A Simple Technique for the Manual Administration of Positive-Negative Pressure Ventilation

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Control of the anesthetized patient's ventilation has become commonplace since the advent of muscle relaxants. Although the use of mechanical ventilators for this purpose is on the increase, in the vast majority of cases manual compression of the breathing bag is the technique most commonly employed. In the absence of an impaired circulation this form of intermittent positive pressure ventilation is in most instances without hazard to the patient. However, as was pointed out in 1953 by Maloney and his co-workers,[1] the application of intermittent positive pressure, manually or mechanically, in patients in respiratory and/or circulatory failure may cause a fall in cardiac output of over 40 per cent. They also demonstrated that the introduction of a negative phase by means of a positive-negative pressure ventilator limits this fall to less than 20 per cent.

Unfortunately, manual compression of the breathing bag is ordinarily the only method of ventilation immediately available to the anesthetist when sudden, unexpected cardiovascular collapse occurs in the operating room. Obviously, a simple means of introducing a negative phase into manually performed intermittent positive pressure ventilation would be exceedingly desirable during such crises, but none has been forthcoming.

The recent availability of self-inflating breathing bags has greatly simplified resuscitation by obviating the need for compressed gas to ventilate patients in respiratory failure. Such equipment has also been useful in ventilating apneic patients being transported to and from the operating room. These bags have in common resilient walls which when compressed, by the nature of their resiliency, resume their original shape. All of these bags, when used in resuscitation, employ nonrebreathing valves of various types so that the bags refill with room air (or oxygen) while the patient's exhaled air is vented to the atmosphere. It occurred to us that if such a bag were used without the valve as the rebreathing bag in an anesthetic circuit, the same resiliency which allows spontaneous refilling might create a negative pressure phase sufficient to be useful in cardiocirculatory collapse.

Two of the above mentioned breathing bags, the Ambu and Puritan bags, lend themselves to use in the operating room (fig. 1). These bags may be purchased separately without

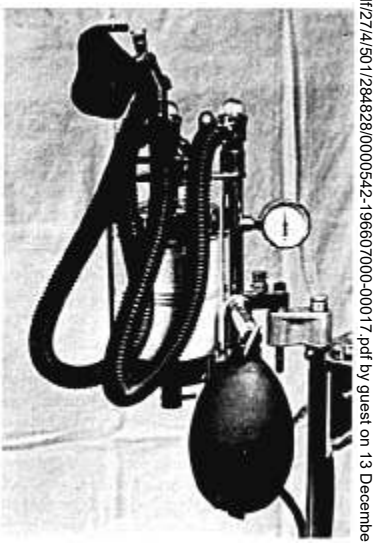

FIG. 1. The Puritan (or Ambu) bag placed in the anesthesia circle in place of the standard rebreathing bag. If the Ambu bag is used the outlet at the bottom of the bag must be plugged.

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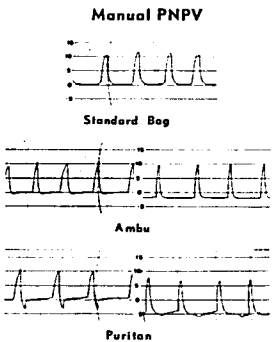

FIG. 2. Pressure curves obtained in an anesthetized patient rendered apneic with succinylcholine. The Ambu and Puritan curves on the left were made using a total gas flow of 600 ml./minute in a closed system, whereas the curves on the right were made with a lower flow and/or in a semi-closed system to increase the degree and duration of the negative phase.

valve or mask, and the Ambu bag, which has two outlets, may be obtained with one opening plugged. The relative ability of these two bags to create a negative phase was compared in a young healthy patient anesthetized with cyclopropane administered in a closed system with a constant, total flow of 600 ml./minute. The patient was intubated and then rendered apneic with a succinylcholine drip. Airway pressure was measured at the mouth using a Stratham P23BC strain gauge connected to a Grass Polygraph. Figure 2 shows the pressures achieved: in the top tracing a standard 3-liter bag produced an airway pressure of about 11 mm. of mercury during inspiration while, as would be expected, there was no negative phase during expiration. Similar positive pressures were achieved on inspiration with the Ambu bag, but on expiration with this flow a negative pressure of slightly greater than 0.5 mm. of mercury was created as shown in the Ambu tracings to the left. The Puritan bag again caused similar positive pressure on inspiration, but during expiration was capable of producing over 3 mm. of mercury negative pressure with this flow, as may be seen in the Puritan tracings on the left. By carefully adjusting the expiratory "pop-off" valve and/or reducing the total gas flow, both the magnitude and duration of the negative phase can be increased, as may be seen in the tracings of both bags on the right. As implied by these studies and borne out by clinical experience, the Puritan bag seems to be superior to the Ambu in providing controllable levels of negative pressure manually. Therefore flow and pressure tracings were subsequently obtained for this bag, using a Fleisch Pneumotachograph, type 3.575, with a Grass differential pressure transducer PT5A, which in turn was connected to the Grass Polygraph. The tracings obtained are shown in figure 3.

Such "negative pressure breathing bags" would seem to provide a safe, simple, readily available, and inexpensive means of applying a negative pressure phase to patients who undergo unexpected cardiovascular collapse while under anesthesia. The customary practice of hyperventilating the patient in shock with a standard breathing bag may in itself be seriously undesirable, for as pointed out above, when circulatory inadequacy exists, positive pressure alone may result in a drastic decrease in venous return, and this, in turn, causes the reduction in cardiac output. Since the delivery of oxygen to the tissues is directly proportional to cardiac output, the vigorous administration of positive pressure breathing to a patient in shock may actually effect a reduction in the availability of oxygen to the

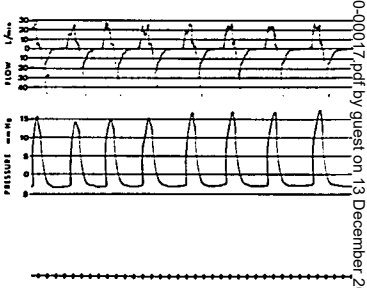

FIG. 3. Pressure-flow curves obtained using the Puritan bag in an anesthetized patient rendered apneic with succinylcholine.

tissues, even though 100 per cent oxygen is given. The beneficial effect of the negative phase during expiration is presumably due to the increased venous return that may be brought about by the augmented negative intrathoracic pressure. What constitutes the optimal degree of negative pressure has been debated by various investigators, but the efficacy of 3 mm. of mercury is born out by the following case report.

A 33 year old woman was undergoing a radical hysterectomy under endotracheal cyclopropane anesthesia given in a closed circle system. Ventilation was being controlled manually. One hour after the induction of anesthesia the patient suddenly bled severely. The pulse rate rose from 84 to 160, while the blood pressure, which had been 110/70, became unobtainable. Cyclopropane was discontinued, and the patient was hyperventilated with 100 per cent oxygen. Whole blood, 1,000 ml., was pumped in over the next 15 minutes, but the blood pressure was still unobtainable, though the pulse rate decreased to 120. At this point the standard anesthesia bag was replaced with the Puritan bag, and the expiratory valve was adjusted until a negative pressure of 3 mm. of mercury was created during expiration. Within 60 seconds the blood pressure was 40/0. To ascertain whether the rise in blood pressure was due to the introduction of a negative phase, the standard breathing bag was again used, and immediately the blood pressure became unobtainable. When this bag was once more replaced by the Puritan bag, the blood pressure almost immediately rose to 60/40. Vasodilator therapy was now instituted and blood replacement continued. When this was adequate, the standard breathing bag was again used without further incident. The patient made an uneventful recovery.

Conclusion

The use of the Puritan (or Ambu) bag as a rebreathing bag in the anesthetic circle would seem to provide a simple, readily available means of manually providing positive-negative pressure ventilation when the anesthetized patient suddenly develops unexpected cardiovascular collapse in the operating room. It may, in fact, provide a temporary, lifesaving support to dwindling cardiac output while definitive therapy is being instituted.

Reference

1. Maloney, J. V., Elam, J. O., Handford, S. W., Balla, G. A., Eastwood, D. W., Brown, E. S., and Ten Pas, R. H.: The importance of negative phase in mechanical respiration, J.A.M.A. 152: 212, 1953.