

Clinical Workshop

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The Effect of Nitrous Oxide on Halothane Output from Fluotec Mark 2 Vaporizers

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During halothane-oxygen anesthesia we found that the inspired halothane concentration increased when 60 per cent nitrous oxide was added to the carrier-gas flow through a Fluotec Mark 2 (Fraser Sweatman Inc.) vaporizer. This increase in halothane concentration occurred despite maintenance of the same total flow as indicated by the anesthesia machine flowmeters and the same concentration setting on the vaporizer. Therefore, we decided to evaluate the effect of nitrous oxide on the accuracy of Fluotec Mark 2 vaporizers.

METHODS

Fluotec Mark 2 vaporizers were studied four ways.

1) Four Fluotec Mark 2 vaporizers were studied on a Boyle anesthesia machine. Halothane concentrations at total flows of 3, 5 and 8 l/min with and without about 60 per cent nitrous oxide (*i.e.*, 3 vs. 2:1, 5 vs. 3:2, and 8 vs. 5:3) were measured at vaporizer dial settings of 0.1, 0.5, 1, 2 and 3 per cent. The 0.1 position is not an engraved setting, but represented the lowest dial setting possible. The order of dial and flow setting was varied. Glycerinized glass syringes were used to obtain duplicate 5-ml gas samples from the delivery tube of the anesthesia machine two to four minutes after initiating flow at each set-

ting. The sampling site was at least 75 cm distal to the vaporizer outlet. These and subsequent samples were analyzed for halothane concentration by gas chromatography using a Beckman GC-2A gas chromatograph with a flame ionization detector and a column consisting of SE-30 (20 per cent) on Chromosorb W at 100 C. Peak height was converted to concentration in volumes per cent by comparison with the peak height produced by a known halothane concentration.

2) One of the four vaporizers was evaluated on five different anesthesia machines at 0.5 and 2.0 per cent settings and 5 l/min flow (5 vs. 3:2).

3) The same four vaporizers were evaluated for 30 minutes at 0.5, 1 and 2 per cent settings and 5 l/min flow (5 vs. 3:2). Gas samples were obtained 0.5, 1, 3, 5, 10, 20 and 30 minutes after initiating flow.

4) The same four vaporizers were studied at the 0.5 setting and the following total flows per minute: 5 liters oxygen; 3 liters nitrous oxide plus 2 liters oxygen; 3 liters nitrogen plus 2 liters oxygen; 3 liters helium plus 2 liters oxygen.

RESULTS

The addition of 60 per cent nitrous oxide at 0.1, 0.5 and 1 per cent dial settings resulted in increased halothane output compared with values obtained with oxygen alone (fig. 1). For example, at the 0.5 setting and 5 l/min oxygen the average halothane concentration delivered by the vaporizer was 0.48 ± 0.07 (SD) per cent. At the same setting, but with

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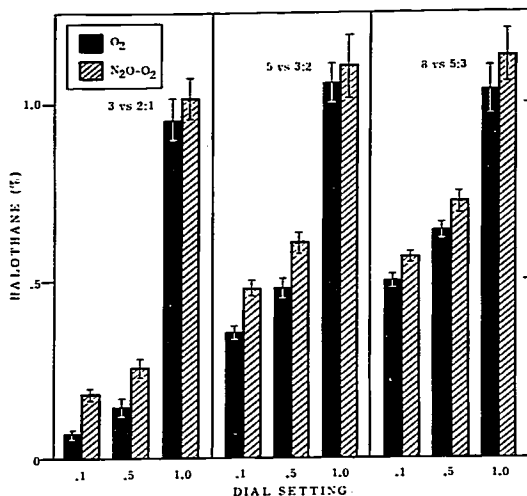


FIG. 1. Average halothane concentrations (\pm SD) delivered by four Fluotec Mark 2 vaporizers at 0.1, 0.5 and 1 per cent dial settings.

3 liters nitrous oxide plus 2 liters oxygen per minute, the average halothane concentration was increased to 0.61 ± 0.07 per cent. At dial settings of 1.5, 2 and 3 per cent the addition of nitrous oxide did not increase the amounts of halothane delivered by the vaporizer.

A single Fluotec Mark 2 vaporizer studied on five models of anesthesia machines at the 0.5 setting delivered halothane concentrations similar to those illustrated in figure 1. At the 2 per cent setting, the addition of nitrous oxide did not influence the vaporizers' halothane output.

That the increase in halothane output with nitrous oxide was not a transient phenomenon is shown by the consistency of results over 30 minutes (fig. 2).

Figure 3 shows results when 60 per cent nitrous oxide, nitrogen and helium were added to the carrier gas flow. Oxygen concentrations, determined by a Beckman oxygen analyzer, were 38–40 per cent with the 3:2 flows and 98–98 per cent with oxygen alone.

Pentec (Frazer Sweetman) vaporizers operate in the same manner as Fluotec Mark 2 vaporizers, and nitrous oxide had a similar

effect. At the 0.1 setting the average methoxyflurane concentration (three vaporizers) was 0.146 per cent with 5 liters oxygen and 3 liters nitrogen plus 2 liters oxygen, 0.164 per cent with 3 liters nitrous oxide plus 2 liters oxygen, and 0.094 per cent with 3 liters helium plus 2 liters oxygen per minute. The effect of nitrous oxide was no longer present at the 0.3 setting.

DISCUSSION

Carrier gas entering the Fluotec Mark 2 vaporizer is split into two streams, designated the "vaporizing chamber" and "bypass" flows.¹ Bypass flow is controlled by a variable-sized opening governed by the concentration-setting dial. We speculate that changes in carrier-gas density may alter the flow diverted through the vaporizing chamber. These data suggest that addition of 60 per cent nitrous oxide to the carrier gas resulted in increased flow through the vaporizing chamber and subsequent increased halothane output. Addition of less dense helium to the carrier gas resulted in a decreased halothane output. Ni-

trogen has a density similar to that of oxygen and the halothane output with both carrier gases was similar. As the concentration dial was turned above the 1 per cent setting, the influence of carrier-gas density was eliminated.

Mr. Wilfred Jones² offered the following explanation for our findings. The major restrictions to gas flow through a Fluotec Mark 2 vaporizer are at the bypass valve and the thermostat. In addition, halothane vapor produces a small amount of pressure, which must be overcome before flow into the vaporizing chamber can occur. Flow characteristics at the bypass valve are such that high-density nitrous oxide results in a greater restriction to flow than when less dense carrier gases are present. Total resistance to flow, therefore, is greater with nitrous oxide, and pressure due to halothane vapor will be overcome sooner. Thus, more flow will enter and pass from the vaporizing chamber when nitrous oxide is present and the resulting halothane output is

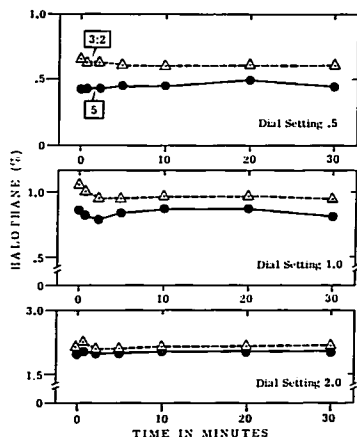


FIG. 2. Average halothane concentrations delivered by four Fluotec Mark 2 vaporizers over 30 minutes. At 0.5 and 1 per cent dial settings the delivered halothane concentration when nitrous oxide was present exceeded that when oxygen alone was flowing through the vaporizer at each sampling time. At the 2 per cent setting the influence of nitrous oxide was not present.

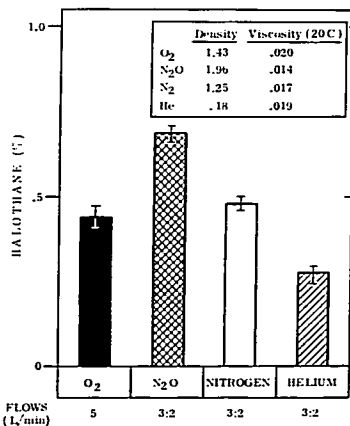


FIG. 3. Average halothane concentrations delivered by four Fluotec Mark 2 vaporizers with different carrier gases. With oxygen alone the average halothane concentration was 0.44 ± 0.07 per cent; it was 0.64 ± 0.06 per cent with nitrous oxide, 0.48 ± 0.04 per cent with nitrogen, and 0.28 ± 0.05 per cent with helium. Nitrous oxide was the most dense, and helium the least dense, of the carrier gases.

greater. At the same total flow there is less resistance to flow at the bypass valve for less dense gases (oxygen, nitrogen and helium), so the pressure exerted by halothane vapor diminishes flow into and from the vaporizing chamber. Above the 1 per cent setting the bypass valve is gradually closed and the influence of carrier-gas density eliminated.

The Fluotec Mark 3 does not behave in this manner because total resistance to flow is greater and is always sufficient to cancel out the small effect of pressure from the halothane vapor.² Indeed, the halothane output was nearly the same with oxygen alone and with 65 per cent nitrous oxide.¹

Fluotec calibration is done with oxygen as the carrier gas.³ Edmondson, in a personal communication to Hill *et al.*,³ stated that more halothane vapor would be delivered if pure nitrous oxide were used as the carrier gas. He did not elaborate upon the mechanism or amount of increased output, but stated that

the change was not large enough to be important clinically.

In our study, the use of 60 per cent nitrous oxide was associated with clinically significant increases in halothane output from Fluotec Mark 2 vaporizers at concentration dial settings up to 1 per cent. This was reflected as increases in inspired and end-tidal halothane concentrations in several patients. If nitrous oxide were added without changing the Fluotec concentration setting, the alveolar halothane would increase, due to both the second-gas effect and the increased delivered halothane concentration. Our results showed that halothane concentrations delivered at 5 liters oxygen per minute and the 0.5 setting and at 60 per cent nitrous oxide at the 0.1 setting were the same (fig. 1). Thus, if the concentration setting were decreased from 0.5 to 0.1 and nitrous oxide added, the end-result could be no change in the halothane concentration delivered plus the added effect of 60 per cent nitrous oxide.

SUMMARY

Halothane output from Fluotec Mark 2 vaporizers was increased when the carrier gas contained 60 per cent nitrous oxide rather than pure oxygen. Above the 1 per cent setting nitrous oxide did not alter halothane output. Nitrous oxide increased carrier-gas density, augmenting flow through the vaporizing chamber with a subsequent increase in halothane output.

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Pneumotachography by the Ionization Principle— A New Approach

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Interest in the changes in pulmonary mechanics in patients receiving intermittent positive-pressure ventilation led to evaluation of the Fleisch pneumotachograph.^{1,2} Flow-measuring devices built on the principle of Poiseuille's law are associated with error of method due to the effects of humidity and temperature, composition of gases, and loss of linear response. Although the error may be minimized by following the suggestions made by the above authors, it was claimed that for

quantitative flow measurement an acceptable degree of accuracy is probably not possible without a computer.³ Recognition of the difficulties encountered in the use of Fleisch pneumotachograph stimulated us to search for a more practical gas-flow-measuring device for continuous respiratory monitoring. The instrument we devised is the JSI † pneumotachograph, which operates on the principle of ionization of gases by radioactive material. The following is a report of some of its functional characteristics, with a description of the principle of pneumotachography by ionization of gases.

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