A DEVICE FOR THE CONTROLLED VENTILATION OF INFANTS AND CHILDREN

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SUMMARY

A self-filling ventilator attachment which will deliver preset volumes from 10 ml to 700 ml is described. It can be operated by most ventilators or by manual inflation. It is a non-rebreathing system and patients can be ventilated with ambient air or anaesthetic gases.

There is a limited choice of paediatric ventilators and most of these are specially designed for neonates and infants and are inadequate for ventilating older children. Most adult ventilators are unsuitable for infants and small children mainly because they are unable to provide the smaller tidal volumes and inspiratory flow rates which are required. Modifications of adult ventilators to make them suitable for paediatric use have drawbacks. The ventilator itself may be converted but this usually means that it is then unsuitable for adult use. A lower inspiratory flow may be obtained by either placing a restriction in series with the ventilator or by disposal of the excess flow through a leak in the circuit or by a dummy lung (artificial compliance and resistance) in parallel with the child's lung. A restriction may only be used with pressure generators and the value of the resistance may be critical. If a dummy lung is used it should have a time-constant equal to the product of the child's lung compliance and airway resistance so that inflation of the child's lungs and the dummy lung occurs simultaneously (Mushin, Mapleson and Lunn, 1962). Changes in the patient's lung compliance and/or airway resistance may require repeated adjustment of these artificial devices in order to maintain steady ventilation.

The central problem in artificial ventilation of infants is related to the administered volume (Okmian, 1966). The minute volume provided should be predictable since its measurement in very small children is difficult (Pask and Lunn, 1965). The Starling animal respiration pump has been used to ventilate infants (Monro and Scrru, 1961) but is limited by an inspiratory-expiratory ratio of 1:1.3 which is greater than that theoretically desirable.

DESCRIPTION

The attachment is a second-stage device designed on the bag-in-bottle principle (figs. 1 and 2) and can be attached to practically any adult ventilator. The volume delivered ranges from 10 ml to 700 ml. The bottle is of clear plastic so the bellows can be seen. The gravity valves (B, C and

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Attachment mounted on adult ventilator. The three gravity valves (B, C, D, see text and fig. 1) are within the circular valve box on the top of the attachment. The bag mount is not shown.

D in fig. 1) are made of Tufnol and can be seen through a perspex valve cover. The rest of the construction is of stainless steel. The bellows are self-filling and the excursion is limited by an adjustable plate with a pointer which indicates the tidal volume on a scale on the side of the bottle. Whatever force is applied in the bottle the set tidal volume cannot be exceeded.

The inlet to the bellows is of \(\frac{1}{2}\) in. (1.9 cm) bore and is fitted with two safety valves (E, F) and a bag mount. To the bag mount should be attached an ordinary anaesthetic reservoir bag of capacity at least equal to the tidal volume. The flow of fresh gases is set to keep this bag full. Any excess gas flow is vented to atmosphere through a preset valve (F). Should the flow of anaesthetic gases fail the inlet safety valve (E) allows ventilation to be continued with ambient air.

The device can be driven manually with a self-inflating bag such as the Ambu. In this case a Ruben or similar valve must be used between the bag and the attachment so that the gases in the bottle may escape to atmosphere during expiration.

**Bellows filling.**

Filling of the bellows only takes place during the expiratory phase of the driving ventilator and is limited by the resistance to gas inflow through the inlet pipe. It also depends on the mass of the bellows disc, the distance through which it has to travel and the fall in pressure within the bottle as the driving ventilator cycles from inspiration to expiration. Filling will be augmented when an expiratory negative phase is used with the driving ventilator. The rate at which the attachment can follow the driving ventilator will depend on the maximum attainable rate of the latter and on the time taken for the bellows to fill with air or gas.
The smaller the patient the higher is the respiratory rate which can be obtained since the smaller tidal volumes required reduce the time needed for filling of the bellows. Using an Ambu bag with Ruben valve to drive the attachment the maximum attainable rate is 160/min at a tidal volume of 20 ml.

**Inspiration (bellows compression).**

The driving ventilator must be set to deliver sufficient air or gas to compress the bellows fully when the device is connected to the patient. Any increase above that required to compress the bellows fully will progressively shorten the inspiratory flow time and will hold the lungs in inflation until the driving ventilator cycles to expiration. In practice the driving ventilator is set to provide more than enough force to compress the bellows and the proportion of the inspiratory time that is allowed for gas inflow to the patient is regulated by the amount of leak allowed at the bottle blow-off valve (A, fig. 1).

**Expiration.**

The change-over from inspiration to expiration occurs when the pressure in the bottle falls and is determined by the cycling of the driving ventilator. The patient’s expirations pass via the expiratory gravity valve (B, fig. 1) into the bottle. The resistance to expiration of this valve is 1 cm H₂O at a flow of 30 l./min. If a negative phase is introduced on the driving ventilator this will be transmitted to the patient. It is unlikely that damage to the lungs could result should too great a negative pressure be applied by accident, since in all positions of the bellows fresh gases or air will be drawn through the system via valves B, C and D, and if the reservoir bag is empty via valve E as well.

The fall in pressure within the bottle is determined by the valves of the driving ventilator. However, should an expiratory valve of the latter stick and so cause a progressive rise in pressure in the bottle there will be, of course, a resistance to expiration. This will be shown on the pressure gauge by failure to return to zero pressure during expiration. The increase in pressure in the bottle will finally keep the bellows compressed and prevent it from filling. No further air or gas can then be forced into the patient; the pressure within the bottle keeps valve B closed and cannot be transmitted to the patient. The final pressure within the patient circuit does not reach dangerous levels. Valve B will withstand a pressure in the bottle of at least 7 lb./sq.in. (500 cm H₂O).

**Cycling.**

The change-over from inspiration to expiration and vice versa is determined by the characteristics of the driving ventilator and the setting of the adjustable valve (A). Although the bellows are self-inflating the expiratory period must not be made shorter than the time necessary for the bellows to fill.

The attachment has been satisfactorily assessed in the laboratory and on neonates, infants, children and adults undergoing surgery. The tidal volumes delivered at low ranges of the scale may be more accurately determined by connecting a graduated syringe to the patient’s end of the tubing and compressing the bellows. This test will also allow for the compressible volume of the patient circuit if it is performed at the same pressure which is to be used for inflation of the lungs. The compressible volume may be kept small by using plastic tubing.* Due allowance should be made for leaks around the endotracheal tube during inflation and so a volume somewhat greater than that predicted may need to be delivered. The pressure gauge will indicate whether pressures higher than desired are being developed. If the driving ventilator is itself driven by anaesthetic gases an alternative source will be required if the attachment is to be used during anaesthesia.

During spontaneous breathing the driving ventilator must be disconnected from the attachment. The bellows will remain stationary. The resistance to inspiration of valves C and D together is 0.5 cm H₂O at a flow of 30 l./min. The attachment may be sterilized by chemical or physical methods. If a Ruben or similar valve is used between the driving ventilator and the attachment, bacterial contamination of the driving ventilator is prevented. Manual operation of the attachment by a self-inflating bag and Ruben valve enables inexperienced persons to

* Size H.E.25, Portland Plastics Ltd., Hythe, Kent.
CONTROLLED VENTILATION OF INFANTS AND CHILDREN

take over the ventilation of patients since the preset tidal volume cannot be exceeded.

The ventilator attachment described is now marketed as the Cape Universal Ventilator Attachment by Cape Engineering Ltd., Warwick.

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REFERENCES

CORRESPONDENCE

None were rejected because of their physical status. Our method was to prepare the patients by giving them acetazolamide 500 mg the evening before operation and 250 mg on the morning of operation to ensure low intra-ocular tension. This premedication was omitted in later patients in the series. Ninety minutes or more before operation dehydrobenzperidol 5 mg was injected intramuscularly. They also had local anaesthetic and mydriatic drops instilled into the eye before proceeding to the theatre. On arrival in the theatre a Gordh needle was placed in a vein in the dorsum of the left hand, and a blood-pressure cuff placed on the left arm. The pressure was taken by auscultation, before proceeding, and at frequent intervals thereafter. Phenoperidine was then injected slowly through the Gordh needle in increments of 0.5 mg and flushed through with saline. The dose was judged to be sufficient when the respiratory rate dropped to about 10 b.p.m., or the speech became slurred, or the patient became very drowsy. This induction dose varied from 1 to 2.5 mg. Most patients received 1.5 mg. The surgeon then prepared the patient and produced akinesia by one of the standard methods. Retrobulbar block was not used in any patient and no other injection of local anaesthetic was given. Akinesia was omitted in later patients in the series. Surgery then proceeded. Respiratory adequacy was judged by the somewhat crude method of observing the movements of chest and abdomen. At the conclusion of the operation the Gordh needle was withdrawn and the patient was returned to the ward, where vital signs were closely watched by a nurse.