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ELECTRONARCOSIS PRODUCED BY A COMBINATION OF DIRECT AND ALTERNATING CURRENT. A PRELIMINARY STUDY

1. Apparatus and Electrodes

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A RECENT Russian article by Anan'ev and his co-workers[1] aroused our interest because it described a new method of producing electronarcosis. Until this report appeared we could find no article on the subject which described a satisfactory method of producing anesthesia by use of an electrical current.[2-6] The Russian authors reported that they had used direct current plus modified alternating current to produce anesthesia in dogs, and that their method did not cause convulsions, respiratory depression, blood pressure abnormalities or postanesthetic central nervous system depression. We were impressed by the account of their method and results, and we decided to try to duplicate them.

The Anan'ev report was specific regarding the wave form and the pattern of application of electrical currents to the experimental animals. The translation of the article did not include a diagram of the circuit they used, but it did describe the characteristics of the circuit and of the instrument which they used. These requirements are summarized below.

(1) The instrument should be so constructed as to deliver, via one electrical lead, direct current plus alternating current so modied as to produce a rectangular wave of 1.0 to 1.4 milliseconds' duration, at a frequency of 100 waves per second.

(2) The electrical circuit should be so devised that the subject would be in the cathode circuit of the output tube to provide voltage constancy despite resistance changes in the subject.

(3) The instrument should deliver 40 or more volts and 40 or more milliamperes.

(4) The instrument should include an oscilloscope to permit constant monitoring of the wave-form, and frequency.

METHOD

One of our coauthors (C. G.) devised a circuit (fig. 1) and constructed the apparatus which we used to produce electronarcosis. The circuit met the requirements as described by the Russian authors.

Eleven unpremedicated mongrel dogs varying in weight from 9.5 to 14.5 kg. were used in the experiment. Electrodes were applied to the head (fig. 2) of each animal and current from the instrument was added in increments as advised by Anan'ev.

It was necessary to decide on some means for determining the presence of anesthesia produced by electronarcosis in the dog. We

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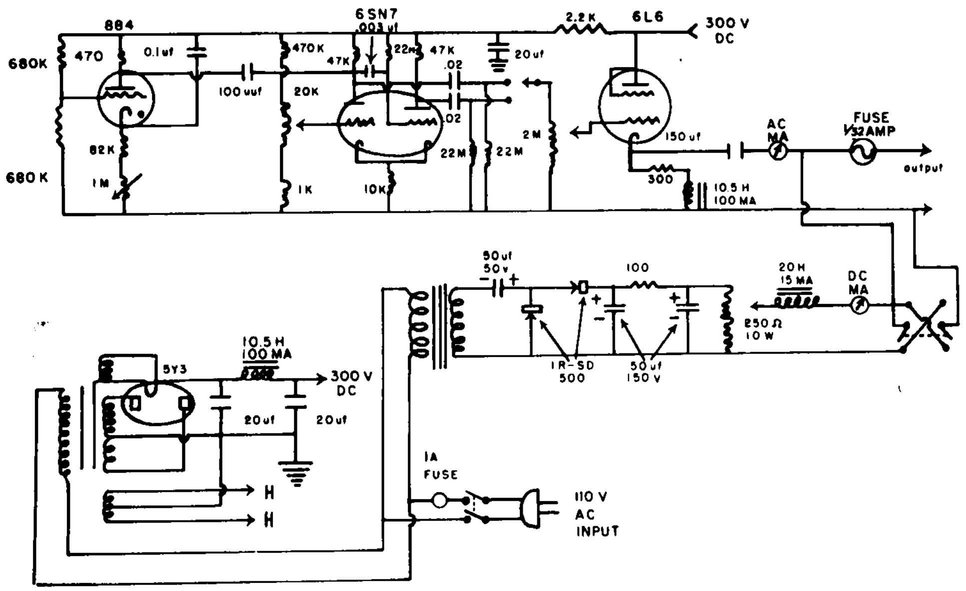

FIG. 1. Circuit for electronarcosis apparatus.

found that any normal awake dog, if an area of its body was pinched with a hemostat, showed alarm, resentment and pain as evidenced by withdrawal, snarling, snapping or yelping. The parts of the body used for test areas were the skin of the abdomen and flank, the pads of the feet, the nasal septum, the ears, and the last inch of the tail. Anesthesia was considered to be present in any dog when closing and locking a 6-inch hemostat on the areas listed failed to produce a response.

On awakening from anesthesia each animal was tested for persistence of skin analgesia.

A record of our observations of each dog was made on a 4 by 48-inch strip of adding machine paper stretched on a board which was ruled into 3/16 inch spaces so that each space represented fifteen seconds of elapsed time. This gave room for comments and insured a record accurate to the nearest fifteen seconds.

RESULTS

Electronarcosis was produced in 9 of 11 dogs by the use of the apparatus constructed for this purpose. The maximal electrical output of our instrument was not sufficient to produce narcosis in 2 dogs.

The amperage required to produce a state of anesthesia was different in each dog. As the production of electronarcosis progressed, eyeball movement ceased first and was followed by loss of response to pinching the skin, nose, and foot pad in that order, but in each dog these responses disappeared at a different current level. The response to stimulation of the tail disappeared in 4 of the 9 dogs when the maximal electrical output of our instrument was applied to them. In the remaining 5 dogs, 3 retained a twitching response to stimulation of the tail, and in 2 the tail response was not abolished although all other test responses were negative.

Surgical procedures were performed on 2 of the 9 dogs while they were in the state of electronarcosis. The first operation was an exploratory laparotomy of twenty-six minutes' duration. This dog moved when the peritoneum was clamped but there was no movement when the peritoneum was pulled and sutured for closure. The second surgical procedure was a ureteral transplant. This dog moved its head when the peritoneum was opened and when a catheter was inserted into the ureter, but there was no other movement during the operation.

The respiratory response to electronarcosis was variable and was no aid in assessing the depth of anesthesia. For example, at a given electrical imput one dog would pant at 130/minute whereas another animal would have a respiratory rate of 12/minute. One animal with a respiratory rate of 16/minute prior to electronarcosis developed panting during narcosis.

None of the anesthetized animals developed cyanosis and the color of the blood in the two dogs that were operated upon remained good throughout the procedure.

The pulse rate during electronarcosis varied from 132 to 60 per minute. Three of the dogs developed pulse rates of 60 to 70 per minute and sinus arrhythmia.

Skeletal muscle relaxation appeared to be adequate for abdominal operations in five dogs, was fair in two dogs, and poor in two dogs.

Salivation was a common complication which developed early in the induction period and persisted throughout the electronarcosis.

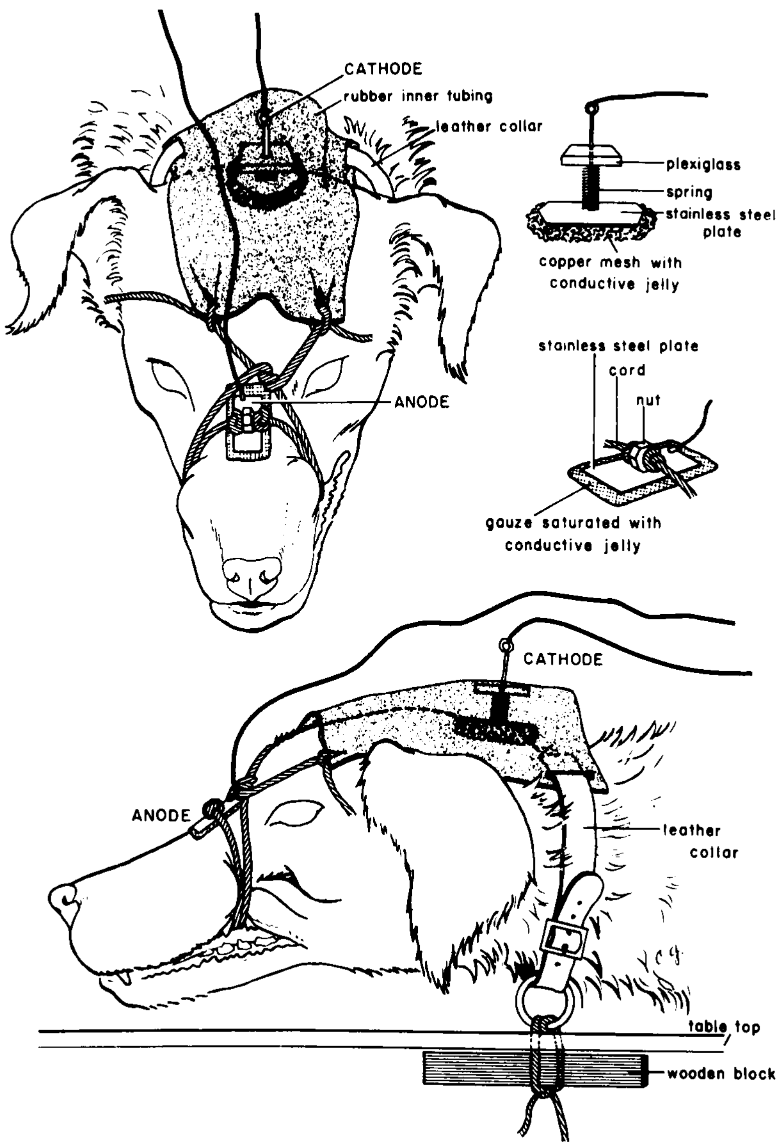

FIG. 2. Sketch showing placement and method of attachment of electrodes.

TABLE 1

RECORD OF ELECTRONARCOSIS IN ONE DOG

Time* Elapsed (minutes)	A.C. (milliamperes)	D.C. (milliamperes)	Comments
(15 seconds)	2½	0	Pulse, 100, respiratory rate 16. Quiet.
5	2½	20	
10	13½	20	Eyes closed and fixed.
18	15	20	Response: skin, paw, nose negative; tail positive.
19	15	20	Turned to back for surgery.
29	15	20	Incision made. Panting. Swallowed. Pulse rate, 66.
31	19	20	Moved when peritoneum cut.
33	20	20	
35	21	20	Blood color good.
36	21	20	Moving slightly.
38	22	20	
50	22	20	Bladder opened and emptied, and it contracted markedly.
84	0	0	Closure completed, dog untied, and current cut off. Righted the awake animal and placed it on the floor. Tail curled over back, panting, seemed happy, came to whoever called her. Awakening was instantaneous. Pulse 84 at time of awakening.

* Timing started with the application of current to the animal.

None of the dogs exhibited convulsions either during or after the electronarcosis.

The awakening of each of the 9 dogs was instantaneous regardless of the length of electronarcosis. Immediately after awakening each dog stood up, trotted about the room, sniffed at the furniture and seemed to display the same "personality" it had prior to the electronarcosis.

Temporary post-narcosis skin analgesia similar to that described by Anan'ev was present in 5 of the 9 dogs. One dog which had undergone an operative procedure found its operative wound forty-five minutes after the narcosis was discontinued. One dog which was permitted to awaken with a heavy hemostat clamped on its flank ignored the clamp for ten minutes. In addition to post-narcosis skin analgesia, for a short period of time tail analgesia was present in one animal, nose analgesia in one, and foot-pad analgesia in two.

A representative record of one experiment is presented (table 1).

Discussion

To produce anesthesia by means of electrical current required an apparatus meeting the specifications outlined in the introduction, an electrode system, a definite pattern of current application, and criteria for the onset and depth of anesthesia.

The apparatus we devised met the theoretical requirements gleaned from the translation of Anan'ev's article, but the power output of the apparatus was inadequate for the production of anesthesia in 2 of 11 dogs on which it was tried. The state of electronarcosis appeared to be a function of the total amperage, the wave-form employed, and the duration of the wave-form. Anan'ev reported that he obtained his results with a wave of one millisecond duration. This very narrow wave appeared to require more voltage than wider waves, if a given amount of amperage was to be delivered in that wave form. Our apparatus had a "ceiling" of 30 volts A.C. and 25 milliamperes. When the one millisecond wave was employed, the amperage output was 15 milliamperes. Our voltage maximum of 30 volts forced us to use the three millisecond wave to gain the last 10 milliamperes of the total A.C. output, and this may account for some of the differences between our results and those described by Anan'ev.

Previous investigators have indicated they had difficulty in maintaining constant electrode contact with the test animal. We had the same problem. Our solution of this problem is shown in figure 2.

The "hood" shown in figure 2 was made of heavy, non-conductive rubber and had several small holes punched in it to simplify the placement of the occipital electrode on heads of various sizes.

As illustrated in figure 2, a collar held the back of the hood to the dog's neck. A light rope ran from the collar through a slot in the table under the dog, and was tied to a bar under the table top. This rope limited the range of the dog's head-movement when struggling occurred. In struggling there was always an effort to lift the head. The lifting motion exerted a downward pull on the collar and tightened the electrode to the occiput. This effect was important because constant electrode contact with the animal was found to be necessary to maintain anesthesia. Painful stimulation resulted if the electrical circuit was broken and re-established. A 2 by 2 by ¼ inch brass mesh pad placed between the occipital electrode and the dog's head prevented sideward movement of the electrode and eliminated the hazard of contact loss.

Another requirement for electronarcosis was a pattern of current application. Anan'ev advocated a slow, thirty-five minute induction period using small quantities of current, but this pattern evoked struggling and discomfort in our dogs. The pattern of current application was changed and, as a result, the induction period was shortened and most of the struggling by the dog was eliminated. Induction was started with alternating current, at 100 waves per second, with a 1.0 millisecond wave duration, and current of 2 to 3 milliamperes. Immediately thereafter increments of direct current were added. Over a five to seven-minute period, the direct current was increased from zero to 20 milliamperes. Alternating current was added thereafter to effect, in 1 milliampere increments. The induction time with our method was fifteen to twenty minutes. The pattern of current application recommended by Anan'ev produced anesthesia, but was slower than ours and, in addition, would not produce anesthesia in a dog in which our pattern failed.

The signs commonly employed to determine the presence and depth of general anesthesia in dogs were of no value in this study of electronarcosis. Dogs in deep electronarcosis did not respond to painful stimulation, but we had no positive means of determining if they were unconscious. Electroencephalography would have been helpful, but the electric current used in the experiments prevented its use. It was startling to see a dog which was insensitive to a painful stimulus, swallow and react to the auditory stimulation of a loud handclap. Dogs under electronarcosis presented a picture comparable to that seen in human beings in stage I plane 3 ether analgesia as described by Artusio.[7] The unpredictable respiratory and cardiac pattern as well as the rapid awakening heightened this impression. The only clinical evidence of anesthesia was the intra-electronarcosis analgesia as determined by the lack of response to painful stimulation, and the post-electronarcosis analgesia.

The criterion we established for anesthesia seemed simple, but the responses to the stimulation were difficult to evaluate. Stimulation had to be sustained as long as fifteen seconds if false test results were to be avoided because moderate electronarcosis delayed responses. Deep electronarcosis was presumed to be present when there was no response to sustained stimulation.

Summary and Conclusions

In this preliminary study, a modification of the electronarcosis method described by Anan'ev and his co-workers was tried on 11 dogs. In 9 of the dogs, satisfactory anesthesia was produced and operative procedures were performed on 2 of these dogs. The longest period of electronarcosis was four hours and twenty-six minutes. Each of the 9 dogs awakened instantly when the current was turned off. No deleterious effects were noted in any of these animals. A method for maintaining constant electrode contact is described. A circuit used for producing electronarcosis is described, illustrated, and discussed. On the basis of the results obtained in the preliminary study, we believe that further and more complete experimental work is justified.

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EPISTAXIS A case of apparently spontaneous epistaxis occurring in a four year old child during rectal and inhalation anesthesia is reported. Respiratory obstruction was produced, and bilateral upper lobe pneumonia developed postoperatively. *(Keil, A. and Cockinays, E.: Epistaxis during Anesthesia, Canad. M. A. J. 83: 166 (July 23) 1960.)*

TEMPERATURE REGULATION In modern, air-conditioned operating rooms, the anesthetized pediatric patient, being virtually poikilothermic and possessing a relatively large surface area, is likely to lose heat. In a series of 600 infants and children between the ages of 1 day and 12 years, the rectal temperature at the end of operation was variable; but under the age of six months, a significant reduction in body temperature was common. In addition to air-conditioning, body temperature reductions are promoted by non-rebreathing techniques of anesthesia, by the exposure of large skin areas or body cavities to the environment, and by the administration of refrigerated blood. The great hazard of such spontaneous hypothermia is *lack of recognition.* Below a body temperature of 34 C., minimal concentrations of anesthetic drugs are necessary. If hypothermia is unrecognized, and normal anesthetic concentrations are continued, the patient will suffer from relative overdosage and may die. The second danger of uncontrolled and unrecognized hypothermia, particularly in infants, relates to the development of the serious and sometimes fatal syndrome of sclerema. This condition is characterized by an induration and rigidity of the skin and subcutaneous tissues which soon acquire "the consistency of thick leather," with eventually many of the soft parts appearing "as rigid as wood or stone." To prevent these complications, as well as those produced by hyperthermia, the body temperature should be monitored continually in every infant and child who is undergoing a major surgical procedure, or one of any length. Regulation and control of body temperature can be obtained satisfactorily in children by utilizing a heating-cooling unit (the Aquamatic-K-thermia unit) which automatically regulates the body temperature of the patient to within 0.5 C. of the level preset by the anesthesiologist. *(Stephen, C. R., and others: Body Temperature Regulation During Anesthesia in Infants and Children, J. A. M. A. 174: 1579 (Nov. 19) 1960.)*