

Flammability of Fluoromar in the Circle Absorption System

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TRIFLUOROETHYLENE ether (Fluoromar)[®] was first prepared by Slukys¹ in 1951. Laboratory and clinical investigation indicated that it was a potent anesthetic which produced minimal cardiovascular and metabolic dysfunction.^{2,3} However, the study reported by Lawrence⁴ indicated that Fluoromar was flammable when used in the concentrations necessary for clinical anesthesia.

Recently, Dornette⁵ published a study of Fluoromar flammability. He used the agent in a closed circle-absorption system, and his results indicated that the lower limit of flammability was much higher than had been previously reported. He suggested that the decreased flammability of samples removed from a closed system was probably due to the saturation of the gas with water vapor.

While the report by Lawrence did not include combustion tests on samples removed from a closed circle-absorption system, it reported results with dry gas samples which had been saturated with water vapor and tested at 23° C.

We believed that Dornette's study was of importance in clinical anesthesia if the results could be confirmed. Therefore, we proposed to determine the lower flammable limit as well as the concentrations of Fluoromar used in a closed circle-absorption system.

Method

Twenty-seven patients from 9 to 75 years of age, scheduled for elective surgical procedures, were selected at random and anesthetized with Fluoromar and oxygen employing a closed circle-absorption technique. The operations consisted of 12 gynecological, 5 orthopedic, and 10 general surgical procedures.

[®] Supplied by the Ohio Chemical and Surgical Equipment Company, Madison, Wisconsin.

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All subjects were either in physical status I or 2.

Preamesthetic medication consisted of pentobarbital (50 to 100 mg.) given orally, and scopolamine (0.3-0.4 mg.) hypodermically, one to one and one-half hours prior to induction of anesthesia. In addition, 15 patients received hydroxyzine hydrochloride (Vistaril) (1 mg./kg.) and four patients received meperidine (25 to 50 mg.).

Fifteen patients were given sleep doses of thiopental (75 to 250 mg.) intravenously, and anesthesia in the remaining 12 was induced with an inhalation technique. Endotracheal intubation was performed on 12 patients aided by 20 to 50 mg. intravenous doses of succinylcholine chloride.

Fluoromar was vaporized in an Ohio Vernitrol and introduced into the anesthetic circuit either by low continuous flows or by high intermittent flows. Blood pressure and heart sounds were monitored throughout in each case, the former by auscultation and the latter with a precordial stethoscope. The anesthesia in all cases was conducted by residents in anesthesiology in various stages of training.

Samples for gas analysis were taken from a T-tube in the expiratory side of the circle between the rebreathing tube and its connection to the anesthesia machine. Samples for analysis were taken at intervals of from three to five minutes during the first 30 minutes of anesthesia, then every eight to ten minutes for the next hour, and thereafter at 15 to 30 minute intervals. Fluoromar concentrations were determined using a Beckman GC 2A gas chromatograph with a Sargent Model SR recorder and disc integrator. The gas chromatograph was calibrated each day of use with a Fluoromar sample of known concentration. The samples were obtained from two sources: (1) a Fluoromar sample prepared by the Ohio Chemical Company and supplied in a small cylinder, and (2) preparation of a sam-

ple by allowing a measured volume of Fluoromar to vaporize in a large sealed container of known volume. The concentration was determined using the standard gas laws.

Gas samples collected at random in a re-breathing bag were also tested for flammability. A sample of this gas was analyzed for Fluoromar concentration, after which a 20-ml. glass syringe was filled with the gas. The gas in the syringe was exposed to the open flame of an alcohol lamp. This test was performed in a darkened room to perceive weak flaming. A duplicate sample of the gas was also exposed to an open spark by means of the equipment shown in figure 1. The plexiglass cylinder was first filled with water and the gas sample drawn into the cylinder as the water was evacuated. The ball electrodes (supplied with the standard electro-surgical unit)

(Electrosurgical unit Model C264 and Ball Electrodes C-263-11, American Gynecologic Makers, Inc.

were used as the sparking electrodes. One electrode was attached to the high active output of the unit and the other electrode was connected with the ground outlet. Both the cutting and coagulation currents were set at 60 on the control panel. This was considered to be the maximal sparking source that might be encountered in an operating room. The spark was applied to the sample gas with the foot control.

Results

All Fluoromar concentrations of 4.5 per cent and above would both flame and explode. However, with concentrations below 5 per cent the magnitude of the flame and explosion was very weak. The majority of samples collected during the first hour of anesthesia were well above 4.4 per cent. After the first hour, concentrations during the remainder of anesthesia were frequently above 4.4 per cent. A composite of the Fluoromar concentrations en-

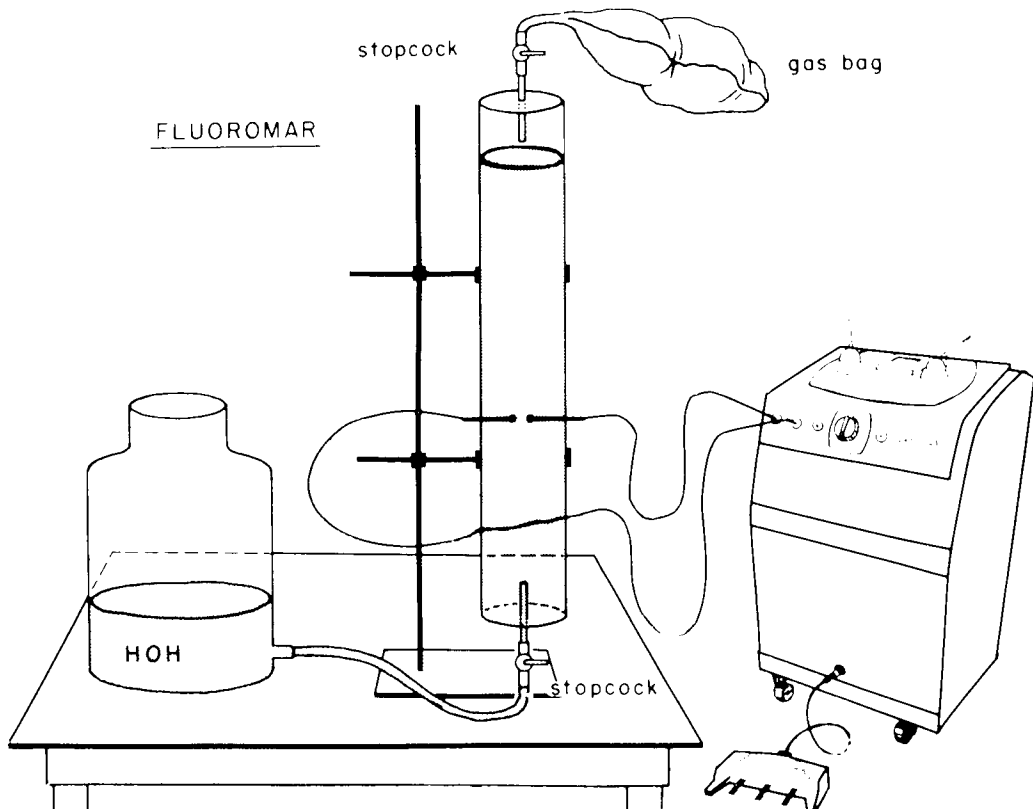


FIG. 1. Equipment used for testing flammability with an electrical spark.

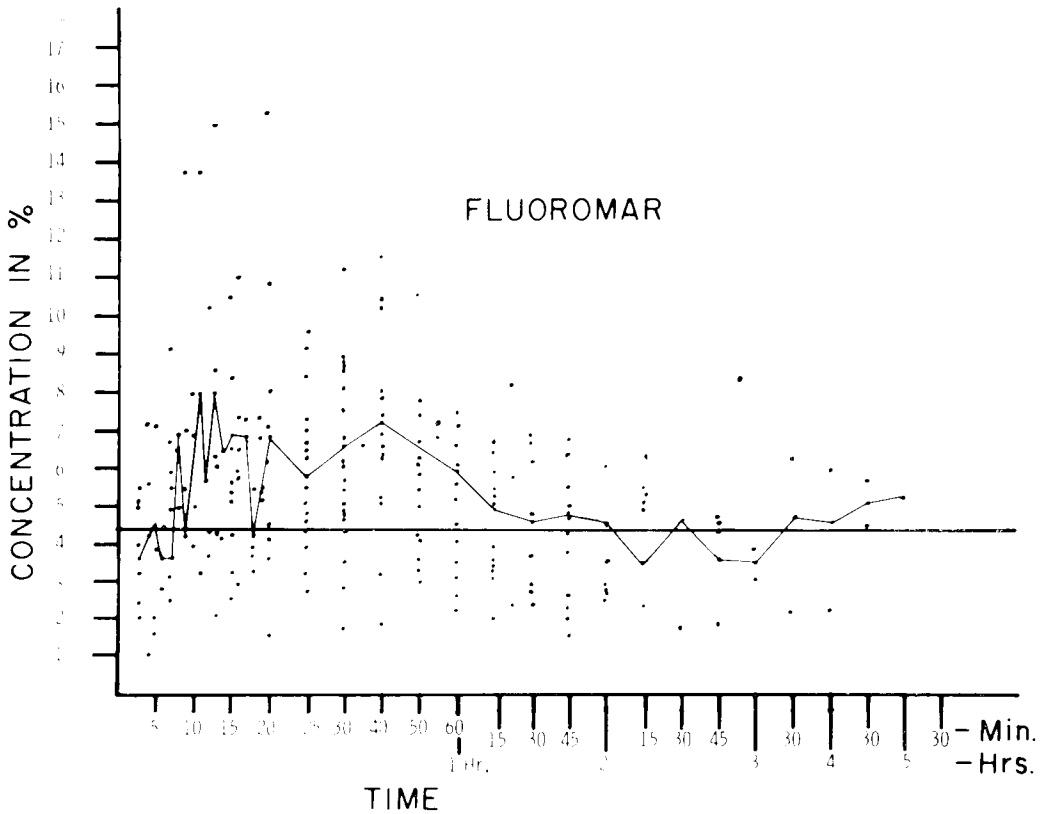


FIG. 2. A composite of the Fluoromar concentrations. *Time* represents elapsed time from the beginning of Fluoromar administration. Small dots represent individual determinations of concentration (some dots represent multiple determinations of the same concentration and time). Straight horizontal line represents lower limit of flammability. Irregular line represents the average of the concentration determined for that time.

countered is shown in figure 2. There was rather wide fluctuation of concentrations in individual patients above and below the lower flammable limit.

Discussion

The results of our study are not in agreement with the data of Dornette,¹⁰ who reported that when used in a closed circle absorption system with oxygen, Fluoromar concentrations below 7.5 per cent would not burn in an open flame. Concentrations of from 7.5 to 9 per cent burned feebly, 9 to 12 per cent moderately well, and only concentrations above 12 per cent would explode. Our study indicates that with conditions similar to those described by Dornette, Fluoromar would both burn and explode at concentrations of 4.5 per cent and above. We used gas

chromatography for analysis whereas Dornette employed chemical analysis. Thus analytical techniques differed in the two studies and may have been a factor contributing to the difference in results.

The 4.5 per cent lower limit of flammability found by us is in agreement with the lower limit of 4.3 per cent observed by Lawrence. He tested dry gas mixtures of Fluoromar and oxygen which had been saturated with water vapor at 23° C.

During the first 40 minutes of anesthesia, Fluoromar concentrations sampled on the expiratory side averaged from 4.2 to 8 per cent with extremes varying from 1 to 15.5 per cent (fig. 2). During this interval 111 concentrations were above and 40 were below 4.4 per cent. Over the next 30 minutes the concentrations gradually declined to average levels of 3.2

to 5 per cent for the remainder of anesthesia. Analysis made after the first 40 minutes of anesthesia showed 70 concentrations above and 48 below 4.4 per cent.

On the basis of the results of our flammability studies, 73 per cent of the Fluoromar concentrations encountered during the first 40 minutes of anesthesia were flammable. After this period and for the remainder of anesthesia, 59 per cent of the concentrations were flammable. We believe that many patients can probably be maintained on nonflammable concentrations of Fluoromar by a skilled anesthesiologist with the aid of muscle relaxants. However, our study shows a wide range of concentrations during clinical anesthesia, and one must presume that such fluctuations above and below the flammable limit would be expected whenever this agent is used with a closed circle technique.

Summary

Fluoromar with oxygen in a closed circle absorption system was employed as the anesthetic agent for 27 patients. Concentrations of Fluoromar in the anesthetic circuit were determined at frequent intervals throughout anesthesia by means of gas chromatography. Random samples of the anesthetic mixture were exposed to both an open flame and to a high frequency spark. Fluoromar concentrations above 4.4 per cent both burned and exploded. Serial determinations made during anesthesia frequently showed concentrations above the lower flammable limit. These results indicate that a closed circle-absorption system utilizing Fluoromar as the anesthetic

agent should be considered a flammable technique.

References

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EXPERIMENTAL MEDICINE Medicine can not advance without investigations on human beings, and abuse of the trust the patient puts in a doctor should not make us fly to the extreme of prohibition. To quote the founder of experimental medicine, Claude Bernard, "The principle of medical morality consists, then, in never performing on man an experiment which could be harmful to him in any degree whatsoever though the results may be of great interest to science—that is, of benefit to save the health of others. . . . So among the experiments that may be tried on man those that can only harm are forbidden, those that are innocent are permissible, and those that do good are obligatory." (*Editorial: Experimental Medicine, Brit. Med. J.* 2: 1108 (Oct. 27) 1962.)