Original article

Comparison of FDO_2 at different flow rates in an adult manual resuscitator with and without reservoir bag: A manikin study

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Abstract

Background: Manual resuscitators are used to manually assist or provide positive pressure breaths during cardiopulmonary resuscitation, suctioning and intrahospital transport. However, the fraction of delivered oxygen (FDO_2) through these devices with different flow rates varies. **Aim:** To study the FDO_2 with manual resuscitator under different conditions. **Methods:** An adult manikin was intubated with 8 mm ID endotracheal tube and ventilated using an adult manual resuscitator. An oxygen analyser was connected between endotracheal tube and the manual resuscitator. The variables included with or without reservoir bag (RB), manual ventilation at 12 or 20 breaths/min and use of one or two hands while the FDO_2 was measured with oxygen flow rates at 2, 4, 6, 8, 10, 12 and 15 (L/min). **Results:** The maximum FDO_2 delivered was 95.3% and 97.6% with RB using one hand and two hands respectively. At ≥ 10 L/min flow, FDO_2 was >90% with RB. At 2 – 4 L/min flow, the FDO_2 was <60% with RB and 25-40% without RB. FDO_2 was slightly higher with ventilation at 12 bpm than with 20 bpm. The effect of one- or two-handed ventilation was variable. **Conclusion:** With the use of a reservoir bag along with the manual resuscitator at an oxygen flow rate above 10 L/min, FDO_2 > 90% can be consistently delivered irrespective of single or both handed breath delivery or the ventilator rate. Without the use of reservoir bag, irrespective of other conditions, it is not possible to deliver FDO_2 > 60% with a manual resuscitator.

Keywords: Manual resuscitator, delivered oxygen concentration, oxygen flow rate.

Introduction

Manual resuscitators (MR) are handheld devices used to manually assist a patient's breathing. These devices are commonly used during cardiopulmonary resuscitation, suctioning and intrahospital transport of patients who require assisted breathing. Oxygen is delivered through a flowmeter and tubing to the MR. Disposable MR was first introduced in the United States in 1985.[1] Since then, many new MRs differing in style from each other have been marketed. Several studies have documented the differences in performance of various MRs in various clinical settings with respect to the fraction of delivered oxygen (FDO_2).[2] Daniel G *et al* bench-tested 16 adult disposable manual resuscitators from nine different manufacturers and found that FDO_2 was significantly affected by reservoir style and the manufacturer design.[3] Barnes TA *et al* studied the FDO_2 variability in 10 different adult MRs with or without the use of RBs. They found that the FDO_2 was ≥ 85% when

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a reservoir bag (RB) is used while the FDO_2 was ≥ 40% without the use of the RB when the oxygen flows were at 15 L/min.[4] They then evaluated these across an operational temperature range of -18° C to 50° C and obtained similar result.[5]

The aim of this study was to determine the FDO_2 using a manual resuscitator at different oxygen flow rates with and without the use of a reservoir bag as well as with one handed and two handed manual ventilation.

Methodology

An adult manual resuscitator (VBM, Medizintechnik GmbH, Germany) of 2000 mL volume was used for the study. An adult manikin (Laerdal R, Airway management trainer, Laerdal Medical, Norway) was used for the study. This manikin was intubated with an 8.0 mm ID endotracheal tube and ventilated using the manual resuscitator. An oxygen analyser (Inmed, Inmed Medicals, Vadodara, India) was placed between the endotracheal tube and the manual resuscitator to measure the FDO_2. A 2-point calibration of the oxygen analyser was done between each trial. An oxygen cylinder (H type) and an oxygen flow meter were used to provide the desired oxygen inflows. A reservoir bag of 2600 mL volume (VBM, Medizintechnik GmbH, Germany) was used.

The FDO_2 delivered by the manual resuscitator (MR) under different simulated clinical conditions with varying oxygen flow rates of 2, 4, 6, 8, 10, 12 and 15 (L/min) were measured. The FDO_2 was measured at two different breath rates (12 or 20 per minute) with or without the use of the RB while manual ventilation was provided either using one handed or two handed technique. The FDO_2 once stable over five consecutive breaths, was recorded. A stop watch was used for delivering timed respiratory rate.

The test was repeated thrice for each oxygen flow and the average of three was taken for analysis. One single individual provided the manual breaths in whole study to minimise the variability in delivered tidal volume that could be created by different hand sizes.

Results

The maximum FDO_2 delivered was 95.3% and 97.6% at 15 L/min flows with oxygen flow rate of 15 L/min, respiratory rate of 12 breaths/min, the use of RB using one handed and two handed manual breath delivery respectively (*Table 1*). With a flow ≥ 10 L/min, the FDO_2 was > 90% with the use of a RB irrespective of ventilator rate and one or two handed breath delivery. Without the use of RB, the FDO_2 was always < 60% with all flow rates and irrespective of one or two handed breath delivery.

With an oxygen flow rate of 2 L/min and respiratory rate of 12/min, the fraction of delivered oxygen obtained dropped to 47% with RB and 28% without RB when two hands were used for providing manual breaths. While it reduced to 45.6% with reservoir bag, it increased to 33% without reservoir bag with one-handed technique. With a respiratory rate of 20 breaths/min and a flow of 2 L/min, the FDO_2 was 40.3 and 27.6% respectively using one handed breath delivery. Using both handed breath delivery, the FDO_2 was further reduced to 37% and 25.3% respectively (*Table 1*).

The FDO_2 with all the flow rates in the study, with both one and two handed breath delivery techniques with or without the use of RB at a breath rate of 12 /min is shown in *Figure 1* and 20 /min is shown in *Figure 2*.

Discussion

FDO_2 is the most important variable with the use of manual resuscitators as this gets significantly affected by presence or absence of the reservoir bag and the oxygen flow rates. In the study, the maximum FDO_2 was delivered when the reservoir bag was used with two handed ventilation (97.6%) at 15 L/min oxygen flow rate. The FDO_2 also was found to increase with a lower respiratory rate (12/min) than with a higher respiratory rate (20/min).

Previous studies also found that FDO_2 varied significantly with variation in the oxygen flow rate and connection of reservoir bag.[9-11]" Clinical practice guidelines issued from the American Association for Respiratory Care for resuscitation in acute care

Table 1: FDO_2 for different variables during the study

Methods	Flow of 2L/ min		Flow of 4L/ min		Flow of 6L/ min		Flow of 8L/ min		Flow of 10L/ min		Flow of 12L/ min		Flow of 15L/ min	
	RR 12	RR 20	RR 12	RR 20	RR 12	RR 20	RR 12	RR 20	RR 12	RR 20	RR 12	RR 20	RR 12	RR 20
With RB 1 hand	45.6	40.3	61	52.3	87.6	78.3	90	86	91.3	90	92.3	95	95.3	94.6
With RB 2 hand	47	37	60	49	83.3	72	89.6	84.6	93.6	93	95	95	97.6	93
Without RB 1 hand	33	27.6	29.6	34.6	47.6	37.6	49.6	38.3	49	37.3	57.3	44.6	56.6	44.6
Without RB 2 hand	28	25.3	31.6	30.6	37.6	38	57.3	34	54.3	41	48.3	43.6	56.3	47

hospitals states that, "manual resuscitators must be capable of providing an FDO_2 of 1.0 even when large volumes are delivered."[12] The specifications of the American Society for Testing and Materials and the International Organisation for Standardisation call for a FDO_2 of at least ≥ 85% when a RB is in place when a delivered tidal volume is 0.6 L with the oxygen flow set at 15 L/min. This study confirms that FDO_2 of ≥ 85% will be delivered with the use of RB at flows ≥ 8L/min. However, formal evaluation of change in FDO_2 with change in tidal volume was not done. An attempt to simulate clinical scenario was made by comparing one handed and two handed manual breath delivery. The effect of two handed breath delivery on the FDO_2 as compared to one handed breath delivery was found to be variable although the person who delivered these breaths was constant throughout the study.

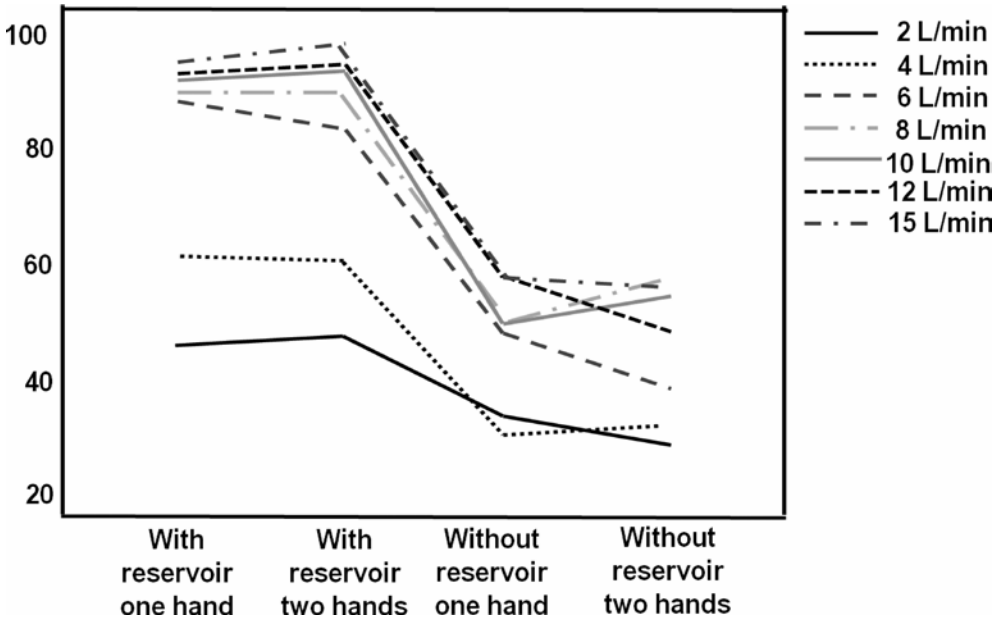

Figure 1: Delivered oxygen concentration at different flow rates of oxygen and with one and two handed ventilation at a manual respiratory rate of 12 breaths/min.

FDO_2 for 20 breaths per minute

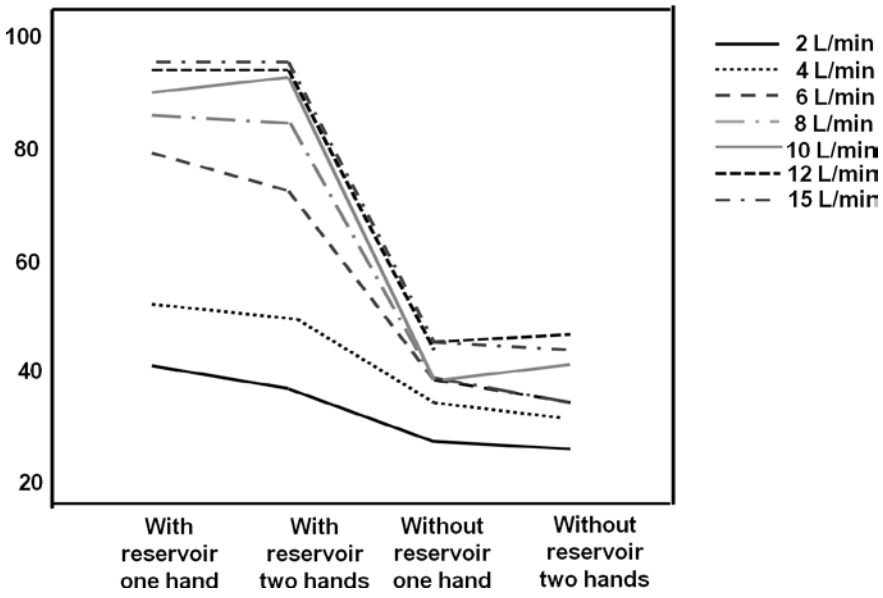

Figure 2: Delivered oxygen concentration at different flow rates of oxygen and with one and two handed ventilation at a manual respiratory rate of 20 breaths/min.

Conclusion

With the use of a reservoir bag along with the manual resuscitator at an oxygen flow rate above 10 L/min, FDO_2 > 90% can be consistently delivered irrespective of single or both handed breath delivery or the ventilator rate. It is not possible to deliver 100% oxygen using manual resuscitator even when it is used with a reservoir bag at the highest flow rate (15 L/min) at a respiratory rate between 12-20/min. Without the use of reservoir bag, irrespective of other conditions, it is not possible to deliver FDO_2 > 60% with a manual resuscitator.

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