PERIPHERAL HAEMODYNAMIC EFFECTS OF ELECTRONARCOSIS*

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ELECTRONARCOSIS is a technique for producing a state of unconsciousness and analgesia with an electric current. This procedure differs in many respects from the familiar concept of general anaesthesia, and the commonly used term "electro-anaesthesia" is therefore somewhat misleading. The word "narcosis" would appear to be the more fitting term since it is derived from the Greek word for the electric eel, narke, which is capable of stunning its prey by the discharge of an electric organ.

Interest in the effects of electric currents applied to the central nervous system of animals and humans is quite old: Benjamin Franklin tells in his letters[1] that he experienced prostration and loss of consciousness when he received a shock from a Leyden jar. In later years Mesmer's experiments with "animal magnetism" did much to discredit the field of electrosleep and it became the favourite topic for quacks and charlatans. Scientific inquiry into the mechanism of electronarcosis received a new stimulus from Russian investigators who reported that human subjects could be anaesthetized with electric current for major surgery. Anaesthesiologists took a great interest in this development since chemical anaesthesia is still fraught with many problems. Among these are a lack of controlability, slowness in induction and emergence, undesirable side effects on respiration and circulation, and complications due to drug hangover in the postoperative period. Therefore, a technique which could produce a painless state in patients with little or no effect on vital functions and body chemistry would be most welcome.

Electronarcosis can be produced by a great variety of wave forms and types of current.[2] The two basic electrical parameters controlling the level of anaesthesia are the amount of current used and the frequency at which it is applied. The relationship of current and frequency to analgesia and relaxation has been the subject of many studies.[3] In general it can be said that a greater degree of analgesia is produced at lower frequencies, while the best relaxation is attained at higher frequencies. Since both analgesia and relaxation are required for satisfactory anaesthesia but cannot be attained at identical frequencies, attempts have been made to construct instruments which will deliver a complex wave form containing both low and high frequency components. Thus, the depth of anaesthesia can be maintained with the low frequency component while relaxation is achieved with a variable high frequency.

The purpose of this study was to investigate peripheral haemodynamic responses during electronarcosis in the isolated forelimb. In a cross-circulation

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experiment, an isolated forelimb of a dog anaesthetized with nembutal was periodically perfused with blood taken from the femoral artery of a dog in electronarcosis.

Methods

Twelve mongrel dogs weighing between 7 and 10 kg were studied. They were grouped in six pairs of comparable size and age, premedicated with prochlorperazine (10 mg), and heparinized. One dog of each pair was anaesthetized with pentobarbital (25 mg/kg) and the left forelimb isolated in a manner described elsewhere.[4] The brachial artery was cannulated and perfused at a constant flow rate by a Sigma motor pump. The venous blood drained into a collecting funnel attached to a reservoir and was returned to whichever animal was providing the perfusing blood at any given time. During control periods the leg was perfused with blood from the nembutalized dog. Since blood flow was held constant by the pump, any change in brachial artery pressure in the isolated limb reflected resistance changes of the skin and muscle vasculature. Vasoconstriction caused an increase in perfusion pressure, vasodilation a decrease in perfusion pressure. This preparation is very sensitive to circulating vasoactive agents and has been used as a bioassay for the peripheral effects of catecholamines, serotonin, histamine, and other humoral substances.

The second dog of each pair was connected to the isolated forelimb through T-pieces inserted into the perfusion circuit as shown in Figure 1. Electronarcosis was produced in this animal by an electroanaesthesia unit* which delivered a dual sine-wave alternating current of mixed low (100 Hz) and high (700 to 10,000 Hz) frequencies of variable intensity. The low-frequency component of the total current was adjustable from 0 to 40 per cent of the total current; the remainder was made up of high frequency current usually in the range of 1,500 to 3,000 Hz. The electrode sites were injected with xylocaine (3 ml of a 1% solution) to produce local anaesthesia. Bitemporal needle electrodes, one to two inches long, were employed, depending on the size of the head. The electrodes were insulated so that only the blank tip was in contact with the tissues. They were placed just anterior to the base of the ears and inside the zygomatic arch as shown in Figure 2. Electronarcosis was started with an instrument setting of 1500 Hz and a current of 1 milliampere. The current was gradually increased to about 20–30 milliamperes at the rate of about one milliampere per 20 seconds. The frequency was increased simultaneously with the current. Final settings were usually in a range of frequency of 2000 to 3500 Hz and a current of 15 to 45 milliamperes. In addition to the perfusion pressure and small vein pressure of the limb, the systemic arterial pressure, the electrocardiogram, and the body temperature of both dogs were recorded.

Results

Figure 3 shows a representative recording from one of our experiments. It can be seen that the brachial artery pressure increased 35 per cent over control

*Model 3380B, Hewlett-Packard Co., Loveland, Colorado.

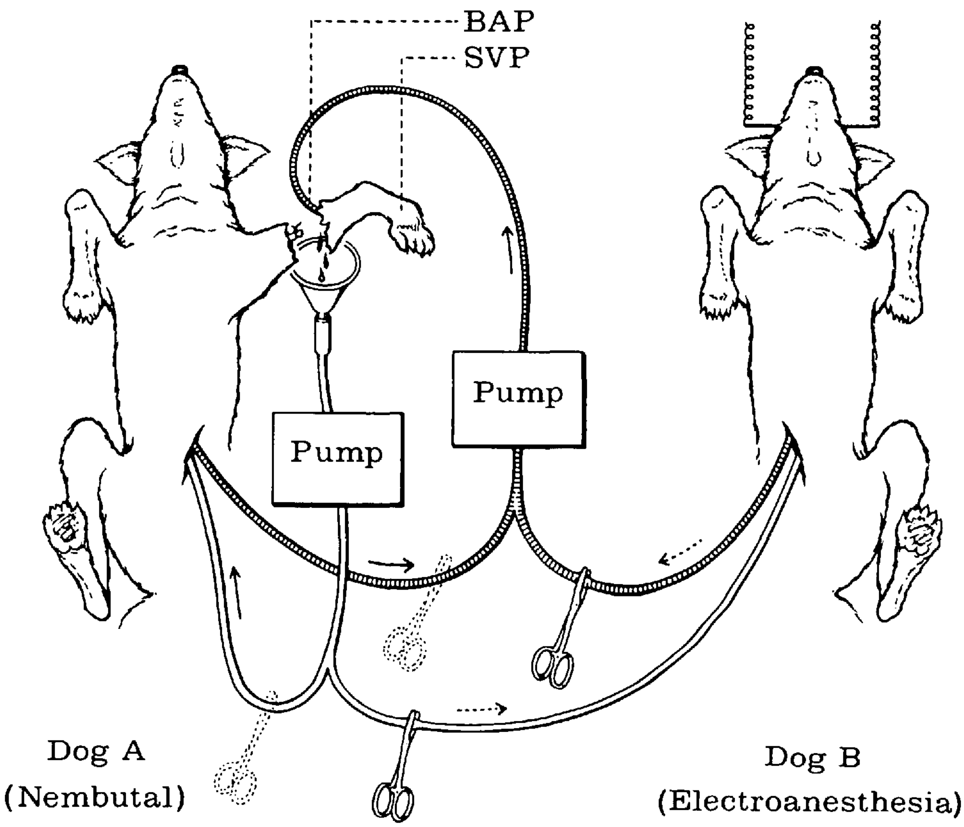

FIGURE 1. Cross circulation experiment showing perfusion of an isolated forelimb of dog A under nembutal anaesthesia with blood from dog B in electronarcosis. Flow was initially adjusted to produce a limb brachial artery pressure (ABP) equal to dog A's systemic arterial pressure and subsequently held constant for the remainder of the experiment. Changes in brachial artery pressure and small vein pressure (SVP) then represented changes in limb resistance downstream from the site of measurement. The large veins were permitted to drain at atmospheric pressure.

when the leg was perfused with blood from the animal under electronarcosis. This was a consistent finding in all animals and appears to be caused by an increased level of circulating vasopressor agents. We cannot say with certainty whether these were catecholamines or vasoactive hormones released from the pituitary. However, when the limb was injected with an epinephrine inhibitor, phentolamine (10 mg), the vasopressor response was markedly diminished. This would indicate that circulating catecholamines were at least in part responsible for the increase in peripheral resistance.

Figure 4 is a graphic representation of the mean vascular response in ten perfusion experiments. There was a marked increase in perfusion pressure, indicating vasoconstriction of limb vessels which could be blocked by phentolamine. Finally, the donor dog was anaesthetized with pentobarbital and the current was turned off. After one hour of pentobarbital anaesthesia, donor blood was again perfused through the isolated limb, this time with no significant change in perfusion pressure. The systemic pressures of both animals were reasonably

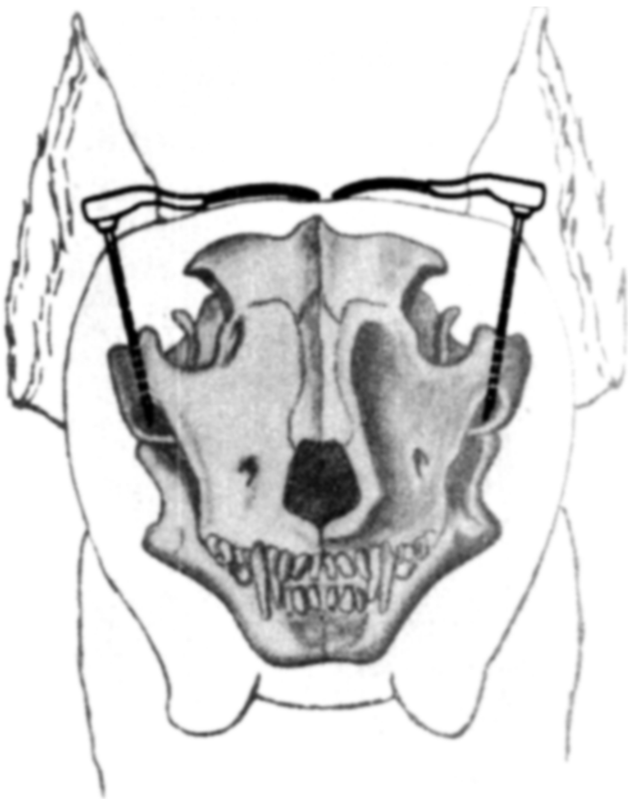

FIGURE 2. Placement of bitemporal electrodes with the tip protruding into the zygomatic arch.

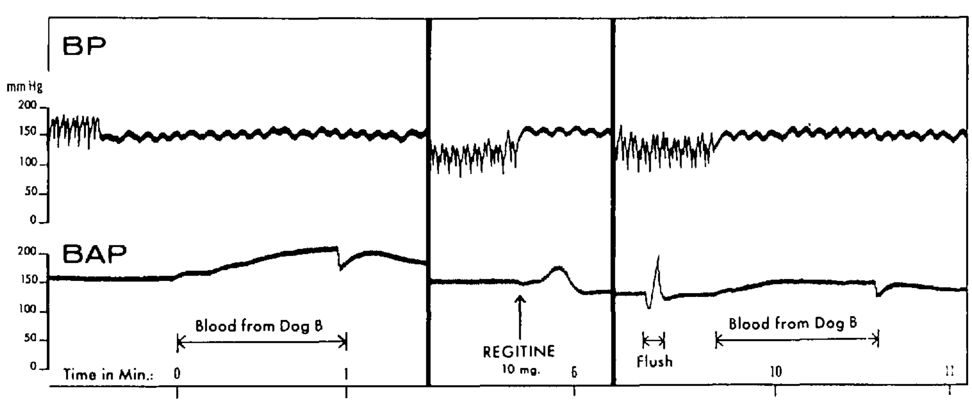

FIGURE 3. Systemic blood pressure (BP) and brachial artery pressure (BAP) of dog A, showing the effect of perfusion of the isolated forelimb with blood from dog B. Systemic pressures of both dogs were alternately recorded by the same pressure transducer; the "spiked" tracing is from the dog under electronarcosis.

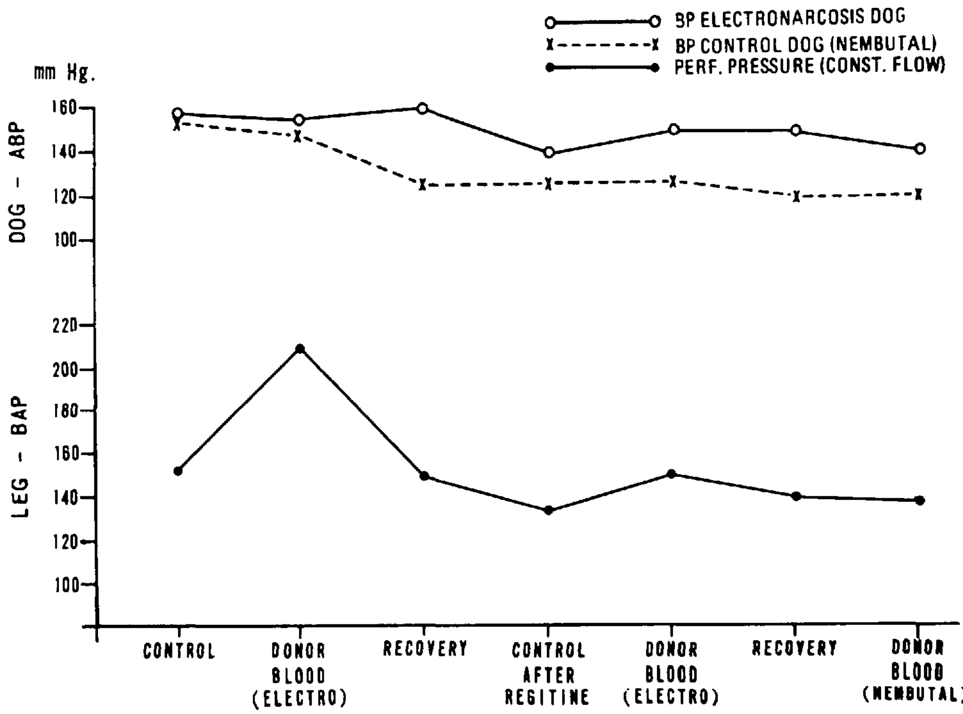

FIGURE 4. Graphic representation of the mean vascular response of ten perfusion experiments. Since blood flow in the isolated forelimb is kept constant by a Sigma motor pump, changes in perfusion pressure represent changes in peripheral vascular resistance.

constant throughout the three-hour experiment, but the pressure of the animal under electronarcosis was on an average 25 mm Hg higher than the pressure of its counterpart.

DISCUSSION

Hardy[5] has reported elevation of epinephrine and norepinephrine levels in plasma of dogs undergoing surgery under electronarcosis. Pentobarbital on the other hand, depressed the hormonal response. He explains the effect of electronarcosis as the result of a marked activation of the autonomic nervous system. Gravenstein *et al.*[6] have reported elevated plasma levels of epinephrine and norepinephrine in patients undergoing electroconvulsive therapy. These patients were shocked with alternating current of 120 volts through bilateral temporal electrodes. It is not clear whether the liberation of catecholamines was caused by a direct effect of the electric shock on autonomic centres or was secondary to the ensuing asystole which lasted up to seven seconds. Other haemodynamic measurements during electronarcosis have been made by Elkins and Vasko[7] of the National Heart Institute (USA). They found that the cardiac output decreased from an average control value of 94 ± 5 ml/kg/min to 81 ± 5 ml/kg/min. Sinus bradycardia and systemic arterial hypertension, frequently seen in their animals, were not influenced by beta adrenergic blockade; the bradycardia, however, could be blocked with atropine or cervical vagotomy.

Some general observations made during the course of these studies indicate that the characteristics of electronarcosis are quite different from those of chemical anaesthesia. The normal signs for measuring anaesthetic depth, such as the pupillar reflexes and the pattern of respiration, are of little value. The anaesthetic state was usually reached when the eye was covered by the second eyelid, the so-called nictitating membrane. The animal was then resistant to painful stimulation but occasionally reacted to sound stimuli. The most remarkable difference between chemical and electrical narcosis was observed at the time of emergence from unconsciousness. While emergence from chemical anaesthesia often is complicated by respiratory depression, delirium, vomiting, or prolonged periods of general restlessness, emergence from electronarcosis was instantaneous with the interruption of the current.

In our experience the more serious problems associated with electronarcosis may be related to muscle spasm rather than cardiovascular disturbance. There may also be minor skin burns caused by improper use of electrodes. Although these reactions indicate that electronarcosis is not yet ready for clinical application, several investigators[8–10] who have used it in humans believe that the procedure will eventually become an important addition to our present techniques. They claim that the elevation of the blood pressure may be prevented by a more sensitive control of milliamperage and the excessive muscle spasm can be overcome by the use of curare. This in turn would necessitate endotracheal intubation and artificial ventilation, invalidating much of the purported advantage of simplified instrumentation.

Summary

The effects of electronarcosis on peripheral haemodynamics were studied in the isolated forelimb preparation of the dog. Forelimbs of dogs under nembutal anaesthesia were severed from the body and perfused at constant flow rate by a Sigma motor pump with blood drawn from animals under electronarcosis. It was found that blood from animals under electronarcosis consistently caused vasoconstriction in the isolated forelimb which could be blocked partially by phentolamine. It is concluded that electronarcosis causes the release of vasoactive substances into the circulation, the bulk of which appear to be catecholamines.

Résumé

On a étudié les effets de l'électronarcose sur l'hémodynamique périphérique dans une préparation d'un membre antérieur de chien, préalablement séparé de l'animal. Des membres antérieurs de chiens sous anesthésie au nembutal ont été séparés du corps et perfusés à courant constant, à l'aide d'une pompe à moteur Sigma, avec du sang d'animaux sous électronarcose. On a trouvé que le sang d'animaux sous électronarcose produisait constamment, dans le membre isolé, une vasoconstriction qui pouvait être partiellement contrôlée par la Régitine. On en conclut que l'électronarcose amène la libération de substance vasoactives dans la circulation; la plus grande partie de ces substances semble être des catécholamines.

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