma. square wave and 50 ma. d.c. through a 500-ohm load.

MONITORING EQUIPMENT: The electronarcosis signal was monitored through the A channel, lower beam, of a Tektronix Type RM-565 Dual Beam oscilloscope equipped with a pair of Type 72 Dual-Trace amplifiers. The output of a crystal-controlled time-marker generator was introduced through the B channel, lower beam, and the Type 72 amplifier set for alternated beam.

The equipment used for ECG recording was somewhat more involved. The pre-amplifier used was a Tektronix Type 122 Low Level Pre-amplifier to which had been added three sets of unbiased clipping diodes—one set was across each side of the balanced input to ground, one set across the output, and the other set was placed immediately after the first stage. The output was fed to channel A of the upper beam oscilloscope amplifier. The output of a second Type 162 Pulse Generator, triggered synchronously with the one used to provide the electronarcosis square wave, furnished an identical square wave which was fed into the oscilloscope via channel B of the upper beam; the Type 72 amplifier being set for subtraction. The amplitude of the cancellation square wave was adjusted so that the net result was an artifact of minimum size. The tracing now showed cancellation transients a small fraction of a millisecond in duration and of displayed amplitude corresponding to approximately one millivolt. The Type 162 Waveform Generator was gated by a 100-cycle negative-going square wave from an asymmetric multivibrator (fig. 1). The duration of this square wave was slightly longer than that of the other two square waves; and the pulse delay controls of the pulse generators were set so that the gating pulse began slightly sooner and ended slightly later than the pulses of the other square waves. This negative gating pulse was also applied to the cathode of the cathode-ray tube so as to blank the beam during pulses from the electronarcosis generator. The output of the upper beam vertical amplifier was also fed into a Sanborn 350 ECG recorder; and as the penwriter was incapable of following the cancellation tran-

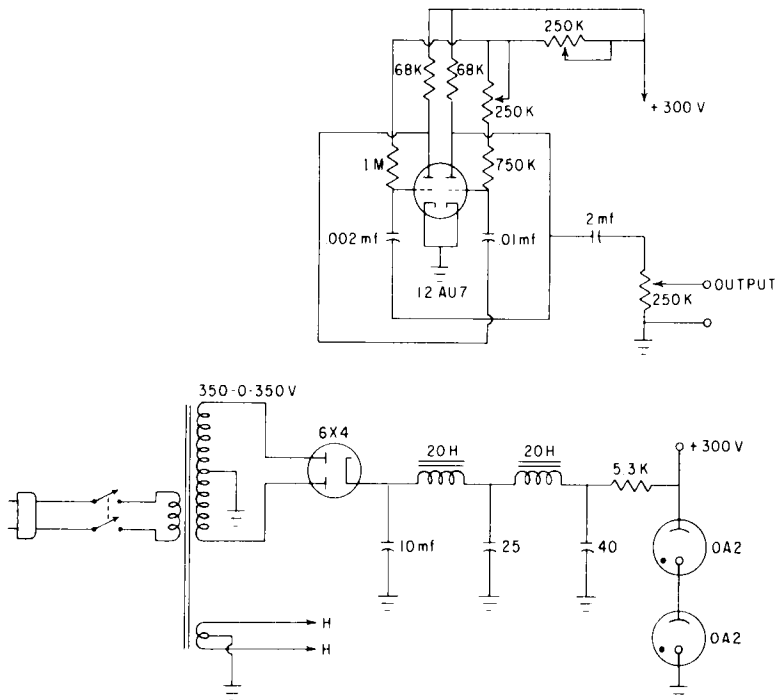


FIG. 1. Multivibrator.

sients, a very satisfactory tracing could be made on paper.

The effects of the apparatus on an incoming signal may be summarized as follows: The balanced push-pull input reduces greatly the magnitude of the electronarcosis signal, provided that the pick-up electrodes are equidistant from the active electronarcosis electrode. The clipping diodes result in rejection of any portion of a signal which exceeds $\frac{1}{2}$ -1 mv. The electronarcosis artifact has now been clipped down to a magnitude comparable to that of the desired signal. Next, a signal essentially identical to what still remains of the artifact is subtracted from it. Finally, blanking of the oscilloscope beam where cancellation transients still persist completes the process. These "holes" in the trace are only barely perceptible at the usual ECG sweep speed. The sequence is illustrated in figures 2 and 3.

Results

Fifty five experiments were performed on 17 dogs to standardize the electronarcosis procedure. ECG monitoring during 8 experiments (on 4 dogs) was done using simple bipolar precordial leads as described. All animals were atropinized prior to induction.

No abnormalities of rate, rhythm, conduction, or shape of complexes were ever seen during continuous monitoring periods of 30 minutes or more except for rare premature ventricular beats. Painful stimulation when an animal was too "light" resulted in movement and an increase in heart rate. No deaths attributable to electronarcosis occurred in any of the dogs used, nor were any behavioral abnormalities seen.

Discussion

In this rather limited series, no cardiac abnormalities appeared to be produced by electronarcosis. Inasmuch as salivation appears to be a problem with all forms of electronarcosis, including this one, all animals were atropinized. This has been reported to reduce the incidence of electronarcosis-induced arrhythmias.

In preliminary experiments, it was found that the animals commonly developed hyperthermia related directly to the power level used and the duration of the period of electronarcosis. One animal died 80 minutes after discontinuation of electronarcosis, at which time rectal temperature was still 106° F. Fever was entirely avoided when gallamine was used as described; this would seem to

indicate that the febrile response noted by us and by other investigators is related to muscle activity rather than to an effect on the hypothalamus.

The mode of action of electronarcosis still remains a matter of conjecture. Two hypotheses seem plausible: One, that the current has a distracting effect; the second, that some actual blockade of sensory input is produced. In either case, the effect is short of total, inasmuch as the animals were often seen to flinch in response to a loud noise and at times appeared to follow moving objects with their eyes. The mechanism of electronarcosis can be best elucidated through the application of improved neural recording techniques, especially electroencephalography and stimulus-response studies. To this end we are at present devoting our efforts.

Summary

In a series of 55 experiments, mongrel dogs were subjected to electronarcosis by the technique of Smith, and the method modified until consistent results were obtained. Electrocardiograms were then taken in a series of 8 experiments on 4 dogs. No abnormalities

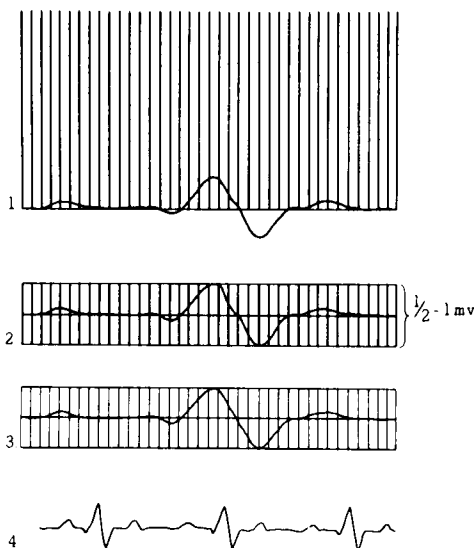


FIG. 2. (1) A diagrammatic representation of an ECG in relation to the electronarcosis artifact. (2) Clipping reduces the magnitude of the artifact to a level comparable to that of the ECG. (3) After artifact cancellation, some cross-hatching of the displayed signal still remains. (4) Appearance of the tracing at 0.2 cm./second sweep speed after blanking.



FIG. 3. Electrocardiogram taken during electronarcosis.

were seen. The methods used to overcome the problem of interference created by the narcosis current are described.

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