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An Arrangement to Prevent Pressure Effect on the Vernitrol Vaporizer

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THE problem of correctly estimating halothane concentrations issuing from vaporizers during intermittent positive pressure breathing in closed circuit anesthesia has been investigated recently by a number of workers. Hill and Lowe [1] ascribed the heretofore unexpected rise in halothane concentration to additional gas which is forced back into the vaporizer during the pressure phase of intermittent positive pressure and which carries extra halothane vapor out with it during the non-pressure phase. This amounts to, practically speaking, an additional vaporizing gas flow through the vaporizer. Lowe and his co-workers [1, 2] solved this difficulty by creating and maintaining the pressure within the vaporizer at 30–40 cm. water above circle pressure. They accomplished this by inserting a needle valve between the vaporizer and the circle. Karl [3] has offered another possible solution using a unidirectional valve and reservoir bag. Pressurizing the vaporizer, while effective, and probably the most practical solution with vaporizers of the Fluotec type, seems to be unnecessarily complex and expensive for vaporizers of the "Copper Kettle" type.

This study was undertaken to assess the efficacy of a one-way valve placed in the anesthesia machine in an attempt to provide a simple and inexpensive solution to this important problem.

METHODS

Halothane concentrations were continuously monitored from the machine outlet of a Heidbrink Series 2000 Kinet-O-Meter with standard Vernitrol vaporizer. An ASC Monitor (Model 10) for halothane was used for continuous determinations, while a Beckman GC-2 gas chromatograph was employed for spot checking and confirming the monitor.

Because of the solubility of halothane in rubber and vinyl, materials in the experimental apparatus were limited as much as possible to metal and polyethylene.[4]

The basic arrangement of equipment is schematically represented in figure 1.

All experiments were conducted with 500 ml. of oxygen flowing as a diluent gas and with the Vernitrol switch (D, fig. 1) in the "Vaporizer On" position. The polyethylene bag (C, fig. 1) and connectors were evacuated as completely as possible with suction before

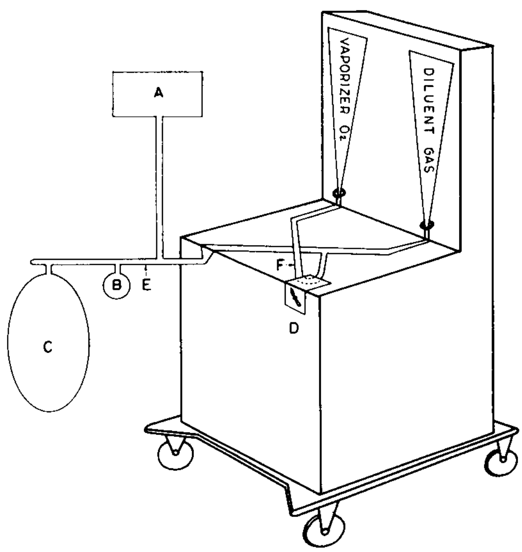

FIG. 1. Arrangement of apparatus. A. Halothane Monitor; B. Aneroid Manometer; C. 15 Liter Polyethylene Reservoir Bag; D. Vernitrol Switch; E. Location of External Valve—Phase II; F. Location of Internal Valve—Phase III.

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each experiment. The experiments were divided into three phases.

Phase I: With no check valve in place and a 20 ml. oxygen flow through the vaporizer, a measured 2 per cent halothane concentration was delivered. This free flow of gas was continued for ten minutes to assure a steady output. Then, after re-evacuation, intermittent positive pressure of 30 cm. of water was applied to the bag for ten minutes at a rate of 20 per minute with an inspiratory-expiratory ratio of 1 : 2. The experiment was then repeated with no oxygen flow through the Vernitrol; and when the concentration of halothane was established at 0 per cent, intermittent positive pressure was again applied to the bag for ten minutes.

Phase II: With an external check valve placed at point E in figure 1, between the machine outlet and the polyethylene reservoir bag, the steps in phase I were repeated.

Phase III: In this portion of the study, an internal check valve was installed at point F in figure 1., in the vaporizer outlet line before it joins the diluent gas line, and on the vaporizer side of the oxygen flush valve. The steps in phases I and II were again carried out.

Results

Phase I: In the initial experiment, with no check valve in the system, a 500 ml. diluent oxygen flow and 20 ml. oxygen flow through the Vernitrol produced the results shown in figure 2.

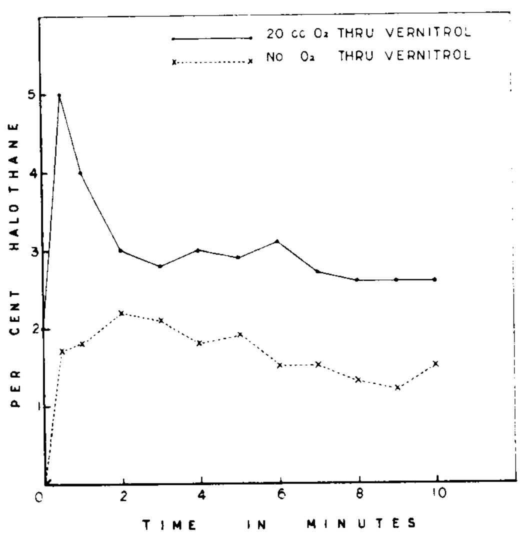

Fig. 2. Halothane concentrations without check valve during intermittent positive pressure.

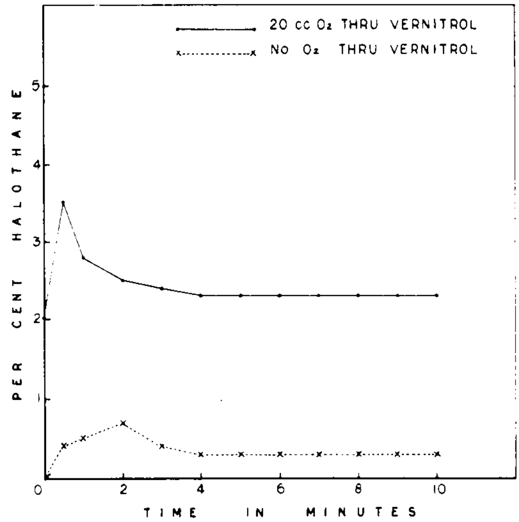

Fig. 3. Halothane concentrations with external check valve during intermittent positive pressure.

At the 30-second point, the halothane concentration actually read off scale, going above 5 per cent momentarily. At the 8-minute point the concentration is seen to level off at 2.6 per cent, which is 0.6 per cent higher than with free flow, or an error of approximately 30 per cent. The results with a 500 ml. diluent flow, but no oxygen flow through the Vernitrol are also shown in figure 2. There is approximately 1.3 per cent halothane delivered, with no flow through the Vernitrol.

Phase II: The first series of experiments was then repeated, but with a competent one-way check valve inserted just outside the machine outlet (Point E, fig. 1). A free flow steady concentration of 2.0 per cent halothane was obtained as previously. Intermittent positive pressure identical to that of the first experiment produced results shown in figure 3. There is an initial peak of 3.5 per cent halothane occurring at 30 seconds which rather quickly settles down to 2.3 per cent and remains at a level 0.3 per cent higher than the free flow 2.0 per cent value, or an error of 15 per cent above the expected halothane concentration. Figure 3 also shows the concentrations obtained when the 20 ml. oxygen vaporizer flow is turned off, the Vernitrol switch left on, and the intermittent positive pressure repeated. There is an initial rise in concentration to a high of 0.7 per cent which comes down at the four minute point to a steady 0.3 per cent and remains at this level.

Phase III: When the experiment was repeated with an internal check valve, the halothane concentration remained at 2 per cent for the entire period of free flow and intermittent positive pressure. When the oxygen flow through the Vernitrol was turned off, the halothane concentration remained at zero at all times. The halothane concentrations were not influenced by pressure, but were those predicted by consideration of temperature and flowmeter settings.

Discussion

There are two main types of halothane vaporizers: (1) those of the Fluotec type which accept all of the gas flow from the machine and only partially saturate it with vapor, and (2) those which saturate a small amount of oxygen completely and depend on dilution of this vapor to the final concentration. This latter type is exemplified by the "Copper Kettle" and the Vernitrol. The first type of vaporizer can produce a steady concentration of halothane only when it is exposed to a steady pressure, whether it is elevated to 30–40 cm. of water above circle pressure as recommended by Lowe *et al.*[2] or maintained at atmospheric pressure as in Karl's ingenious though limited solution. This is because there is a great excess of highly unsaturated gas available to this first type of vaporizer, both on the inlet side and on the outlet side. The Vernitrol and Copper Kettle on the other hand are already fully saturating the gas which flows through them, and it is necessary only to prevent the passage of unsaturated gas backward into the vaporizer.

The external check valve used in phase II of this study is a modified Dome Valve such as is used on circle absorbers, and similar to the "Foregger Respirator Back Pressure Check Valve," both in function and placement. The effect of intermittent positive pressure on halothane concentrations was significantly lessened by this external valve but not entirely eliminated. This is because the intermittent positive pressure causes the diluent gas flow to back up into the vaporizer during the time that the check valve remains closed. We were able to prove this by using nitrous oxide as a diluent gas and detecting this nitrous oxide in the interior of the previously purged vaporizer by means of gas chromatography. This was not surprising since Lowe *et al.* performed their studies with an external check valve in place with similar results.

Figures 2 and 3 show that the highest concentrations are achieved during the first few minutes after beginning intermittent positive pressure, and that the greatest danger therefore is in starting and stopping artificial respiration repeatedly. It should also be borne in mind that with no valve in place, concentrations below 1.3 per cent cannot be achieved if respirations are assisted or controlled with closed system anesthesia, unless the Vernitrol switch is in the "Vaporizer Off" position.

The internal check valve used in phase III is a stainless steel ball check valve having 1/8 inch female pipe threads on the inlet and outlet.† With the addition of a 1/8 inch brass short-nipple on the outlet side, it can be installed inside the Series 2000 Kinet-O-Meter without any modification of existing parts (fig. 4). The back pressure created by this valve at 200 ml. Vernitrol O_2 flow is 53 mm. of mercury which produces a flow meter error of 7.5 per cent. This will cause an error in halothane concentration of less than 0.1 per cent. The opening pressure of this valve can be reduced by carefully cutting off coils from the stainless steel spring if desired, but this is not thought to be necessary. While this study was limited to the standard Vernitrol vaporizer, it seems safe to assume that the installation of an internal check valve will give the same result with any vaporizer of the fully saturating type. The described valve can be adapted to fit the "Copper Kettle" by the use of appropriate fittings.

We do not believe an external check valve is an adequate solution to this problem and we believe all future gas machines which incorporate a vaporizer of the fully saturating type (Vernitrol or "Copper Kettle") should have a built-in internal check valve. It is fur-

† Hoke stainless steel ball check valve #60100-2-Vitron—A "O" ring; Hoke Inc., Cresskill, New Jersey.

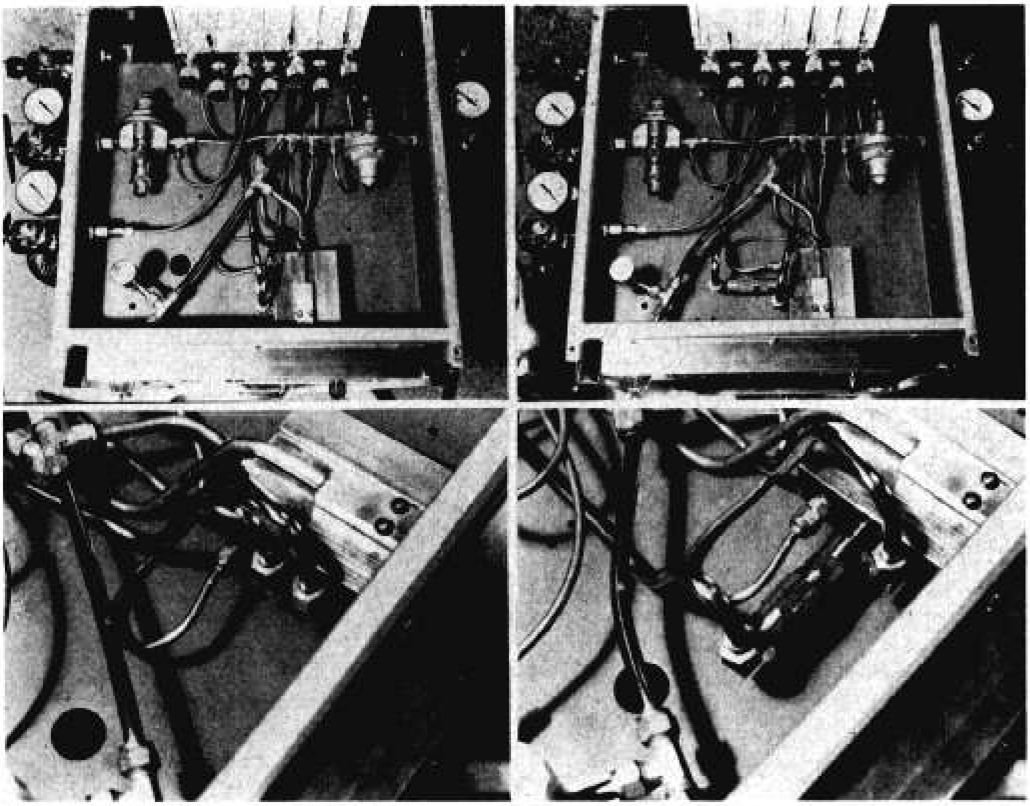

FIG. 4. Overall and closeup views of Heidbrink Series 2000 Anesthesia Machine with top removed. *Left:* Before installation of valve. *Right:* Same machine after installation of valve.

ther hoped that low cost check valves will be made available for field installation by factory trained personnel. Until such time, the valve described has been found to be effective, inexpensive, and easily installed by hospital personnel.

SUMMARY

The effect of intermittent positive pressure on the halothane output of a standard Vernitrol vaporizer was investigated without a back pressure check valve, with a valve placed externally, and with a valve placed inside the machine. The latter location was chosen to isolate the vaporizer from the diluent as well as circle gas. This internal valve was found to be superior, and to completely eliminate the increase in halothane concentrations otherwise seen with intermittent positive pressure in the kettle type of vaporizers.

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