Resuscitation of the Newborn

AN IMPROVED NEONATAL RESUSCITATOR

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SUMMARY

Insufflatory resuscitation of a newborn baby that has not breathed presents many problems. These are dependent not only on the size and prematurity of the neonate, but on the amount of fluid which is present in the alveoli of the lungs, and the absence of the functional residual capacity (FRC). Before adequate gaseous exchange can take place the fluid must be driven out of the alveoli and the FRC established. Transpulmonary pressures as high as 80 cm H_2O may be necessary. This places a unique demand on a resuscitator which can be used safely at birth. It must be able to achieve such pressures without injuring the lungs; yet once the FRC has been established, it must be able to adapt itself to the differing ventilatory requirements, without altering the blood chemistry of the neonate.

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CLINICAL SIGNIFICANCE

Insufflatory resuscitation of all subjects, including neonates who have already breathed, presents few problems. This is mainly due to the functional residual capacity (FRC) which gives the lung its spongy consistency. In order to restore normal gaseous exchange only comparatively low pressures (6 - 10 cm H_2O) need be applied to the bronchial tree—irrespective of the size of the subject. This is easily accomplished by squeezing a rubber bag intermittently, 20 - 40 times per minute, and inflating the lungs with a volume of gas approximating the tidal air of the subject. The smaller the subject, the quicker the ventilations.

In actual practice, since resuscitators currently in use do not incorporate a pressure gauge, the degree of ventilation is determined by the 'educated eye' and the 'educated hand'. The eye observes the expansion of the thoracic cage while the hand gauges the pressure by 'feeling' the bag when it is compressed.

However, resuscitation of neonates that have *not* breathed is an entirely different matter and is potentially dangerous. It has been well documented that a good deal of neonatal morbidity and mortality can be ascribed to the grave effects of excessive hyperventilation of the lungs. Underventilation can also be indicted.

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These hazards are associated with the inescapable fact that the lungs of a neonate who has not breathed are entirely different from those of one who has already breathed. Instead of possessing the FRC the alveoli contain fluid. Before adequate gaseous exchange can take place this fluid must be forced out of the lungs. Furthermore, the pressure which is required to initiate respiration is proportionately dependent on the amount of FRC in the alveoli. Since there is no FRC, greater pressure will be necessary.

To overcome these factors transpulmonary pressures as high as 80 cm H_2O may be required, especially in small prematures.[1] But, in order not to damage the terminal bronchioles, which are not protected by the fluid, these high pressures must be of extremely short duration.[2]

Since there can be practically no movement of the thoracic cage while the fluid is being expelled and the FRC initiated, the 'educated eye' is of little aid in a situation such as this. Nor would the hand be able to gauge a few cubic centimetres of gas subjected to a pressure of 80 cm H_2O. The truth of the matter is that these methods could be dangerous if applied to a neonate who has not breathed.

Pulmonary resuscitation of such a neonate therefore places a unique demand on a resuscitator which can be safely used at birth. In order to provide adequate transpulmonary pressure it must be able to generate even higher pressures to compensate for the loss of pressure resulting from the ballooning of the cheeks, and from gas which may be forced into the stomach when a face-piece is used. Similarly, it will have to overcome the loss of pressure set up by the endotracheal adapter and tube if the trachea is intubated. And finally, once the FRC has been established, the resuscitator must be able to adapt itself to the smaller pressures which become necessary, yet maintain adequate ventilation without disturbing the blood chemistry of the neonate.

THE APPARATUS

The resuscitator described here overcomes the difficulties listed above. But, in order to accomplish this effectively, the bellows must be compressed fully and as often as possible. This has been preset to cycle at 60 ventilations per minute. By so doing, a maximum pressure of 200 - 230 cm H_2O can be generated in less than one-third second. Since the narrow lumen of the endotracheal adapters and tubes which are used in neonatal resuscitation are capable of setting up resistances of $\pm$ 100 cm H_2O, there is still available adequate pressure to deal effectively with the bronchial tree.

To obtain these high pressures practically all the contents of the bellows may have to be forced through the escape pressure vent. However, as more alveoli are cleared of fluid, more gas can enter the lungs and less is forced through the vent. Smaller pressures therefore become progressively less until the FRC has been fully established.

Similarly, the resuscitator can adjust itself to the ventilatory requirements of different thoracic capacities. The smaller the neonate, the greater the pressure required to insufflate the lungs (this is an application of La Place's law), but more gas will be forced through the escape pressure vent and less gas will reach the lungs than in a larger neonate.

The resuscitator (Fig. 1) consists of a polypropylene accordion-like bellows (capacity 100 cm^3) which is attached to a clear polystyrene valve assembly which terminates in a taper. This fits the universal 22-mm face-piece aperture. The universal 15-mm endotracheal adapter, as well as a special 5-mm adapter (this is supplied with the unit) fits into the taper (Fig. 2). The other end houses a valve which embodies the attachment for supplementary oxygen. The valve consists of a purple disc which is firmly pressed into its seat when the bellows are compressed. This prevents the gases escaping through the air vents in the seat (Fig. 3) and also through the lumen of the oxygen limb which is attached to the back of the seat. The gases are therefore directed towards the respiratory passages.

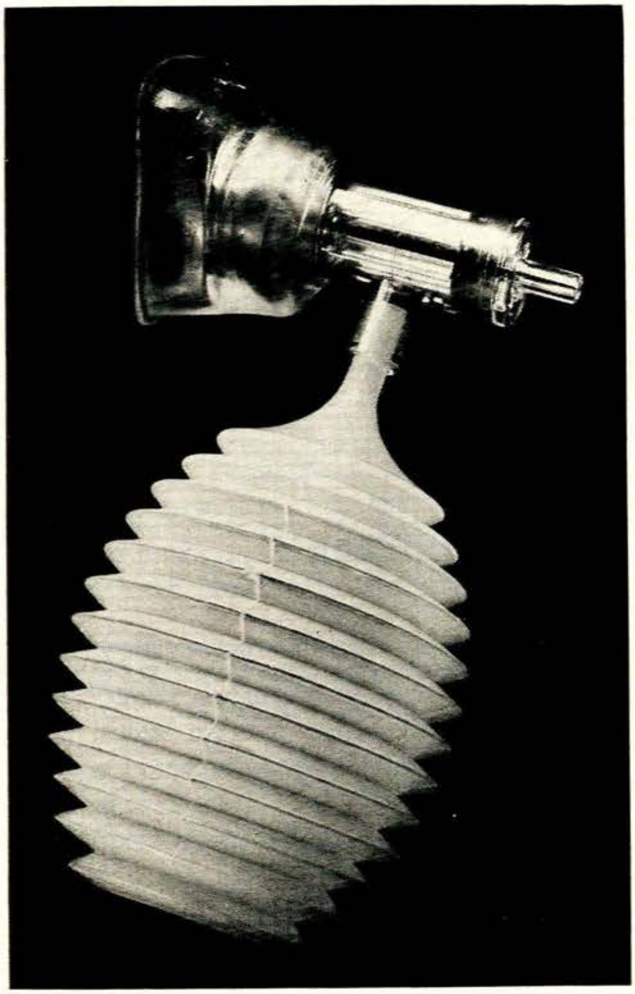

Fig. 1. See text.

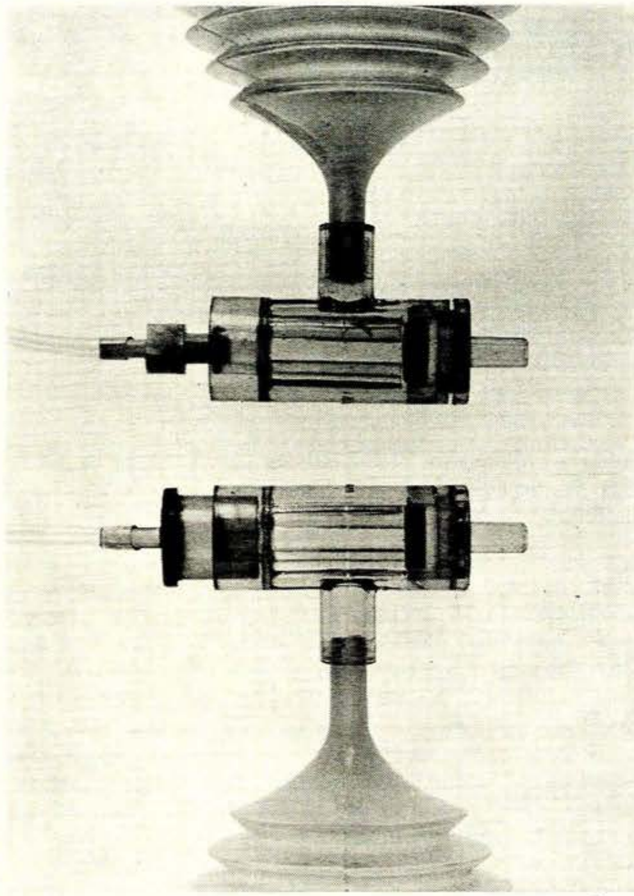

Fig. 2. See text.

Just above the horizontal attachment for the bellows is a small aperture (Fig. 3). This is an escape pressure vent. It provides continuous pressure relief during insufflation and also permits fresh air intake as the bellows refill. Fresh air is also sucked in through the air vents in the valve seat as the negative pressure exerted by the bellows lifts the disc. Since there is no non-rebreathing valve the exhaled gases are also sucked into the bellows as they re-inflate.

After a typical ventilation 20% of the volume of the filled bellows will consist of exhaled air. The remaining 80% will be air from the ambient atmosphere, or air supplemented with oxygen. However, there is no possibility of either CO_2 intoxication or alkalosis occurring. The combination of hyperventilation and the rebreathing maintains normal blood levels of CO_2, provided the simple instructions of compressing the bellows fully and as often as pos-

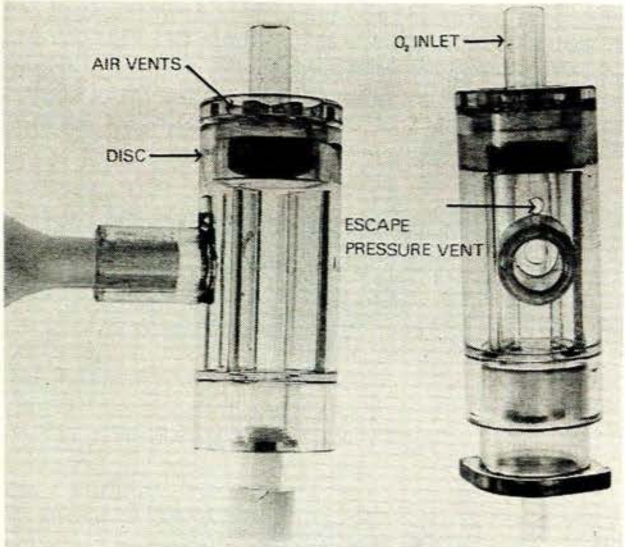

Fig. 3. See text.

sible are adhered to. This has been substantiated by a trial series in the USA[3] and widespread use in South Africa and the UK.

There should also be no apprehension about damage to the lungs. The capacity of the bellows and the size of the pressure escape vent are critical factors preventing this. However, to avoid underventilation when a face-piece is used, an airway should not be inserted. This may prevent the face-piece fitting correctly. In any case the tongue of a newborn baby never falls back.

Oxygen Supplementation

This is fool-proof. A 3 - 6 litre per minute flow through the oxygen attachment will enrich the mixture to 75 - 80% oxygen without disturbing the pressures. If excessively high volumes of oxygen are inadvertently administered, only insignificant changes in pressure become manifest. Any substantial increase is prevented by the limited clearance between the disc and its seat. The excess oxygen will be deflected from the face of the disc and vented through the air holes in the seat into the ambient atmosphere.

The resuscitator is supplied with a face-piece and an endotracheal adapter with tube. They are all sterilised and disposable.

REFERENCES

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3. Kirby, R. R. Personal communications.