ETHER ANALGESIA: INSPIRED CONCENTRATIONS, FLAMMABILITY AND LEVELS IN ARTERIAL BLOOD

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A RE-EVALUATION and detailed description of the first stage of diethyl ether anesthesia in man was reported by Artusio (1, 2). An electroencephalographic level was delineated by Bellville and Artusio during the analgesic stage (3). This degree of central nervous system depression was subjected to frequency spectrum analysis and found to contain predominantly 24-cycle activity. The beneficial nature of light levels of anesthesia for patients with severe cardiovascular disease was pointed out. Because of the absence of deleterious reflex activity occurring during this level of anesthesia, and its apparent minimal disturbance to physiologic processes, it was of interest to determine the concentration of diethyl ether in the inspired mixture and its concomitant level in arterial blood during analgesia. The explosibility of the inspired mixture during maintenance of the analgesic stage was also tested.

METHOD

Twenty-two unselected patients undergoing cardiac surgery were given premedication of 0.2 mg. of atropine sulphate and anesthetized with diethyl ether, as previously described by Artusio. The analgesic stage was established with the patients responding to the spoken voice. Electroencephalographic activity was monitored continuously, providing an objective criterion of depth. The electrocardiogram (oscilloscopic), blood pressure (sphygmomanometric), pulse, and respiratory rate were monitored during analgesia.

Following at least 20 minutes of stabilization in the analgesic state, samples of the inspired mixture were taken in duplicate. These were taken from an outlet in the inspiratory tubing of a closed circle carbon dioxide absorbing system and checked for concentration of ether. Samples of the inspired mixture were tested for explosibility in the Thomas spark ignition chamber. This chamber develops approximately 5,000 volts at 8 to 10 milliamperes.

Simultaneously, 10 cc. of arterial blood were taken, by the surgeon, from the arch of the aorta by direct needle puncture, sealed, and immediately refrigerated. These samples were analyzed for diethyl ether concentration within two hours after collection, by the method of Ronzoni (4) and Kibler (5) as modified by Gilder (6). Gilder's modi-

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fications included the use of a silicone fluid to prevent foaming of blood and the titration of excess dichromate with 0.01N ferrous ammonium sulfate using 0.01M diphenylaminesulfonic acid as indicator. For complete oxidation of ether it was found necessary to boil the dichromate mixture 20 minutes for blood, and 5 minutes for gas.

Results

Observations were made on 15 patients—5 males and 10 females—from whom 48 inspiratory mixtures were collected and the ether concentration determined. The mean value for diethyl ether in the inspired mixture was 1.2 volumes per cent. The range for all samples collected was 0.6 volume per cent to 1.7 volumes per cent. The standard error of the mean was ± 0.056.

Inspired mixtures were collected from 22 patients during analgesia to determine explosibility. Thirty gas collections were tested. In no instance did any of these mixtures produce either a flash or an explosion.

Arterial samples were collected from 13 patients and the diethyl ether determinations showed a mean concentration in arterial blood of 32 mg. per cent and a range of from 17 mg. per cent to 62 mg. per cent. The standard error of the mean was ± 3.13. The mean air to blood ratio during analgesia of not more than 2 hours duration was 1 to 10.

Discussion

Haggard reported 3.7 volumes per cent to 4 volumes per cent of diethyl ether in the inspired mixture during surgical anesthesia (7). Ronzoni (4) and Robbins (8) have separately reported values within this range for maintenance of surgical anesthesia in well saturated dogs. Our values, ranging from 0.6 volume per cent to 1.7 volumes per cent, show that the inspired concentrations to maintain analgesia are only one-fourth of that necessary to maintain surgical anesthesia, as found by other workers.

Faulconer correlated concentrations of diethyl ether in arterial blood with specific electroencephalographic patterns during anesthesia (9). He found 63 mg. per cent in arterial blood, in association with Courtin level 1. However, level 1, using Courtin's criteria, was a deeper level of depression than the predominantly 24 cycle activity described by Bellville and Artusio (3). During the latter electroencephalographic level, an average ether arterial concentration was found to be 32 mg. per cent. These values suggest a lower arterial blood level during analgesia than during surgical plane one. The wide margin of ether concentration in arterial blood may reflect the fact that the amount of ether necessary to maintain analgesia is dependent upon the intensity of stimuli from moment to moment during a surgical procedure. The more intense stimulation requires a larger amount

of ether to maintain the analgesic state, whereas it is adequately maintained by lower concentrations of ether during periods of less stimulation. Clinically, the lower ether levels of analgesia appear less depressing to the central nervous system, circulation, and ventilation. All this is salutary in minimizing disturbance of physiologic processes.

From previous studies made in our laboratory, we have reported concentrations of diethyl ether in venous blood during analgesia to be 15 mg. per cent. This arterio-venous difference is due to ether uptake by unsaturated tissues during the analgesic stage of approximately two hours duration.

Haggard (7) and Ronzoni (4) have reported air to blood ratios of 1 to 15 and 1 to 14 respectively, in dogs that have been carried in plane 3 of stage 3 (Guedel) with concentrations of 3 to 4 per cent ether in inspired air. Robbins pointed out that this ratio was a function of saturation of tissues with ether (8). His studies also showed that anesthetic induction and maintenance for 2 hours with concentrations of about 3 per cent resulted in a ratio of 1 to 10, while induction and maintenance with high concentrations resulted in a ratio of 1 to 15. The air to blood ratio found in this study, of 1 to 10, reflects a low level of saturation during analgesia of not more than 2 hours.

Studies by the Bureau of Mines on flammability of ether in oxygen mixtures indicate the lower limit of flammability is approximately 2 volumes per cent of ether, for spark energies up to 10 millijouls (10). The ether concentration in oxygen found in the inspired mixture in this study lies outside this lower limit of flammability. All inspired gas mixtures studied during analgesia failed to explode. Samples taken during light surgical anesthesia (clinical stage 3, plane 1 or an electroencephalographic level containing predominantly 1 to 3 cycles per second) exploded consistently. The use of ether in analgesia, however, should not be considered a nonexplosive technique. It may become necessary at any time during the surgical procedure to increase the concentration of ether in the inspired mixture, which would immediately bring the mixture into the explosive range.

Summary

The mean concentration of diethyl ether in the inspired mixture during analgesia as determined clinically and electroencephalographically was 1.2 volumes per cent. The lower limit of flammability is approximately 2.0 volumes per cent. The mean arterial blood concentration during the analgesic stage was 32 mg. per cent. The air to blood ratio during analgesia of up to 2 hours duration was 1 to 10. The inspired ether-oxygen mixture during maintenance of the analgesic state was nonexplosive. The highest concentration of diethyl ether in oxygen did not exceed 1.7 volumes per cent. The use of diethyl ether to produce analgesia should not be considered a nonexplosive technique.

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