CURRENT COMMENT

STUART C. CULLEN, M.D., *Editor*

GADGETS

Portable Unit For Fluothane-Air Anesthesia ("PUFFA")

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A simple and safe Portable Unit For Fluothane-air Anesthesia ("PUFFA") was devised by combining a self-inflating nonrebreathing type of reservoir bag with a breath-through type vaporizer. It was thought that such a unit, by providing a means of assisting or controlling respiration, might overcome some of the disadvantages of halothane-air anesthesia administered by the open-drop technique as reported by others.[1, 2] Also, a device for safely administering halothane anesthesia without dependence upon compressed gases and flow-meter equipment might be of considerable practical value in a number of routine hospital situations requiring portable nonflammable inhalation anesthesia, as well as under certain unusual circumstances which might occur in civilian or wartime disaster. Such a unit was constructed and tested, and the results are presented in this report.

FIG. 1. Assembly of "PUFFA" showing modified reservoir bag connected by corrugated breathing tube to breath-through type vaporizer regulated and calibrated for halothane.

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MATERIALS AND METHODS

The Unit. The essential components for "PUFFA" were provided in two existing, but previously unrelated, pieces of equipment—a self-inflating, nonrebreathing reservoir bag and a breath-through type ether vaporizer.

The unit was assembled simply by connecting the vaporizer to the reservoir bag with a standard corrugated breathing tube (fig. 1). A mushroom valve was added to the exhalation orifice of the nonrebreathing valve (modified Lewis-Leigh valve) to prevent inhalation of air except via the anesthesia system during spontaneous breathing. The reservoir bag, designed to re-inflate iself after being emptied of its contents by manual compression, serves as a bulb-syringe type reservoir bag providing halothane vapor with air as the vehicle when its tail is connected to the outlet of the vaporizer charged and regulated to deliver halothane. Whether respirations are spontaneous or controlled, the reservoir bag serves also as a mixing chamber to provide a more uniform concentration of halothane vapor for inhalation than if the inspired mixture were inhaled directly from the vaporizer. The dial setting of the vaporizer may be regulated to provide appropriate concentrations of halothane vapor in air for the safe administration of anesthesia using clinical signs as a guide. It may be set also to completely bypass the vaporizer in order to permit air alone to enter the bag. The reservoir bag provides a means of supporting ventilation manually, with or without halothane, as indicated. Except when compressed, the reservoir bag re-

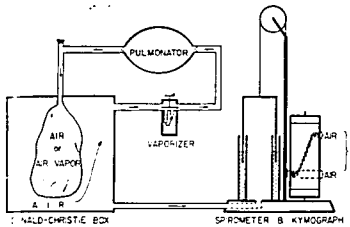

FIG. 2. Diagrammatic scheme for calibrating "PUFFA." Volumetric method by the Donald-Christie spirometric technique (see text).

tains the inflated shape even with spontaneous breathing through it.

Calibration. The vaporizer, charged with 4 ounces of halothane, was calibrated at room temperature (25 C. water bath) by using the Donald-Christie spirometric technique (fig. 2). The concentrations of halothane vapor delivered by the "PUFFA" were calculated by measuring the volume of air drawn in and the volume of halothane-air mixture discharged during intermittent manual compression of the reservoir bag at various rates and magnitudes and at various vaporizer settings.

The "PUFFA" was calibrated first with different dial settings while the rate and magnitude were kept constant (fig. 3), and then at different rates and magnitudes while the dial setting was kept constant (fig. 4).

Clinical Studies and Application. The "PUFFA," having been calibrated and found to deliver reasonably safe anesthetic concentrations of halothane vapor, was applied clinically to administer anesthesia in a series of selected patients, and controlled studies were conducted during the course of anesthesia in 3 of these patients to correlate quantitative data with clinical observations concerning the adequacy of oxygenation and carbon dioxide elimination.

Patients selected for controlled studies were young and healthy adults without known systemic disturbances who were scheduled for minor elective surgery. Premedication consisted of pentobarbital 100 mg. by mouth two hours preoperatively followed by meperidine 100 mg. and atropine 0.4 mg. intramuscularly one hour preoperatively. Anesthesia was induced and maintained with halothane alone administered by inhalation from the "PUFFA." Blood samples were drawn anaerobically in heparinized syringes from the brachial artery via an indwelling Cournand needle, first during a control period immediately preceding the induction of anesthesia and subsequently during four test periods while surgical anesthesia was maintained with (a) halothane-air mixture during spontaneous ventilation, (b) halothane-air mixture during controlled ventilation, (c) halothane-oxygen mixture during spontaneous ventilation, and (d) halothane-oxygen mixture during controlled ventilation. Halothane-oxygen mixture was administered from the "PUFFA" by attaching a reservoir bag containing 100 per cent oxygen to the inlet of the vaporizer.

Hydrogen ion concentrations were measured anaerobically with a Beckman *p*H meter (model G) within a few minutes after the blood was drawn. Within two to three hours of sampling, oxygen and carbon dioxide content were measured volumetrically with the Van Slyke machine using Goldstein's method as modified by Holaday,[3] oxygen capacity was determined, and the degree of oxygen saturation was calculated. The partial pressure of oxygen was derived from the oxygen dissociation curve, and the partial pressure of carbon dioxide was derived from the *p*H and the carbon dioxide content of plasma converted from that of whole blood according to the nomograms of Van-Slyke and Sendroy.[4] Alternate electrocardiograms and electroence-

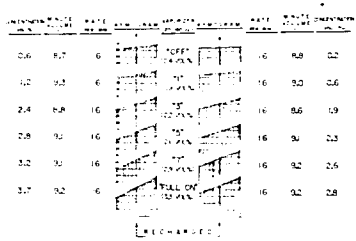

FIG. 3. Calibration of "PUFFA" at room temperatures (25 C.). Concentrations of halothane in air delivered by "PUFFA" at various dial settings during intermittent manual compression of the reservoir bag at a constant rate and magnitude.

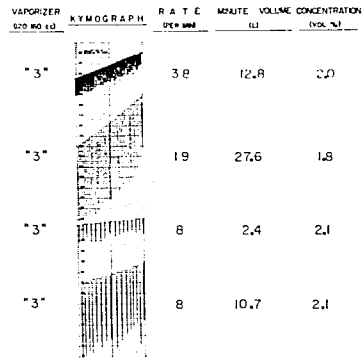

FIG. 4. Calibration of "PUFFA" at 25° C. Concentrations of halothane in air delivered by "PUFFA" at a constant dial setting during intermittent manual compression of the reservoir bag at various rates and magnitudes.

phalograms were obtained continuously using a remote control recorder in conjunction with a cardioscope.

RESULTS

Calibration values for the "PUFFA" are presented in figures 3 and 4. The concentrations of halothane vapor ranged from 0.2 volume per cent to 3.7 volumes per cent depending upon the dial setting of the vaporizer when intermittent manual compression of the reservoir bag was maintained at a relatively constant rate and magnitude to produce a minute volume of approximately 9 liters (fig. 3). The concentration of halothane progressively increased as the dial setting was advanced a step at a time from "off" to "full on." When the highest dial setting was reached, the vaporizer was recharged and the calibration was repeated as the dial setting was changed in reverse fashion, *i.e.*, from "full on" to "off." The recharging of the vaporizer might explain at least in part the slight discrepancies in the reciprocal values obtained at the same dial settings during the two calibration procedures. At a given dial setting ("3"), changing the rate and magnitude of intermittent manual compression of the reservoir bag did not appreciably alter the concentration of halothane being delivered (fig. 4).

The results of a typical controlled study during clinical anesthesia are illustrated in figure 5. Individual and average values obtained from this and other controlled studies (table 1) indicate that a change occurred toward mild hypoxia and hypercarbia relative to the control period during spontaneous ventilation with halothane-air mixture. During controlled ventilation with halothane-air mixture oxygenation improved toward control values and carbon dioxide values fell below those of the control period. During either spontaneous or controlled ventilation with halothane-oxygen mixture, oxygenation exceeded control values. The highest carbon dioxide values were found during spontaneous ventilation with halothane-oxygen mixture, but even these were well within tolerable limits, and controlled ventilation reversed this slight tendency toward respiratory acidosis to the same degree as when controlled ventilation with halothane-air mixture was used.

Electrocardiographic and electroencephalographic patterns were characteristic for light

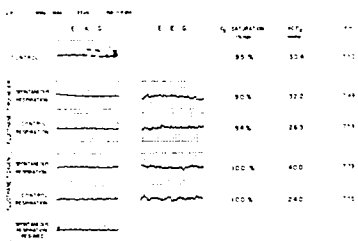

FIG. 5. Results of a typical study during the control period and while surgical anesthesia administered by the "PUFFA" was maintained with halothane-air mixture during spontaneous ventilation, halothane-air mixture during controlled ventilation, halothane-oxygen mixture during spontaneous ventilation, and halothane-oxygen mixture during controlled ventilation. Note nodal rhythm appearing in electrocardiogram during both spontaneous and controlled ventilation with halothane-air mixture and during controlled ventilation with halothane-oxygen mixture with return to normal pattern when spontaneous ventilation was resumed. Blood gas values and electroencephalographic patterns suggest that nodal rhythm was not related to the degree of oxygenation and carbon dioxide elimination but may have been associated with the depth of halothane anesthesia.

Halothane anesthesia.[5] Occasional electrocardiographic evidence of transient nodal rhythm was observed, but such changes in the electrocardiographic pattern did not appear to have any consistant relationship to the degree of oxygenation or carbon dioxide elimination (fig. 5).

The "PUFFA" was applied for the adminis-

TABLE 1

Effect of Halothane-Air and Halothane-Oxygen Anesthesia Administered by the "PUFFA" During Spontaneous and Controlled Ventilation upon Arterial Blood Gases and pH

Patient	Ventilation	Oxygen			Carbon Dioxide		pH
		Cap. (Vol. %)	Sat. (%)	P_{O_2} (mm. Hg)	Cont. (Vol. %)	P_{CO_2} (mm. Hg)	
(1) 31 yrs. Male	Control	17.5	96	96	42.3	28.5	7.51
	Spont. Resp. Halothane-Air	17.5	87	61	45.1	31.0	7.50
	Contr. Resp. Halothane-Air	17.5	93	79	42.2	29.2	7.50
	Spont. Resp. Halothane-O_2	17.5	100+	100+	46.1	43.1	7.35
	Contr. Resp. Halothane-O_2	17.5	100+	100+	41.3	29.7	7.48
(2) 27 yrs. Female	Control	14.0	100	100+	47.2	26.8	7.58
	Spont. Resp. Halothane-Air	13.7	95	92	47.7	32.5	7.49
	Contr. Resp. Halothane-Air	13.7	96	93	41.3	21.3	7.62
	Spont. Resp. Halothane-O_2	13.7	100+	100+	50.7	39.6	7.42
	Contr. Resp. Halothane-O_2	13.7	100+	100+	43.6	23.0	7.62
(3) 23 yrs. Male	Control	14.3	100	100+	45.8	30.4	7.50
	Spont. Resp. Halothane-Air	14.3	90	70	47.7	32.2	7.49
	Contr. Resp. Halothane-Air	14.3	94	80	42.2	26.3	7.59
	Spont. Resp. Halothane-O_2	14.3	100+	100+	48.5	40.0	7.39
	Contr. Resp. Halothane-O_2	14.3	100+	100+	40.2	24.0	7.55
Average	Control	15.2	98.6	100+	45.1	28.6	7.53
	Spont. Resp. Halothane-Air	15.2	90.7	74	46.8	31.9	7.49
	Contr. Resp. Halothane-Air	15.2	94.3	84	41.9	25.6	7.57
	Spont. Resp. Halothane-O_2	15.2	100+	100+	48.4	40.9	7.39
	Contr. Resp. Halothane-O_2	15.2	100+	100+	41.7	25.6	7.55

FIG. 6. "PUFFA" in use with ventilation meter attached to expiratory valve.

tration of anesthesia using clinical signs as a guide without controlled studies in other selected patients. The induction and maintenance of anesthesia in these patients was smooth and uneventful, and no serious complications ensued. The patient's color, ventilatory activity, pulse, blood pressure, and eye signs always were closely observed during induction and maintenance of anesthesia, and halothane concentrations were regulated accordingly with manual support of ventilation whenever indicated. Spontaneous ventilation appeared adequate during light anesthesia in patients who had been spared heavy premedication and who had received no thiopental or muscle relaxant drugs.

DISCUSSION

The Portable Unit For Fluothane-air Anesthesia ("PUFFA") is a simple and inexpensive halothane inhaler which, without depending upon compressed gases or flowmeters, provides a means of maintaining adequate ventilation during regulated depths of anesthesia.

The concentrations of halothane delivered by the "PUFFA" are within a safe anesthetic range and can be regulated according to the dial setting of the vaporizer without being altered significantly by the rate or magnitude of ventilation.

Although both relative hypoxia and hypercarbia accompanied inadequate ventilation during halothane-air anesthesia, this could be corrected readily by either assisting or controlling ventilation as indicated. Spontaneous ventilation appeared adequate during light anesthesia in patients who were not depressed by heavy premedication, supplementary thiopental, or muscle relaxant drugs. This is in keeping with findings previously reported regarding respiratory responses to carbon dioxide during ether and cyclopropane anesthesia.[6] It should be remembered that the "PUFFA" was devised for use primarily in situations where more conventional and elaborate equipment is not readily available. Halothane-air is not a comparable substitute for halothane-oxygen if maximum oxygenation is required. Excessive manual ventilation with halothane-air in an attempt to maintain adequate oxygenation may involve certain risks associated with respiratory alkalosis as decreased cerebral blood flow and a further reduction in the availability of oxygen for the brain.[7] Ventilation with the "PUFFA" may be regulated according to predicted requirements derived from Radford's nomogram [8, 9] by the innovation of a ventilation meter attached to the expiratory valve (fig. 6).

The occasional electrocardiographic evidence of transient nodal rhythm in some of the patients studied did not seem to bare any relationship to the degree of oxygenation or carbon dioxide elimination since it appeared even during controlled ventilation with halothane-oxygen mixture (fig. 5). Rather, it appeared associated with the depth of halothane anesthesia. Others have reported various types of arrhythmias occurring during halothane anesthesia, presumably due to halothane *per se*.[1, 5, 10, 11]

As with most any anesthetic agent or technique, the safe use of the "PUFFA" is dependent upon the anesthesiologist's ability to apply it with understanding and knowledge and his willingness to attend to its moment to moment regulation in accordance with the patient's requirements. Its virtues are simplicity, portability, and versatility.

SUMMARY

A Portable Unit For Fluothane-air Anesthesia ("PUFFA") has been described, and the results of its use in a series of selected patients has been evaluated by analyzing data obtained from both clinical and laboratory observations.

The advantages of the "PUFFA" would appear to be considerable especially in emergency situations requiring a nonflammable inhalation anesthetic and a simple and safe portable inhaler which permits ventilation to be supported manually without elaborate equipment.

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Intermittent Vacuum Regulator

Dr. Russell C. Smith, of Bethlehem, Pennsylvania, reports on an intermittent vacuum regulator, held on the wall by attaching to a conventional wall outlet which not only provides a functional improvement over the floor-type suction pumps, but also helps eliminate the hazards and wasted space of an equipment-cluttered floor.

Unlike an electrically operated suction pump, the intermittent vacuum regulator provides positive control of the suction being applied to the patient and cycles automatically to a definite return to atmospheric pressure at pre-set intervals. Dr. Smith uses the intermittent vacuum regulator most commonly in the recovery room for controlled gastro-intestinal drainage through a Levine tube in the stomach or a Miller-Abbot or Cantor tube in the intestine. The unit has an operating cycle of approximately 20 seconds, with suction applied to the patient for approximately 10 seconds and a complete absence of vacuum for the following 10 seconds. Settings are provided for the application of "high" or "low" suction: 120 and 90 mm. of mercury respectively. The drainage bottle, set at eye-level or below, rather than on the floor, is readily visible to nursing personnel.

The intermittent vacuum regulator permits a return to atmospheric pressure during the "off" portion of the cycle and creates a reversal of the fluid flow. This reversal flushes solids that block the catheter and thus reduces the necessity for periodic flushing by personnel. In similar manner, tissue occlusion of the catheter is avoided, so there is continued removal of the fluids without injury to tissue.

The intermittent vacuum regulator compensates for varying line vacuum without being affected itself. An indicator on the regulator follows the course of the cycle, so that the attending nurses can see at a glance the operation of the unit. The piped vacuum system, with its relatively high volumetric