CRANIAL APPLICATION OF A PULSED DIRECT ELECTRIC CURRENT AND RANDOM SOUND IN DOGS

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SINCE THE PUBLICATION of the work of Anan'ev,¹ interest has been taken in direct electrical current with a superimposed square wave for anaesthetic purposes. This report describes some of the effects of a pulsed direct current applied to dogs, and the use of random noise.

The electrical apparatus—a D C generator—was designed and built by one of us (W J C). It is a power amplifier capable of 100 volts into 400 ohms, driven from the internal pulse generator, D C voltage source, the external input, or a combination of these (Figure 1). The pulse generator has adjustable repetition rate and pulse width, all three inputs being amplitude-adjustable prior to the

FIGURE 1 Direct-current generator

mixer. The mixer drives the power amplifier as shown. For the final power stage a solid-state amplifier was designed with feedback arranged to give a constant current output over a constant voltage. Small changes in resistance of the dog and electrode contacts would then not effect the current. Care was exercised to see that the pulse generator—a free-running multivibrator with pulse shaping—gave a “clean” square pulse. It was possible to set on a D C level and add to it a pulse of chosen width and repetition rate and have the output D C level unaffected by the addition of the pulses.

The random-noise generator used for some phases of the experiment was the General Radio Type 1390-B. This generator is designed to deliver the same level of noise at any frequency in the range being used. A narrow band is used for measurement.

Palladium electrodes 2 cm in diameter and a conducting gel were maintained

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in position by two alternative methods. A tong type holder as suggested by Smith² allowed current to pass between the posterior hard palate (anode placement) and the posterior part of the vertex (cathode placement). A second method allowed firm application of the anode in the mid-line below the eyes, and of the cathode in the same position as before. Each palladium conductor was set in a plastic disk mounted on a rod, the whole being movable up and down a close-fitting plastic sleeve, but allowing the conductor to project beyond the end of the sleeve. The rod could be immobilized at any desired level inside the sleeve—one end of which was threaded—by means of a threaded disk fixed to the rod. The plastic sleeves, suitably positioned, were incorporated in a plaster cast made for the head of each dog. The ears and eyes were not covered. The cast was then bivalved horizontally at the level of the angles of the mouth. This permitted easy application of the cast, adhesive tape being used to keep the segments firmly in apposition.

Six mongrel dogs 14–25 kg in weight, selected for their similarity in head shape, were used, and attempts were made to assess the effects of different current applications in each dog, using the two alternative electrode placements. Before the casts were made the heads were shaved. Prior to each experiment thiopentone 15 mg/kg was administered intravenously followed by endotracheal intubation, except on six occasions when a combination of dihydrobenzpyridol 0.2–1.0 mg/kg and fentanyl 0.004–0.02 mg/kg was substituted for thiopentone. Analgesia was assessed by the muscular and respiratory response to the application of a haemostat to the distal part of the tail, dorsum of paws, and abdominal wall. The electric current was not applied until signs of spontaneous arousal were present. Blood pressures were measured by arterial cannulization and temperature by rectal thermometer.

The direct current was introduced first, increasing at 5 ma a minute until a maximum of 20 ma was reached. The first 5 ma produced no visible alteration in respiration or muscle tone, but as the current increased, slight movements of the head and limbs occurred. The use of a high rate of current flow did not appear to be advantageous and in the majority of experiments the direct current was limited to 5 ma.

A variety of pulsed currents were used, each introduced smoothly at 5 or 10 ma/minute, and the results are as follows:

100 c p s 1 ms—to a maximum of 135 ma At 5 ma the dog remained motionless, would get up if the current was turned off, and could be aroused by a loud noise. Respiration was slow, regular, with adequate volume, and analgesia was absent. When the current was increased muscle tone increased and tremors occurred, first in the forequarters and spreading to the rest of the body. These signs persisted whether the current was added at 5 or 10 ma per minute, and as it increased respiration became more embarrassed by muscle spasm and defaecation sometimes took place.

100 c p s 2 ms—to maximum of 37 ma Alteration in muscle tone and respiratory changes were infrequent, but though the animal was motionless, relaxed, and rousable only by a very loud noise, response to painful stimuli was invariably present regardless of the electrode placement.

200 c p s. 2 ms—to maximum of 50 ma Muscle tremors occurred and no analgesia was achieved

200 c p s. 1 ms—to maximum of 42 ma Results were similar to those obtained with 200 c p s and 2 ms

200 c p s. 2 ms—followed by 100 c p s 1 ms Pulsed direct current was increased to approximately 35 ma over a period of one minute and at this point the frequency was reduced to 100 c p s and the current increased to 50 ma The pulse width was then reduced to 1 ms and the current increased to 100 ma Muscle spasm, respiratory stimulation ensued, with absence of analgesia

Rectal temperatures invariably increased up to 25° C above the resting level This could be controlled with the use of ice packs or paralysis with succinylcholine and artificial ventilation Application of electric current to the animals resulted in a substantial increase in systolic and diastolic pressures, particularly when signs of muscular activity were present This hypertension also occurred after paralysis with succinylcholine and artificial ventilation A gradual return to almost normal levels occurred, but any subsequent alterations in current flow produced further increases in blood pressure A comparison was made between the tong and cast technique of electrode placement on six different dogs with each of the electrical currents used Similar results were obtained in both groups

The intravenous administration of fentanyl and dihydrobenzpyridol sedated the animals but intubation was technically difficult Currents of 100 c p s 1 ms or 100 c p s 2 ms were applied through cast electrodes, but a response to painful stimuli was invariably present

Random-noise In seven experiments random noise was added to the peaks and troughs of the pulsed wave applied to the animal through the cast electrodes Noise in the range of 20 kc or 500 kc was used, with peak excursions of 33 ma, and combined with a pulsed current of 100 c p s 2 ms, or 200 c p s 1 ms Whenever the random noise was begun the animal would struggle slightly, the eyes opened, and the eyeballs oscillated slowly A quiescent state did not return and analgesia could not be demonstrated The application of random noise alone through cast electrodes produced a quiescent state from which the animal could be aroused by a loud noise Respiration at this time was of adequate volume and unembarrassed by muscle spasm The limbs were relaxed Analgesia was absent Increase of current beyond 25 ma invariably produced the muscular complications associated with previous current patterns

DISCUSSION

In a number of experiments there were indications of at least some degree of analgesia, but on more careful observation it was concluded that muscle spasticity masked response to painful stimuli In any case analgesia failed to occur in any animal that was relaxed and breathing adequately As the electrical current could be used to maintain the dogs in a quiescent to relaxed state, it was thought that the use of an analgesic drug which could if necessary be administered pre-operatively by intramuscular route might be combined with it

Fentanyl (McNeil) is a morphomimetic drug and droperidol (McNeil) is a drug with sedative and tranquillizing properties. The drug combination was used for sedative purposes and no attempt was made to render the animals analgesic prior to the application of electric current. The fact that no satisfactory technique could be developed applies only to these drugs in the dosage used. It is possible that a suitable combined technique could be devised in the future.

The application of electrical random noise, or a pulsed direct current, to an animal already quiescent under the effects of a pulsed current or random noise, produced signs of stimulation. It appears that the additional current acts as an extraneous stimulus producing arousal and that the initial quiescent state of the animal is akin to hypnosis. Possibly in some cases there could be a significant relationship between the administrator, electrical current, and the presence of analgesia at these current levels.

Although the dogs' behaviour in the period between experiments did not apparently change, the animals were untrained and no attempts were made to assess cerebral function. The work of Lilly³ and his colleagues indicates caution in the use of unidirectional currents because of possible cortical injury, and as a direct current up to 20 ma appeared to have no anaesthetic value, only 5 ma was employed in the majority of cases.

It was concluded from these experiments that the method of electrode placement described was satisfactory, particularly if there was a possibility of unexpected movements by the dog. A variety of electrical currents could maintain a quiescent and relaxed state, but analgesia, by the standards of assessment used, could not be produced.

SUMMARY

A pulsed direct electrical current was applied to the heads of adult dogs through palladium electrodes. These were located on the posterior hard palate andinion, or between the eyes and just behind theinion. In the latter instance a plaster cast was used to keep the electrodes in position. Prior to the current application the animals were sedated with thiopentone, or, in a few cases, with a combination of fentanyl and droperidol.

Currents used were 100 c p s 1 ms to a maximum of 125 ma, 100 c p s 2 ms to a maximum of 37 ma, 200 c p s 2 ms to a maximum of 50 ma, 200 c p s 1 ms to a maximum of 42 ma, random noise in the range 20 kc or 500 kc to a peak of 33 ma. A variety of currents produced a relaxed quiescent animal but analgesia could not be demonstrated. An increase in current produced muscular spasticity.

RÉSUMÉ

Au moyen d'électrodes en palladium, nous avons appliqué un courant électrique direct (pulsatile) sur la tête de chiens adultes. Nous avons placé ces électrodes l'une sur la partie postérieure du palais dur et l'autre sur l'inion, ou encore entre les yeux et juste en arrière de l'inion. Dans cette dernière éventualité, nous avons

employé un plâtre pour maintenir les électrodes en place. Avant d'appliquer le courant, nous avons donné une sédation aux chiens; parfois nous avons utilisé du thiopentone ou, dans quelques cas, un mélange de fentanyl et de dropéridol.

Nous avons employé les courants suivants: 100 c.p.s., 1 ms jusqu'à un maximum de 125 ma; 100 c.p.s., 2 ms jusqu'à un maximum de 37 ma; 200 c.p.s., 2 ms jusqu'à un maximum de 50 ma; 200 c.p.s., 1 ms jusqu'à un maximum de 42 ma; bruit (occasionnel) de l'ordre de 20 kc à un maximum de 33 ma.

Une variété de courants ont produit chez l'animal une détente et un repos, mais nous n'avons pas pu démontrer d'analgésie. Une augmentation du courant a provoqué des spasmes musculaires.

REFERENCES

1. ANAN'EV, M. G., GOLUBEVA, I. W., GUROVA, E. V., KASHCHEVSKAIA, L. A., LEVITSKAIA, L. A., & KHUDYU, YU. B. Preliminary Data on Experimental Electronarcosis Induced with Apparatus of Scientific Research Institute of Experimental Surgical Apparatus and Instruments. *Eksp Khir* 4:3 (1957) *translated in Anesthesiology* 21:215 (1960).
2. SMITH, R. H. & CULLEN, S. C. Electronarcosis by Combination of Direct and Alternating Current. 3. Electrodes and Electrode Holders. *Anesthesiology* 23:682 (1962).
3. LILLY, J. C., AUSTIN, G. M., & CHAMBERS, W. W. Threshold Movements Produced by Excitation of Cerebral Cortex and Efferent Fibers with Some Parametric Regions of Rectangular Current Pulses (Cats and Monkeys). *J Neurophysiol* 15:319 (1952).