CURRENT COMMENT AND CASE REPORTS

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As indicated in the introduction to the first attempt at revision and revivification of this Section it is intended to include the exchange of information similar to that which takes place at informal gatherings. It was not anticipated that poetry (†) would be one of the contributions. Louis W. Lewis now at the University of Michigan and a former associate of F. A. D. Alexander's submits the following which represents a concept of the management of pain that he secured during his association with Dr. Alexander. In publishing this, the privilege of limiting the extent to which ANESTHESIOLOGY shall approximate any existing anthology of verse is reserved.

Rows of men
    Confined to bed,
Some ill at ease
    Some nearly dead.

Amputees
    And post-op. cases,
Men with both
    Their legs in braces.

Burns and cuts
    And kidney stones . . .
Their time is told
    In stifled moans.

Pain, their one denominator
Morpheus, their blest Emancipator.

To conquer pain
    Dull not the mind,
Nor slow the breath,
    Nor cause to find
The soul addicted . . .
    And in this way
Doubly afflicted.

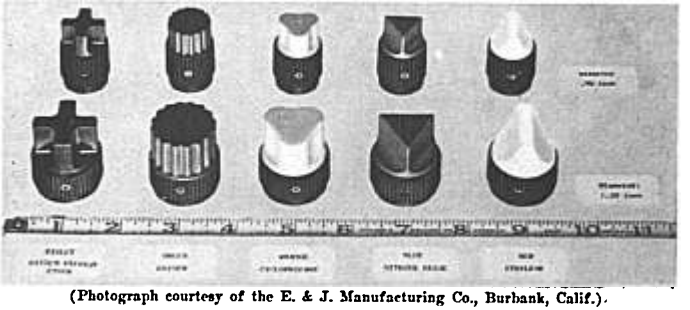
Though opiates may
    The pain control
This is a costly
    Dangerous goal.
But with a dart
    Deny the pain
Any access
    To the brain.
Stay the impulse
    From the part
With a liquor
    In this dart.

Dispel the pain but keep the soul.
This, the therapeutic goal.

A PLEA

In a communication to this section, William H. L. Dornette, formerly of the University of Wisconsin and now with John Dillon at U.C.L.A., continues his plea for standardization of anesthetic equipment. He is impressed with a step made in this direction by one manufacturer who has used Braille-type knobs on the valves controlling flow of gases. After experience with electronics equipment used by the Armed Forces, and after an indication of interest by the Air Force, the company made these available for application to anesthetic appliances. For the anesthetist who is confronted with the necessity of using a machine in the darkness associated with endoscopy, and so forth, and also for those who are interested in diminishing the chance of error in the administration of gases and vapors, these easily identifiable knobs promise to be useful. Color coding in accordance with the ICC standard enhances the identification. In the machine presently available, the code is increased by the addition of purple as the color code for ether-oxygen mixtures.

Eight shapes in two sizes are available. The figure illustrates the knobs available for oxygen, ether and the gaseous anesthetics. Dr. Dornette suggests that other manufacturers seriously consider adopting this system.



(Photograph courtesy of the E. & J. Manufacturing Co., Burbank, Calif.).

COMPLICATION OF THE USE OF VINYL ETHERS

Charles Whitcher, Kenneth Sugioka, David Davis, of the Anesthesia Department, and Claude Yarbro, of the Biochemistry Department at the University of North Carolina, report a case in which there was an unsuspected complication of the use of a vinyl ether. Their report follows.

During a recent ventriculoperitoneostomy on a child, everyone in the operating room noticed a lacrimation and a severe burning sensation about the eyes. An irritating odor resembling acetaldehyde was evident. Nitrous oxide and ethyl vinyl ether in a nonrebreathing system were being used. The neurosurgeon had draped around the operative field with a plastic shield after a skin preparation with tincture of iodine which was not washed off. The exhalation flap of the nonrebreathing valve was opening under drapes which were nearly airtight with consequent prolonged contact between the ethyl vinyl ether vapor and a rather large surface area of iodine prepared skin. During the operation the iodine on the skin was decolorized. It seemed likely that a reaction between ethyl vinyl ether and iodine might account for the odor, the lacrimation and the burning sensation about the eyes. These special conditions, including iodine, plastic draping over a nonrebreathing system with a vinyl ether, would rarely arise in ordinary clinical anesthesia.

In a personal communication, Dr. William H. L. Dornette (U.C.L.A. Medical School, Los Angeles) informed the authors that he noticed a lacrimation and a burning sensation about the eyes during surgical operations on dogs after iodine skin preparation and anesthesia with open drop ethyl vinyl ether.

Vinyl ethers in the presence of small amounts of alcohol are known to react readily with free iodine. The products formed are dependent on the conditions, ratio of reactants and extent to which secondary reactions may occur. Normally, the preodminating reaction involves the formation of iodo-acetal from vinyl ether, but acetaldehyde also may be produced as a result of the simultaneous formation of free acid, and this in turn may further react with iodine to form iodoacetaldehyde. (Alternatively, the latter may also result from the hydrolysis of the iodo-acetal.) Test tube experiments conducted in the laboratory of the authors indicate that the reaction products contain a high percentage of acetaldehyde, as well as a powerful lacrimator substance which is believed to be iodoacetaldehyde. Chautard (Ann. Chim. et Phys. 16: 145, 1889) has reported that iodoacetaldehyde is a powerful respiratory irritant and that elaborate precautions are necessary when working with it. The necessity of eliminating the production of such lacrimator and respiratory irritants in the operating room is obvious.

The use of vinyl ethers should be avoided whenever any of the vapor will contact large surface areas prepared with iodine tincture, as under plastic drapes with non-rebreathing systems.

FINE LUMBAR PUNCTURE NEEDLE (Modification of Technique)

Jack Frumin of Presbyterian Hospital in New York has successfully introduced anesthetic drugs intrathecally through either a 28 gauge or 30 gauge needle. To facilitate the introduction of either of these fine gauge needles and to minimize bending and breakage, he first introduces by standard technique an 18 gauge short bevel needle into the peridural space and passes the smaller needle through it. The small gauge needles should be about 1 centimeter longer than the 18 gauge needle. Verification of entrance of the fine gauge needle into the intrathecal space is dependent upon establishment of anesthesia because detection of entrance by palpation or by drip or aspiration of spinal fluid does not occur.

He anticipates that there will be a significant reduction in the incidence of post lumbar puncture headache with the use of the fine gauge needles. In 30 patients in whom the technique has been used, there were no headaches.

THE REMAINING MATERIAL IN THE SECTION IS PRESENTED ESSENTIALLY AS SUBMITTED

VENTILATOR

This communication deals with the design and preliminary use of a mechanical unit for artificial ventilation.

A number of devices for artificial ventilation during anesthesia have been described (1–6). The mechanical respirator described herein represents an attempt to assemble a useful adjunct for the anesthetist from readily available components. The present design simulates the manual compression of the breathing bag during controlled ventilation in paralyzed, curarized, or hyperventilated anesthetized patients. The unit is not intended to assist spontaneous but inadequate breathing.

Since the anesthetist gains much information by use of the breathing bag, especially at times when evaluating the patient's ventilatory status, this respirator is not proposed as a complete substitute for the breathing bag. On the other hand, mechanical ventilation

is useful during prolonged procedures when the patient's condition is stable. Availability of such a unit relieves the anesthetist when necessary for attending to other therapeutic details. During these periods, the patient's ventilation is assured by mechanical means requiring little attention from the anesthetist.

The present model has been employed in delineating the ranges of tidal volume and inspiratory and expiratory timing. Although redesign of the unit would greatly simplify its construction, the present model has been satisfactory for both research and clinical use.

DESCRIPTION OF RESPIRATOR

A schematic diagram of the respirator is shown in figure 1. The essential parts are the bellows (A), a motor which operates the arm (B), and the counterweight (C).

The bellows is molded rubber with an approximately 8 inch square cross-section. Metal strips are cemented to the sides of the convolutions of the bellows so as to minimize bulging under pressure. This reinforcement minimizes the loss in delivered volume when the respirator works against either an increasing airway resistance or a decreasing lung compliance. One end plate of the bellows is fixed; the other end plate is hinged at one side so that the bellows executes the type of motion indicated.

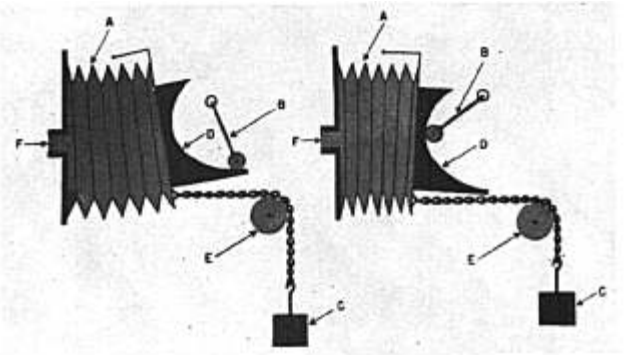


FIG. 1. Schematic drawing of respirator.

The arm (B) is mounted on the shaft of a pressure-driven Trico windshield wiper motor with a 50 degree swing (Model FPSC 50). Oxygen or compressed air at a pressure of 30 to 55 p.s.i. is employed. A ball-bearing wheel on the end of the arm operates against a cam (D) which is mounted on the bellows end plate. The 50 degree swing of the arm moves the wheel over a segment of the cam. The cam is so shaped that the volume delivered by this motion may be varied by rotating the pressure motor about its shaft, so that the arm operates over a different segment of the cam. Volumes up to nearly 2 liters are provided to permit an adequate ventilation when the leak of the semi-closed system is present. A pointer, which is attached to the moving end of the bellows, indicates on a scale the volume delivered. The pressure motor, as supplied by the manufacturer, is provided with a common exhaust from both ends of its cylinder. A needle valve on this exhaust controls the cycling rate. For the respirator here described the motor was modified by the addition of 2 more needle valves arranged to bleed each end of the chamber separately. Adjustment of these needle valves provides separate controls for the duration of inspiration and the duration of expiration.

Use of the counterweight (C) is optional. This weight expands the bellows actively during the expiratory phase in order to develop negative airway pressure. The amount of negative pressure is regulated by the amount of weight.

A special large bore three-way stop cock at the outlet of the bellows permits connection of either the conventional bag or the bellows to the breathing circuit. Thus the anesthetist may quickly select either the breathing bag or bellows. An aneroid manometer is employed to indicate airway pressure.

A conventional closed circle system and a 1,250 gram absorber are, for convenience, made an integral part of the unit. A popoff valve is placed in the expiratory circuit. Elimination of the expiratory breathing tube and use of a flow-actuated valve on the inspiratory tube at the patient's airway converts the system for non-rebreathing. Either air or metered anesthetic mixtures may be fed into the breathing circuit near the three-way stop cock.

In practice, the patient's spontaneous ventilation may be measured by connecting the bellows, by means of the three-way valve, to the breathing circuit while the arm (B,

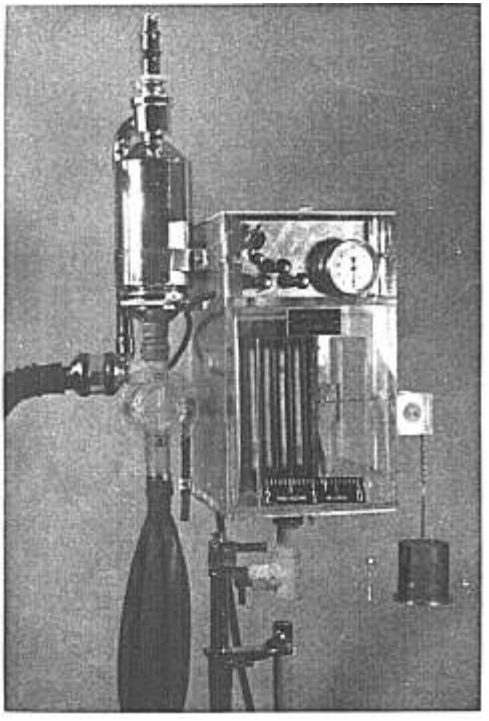


FIG. 2. Photograph of respirator.

fig. 1) is left in the retracted position. For this purpose the counterweights are removed. Resistance of the bellows during inspiration varies between 1 and 2 cm. of water.

Delivered volume of the respirator may be varied between 400 and 1,800 cc. Cycling rate is adjustable between 8 and 50 cycles per minute. Pressure excursions may be controlled, at the discretion of the anesthetist, by the quantity of gas admitted to the breathing circuit. Intermittent positive pressures up to 50 cm. of water may be developed or positive-negative excursions up to 20 cm. positive and 20 cm. negative may be employed. Inspiratory or expiratory durations may be varied between 0.25 and 3.0 seconds.

When oxygen is employed to drive the pressure motor, the needle valve which controls the rate may be connected so as to feed the oxygen through a flexible reservoir bag (vented) to the bellows. In this way oxygen utilized for the power to drive the respirator may be partially used to maintain oxygen content of the breathing circuit. A photograph of the respirator is shown in figure 2.

METHODS

Adult anesthetized patients were given controlled ventilation with the respirator for periods up to 3 hours during surgery. Premedication consisted of 10 mg. of morphine sulfate and 0.4 mg. of scopolamine hydrobromide one and a half hours prior to induction.

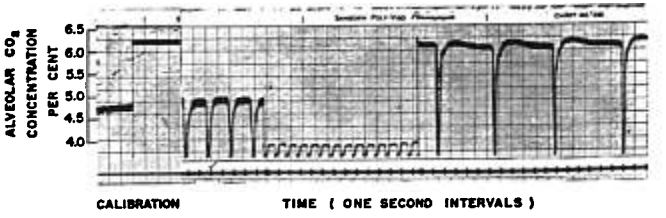


FIG. 3. Sample record of CO_2 concentration for three different respirator cycling rates.

Anesthetic agents consisted of ether-oxygen; ether-cyclopropane-oxygen; nitrous oxide-oxygen-Demerol®; nitrous oxide-oxygen-Pentothal®. In all patients the circle breathing system was employed.

Maintenance of an adequate ventilation was judged on the basis of breath-to-breath measurements of alveolar carbon dioxide concentration. For the latter technique, fractional sampling similar to that described by Collier, Affeldt, and Farr (7) was employed. A Kirchhoff valve was used to couple the patient's cuffed endotracheal tube to the circle breathing system. A flow of 500 cc. per min. was drawn continuously from a point 2 to 5 mm. distal to the expiratory valve of the Kirchhoff valve. A No. 6 ureteral catheter, 2 feet in length, was used for sampling. The sample was drawn through the microcatheter sample cell of the Liston Becker Model 16 CO_2 Analyzer by means of a pump. A rotameter (0–700 cc. per min.) was connected to the outlet of the pump to permit monitoring of the sampling flow rate. A 1-liter bottle was connected between the analyzer and the pump to eliminate pressure pulses in the sample cell. The signal from the CO_2 analyzer was amplified and recorded by a Sanborn DC amplifier and direct-writing oscillograph. The reading corresponding to zero per cent CO_2 was suppressed and the amplification increased to provide a full scale deflection for the change between 4.0 and 6.5 per cent CO_2. Standard mixtures of 4.84 and 6.24 per cent CO_2 in oxygen were used for calibration of the CO_2 analyzer before and after each study. Figure 3 shows sample CO_2 records in one patient for various respirator adjustments.

Alveolar CO_2 concentrations were measured following induction, during maintenance of anesthesia, and during special procedures. At the end of the surgical procedure the counterweights were removed from the respirator and the pressure motor turned off with arm (B) retracted. The period of apnea and the alveolar CO_2 concentration at the termination of apnea were recorded.

Sample airway pressures were recorded using a differential diaphragm manometer with one side open to the air. The transducer was a Schaevitz differential transformer. The output was amplified and recorded on a Sanborn recorder. Sample recordings showing various pressure swings are illustrated in figure 4.

RESULTS AND DISCUSSION

The respirator has been used satisfactorily during 28 surgical procedures. Table 1 summarizes the carbon dioxide measurements during 12 of these procedures.

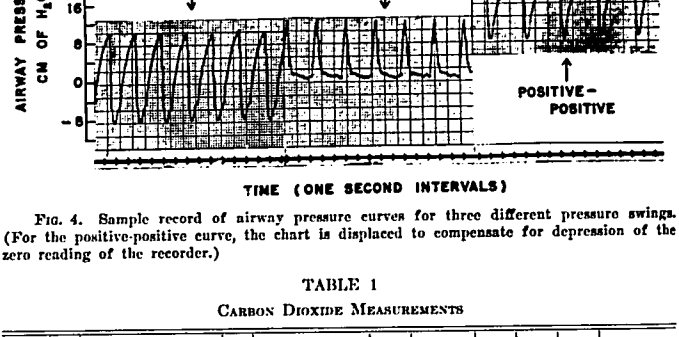


FIG. 4. Sample record of airway pressure curves for three different pressure swings. (For the positive-positive curve, the chart is displaced to compensate for depression of the zero reading of the recorder.)

TABLE 1

CARBON DIOXIDE MEASUREMENTS

Patient	Age, years	Operative Procedure	Duration, hours	Anesthetic Agents and Relaxants	Alveolar CO_2 at start, %	Alveolar CO_2 maintenance range, %	Alveolar CO_2 at end, %	Period of apnea, seconds	Alveolar CO_2 post-apnea, %	Typical Respirator Pressure Range
R. W.	45	Radical mastectomy	2.8	N_2O-O_2-Demerol	5.7	4.9 to 6.5	5.7	8	5.6	0 to +12
C. P.	33	Commissurotomy of lip	0.8	N_2O-O_2-Demerol	6.5	5.8 to 6.5	5.8	203	6.7	−7 to +20
A. A.	70	Suprapubic cystotomy	0.8	N_2O-O_2-Demerol	5.6	5.0 to 6.8	6.7	0	7.0	−10 to +12
M. K.	68	Resection and colostomy	3.3	N_2O-O_2-Demerol	6.5	5.1 to 6.5	6.0	960	6.9	−6 to +12
A. B.	46	Repair of suprapubic cystotomy	1.5	N_2O-O_2-Demerol	6.5	5.2 to 6.2	6.2	11	6.5	−1 to +12
J. C.	60	Amputation of penis	2.4	N_2O-O_2-Demerol-Pentothal	6.4	4.9 to 6.6	6.5	24	6.6	0 to +32
E. B.	53	Hysterectomy	2.3	N_2O-O_2-Pentothal Curare	5.2	4.0 to 5.6	5.1	210	6.5	−6 to +14
M. B.	74	Hysterectomy	2.2	N_2O-O_2-Pentothal Curare	5.8	4.9 to 5.8	5.0	42	4.9	−10 to +25
J. M.	72	Gastrostomy	1.8	Ether-O_2 Curare	5.0	4.6 to 6.3	6.3	0	6.5	0 to +20
C. M.	65	Wedge resection, left lung	3.0	Ether-O_2	4.7	5.0 to 6.5	5.8	12	6.5	−10 to +10
C. J.	58	Gastrostomy	1.1	Ether-O_2	6.3	4.6 to 6.2	6.1	4	5.6	−5 to +8
K. T.	59	Biopsy, gastric polyp	1.5	C_2H_5-Ether-O_2	4.6	5.3 to 5.9	5.7	105	6.8	−2 to +10

Considerable variability was encountered in the ventilation required in different patients to maintain normal alveolar CO_2 concentrations. The largest ventilations were required during second plane ether anesthesia. Tidal volumes ranged between 400 and 1,100 cc. Rates varied between 10 and 50 per minute. Moreover, as shown in table 1, there was wide variation in the airway pressure ranges associated with the required ventilation. Negative expiratory pressure phases were employed only when hypotension appeared to be associated with intermittent positive pressure breathing. In all such instances lowering of the mean airway pressure by introducing negative pressure during the expiratory phase was followed by an elevation in blood pressure. Pressure curves developed by the respirator may be adjusted at the discretion of the anesthetist. It should be emphasized, however, that other parameters of artificial ventilation are more significant in the use of the fixed-volume respirator. The volume delivered from the bellows should be the primary consideration, in the same manner that the anesthetist compresses the bag until he feels that he has inflated the patient's lung with an adequate tidal volume. The pressure developed by delivery of a given tidal volume to the patient then depends upon several factors: the rate of flow, the resistance of the airway and breathing circuit, and the compliance of the lungs and thorax.

Thus there is a fundamental difference between the fixed-volume and the pressure-cycled modes of operation. The fixed-volume device is designed to deliver approximately the volume for which it is set, independent of the pressure required. The pressure-cycled device delivers at a relatively fixed flow pattern only that volume necessary to attain the cycling pressure. With changes in airway resistance and lung-thorax compliance the volume delivered by the pressure-cycled unit may vary markedly. This does not duplicate the action of the anesthetist's manual compression of the bag. For example, when partial obstruction of the airway develops the pressure-cycled unit tends to chatter; whereas the anesthetist, executing controlled ventilation, automatically increases the force of manual compression on the bag to deliver an adequate tidal volume at the pressure required. Although he utilizes the observation of increased pressure to detect the partial obstruction, he tends to continue the forceful inflation, although perhaps at a slightly slower rate. In any case he does not triple or quadruple the rate of compressions and allow alveolar ventilation to be markedly impaired. The fixed-volume respirator does not suffer the above disadvantage of the pressure-cycled respirator. Even though increased pressure may be required, the respirator continues to deliver approximately the volume for which it is set, though at a slightly slower rate. The pressure exerted on the airway is no more than that required to deliver an adequate tidal volume. Hence minute-to-minute adjustments of the pressure curve are unnecessary. Reading of the aneroid manometer gives the anesthetist information comparable to that which he is accustomed to feel with his hand on the bag.

It has not been found necessary to employ relaxants to establish and maintain controlled ventilation with the respirator. Curare or succinylcholine was used on the basis of surgical indications.

Alevolar CO_2 concentrations were maintained between 4.0 and 6.8 per cent in the series of patients shown in table 1. The longest duration of apnea was fifteen minutes in patient M. K. In this case the alveolar CO_2 concentration was maintained 0.7 per cent lower than that recorded just prior to starting the respirator. Other patients (J. C. and R. W.) were similarly ventilated but did not show apnea longer than twenty-four seconds. Apparently patient M. K.'s central respiratory threshold to CO_2 was elevated above normal and this patient was relatively hyperventilated with the respirator. The absence of prolonged apnea in all other patients indicates that marked hypocapnia is not required to maintain cessation of respiratory effort and that controlled ventilation may be carried out for considerable periods with only mild, if any, hyperventilation. Of particular interest is patient C. J. in whom an arrest of respiratory activity was attained for over an hour by means of the respirator. During most of this time an alveolar CO_2 concentration above that associated with spontaneous respiration was maintained. No

apnea occurred upon discontinuing the respirator. Such data suggest that factors other than a lowered CO_2 level produce inhibition of respiratory effort for prolonged periods. It would seem that such inhibition may be of vagal origin and may be related to the repetitive stretch stimuli applied to the lung during controlled ventilation.

SUMMARY

A simple reliable respirator for controlled ventilation of anesthetized patients has been described. Use of this device, together with a competent circle filter, has prevented the development of respiratory acidosis. Operation of the respirator has been found to be convenient, reliable, and sufficiently flexible to meet the varying needs of the patient.

CO_2 analysis has demonstrated that mechanically controlled ventilation, properly adjusted results in essentially normal CO_2 levels in the patient.

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