CURRENT COMMENT

STUART C. CULLEN, *Editor*

GADGETS

Intermittent Positive Pressure Respirator

Drs. M. J. Frumin, A. S. J. Lee, and E. M. Papper of the Presbyterian Hospital of New York, describe a convenient and reliable intermittent positive pressure respirator. It has three basic design features: (1) Only two control settings have to be varied—respiratory rate and inspiratory pressure—and they are independent of each other. (2) Many safety features are included but require no adjustments. (3) The apparatus is rugged and reliable in operation and uses no delicate or sensitive parts.

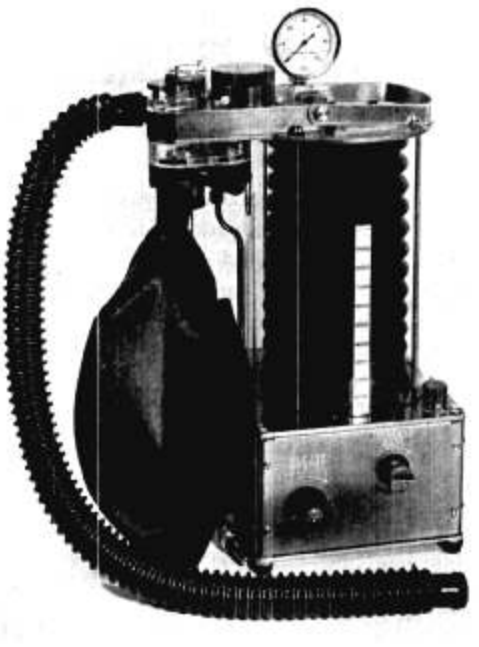
Even though the chief components will be described in detail, in practice the operator merely turns two knobs to adjust independently the respiratory rate and the inflating pressure. The resultant tidal volume is immediately visible and can be measured directly. This simplicity of design and operation permits a ready appraisal of the functioning of the apparatus and simplifies training of personnel in its use.

The respirator can be considered as two separate pneumatic circuits—one containing the gases to be respired and the other which furnishes the power to operate the apparatus. The respired gases are contained in a corrugated rubber bellows which hangs in a transparent dome. The bellows is compressed by intermittently raising the gas pressure in the dome.

The source of power for compressing the bellows and for cycling the apparatus is compressed gas at 35–60 psi. This pressure is first reduced to 20 psi by a fixed pressure regulator, thereby preventing any variation in action of the apparatus because of line pressure variations. The gas at 20 psi is delivered to a variable low-pressure regulator and to a compressed air motor. The output of the variable regulator can be set between 0 and 40 mm. Hg. An actuating valve connects the dome alternately to the output of the variable regulator and to atmosphere. When the dome is connected to the variable regulator, gas enters it at the pressure setting of the regulator, compresses the bellows and produces inspiration. When the dome is connected to atmosphere, the weighted bellows is allowed to expand and passive exhalation occurs. The cycling of the actuating valve is brought about by a cam rotated by a compressed air motor powered by the 20 psi gas regulator. The rate of cycling of the air motor is controlled between 4 and 40 per minute by a needle valve in the gas line to the air motor. The phasing of the breathing pattern is preset by the fixed cam to produce an inspiratory-expiratory duration ratio of 1 : 2. The tidal volume may be estimated from the movement of the bellows against a graduated scale on the dome.

The apparatus may be used in a nonrebreathing system for supplying O_2, room air or room air enriched with O_2 without any accessory equipment other than a nonrebreathing valve described previously (ANESTHESIOLOGY 20: 383, 1959). It may also be used in a nonrebreathing system for anesthesia purposes when supplied with an anesthetic mixture. Finally, it can be used in a circle system in conjunction with any anesthesia machine.

Breathing gases may be supplied in various ways to the respirator: (1) Room air by opening the room air inlet port, (2) Anesthetic mixtures through a small bore rubber tubing connected by the 5/16 inch diameter mixture inlet, (3) Anesthetic mixtures through 7/8 inch diameter corrugated tubing through the room air inlet port, (4) If compressed O_2 is used to power the respirator, O_2 can be admitted from the 20 psi regulator to the patient cir-



cuit through a needle valve, (5) Room air through the emergency room air inlet, (6) Anesthetic gases in a circle system are supplied by the anesthesia machine. Here, the respirator is connected to the anesthesia machine in place of the reservoir bag of the circle apparatus.

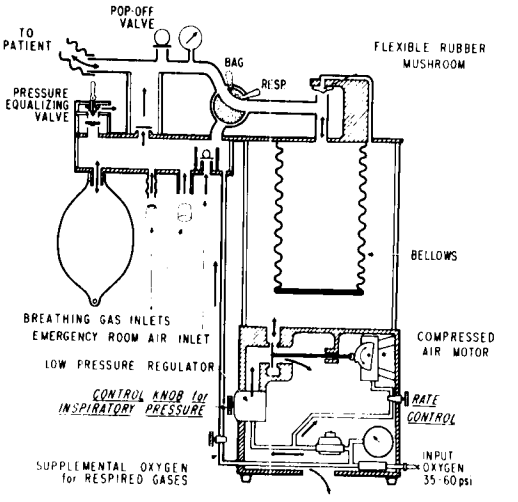
The important safety features are: (1) An overpressure safety valve which is preset for 25 mm. Hg but which can be raised to 40 mm. Hg or higher by manually adding additional weights. This prevents the imposition of more than this preset pressure to the patient's lungs under any circumstance.

(2) A new type of valve prevents any rise in pressure above atmospheric during the exhalation phase when the respirator is used with a circle system. This is a pressure equalizing valve. A thin flexible rubber "mushroom" covers an escape port in the line going to the circle apparatus. The interior of the "mushroom" is connected through a duct to the dome containing the bellows. During inspiration, the interior of the "mushroom" is at the same pressure as the dome and, therefore, always higher than the pressure within the bellows, and as such seals off the escape port. During exhalation, the pressure in the dome and, therefore, also in the "mushroom" goes to atmospheric. Consequently, any rise in pressure in the bellows at this time caused by excess inflow of gas into the circle system will raise the "mushroom" off the port and will be dissipated to atmosphere.

(3) If sufficient gas is supplied to the system, the volume in the bellows will gradually become smaller. Under this circumstance, the re-expansion of the bellows during the exhalation phase produces enough negative pressure in the patient line to open the emergency air intake check valve (loaded to 3 mm. Hg) and provide the patient with room air for the next and succeeding breaths.

(4) Another pressure equalizing valve described elsewhere (ANESTHESIOLOGY 20: 383, 1959) is incorporated in the respirator to prevent overdistention of a reservoir bag.

In addition to the bellows used for the automatic intermittent positive pressure breathing, an ordinary reservoir bag is provided together with a selector valve. The patient may be given automatic intermittent positive pressure respiration through the bellows as described, or respired with this external bag. This bag receives all of the breathing gases supplied to the respirator except during intermittent positive pressure breathing in a circle system. The circle system can either be entirely closed or may have a leak which compensates for additional gases being added to the system. As pointed out previously, if the inflow rate into this semi-closed circle system



is either deliberately or inadvertently higher than that due to the leak, then the pressure in the system during expiration will never rise above atmospheric. Likewise, inspiratory pressure higher than those produced by the original setting of the pressure regulator will not be produced by excessive inflow rates.

During the inspiratory phase the gases admitted to the system are temporarily stored in the reservoir bag and are only drawn into the bellows during the exhalation phase. In this way, the movement of the bellows gives the correct tidal volume, except for the compliance of the connecting tubing and the actual compression of the gases in the system itself. The compression of the gases in the respirator itself during inspiration requires a correction in the indicated tidal volume of approximately 30 ml. per 10 mm. Hg positive pressure applied. When 30 inches of conventional distensible corrugated rubber tubing is added to the respirator, the correction increases to about 70 ml. per 10 mm. Hg positive pressure.

When the patient is receiving 100 per cent O_2 and it is important to conserve this gas, the O_2 used for the compression of the bellows can be diverted to the reservoir bag and can thus be respired by the patient.

The respirator weighs approximately 18 pounds and is approximately 19 inches high. It is durably constructed and all valves in the patient's circuit are enclosed in transparent plastic to allow for complete visibility.

The system described here does not provide a negative pressure to exhalation nor does it allow for changing the phase relationship of inspiration to exhalation. However, in a year's trial in 200 patients and under a wide variety of conditions, it has proven quite satisfactory.

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Simplication of Method for Determination of Ether

The Drs. Price have simplified their ether determination method (ANESTHESIOLOGY 17: 293, 1956), so that the titration step can be omitted. In place of this they now measure the optical density of the solution to be analyzed at a wave length of 445 mu. The optical density of dichromate peaks at this wave length while that of reduced dichromate is nearly zero. From this the milligrams of ether present in the sample can be calculated as:

$$\text{mg. ether} = 4.63\left(1 - \frac{\text{O.D. Sample}}{\text{O.D. Blank}}\right)$$

The blank optical density is that of the unreduced dichromate solution made as described in the original method. The density of the sample is that observed after incubation of the reagents in the presence of the blood sample, also as described in the original method. For many uses this formulation is sufficient. For the most accurate determinations it is necessary to correct for the fact that the density of reduced dichromate is not zero at 445 mu. This may be done by reading the solutions at another wave length, preferably 600 mu, and solving directly for the relative proportions of reduced and unreduced dichromate present in the unknown solution. The method is as accurate as that employing titration in the average person's hands, and perhaps even more so. It is also shorter and has cut the time for analysis by the method roughly 30 per cent.

CASE REPORT

Successful Resuscitation after "Death" from Lightning

Dr. Sadao Morikawa of the Department of Anesthesiology and Dr. Felix Steichen of the Department of Surgery, Baltimore City Hospitals, are reporting this case of resuscitation for the following reasons: (1) It demonstrates that the accident room diagnosis "dead on arrival" should not discourage resuscitative efforts. (2) Cerebral anoxia as prolonged as

in this patient may be followed by complete neurological recovery. (3) The aftercare this patient received was just as necessary for his survival as the prompt respiratory and cardiac resuscitation.

A 10 year old boy, while riding his bicycle during a thunderstorm on July 24, 1959, was struck by lightning at approximately 3:20 p.m. A playmate found him apparently lifeless and applied the back-pressure arm-lift method of artificial respiration for approximately 10 minutes. The ambulance men (untrained, nonprofessional volunteer rescuers) found the boy at 3:38 p.m. motionless, without breathing movements, and cyanotic. At this time a radial pulse was palpable, according to the playmate, a boy scout. During transportation to the hospital they applied an automatically cycling resuscitator which failed to "move the boy's chest." Although they held the boy's head tilted backward, the resuscitator "chattered" throughout the entire trip to the hospital, indicating airway obstruction. The ambulance men recognized the failure of their equipment, but did not know how to correct the situation. They had not been taught how to hold the patient's mandible forward nor did they have an artificial oropharyngeal airway. These rescuers were not trained in exhaled air resuscitation. The rescuers did not check for vital signs during transportation.

On arrival at the Baltimore City Hospitals at 3:45 p.m., the boy was apneic, ashen gray, pulseless, flaccid and cold, apparently dead. His pupils were maximally dilated. Mouth-to-airway breathing was started immediately, producing good chest movements. Simultaneously the thorax was opened and the heart was found to be in asystole. After 5 minutes of mouth-to-airway breathing and manual systole, adrenalin 2.0 mg. was injected into the left ventricle and spontaneous cardiac contractions started. At 3:55 p.m. mouth-to-airway breathing was replaced by intermittent inflation of the lungs with oxygen through a tracheal tube and hypothermia was induced immediately by applying crushed ice. At 4:00 p.m. the lips became pink and the blood pressure was 100/60. At 4:05 p.m. the pupils started to become smaller.

From the accident room the patient was transferred to the operating room, where the thoracotomy incision was closed and tracheotomy was performed. During that time the patient had received 100 cc. of dextran, and 250 cc. of plasma. Between 5 and 6 p.m. spontaneous diaphragmatic contractions started, the carinal cough reflex returned, the blood pressure was 140/90, the heart rate 64 and regular, the temperature 31 C.

During the first 4 days of his hospital stay he was deliberately hyperventilated with a piston respirator (intermittent positive pressure breathing) via the tracheotomy tube. His rectal temperature was maintained between 29 and 32 C. An intravenous drip of succinylcholine was used to control shivering during the induction of hypothermia. On the day following admission, the boy had generalized convulsions, which were controlled with succinylcholine until barbiturates and Dilantin could take effect. In addition urea 1.5 Gm./kg. was given intravenously to reduce brain swelling, which presumably was present as a sequel of cerebral hypoxia.

One small burn on the left side of the scalp and one on the left heel were noticed, indicating entrance and exit marks of the lightning current.

On the 3rd hospital day the boy appeared to recognize his father once, on the 4th day he responded briefly to verbal stimuli, but otherwise remained in deep coma. When the piston respirator was disconnected on the fourth day the patient's spontaneous breathing was adequate. His body temperature was kept at normothermic levels after the fifth day because of the development of bilateral pneumonia. The intermittent use of a Bennett Respirator (intermittent positive pressure breathing), utilizing oxygen supersaturated with water vapor, meticulous tracheobronchial suction, postural drainage, coughing maneuvers, antibiotics, and four bronchoscopic aspirations, resulted in clearing of his lungs within three days.

On the sixth day after admission the patient responded again briefly to verbal stimuli. He whispered his age and counted fingers correctly. On the tenth day he was suddenly fully conscious, asked for food, and remained awake and rational subsequently.

He was fed intravenously for the first 7 days, by gastric tube thereafter until the 15th day

and from then on he ate and drank. He was out of bed and walking on the twenty-third day and discharged on the thirtieth day. At this time he had a slight nasality of his speech and some trouble in swallowing as the only aftereffects. Two months after the accident he was back at school. An I.Q. test done before his discharge from the hospital gave the same result as one done 3 months prior to the accident. At the present time he is neurologically and mentally normal.

The physicians who took care of this patient were residents in surgery and anesthesiology, who were in constant attendance at his bedside in the Intensive Care Unit for 7 days and nights. They were aided by consultants in pediatrics and neurology.

The duration of circulatory arrest in this case is unknown, but apnea was known to have existed for 15 to 20 minutes. We may speculate that postanoxic cerebral edema was prevented or reduced by the immediate induction of hypothermia, the deliberate overventilation (respiratory alkalosis), the intravenous use of urea, or a combination of these factors.

CORRESPONDENCE

Respiratory Arrest and Intraperitoneal Neomycin

To the Editor.—The interesting article "The action of some antibiotics on the human intercostal nerve-muscle complex," by Drs. Sabawala and Dillon (ANESTHESIOLOGY 20: 659, 1959) seems to prove that the combination of intraperitoneal neomycin with ether anaesthesia leads to respiratory paralysis. These cases of respiratory arrest known in the literature all took place during ether anaesthesia. However, I described a case of respiratory arrest, lasting for two hours, following intraperitoneal administration of neomycin during anaesthesia with thiopentone/*d*-tubocurarine/nitrous oxide /oxygen, but *without ether*, in a 47 year old woman, who underwent a gastrectomy for a perforated duodenal ulcer (*Arch. chir. neerl.* 11: 356, 1959). A few months previously this patient underwent a hysterectomy and prolapse operation. I gave that anaesthesia as well (thiopentone/*d*-tubocurarine/nitrous oxide/oxygen) but this time without respiratory difficulties.

How do Drs. Sabawala and Dillon explain the respiratory arrest due to intraperitoneal neomycin during anaesthesia without ether?

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SINGLE-DOSE CAUDAL In a group of 114 obstetric patients, single-dose caudal anesthesia was used for anesthesia for delivery. One per cent procaine and lidocaine only occasionally provided satisfactory anesthesia; 2 per cent lidocaine was satisfactory in 68 per cent of the deliveries but was abandoned because of reported high toxicity of this drug. Chloroprocaine hydrochloride was used in a 2 and also 3 per cent concentration. The results were satisfactory in 85 per cent of the administrations, the majority of the 15 per cent failures being due to technical difficulties. Of the 7 failures, 4 were due to inability to locate the caudal space and 3 followed persistent aspiration of blood, the method then being discontinued. With the use of a short needle and avoidance of giving more than 20 cc. of solution, this is a satisfactory type of anesthesia for delivery. (*Gotchel, R. P., and West, W. A.: Single-dose Caudal Anesthesia in Obstetrics, Obst. & Gynec. 14: 652 (Nov.) 1959.*)