

## Prevention of Increased Pressures in Anesthetic Vaporizers with a Unidirectional Valve

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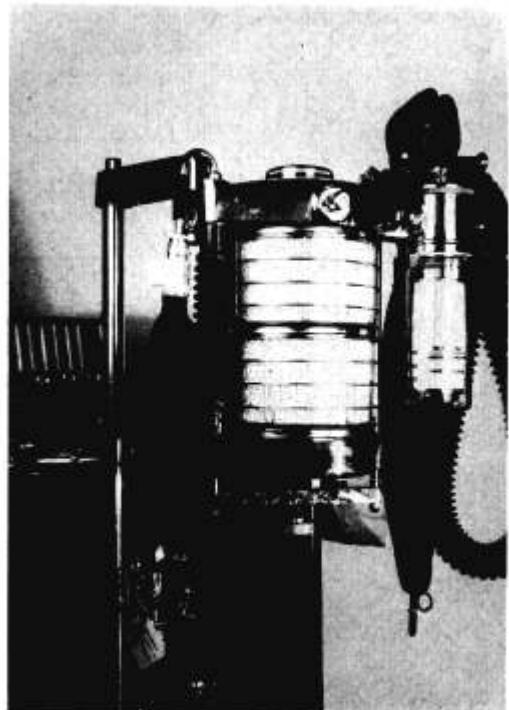
The positive pressure of assisted or controlled ventilation during anesthesia is transmitted to an anesthetic vaporizer outside the breathing circuit. Hill and Lowe<sup>1</sup> have demonstrated that this produces markedly increased concentrations of volatile anesthetic agent delivered to the anesthetic system. This is especially significant when total rebreathing or low flow partial rebreathing techniques are used. Pressurization of the vaporizer to a level above that produced by positive pressure ventilation has been recommended to prevent this potentially dangerous phenomenon.<sup>1, 2</sup> Karl<sup>3</sup> has also noted this phenomenon, and has recommended that a unidirectional valve be placed between the anesthetic system and the vaporizer, so that the positive pressure of controlled ventilation could not be transmitted to the vaporizer. A small rebreathing bag is placed between the valve and vaporizer to collect the inflow gases while the valve is closed. The simplicity of this method would make it preferable to the pressurizing of vaporizers. However, according to Karl, a negative pressure phase of ventilation is necessary to empty the bag during expiration; otherwise the bag becomes distended quickly, and does not empty. Hence, a mechanical ventilator would be necessary using a valve and bag system, and the "simplicity" of this method for preventing positive, fluctuating pressures within a vaporizer would be lost. The study below shows that a valve-and-bag assembly does indeed prevent a rise in pressure within the vaporizer, and that, using an adequate valve, a negative pressure phase of ventilation is unnecessary.

### METHOD AND RESULTS

The valve studied was simply a Leigh valve with the exhalation port taped shut. It was attached to a 0.5-liter conductive rubber breathing bag and was placed in the delivery line of a Heidbrink "2000" series anesthetic

machine, between the outlet of the machine and the anesthetic circuit. The valve was placed as close to the inlet to the circuit as possible (see photograph). For this study, a "Y" connector was placed at the tail of the bag, to which a water manometer was attached. The circle system of the machine was "closed" by placing a single corrugated breathing tube between the inhalation and exhalation ports on the absorber head; the popoff valve was shut completely.

Studies were carried out in two ways. First, a constant pressure of 20 centimeters of water was applied to the circle, by manually compressing the breathing bag until the manometer mounted in the absorber head registered 20 cm. Oxygen was then allowed to flow into the circle at various flow rates, from 0.5 to 4.0 liters per minute. The time required for the pressure within the delivery hose to begin



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to rise was noted. It was found that, at a 0.5 liter flow rate, a pressure of 20 centimeters of water could be maintained in the circle for 20 seconds before there was a significant rise in pressure in the delivery hose. During this time the small bag slowly filled; then, at 20 seconds, when the bag was nearly full, the pressure rapidly rose to 20 cm. and stabilized at that level. At 1.0 liter per minute flow, 10 seconds was required before the pressure began to rise; at 2.0 liters, five seconds; and at 4.0 liters, one second.

Studies were then done using intermittent positive pressure. A pressure of 20 centimeters of water was produced in the circle 20 times per minute by manually compressing the breathing bag of the circle system. The pressure peak was maintained for approximately one second. An automatic ventilator was not used so that a negative pressure phase could be definitely excluded. Flow rates of oxygen into the circle were again varied between 0.5 and 4.0 liters per minute. It was found that at flow rates of 1.0 liter or less, the pressure in the delivery tube fluctuated slightly, but never rose above one centimeter of water. With flow rates from 1.0 to 4.0 liters per minute, there was gradually increasing fluctuation, but the pressure never rose above three centimeters. At all flow rates, pressure always fell to zero when the pressure on the circle breathing bag was released. The small collecting bag was seen to enlarge slowly during the positive pressure phase, and then empty itself when the circle pressure fell to zero.

#### DISCUSSION

In low ranges of flow, the valve-and-bag system studied above can prevent an increase in pressure within an anesthetic vaporizer. Using a 0.5-liter bag, flows up to four liters per minute are tolerated well. However, at that level the system begins to fail, since the bag becomes too rapidly filled and distended. No doubt a larger bag would allow greater flow rates.

The valve must be completely competent. Otherwise pressure is transmitted back into the delivery line, and the collecting bag rapidly distends during the positive pressure phase.

It is necessary to use a valve with a large lumen and low resistance to gas flow. Otherwise the bag will not empty itself during the expiratory phase of ventilation, and will distend to an alarming degree when the system is "flushed." The Leigh valve, with a large internal diameter and light valve leaf, is excellent in this regard. It is also important that the valve-and-bag assembly be placed in the delivery line as close to the anesthetic circuit as possible. The rubber tubing of the delivery line offers a resistance to gas flow which is proportional to its length, according to Poiseuille's law. Therefore a long length of tubing between the valve and the anesthetic circuit may offer enough resistance to seriously interfere with proper emptying of the reservoir bag during the phase of zero circuit pressure. This may explain why Karl, who interposed a long tube between his valve and circuit, found it necessary to use a negative pressure phase in order to empty the bag.<sup>3</sup> In contrast, the bag in this study was seen to slowly fill from the gas source during the positive pressure phase of ventilation, and then to empty itself during the phase of zero circuit pressure. A negative pressure phase of ventilation was not necessary. A valve-and-bag assembly which meets the specifications as outlined above therefore constitutes a simple, effective means of preventing pressure changes within a vaporizer during controlled or assisted ventilation.

#### SUMMARY

Positive pressure ventilation is known to produce marked changes in the vaporization of volatile anesthetics in vaporizers outside the anesthetic circuit, since this pressure is transmitted via the delivery line to the vaporizer. This may be entirely prevented if an adequate check-valve and collecting bag system is interposed between the breathing circuit and the vaporizer. The valve must be completely competent. The valve opening must be large enough and close enough to the anesthetic circuit that there is minimal resistance to gas flow. A 0.5-liter collecting bag is of adequate volume for use with low flow anesthetic techniques.

## REFERENCES

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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<sup>1</sup> 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<sup>1, 2</sup> 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<sup>3</sup> 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 Flutec 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.<sup>4</sup>

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

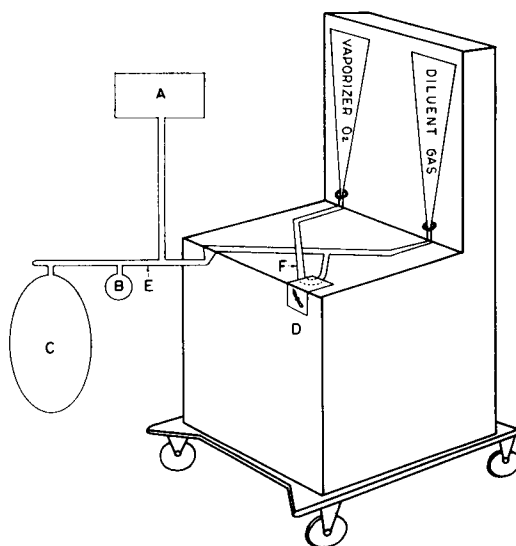


FIG. 1. Arrangement of apparatus. A. Halothane Monitor; B. Aneroid Manometer; C. 15 Liter Polyethylene Reservoir Bag; D. Vernitrol Switch; E. Location of External Valve—Phase II; F. Location of Internal Valve—Phase III.

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