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A simple strategy to improve first breath oxygen delivery by self inflating bag

Kishore S. Agarwal *, Jacob M. Puliyel

Department of Paediatrics and Neonatology, St. Stephen's Hospital, Tis Hazari, Delhi-110054, India

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Abstract

The text book of Pediatric Advanced Life Support of the American Heart Association recommends that a reservoir is used with a self inflating bag valve device. The figure in the book suggests that if such a device is connected to an oxygen supply, the oxygen will fill the bag first and then go on to fill the reservoir. However the valve structure of the self-inflating device does not permit active entry of oxygen into the bag, unless the bag is deflated and allowed to reinflate, drawing oxygen from the reservoir. We did this study to test the concentration of oxygen delivered in the first few breaths with the help of a Miniox-III oxygen monitor probe (MSA Medical Products, Pittsburgh, PA 15230) inserted into a self inflating bag (AMBU). Twenty-one percent oxygen is delivered with first breath and it rose to 42 and 58% with the second and third inflations, respectively. Eighty percent oxygen was achieved after eight reinflation cycles. We developed a formula to calculate the concentration of oxygen in the bag after each inflation effort, assuming that there was no passive diffusion of oxygen. We suggest that compressing the bag 8–12 times prior to putting the mask to the face of the patient will allow 80% oxygen to be delivered with first breath.

Keywords: Bag-valve-mask; Oxygen; Neonatal resuscitation; Pediatric resuscitation

1. Introduction

The American Heart Association and American Academy of Pediatrics in their Text Book of Pediatric Advanced Life Support [1] and Neonatal Resuscitation [2] recommend that all newborn babies who require positive pressure ventilation at birth, be resuscitated with high concentrations of oxygen, using either continuous flow into an anaesthetic bag or a self-inflating bag with reservoir. When a self-inflating bag is used with a reservoir and oxygen, 90–100% oxygen is delivered. This study was done to check the oxygen delivered during the first few breaths using an Ambu bag, as a prototype of self-inflating bags, as it was realized that there is an error in the way the gas flow is depicted in the diagram of the textbook.

2. Material and methods

The probe of a Miniox-III oxygen monitor (MSA Medical Products, Pittsburgh PA 15230) was inserted into a 450 ml Ambu bag, as shown in Fig. 1. A corrugated reservoir (100-ml) was attached. The Miniox was calibrated in air as recommended by the manufacturer. Oxygen flowing at 5 l/min was connected to the oxygen inlet port. The volume of air expelled with each compression of the bag was collected and measured by the displacement of water. The apparatus required for the study was rigged up locally.

The bag was compressed to expel 50 ml of gas and then allowed to reinflate. The oxygen concentration recorded on the Miniox-III monitor was

* Corresponding author. Tel.: +91-11-3966021; fax: +91-11-3932412.

E-mail address: puliyel@vsnl.com (K.S. Agarwal).

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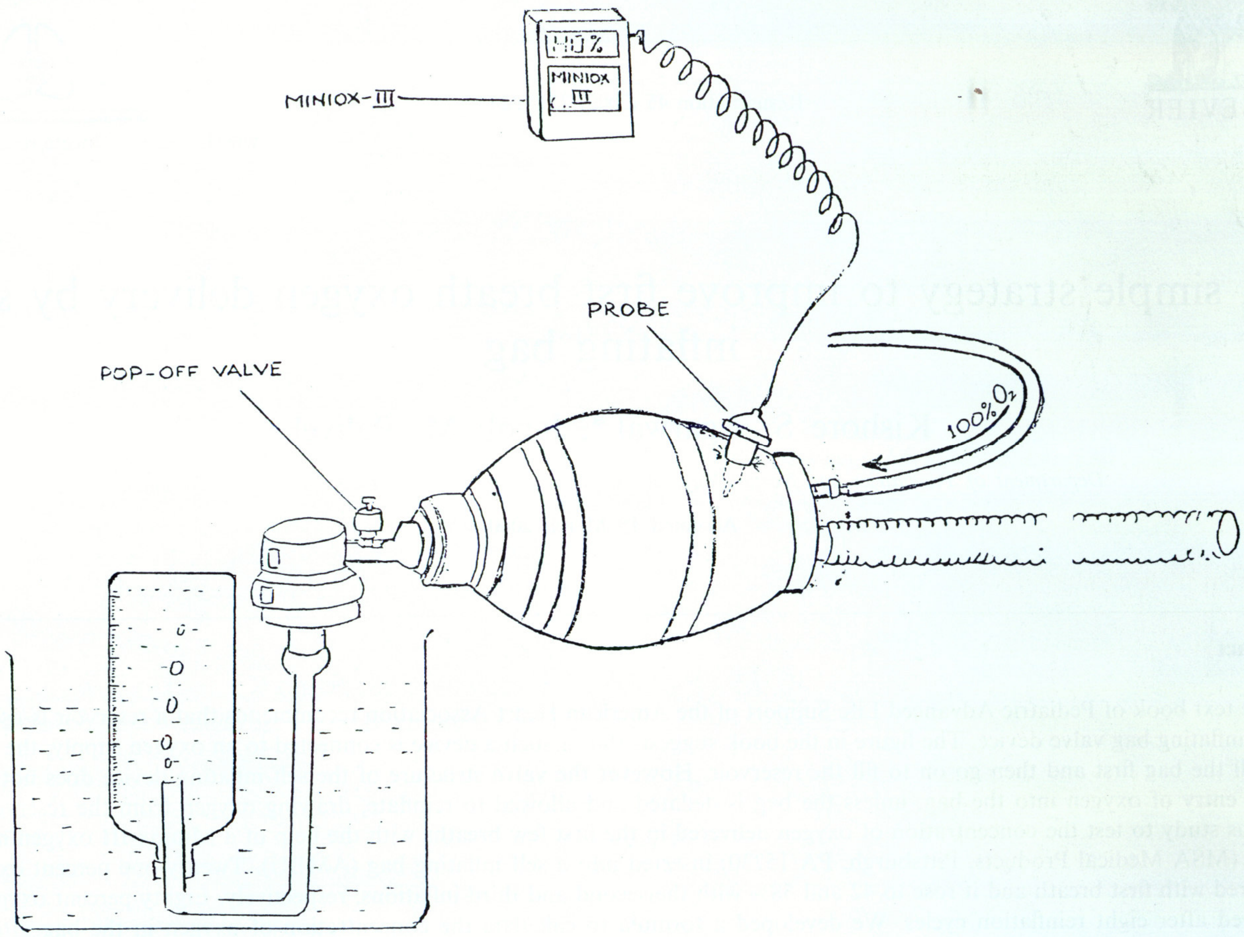

Fig. 1. Apparatus used in experiment.

noted. As this meter requires 30 s to record oxygen saturation, 30 s were given between compressions to allow it to register the new oxygen concentration. The process was continued until there was no further rise of oxygen concentration in the bag.

The whole experiment was repeated three times. The mean of three readings was taken.

3. Results

The mean concentration of oxygen in the bag after each compression is shown in the bar diagram (Fig. 2). The first breath delivers air with 21% oxygen. The oxygen concentration in the bag rose slowly and reached 80% after eight compressions.

4. Discussion

There has been controversy about the use of 21 versus 100% oxygen in the resuscitation of preterm babies [3]. However the consensus at present is that there is insufficient data to recommend changes to current guidelines of using 100% oxygen [4].

The textbook of Pediatric Advanced Life Support describes how this is to be delivered. Fig. 3 is a reproduction of the diagram given in the textbook of Pediatric Advanced Life Support [1] of the American Heart Association and the American Academy of Pediatrics. The figure in the textbook

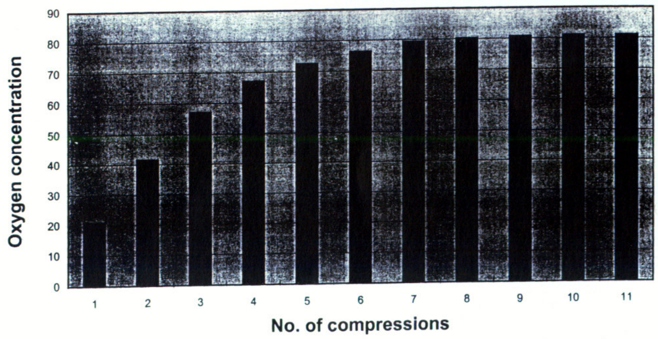

Fig. 2. Rise in oxygen concentration after each compression.

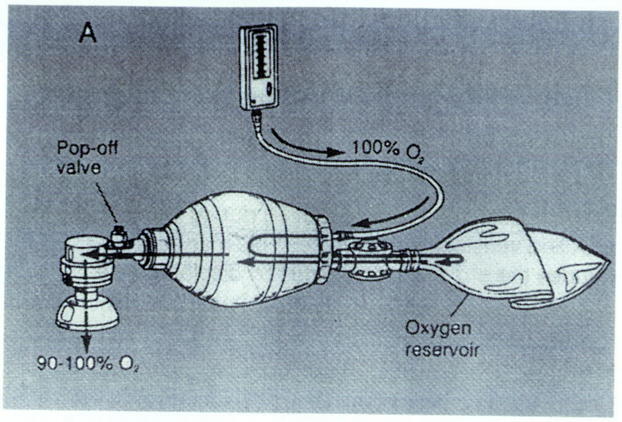

Fig. 3. Reproduction of the diagram given in the textbook of Pediatric Advanced Life Support of the American Heart Association and the American Academy of Pediatrics.

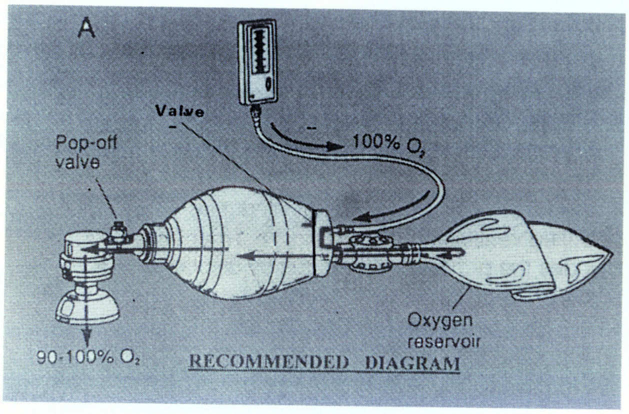

Fig. 4. The inlet valve of the Ambu bag directs oxygen into the reservoir.

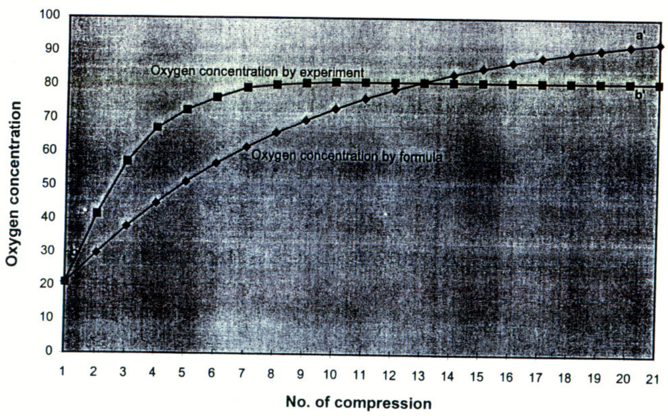

Fig. 5. Oxygen concentration achieved after experiment and calculated by formula.

of Neonatal Resuscitation [2] is also similar in its essentials. It gives the impression that oxygen from the oxygen inlet directly enters the bag and then goes out to fill the reservoir. This is not correct. The inlet valve of the Ambu bag directs oxygen into the reservoir as shown in Fig. 4. Oxygen enters the Ambu bag after compression, during re-inflation from the reservoir and oxygen inlet source.

If a 450 ml Ambu bag is used and is compressed to deliver 50 ml air to the neonate, it will draw in 50 ml oxygen on re-inflation to replace the air expelled. This oxygen is diluted in the 400 ml of residual air in the Ambu bag. The concentration of oxygen in the bag rises in a steady graded manner with each compression (until a maximum concentration is achieved).

If the assertion above is true then the rise of oxygen in the bag after '*n*' compression–reinflations can be calculated by the mathematical formula.

$$A_n = 100 - [(100 - A_0)\ (1 - Y/X)^n]$$

where A_n is the concentration of oxygen after n number of compressions, A_0 is the concentration of oxygen at the start of procedure (usually 21%), X is the capacity of self-inflating bag (450 ml) and Y is the volume of air expelled after each compression (50 ml).

The curve aa′ (Fig. 5) shows the theoretical rise of oxygen in the bag using the above formula. This matched the observed rise of oxygen (curve bb′) achieved in our experiment. The maximum oxygen concentration achieved in the experiment was 80%. The mathematical model assumes that only 50 ml 100% oxygen enters the bag each time when the bag reinflates and that there is no leaking of oxygen into or out of the bag. In practice, oxygen leaks from the reservoir into the bag, when the concentration of oxygen in the bag is low. This is the explanation for the higher observed values noted in the experiment than the theoretical values (see curve). At higher concentrations of oxygen in the bag, oxygen leaks outwards and the highest concentration achieved in the bag, in this experiment, was 80%. The leak into and out of the bag is exaggerated by the lag period of 30 s given between compression (for the Miniox to record the new oxygen level). Greater conformity to theoretical values can be expected if the bag is compressed in quick succession, as in a real life emergency situation. Eighty percent oxygen saturation is achieved after 12 compressions according to the formula. This formula can help predict the oxygen delivered by any size of bag, if the volume of the bag, and the gas expelled, in each compression, is known.

Our experiment suggests that the diagram in the textbook should be altered to improve the illustration of the function of the inlet valve system. It also follows that to prime the bag with oxygen it may be compressed 8–12 times prior to application to the baby. It must be done during the immediate preparation stage, before the arrival of the asphyxiated baby. This will enable 80% oxygen to be delivered with the first breath.

The concept in the modified picture will also help explain, the text book of Neonatal Resuscitation [5]: "If the bag has an open end reservoir, the oxygen will seek the route of least resistance and flow out of the end of the reservoir, with little, if any, oxygen going through the valve assembly to the patient".

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