ELECTRICAL ANAESTHESIA THE USE OF A COMBINATION OF ALTERNATING AND DIRECT ELECTRICAL CURRENT IN DOGS*

J W R MCINTYRE F F A R C S AND P JAMES VOLOSHIN B SC

THE POSSIBILITY of producing surgical anaesthesia by electrical means without the use of drugs has been an interesting speculation for many years and the actions of a variety of alternating or direct currents have been investigated and reviewed¹ Results were unsatisfactory until Anan'ev produced effective anaesthesia in dogs using a constant direct current with a superimposed square-wave alternating current,² and this was followed by further accounts of the use of such a combination of current³⁻⁷ Apparatus similar to that described by Smith and his colleagues³⁻⁷ was constructed in this department and reproductions of the wave form produced are shown in Figures 1 and 2 Observations on its use are reported here

FIGURE 1 6.4 ma d.c. peaking at 168 ma 200 c.p.s. 1 msec/cm 470 ohm load

A total of eight dogs were used. After the administration intravenously of thiopentone 15 mg/kg the animals were intubated intratracheally and the electrodes placed in position: the cathode on the vertex and the anode on the roof of the mouth. Palladium electrodes were used and saturated saline on gauze maintained electrical contact. These were maintained in place with a metal electrode holder.⁸ When a clamp applied to the distal inch of the tail produced imme-

From the Department of Pharmacology and Anaesthesia, University of Alberta, Edmonton, Alberta.

FIGURE 2 8.5 ma d.c. peaking at 17.2 ma 100 c.p.s. 1 msec/cm 470 ohm load

date and definite movement of limbs and respiratory changes the effect of the thiopentone was considered to have waned sufficiently and observations on the effect of the electric current were begun.

In the initial experiments 20 ma d.c. was applied at once. Alternating square wave current of 100 c.p.s. and 2 msec duration was then introduced more slowly by mechanical means taking approximately 10 minutes for a final current of up to 6.4 ma peaking at 168.0 ma to be reached. However associated as they were with severe disturbances of respiration the slower rates appeared to offer only disadvantages and it was found that an increase to 200 c.p.s. made a more rapid induction with less respiratory disturbance. Although a smooth respiratory pattern was established analgesia was almost invariably inadequate. Further investigation revealed that a decrease in wave width down to 1.0 msec and cycles per second to 100 was associated with an increase in effective analgesia at currents of 12–13 ma peaking to 60–90 ma. Analgesia was considered present when there was no limb movement respiratory or blood pressure response to the sustained application of a clamp to the distal inch of the tail the abdomen and the dorsal surface of the paws. The auditory response was tested at this time with a toy pistol and no muscular respiratory or blood pressure response occurred.

The technique finally adopted was as follows. 20 ma d.c. was applied at once and 200 c.p.s. 2.0 msec a.c. introduced at an even rate during the next two minutes until a final current of 9.0 ma peaking to 40.0 ma was reached. Immediately following this the wave width and frequency were reduced together and the alternating current continually increased to compensate for the decrease in current flow. A wave width of 1.5 msec at 125 c.p.s. was sometimes adequate or there was further reduction to 1.0 msec at 100 c.p.s. Current flow varied

between 12 and 13 ma peaking to 60–90 ma. These secondary current changes took another three minutes and the values then remained unchanged throughout the experiment.

Anaesthesia was maintained from 1 to 1½ hours. The animals awakened immediately the current was discontinued, apparently none the worse for their experience. However, it was considered advisable to give a small dose of thiopentone prior to discontinuing the current to avoid the brief period of excitement associated with the removal of the electrodes.

When this technique had been developed the blood pressure and pulse were monitored for one hour by intra-arterial cannulation. Unlike experiences with a 700 c p s sine wave, significant increases in pressure or pulse rate did not occur except during induction when there was usually a transient fall of 10–20 mm Hg. This was probably due to changes in respiration which increased in rate, depth, and expiratory effort. As the induction continued the respiration slowed to a rate of 6–10/min, the tidal volume remained raised but became smoother and relatively effortless. When the wave width reached 10–10 msec it became increasingly stertorous. Thus, though limb relaxation would be satisfactory, the abdominal muscles would be tense. It was at the time that respiration tended to become more forceful that the full onset of analgesia seemed to occur, and it was difficult, though often possible, to achieve one without the other. Occasionally the hind legs were well relaxed and the fore legs spastic in the early stage of anaesthesia. The tongue, neck, and facial muscles continued to fasciculate throughout the anaesthesia and endotracheal intubation was mandatory. Intubation interferes with the dog's heat-regulating mechanism and temperature increases were of the order of 1–3 degrees Centigrade unless precautions were taken against this. Oxygen consumption was measured using the technique of Severinghaus and Cullen⁹ and, when compared with that of the dog under thiopentone, was increased by 20–100 per cent. Creatinine clearance tests were performed with three dogs and the glomerular filtration rate was increased from 17.6 to 21.5 and 15.2 to 24.6 in two and decreased from 27.8 to 20 ml/min in the third. Adrenaline was administered intravenously to four dogs in varying dosage: 1.13 mg, 5.0 mg, 5.26 mg, and 100 mg/kg. On no occasion did these initial injections produce pulse irregularities, and the pulse rate and blood pressure returned to the original levels. During anaesthesia the pulse remained regular and atropine was omitted after the early experiments. The total duration of electric current to which each dog was subjected was 12 hours approximately. Post-mortem histological examination of the brains of four animals revealed no abnormality.

The technical difficulties with electrode placement and respiratory obstruction in our hands necessitated the use of thiopentone. The effect of this drug on the electrical activity of the brain or the relatively low currents used may account for the difference in technique and results of this work from those reported by Smith and his colleagues, although these findings support the contention that minimizing the ratio of peak to basal current flow reduces muscle response. In addition to electrode placement one major problem in assessing results was the inability, using this apparatus, to alter wave form and current flow independently. This will be possible in an apparatus now under construction. The conclu-

sion reached was that, although anaesthesia was produced by the particular method described, the raised oxygen consumption, due among other things to increased respiratory work, and the modest degree of muscular relaxation made it unsatisfactory in its present form. However, results were much superior to those produced by a 700 c p s sine wave used alone and there was the tantalizing impression that an ideal technique using electric current could be developed.

SUMMARY

Observations on the use of an apparatus producing an alternating square wave superimposed on a direct electric current are made. Thiopentone 15 mg/kg was administered intravenously to dogs and the animals were intubated. When definite muscular, respiratory, and cardiovascular response to painful stimuli had returned, electric current was applied through palladium electrodes on the vertex and the roof of the mouth. After preliminary experiments the technique adopted was the immediate application of 20 ma d-c and introduction of 200 c p s 2 msec wave width a-c during the ensuing two minutes until a final current of 9 ma peaking to 40 ma was reached. The wave width and frequency were then reduced simultaneously and the current increased to maintain current flow. Wave widths of 1.5 msec at 100 c p s was sometimes adequate or there was further reduction to 1.0 msec 100 c p s. Current flow varied between 12 and 13 ma peaking at 60–90 ma. These secondary current changes took about three minutes. Anaesthesia was maintained for 1–1½ hours. Significant changes in blood pressure did not occur. Satisfactory respiratory exchange was maintained during induction but maximal analgesia tended to be associated with deep stertorous respiration. Glomerular filtration rate was not significantly diminished. Rectal temperature increased 1–3 degrees Centigrade and oxygen consumption increased 20–100 per cent above that of the dog under the influence of thiopentone.

The conclusion reached was that, although the technique developed was unsuccessful in the production of optimum conditions for surgery, it was much superior to a 700 c p s sine wave current, and it was thought that a satisfactory technique of electrical anaesthesia would ultimately be developed.

RÉSUMÉ

Nous faisons des observations au sujet d'un appareil pouvant produire une onde de courant alternatif superposée à un courant électrique continu direct. Nous avons donné à des chiens du thiopentone par voie endoveineuse à la dose de 15 mg/kg, et les avons intubés. Lorsque nous avons pu obtenir une réponse musculaire, respiratoire et cardio-vasculaire positive aux stimuli douloureux, nous avons appliqué un courant électrique au moyen d'électrodes de palladium appliquées sur le vertex et sur le plafond de la bouche. Après des essais préliminaires, la technique adoptée a consisté en l'application immédiate d'un courant direct de 20 ma et l'introduction d'une onde de courant alternatif de 200 c p s 2 ms au cours des deux minutes suivantes jusqu'à ce que nous ayons atteint un courant final de 9 ma à 40 ma. La largeur de l'onde et sa fréquence étaient, par la suite,

simultanément réduites et le courant augmenté pour maintenir le débit. Des largeurs d'onde de 15 ms à 100 cps étaient quelquefois suffisantes, ou nous faisons une réduction additionnelle à 10 ms 100 cps. Le débit du courant a varié entre 12 et 13 ma avec sommet à 60-90 ma. Ces changements de courant secondaires ont nécessité environ trois minutes.

L'anesthésie s'est maintenue durant 1 heure à 1¼ heure. Nous n'avons pas observé de changements importants de la tension artérielle. Au cours de l'induction, les échanges respiratoires se sont maintenus, mais l'analgésie maximale a semblé s'accompagner d'une respiration profonde et stertoreuse. La filtration glomérulaire n'a pas diminué de façon importante. La température rectale s'est élevée de 1 à 3 degrés centigrades et la consommation d'oxygène a augmenté de 20 à 100 pour cent au-dessus de celle du chien soumis à l'anesthésie au thiopentone.

Nous en sommes venus à la conclusion que, bien que la technique mise à point n'a pas été efficace pour produire des conditions opératoires optimales, elle s'est avérée bien supérieure à celle de 700 cps sans onde de courant, et nous avons l'impression qu'une technique satisfaisante d'anesthésie électrique pourrait ultérieurement être mise au point.

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