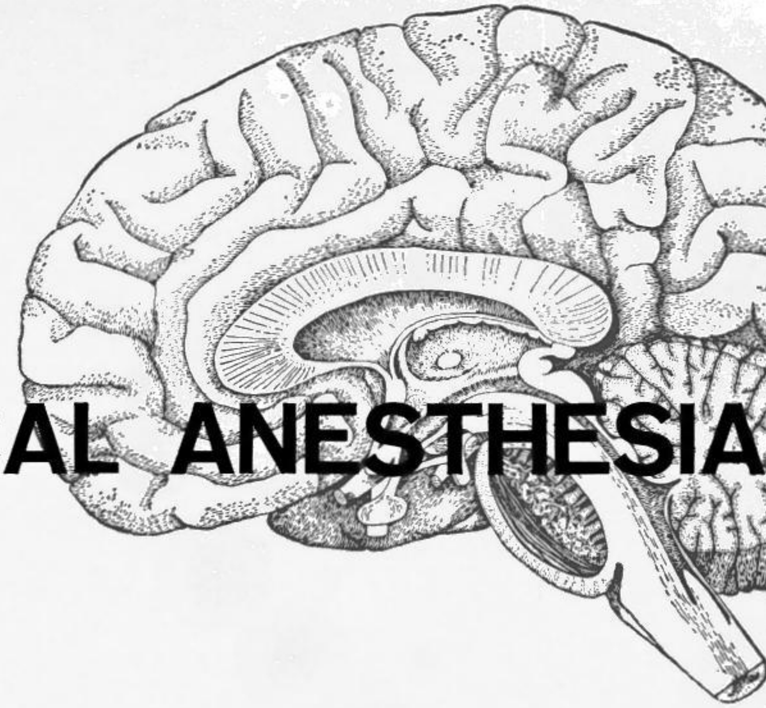
COVER STORY

Small alternating currents applied via surface electrodes to the brain produce instant sleep or anesthesia



ELECTRICAL ANESTHESIA

By JAMES W. BRAY*

Cover photo by Irvin Jaynes

SCIENTISTS BECAME INTERESTED IN THE effects of electric currents on the brain as early as 1875. By proper choice of waveform and current level, it seemed possible to produce a sleep deep enough to allow surgery to be performed satisfactorily on humans. This condition is called *electrical anesthesia.*

The term *anesthesia* was chosen because it describes a state in which portions of the nervous system are depressed to a point where muscles are relaxed and pain perception is removed. One frequently hears the term *electronarcosis*, which does not mean the same. In narcosis, the patient may be completely or partially unconscious, but not truly anesthetized. Operations may not be possible in narcosis because some muscle tone remains, and the patient may respond to painful stimuli by movement.

As early as 1875, German scientists noted that when direct current was passed through water containing live fish, they became insensitive to pain and oriented themselves according to the direction of current flow. In 1890, d'Arsonval caused anesthesia in rabbits with high-frequency ac (2.5 to 10 kc). In 1902, interrupted dc was used to produce deep anesthesia in rabbits and dogs.

In 1910, Louise Robinovitch used interrupted dc to bring about *regional* anesthesia in man. Regional anesthesia implies a block of specific nerve pathways outside the central nervous system. The rest of the nerves remain functional. Her first case consisted of an amputation of four toes. She also described the first practical application of electronarcosis for operations in animals.

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The first human subject was a scientist named Leduc who subjected himself to *electric sleep*, using 35 volts at 4 ma (Fig. 1). The current was left on for 1 hour, then turned off. The patient awoke normally a short while later. Electrodes were placed on the forehead (−) and the palm of the right hand (+).

Electric sleep means simply a loss of consciousness. The depth of sleep is not sufficient to deaden pain or relax muscles enough for operations. Equipment suitable for electric sleep is also suitable for regional or general anesthesia and vice versa (provided the current capacity is sufficient). Only the magnitude of the current (and voltage) and electrode placement are changed according to the type of anesthesia (or sleep) required.

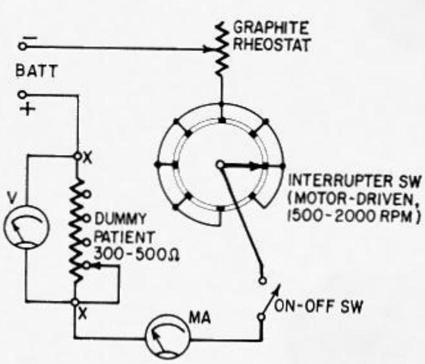

Fig. 1—Early electrical anesthesia apparatus used by Robinovitch in 1910. Electrodes are connected at points marked X, after adjustment.

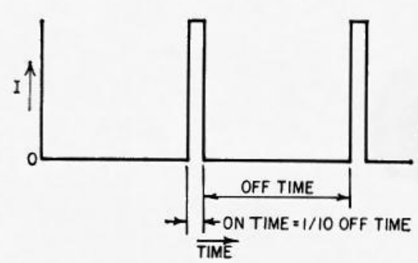

Fig. 2—Pulses produced by apparatus in Fig. 1.

The apparatus in Fig. 1 was used both for electric sleep and anesthesia. The dummy patient (resistor) is connected in the circuit, and the proper resistance selected with the slider. The main on-off switch is closed and the interrupter switch is stopped on a contact, allowing current to flow through the circuit. The rheostat is now adjusted to give the correct voltage (E) and current (I_T). Next, the motor which rotates the interrupter switch is started. Arrangement of the contacts on this switch allows the duty cycle (on-off ratio) to be changed. For best results, a ratio of $I_I = I_T/10$ is used, in which I_I is the current with the interrupter operating and I_T is the steady-state current (no interruption).

For example, if $I_T = 20$ ma, adjust contacts so that $I_I = 2$ ma. The pulses thus formed are shown graphically in Fig. 2. A combination of motor speed and number of contacts is chosen to give from 6,000 to 12,000 interruptions per minute (100 to 200 pulses per second).

Recent developments

Nothing much happened in this field until 1941 when spinal anesthesia was produced in animals with direct current. In the early 1950's Knutson began experimenting with 700-cycle sine-wave current, reporting animal studies in 1954. In 1956, he described its use on human patients. Following this work, Dr. James D. Hardy and his co-workers at Jackson, Miss., used similar techniques to produce electrical anesthesia in 12 patients. The equipment (Figs. 3 and 4) consisted of a low-distortion 700-cycle sine-wave oscillator. The output of the oscillator was fed to a good-quality audio amplifier that delivered approximately 150 ma to a load impedance of 250 ohms. (A multitap modulation transformer was substituted for the usual output transformer. Besides matching impedances, it also isolates the patient from ground—a desirable feature for his protection. Also, stray currents through accidental grounding of the patient are eliminated.) A monitor oscilloscope and a loudspeaker were connected. (Work with sine waves indicated that a pure waveform was important.) Meters were arranged to measure the output voltage and current. Protective fuses were placed in the output circuit.

Silver-plated electrodes of the type used with electrocardiographs were placed over the temples and held in place by rubber straps. Currents of 35 to 50 ma at 700 cycles were sufficient to cause anesthesia deep enough for surgery in dogs. Animals were held under from 6 to 8 hours by this method. When the current was turned off, the animals regained normal activity almost immediately, yet showed no effects of pain from the site of the operation for some time afterward.

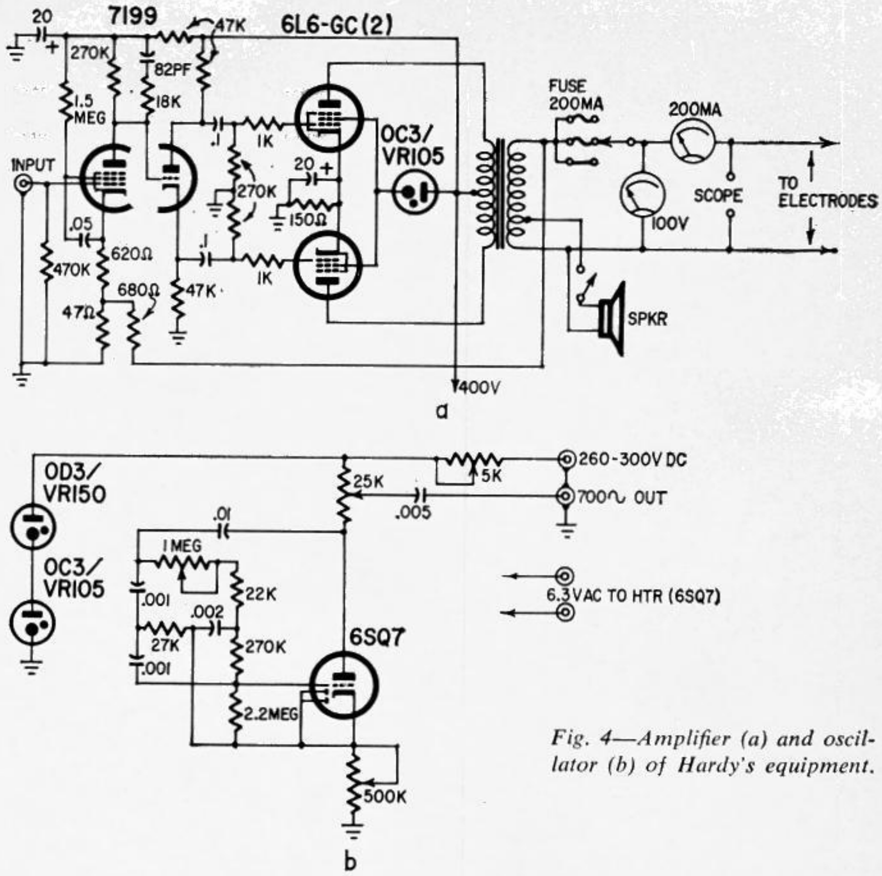

Fig. 4—Amplifier (a) and oscillator (b) of Hardy's equipment.

The Russians have claimed success with a combination of 100-cycle square-wave pulses 1.0 to 1.4 milliseconds wide superimposed on dc. This is essentially the same technique as used by Robinovitch (Fig. 2) except that pulses were superimposed on a dc bias instead of going from zero to maximum as shown. Electrodes were placed on the eyelids and at the base of the skull. Electronarcosis in dogs was achieved with 6- to 12-ma current (35 to 40 volts). Some anesthetic effects lasted 10 to 30 minutes after the current was switched off.

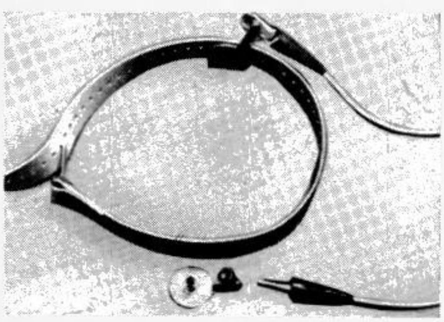

Fig. 3 (above and below)—Instruments used by Dr. Hardy in anesthetizing animals and humans.

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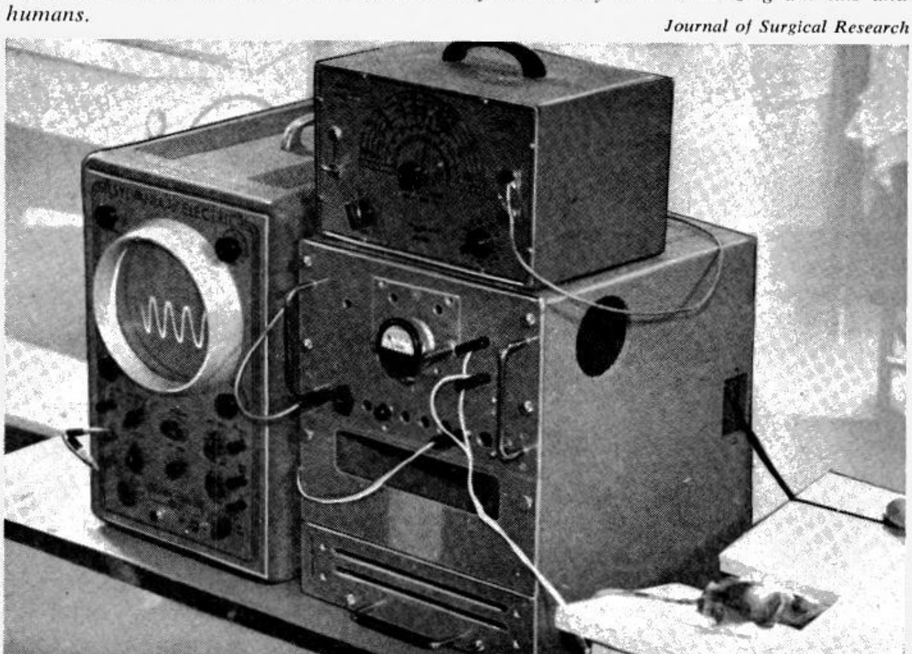


Following the lead of the Russians, Smith and Cullen at the University of California described a method in which a 100-cycle square wave is superimposed on a 20-ma direct current and the combination applied to the patient. The dc bias is believed to act as a cushion which eliminates the possibility of convulsions that often occur with "raw" square-wave pulses. Duration of the square waves is 2 msec, at 4 to 10 ma.

A thyratron pulse generator with associated shaping circuits is used. A 6L6 in the output serves as a constant-current device, and output current is measured with a rectifier type milliameter. Steady dc is added from a separate power supply suitably filtered. A 50-ma dc meter measures the current from the dc source.

An interesting effect was observed by these workers: the postoperative condition of the animal was better after using one oscillator than with another oscillator which was apparently identical. Upon close examination with a fast-rise-time scope, "noise" was detected on the wave of the generator which gave the poorer results. This seems to fit in with the feeling of some investigators

Anesthesia & Analgesia

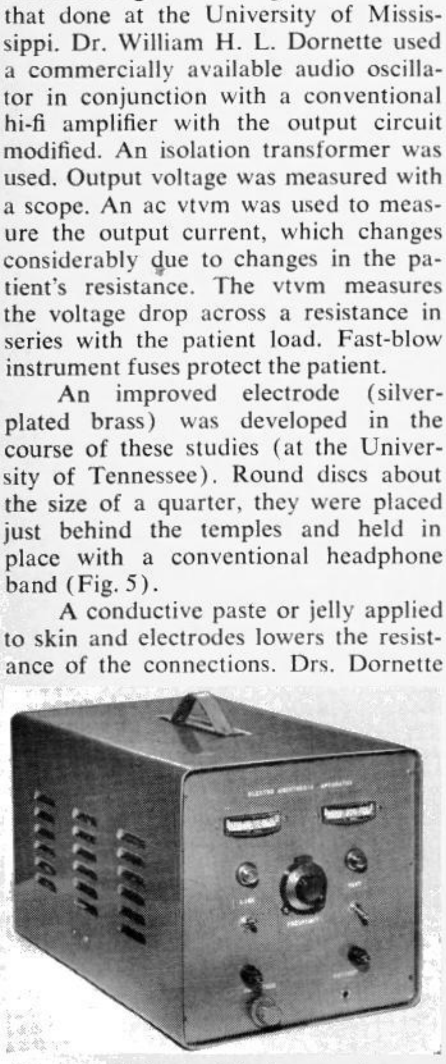
Fig. 5—Electrodes developed at the University of Tennessee.

that purity of waveform is most important.

The work at the University of Tennessee Medical Units at Memphis proceeded along the same general lines as that done at the University of Mississippi. Dr. William H. L. Dornette used a commercially available audio oscillator in conjunction with a conventional hi-fi amplifier with the output circuit modified. An isolation transformer was used. Output voltage was measured with a scope. An ac vtvm was used to measure the output current, which changes considerably due to changes in the patient's resistance. The vtvm measures the voltage drop across a resistance in series with the patient load. Fast-blow instrument fuses protect the patient.

An improved electrode (silver-plated brass) was developed in the course of these studies (at the University of Tennessee). Round discs about the size of a quarter, they were placed just behind the temples and held in place with a conventional headphone band (Fig. 5).

A conductive paste or jelly applied to skin and electrodes lowers the resistance of the connections. Drs. Dornette and James H. Price are now experimenting with an electrode system which places the electrodes against the roof of the mouth and the top of the head (Fig. 6).



Dornette electro-anesthesia apparatus.

Future outlook

Although some progress has been made through these studies in electrical anesthesia, a considerable amount of work remains to be done before it can be used as routinely as other types of anesthesia. Many problems are yet to be solved. The effectiveness of this method depends heavily on electrode placement, on making low-resistance connections to the patient, and on other factors. There is considerable muscular tension during electrical anesthesia and drugs must be used to relax the muscles so that operations may be performed.

Carolina Medical Electronics, Inc.

A typical commercial electrical anesthesia device that uses 700-cycle sine waves.

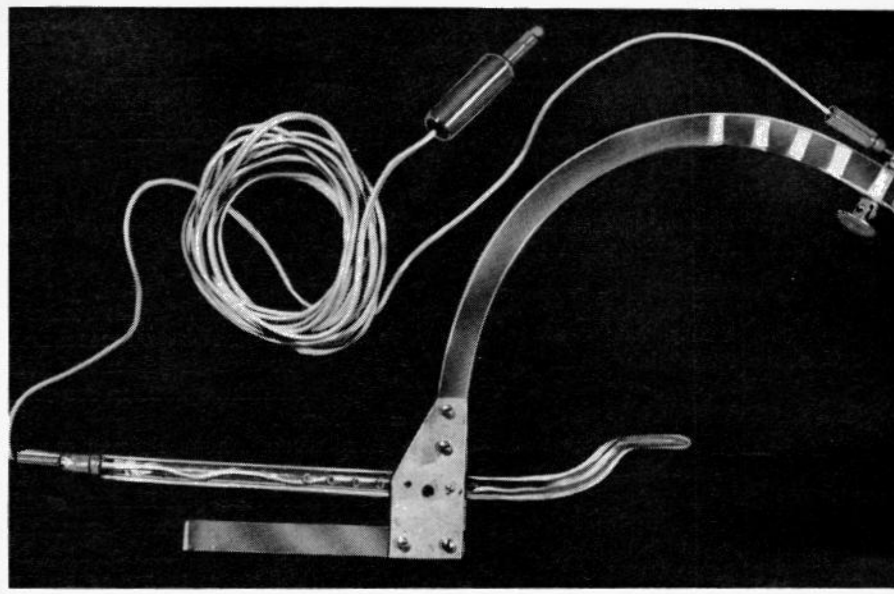


Fig. 6—Experimental electrode with contacts for roof of mouth and top of head.

If electrical anesthesia can be perfected to where it can be used repeatedly with success (with little or no side effects) it may prove to be an "ideal" anesthetic. The patient could be rendered unconscious almost instantly, and maintained in this condition as long as necessary by adjusting the current. Then the current could be shut off and the patient would awake immediately without the undesirable aftereffects of the usual chemical anesthetics (ether, cyclopropane, etc.). In addition, fire and explosion hazards accompanying would be eliminated. Elderly patients and those with low blood pressure as well as people suffering from respiratory infections could undergo operations more safely with electrical anesthetic.

It has obvious advantages for remote places such as field hospitals, emergency surgery or first-aid facilities in portable vans, tents or ambulances, and is readily adaptable to common power sources. Portable units could be brought to the patient's room and he could be anesthetized before leaving it, relieving needless anxiety while being prepared for the operation. A large hospital could be equipped with a central electrical anesthesia generator (in addition to a standby unit) which could supply all its operating rooms. Valuable space in the operating room could be gained, because, with such a central system, only patient leads and controls and monitoring meters would be required in a particular room.

Continued study should make this exciting new type of anesthesia a safe and effective aid to physicians in their continuing efforts to relieve suffering.

END

CAUTION

We strongly advise readers against experimenting with the methods described in this article. They have not been developed to the point where they are safe for untrained persons to use. Convulsions or permanent damage to the brain may result from misuse of electrical anesthesia.