Yonsei Medical Journal
Vol. 42, No. 2, pp. 242 - 246, 2001

The Changes in Delivered Oxygen Fractions Using Laerdal Resuscitator Bag with Different Types of Reservoir

Soon-Ho Nam, Ki-Jun Kim, Yong-Taek Nam, and Jae-Kwang Shim

Department of Anesthesiology, Yonsei University College of Medicine, Seoul, Korea.

One of the disadvantages of the Laerdal resuscitator bag is that it does not deliver a high concentration of oxygen without a reservoir and an appropriate technique of ventilation. With a specific device that is able to compress a resuscitator bag mechanically at a regular volume, ventilator rate, and speed, we evaluated the effects of various factors (the tidal volume, the ventilator rate, the oxygen flow rate, the type of reservoir) of the Laerdal resuscitator bag during positive pressure ventilation that affect the delivered oxygen fraction (F_DO_2) and also whether 250 mL and 500 mL corrugated tubes could be used as substitutes for the reservoir bag. The 250 mL corrugated tube increased the F_DO_2 to over 96% with an oxygen flow rate of 15 L/min. The 500 mL corrugated tube increased the F_DO_2 to over 96% with an oxygen flow rate of 10 L/min regardless of the ventilator rate at a fixed tidal volume of 500 mL. At the identical fixed tidal volume of 500 mL, the 1600 mL reservoir bag increased the F_DO_2 to over 92% with an oxygen flow rate of 5 L/min and to over 96% at 7.5 L/min regardless of the ventilator rate. We concluded that the F_DO_2 of the Laerdal resuscitator bag depends on various factors such as tidal volume, ventilator rate, oxygen flow rate, and type of reservoir and both the 250 mL and 500 mL corrugated tubes can be used as substitutes.

Key Words: Oxygen fractions, laerdal resuscitator bag, reservoir, corrugated tube

INTRODUCTION

In the emergency room or intensive care unit, a high oxygen fraction is often required during positive pressure ventilation with a resuscitator bag to prevent hypoxia and increase tissue oxygenation during cardiopulmonary failure.[1] The currently used resuscitator bags can not deliver a high enough oxygen fraction without a reservoir or specific technique during positive pressure ventilation.[2] The variables affecting the oxygen fraction are the presence of a reservoir,[3] the ventilator rate and the refilling time of the bag.[4] There are some studies reported on the delivered oxygen fraction (F_DO_2),[2,3-6] but they were mainly based on the tests of ventilating lung manually. Therefore, a specific device which enables a resuscitator bag to be compressed mechanically at regular intervals was designed and the F_DO_2 of the Laerdal resuscitator bag was measured according to the changes in tidal volume, ventilator rate, and minute volume. This study was performed with and without reservoir bag, and with corrugated tubes.

One of the main objectives of this study was to evaluate the effects of various factors (the tidal volume, the ventilator rate, the oxygen flow rate, the type of reservoir) of the Laerdal resuscitator bag during positive pressure ventilation that affect the F_DO_2. Another objective was to determine whether 250 mL and 500 mL corrugated tubes could be used as substitutes for the reservoir bag.

MATERIALS AND METHODS

A Laerdal resuscitator bag (Laerdal silicone resuscitators®, Laerdal Co., Stavanger, Norway) airtight in a wooden box, which can also be connected to an anesthetic machine ventilator (Dameca DK 2610, Copenhagen, Denmark). The non-rebreathing valve, intake valve and the nipple for the Laerdal resuscitator bag oxygen tubing were exposed. An oxygen analyzer (Puritan Bennett 7820 oxygen monitor, PB, CA, USA) and a spirometer (Boehringer, Ingelheim, CT, USA)

Received October 5, 2000
Accepted February 8, 2001

was attached between the non-rebreathing patient valve and the test lung (DLL, Michigan Instruments, Grand Rapids, MI, USA). The nipple for oxygen tubing was connected to the wall oxygen source. For regular compression of the self-refilling ventilation bag, the sealed wooden box was connected to the bellows of the anesthetic machine ventilator (Fig. 1, and 2) and the inspiration:expiration ratio was fixed at 1:2.

To observe the effects of each of the variables affecting the F_DO_2, the corresponding F_DO_2 was measured whilst altering each of the variables (tidal volume, ventilation rate per minute, minute volume, oxygen flow rate, 1600 ml reservoir bag, 250 ml and 500 ml corrugated tubes). Prior to each F_DO_2 measurement the oxygen analyzer was calibrated at room air for 5 minutes. When the F_DO_2 reached a plateau at each supplemental oxygen flow rates, the corresponding F_DO_2 was measured.

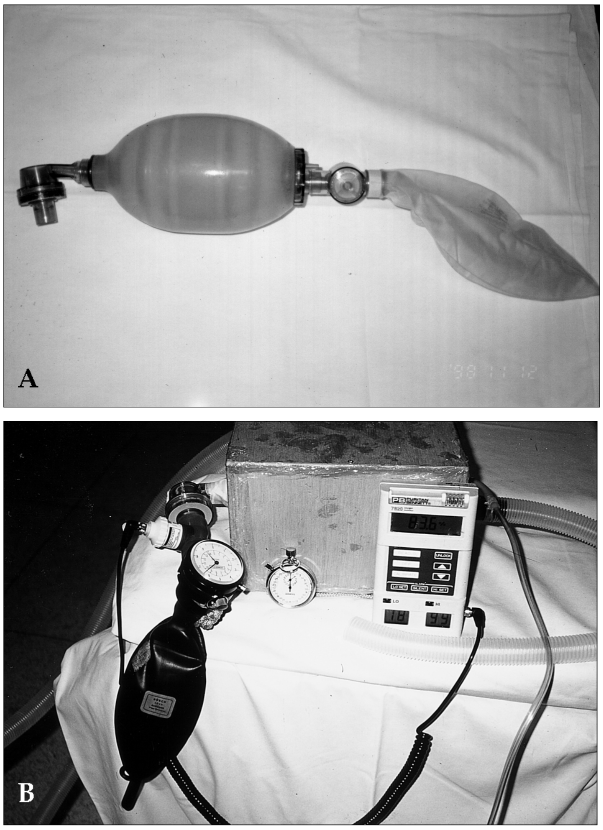

Fig. 1. The Laerdal resuscitator bag (A) and the sealed wooden box which encompasses the Laerdal resuscitator bag connected to a test lung, a spirometer and an oxygen analyzer (B).

RESULTS

The corresponding F_DO_2 according to the changes of the tidal volume and the ventilator rate at a fixed minute volume (5000 mL) (Fig. 3)

Without a reservoir bag or a corrugated tube, the F_DO_2s measured were 49%, 55%, 60%, 65% and 69% at oxygen flow rates of 5 L/min, 7.5 L/min, 10 L/min, 12.5 L/min and 15 L/min respectively. When using a 250 mL corrugated tube, the corresponding F_DO_2s were 89%, 95%, 96% and over 96% with oxygen flow rates the same as above. With a 500 ml corrugated tube, the corresponding F_DO_2s measured were 91%, 96% and over 96% at oxygen flow rates of 5 L/min, 7.5 L/min and over 10 L/min respectively. When a reservoir bag was used, the F_DO_2s measured were over 92% and over 96% at oxygen flow rates of 5 L/min and over 7.5 L/min respectively.

The F_DO_2 as a function of the ventilator rate at a fixed tidal volume (500 mL) (Fig. 4)

Without a reservoir bag or a corrugated tube, the F_DO_2 progressively decreased as the ventilator rate was increased. As the oxygen flow rate was increased, the F_DO_2 progressively increased. However, even though the oxygen flow rate was increased to 15 L/min the corresponding F_DO_2

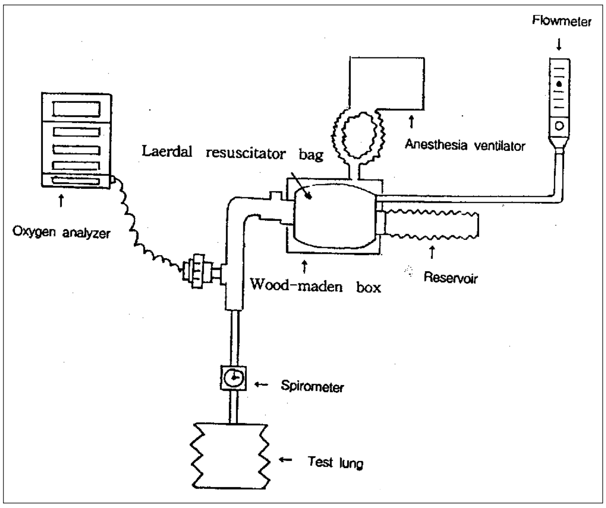

Fig. 2. Schematic drawing of the sealed wooden box with its connection to a test lung, a spirometer, an oxygen analyzer and a bellow of an anesthetic machine ventilator.

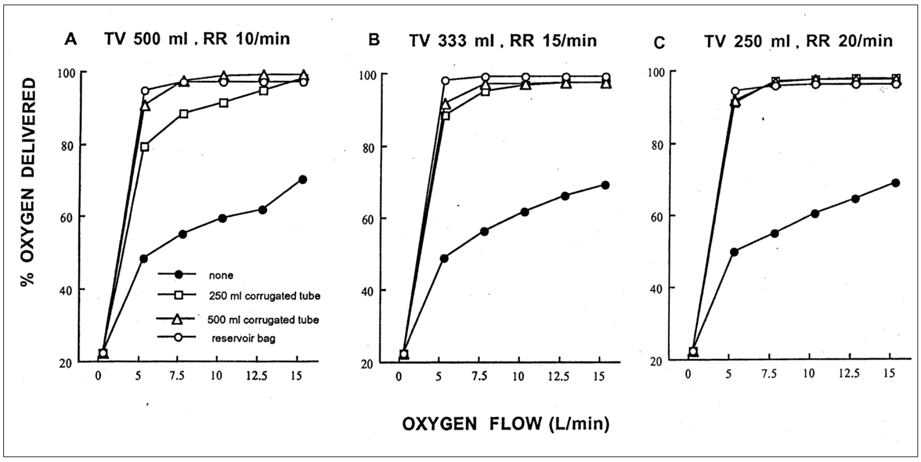

Fig. 3. The corresponding F_DO_2 according to the changes of the tidal volume and the ventilator rate per minute at a fixed minute volume (5000 mL).

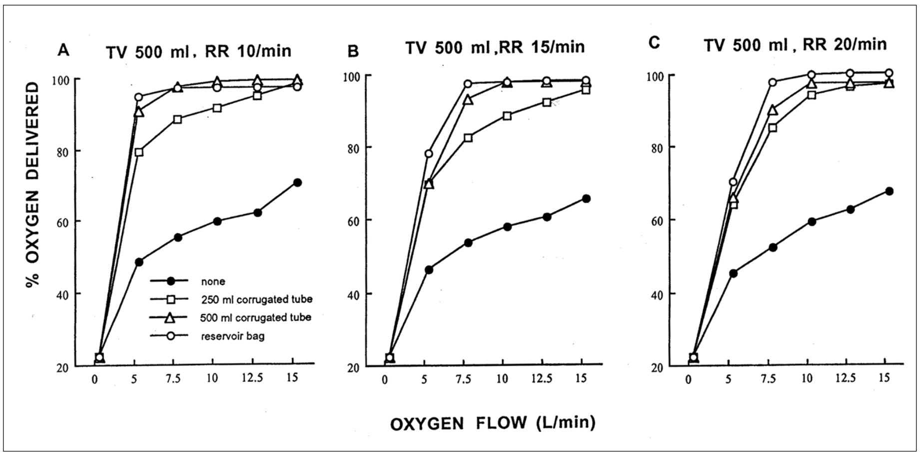

Fig. 4. The corresponding F_DO_2 according to changes in the ventilator rate per minute at a fixed tidal volume (500 mL).

was only 69% at a ventilator rate of 10/min. When a 250 mL corrugated tube with an oxygen flow rate of 5 L/min was used, the measured F_DO_2s were 78%, 68% and 63% at ventilator rates of 10/min, 15/min and 20/min, respectively. At an oxygen flow rate of 15 L/min, the F_DO_2 increased to over 96% regardless of the ventilator rate. When a 500 mL corrugated tube with an oxygen flow rate of 5 L/min was used, the F_DO_2s measured were 90%, 69% and 65% at ventilator rates of 10/min, 15/min and 20/min respectively. The F_DO_2 increased to over 96% when an oxygen flow rate of 10 L/min was used, regardless of the ventilator rate. When a reservoir bag was used with an oxygen flow rate of 5 L/min, the F_DO_2s were 93%, 77% and 69% at ventilator rates of 10/min, 15/min and 20/min respectively. The F_DO_2 increased to over 96% when the oxygen flow rate was more than 7.5 L/min, regardless of the ventilator rate.

The corresponding F_DO_2 according to the changes of the tidal volume at a fixed ventilator rate (10/min) (Fig. 5)

Without a reservoir bag or a corrugated tube, the F_DO_2 progressively decreased as the tidal volume increased, and as the oxygen flow rate was increased, the F_DO_2 progressively increased. However at a tidal volume of 250 mL, even when the oxygen flow rate was 15 L/min, the F_DO_2 was only 74%. When a 250 mL corrugated tube was used at an oxygen flow rate of 5 L/min, the measured F_DO_2s were 95%, 78% and 55% at tidal volumes of 250 ml, 500 ml and 600 mL respectively. When the oxygen flow rate was increased to 15 L/min, the measured F_DO_2s were 99%, 97% and 86% at the same tidal volumes as above. When a 500 mL corrugated tube was used, the corresponding F_DO_2s were 96%, 89% and 83% at an oxygen flow rate of 5 L/min and 99%, 98% and

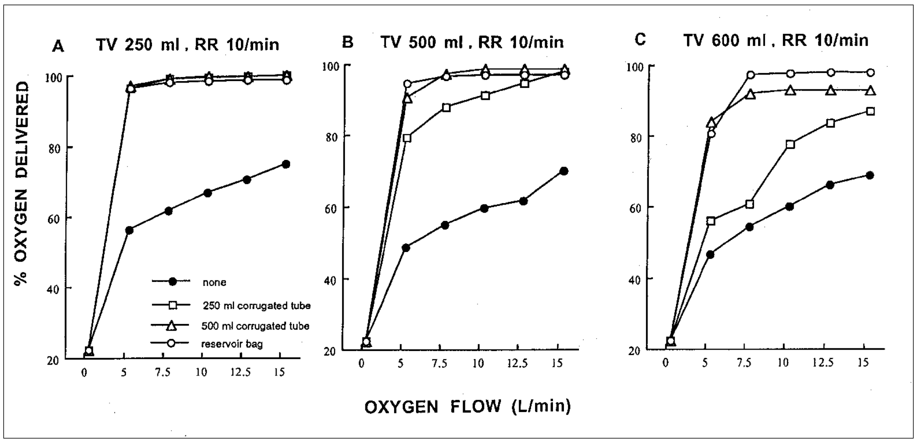

Fig. 5. The corresponding F_DO_2 according to changes in the tidal volume at a fixed ventilator rate (10/min).

92% at an oxygen flow rate of 15 L/min. When using a reservoir bag, the corresponding F_DO_2s measured were 95%, 93% and 79% with an oxygen flow rate of 5 L/min. When the oxygen flow rate was increased to more than 7.5 L/min, the F_DO_2 increased to over 96% regardless of the tidal volume.

DISCUSSION

There are many types of resuscitator bags (the PMR II, the Intertech, the Pedi-Blue, the MPR, the LSP, the CPR, the Pulmonex, the Ambu, the Laerdal Resusci 2, the Hope 2, the Air bird etc.) according to the manufacturers. Although several studies have been carried out to demonstrate the characteristics of various types of resuscitator bags and F_DO_2,[2,3-6] most of them were performed with positive pressure ventilation by manual compression. Because the accuracy of the F_DO_2s reported for resuscitator bags during positive pressure ventilation by manual compression was questionable, a specific device was designed to achieve regular mechanical compression of the resuscitator bag. With this, the F_DO_2 of the Laerdal resuscitator bag, which has been widely used since the past, was measured.

Carden et al.[6] showed that at an oxygen flow rate of 15 L/min with a minute volume of 8 L/min the maximum F_DO_2 of the Laerdal resuscitator with a 250 mL reservoir bag was approximately 70%. Cambell et al.[2] showed that the F_DO_2 increased from 21% to 41% with an oxygen flow rate of 15 L/min without reservoir, regardless of the ventilator rate. In addition, they showed that attaching a 100 mL corrugated tube increased the F_DO_2 from 41% to 53% regardless of the ventilator rate. It was shown that increasing the corrugated tube volume to 400 mL increased the F_DO_2 to 82%. Replacing the corrugated tube with a 2.5 L reservoir bag further increased the F_DO_2 to 95% even at a ventilator rate of 20/min and to 100% when the ventilator rate was reduced to 12/min. They also showed that despite using a 2.5 L reservoir bag, reducing the oxygen flow rate from 15 L/min to 10 L/min caused a significant reduction in F_DO_2 from 95% to 73% at a ventilator rate of 20/min. However, no change was observed when a ventilator rate of 12/min was used. Hence, they recommended that a 2.5 L bag with an oxygen flow rate of 15 L/min be used as the reservoir for the Laerdal resuscitator bag and not the corrugated tubes.

In our study, the 250 mL corrugated tube increased the F_DO_2 to over 96% when the oxygen flow rate was 15 L/min and the 500 mL corrugated tube increased the F_DO_2 to over 96% when the oxygen flow rate was 10 L/min. This was regardless of the ventilator rate at a fixed tidal volume of 500 mL. The 1600 mL reservoir bag increased the F_DO_2 to over 92% when the oxygen flow rate was 5 L/min and to over 96% when the oxygen flow rate was 7.5 L/min at a fixed tidal volume of 500 mL regardless of the ventilator rate.

To provide adequate positive pressure ventilation in adults, a tidal volume of 10-15 mL/kg and a ventilator rate of 10-12/min is necessary and a ventilator rate of 20/min in children and infants.[7]

Furthermore based upon our results, It is proposed that except in patients requiring hyperventilation, the 250 mL and 500 mL corrugated tubes can be used as substitutes for the reservoir bag. Moreover, If high oxygen flow rates can be supplied, the F_DO_2 can be increased more rapidly.

In conclusion, the F_DO_2 of the Laerdal resuscitator bag was shown to depend on various factors: the tidal volume, the ventilator rate, the oxygen flow rate, the types of reservoir. On the basis of these results with appropriate oxygen flow rates, both 250 mL and 500 mL corrugated tubes can be used as substitutes for the reservoir bag.

Ki-Jun Kim, M.D.
Department of Anesthesiology,
Yonsei University College of Medicine,
C.P.O. Box 8044, Seoul 120-752, Korea.
Tel: 82-2-361-6428, Fax: 82-2-312-7185,
E-mail: kkj6063@yumc.yonsei.ac.kr

REFERENCES

1. American Heart Association Committee on Emergency Cardiac Care. Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). JAMA 1986;255:2841-3044.
2. Campbell TP, Stewart RD, Kaplan RM, DeMichiei RV, Morton R. Oxygen enrichment of bag-valve-mask units during positive pressure ventilation: a comparison of various techniques. Ann Emerg Med 1988;17:232-5.
3. White RD, Gilles BP, Polk BV. Oxygen delivery by hand-operated emergency ventilator devices. JACEP 1973;2:105-8.
4. Priano LL, Ham J. A simple method to increase the FDO2 of resuscitator bags. Crit Care Med 1978;5:48-9.
5. Carden E, Chir B, Hughes T. An evaluation of manually operated self inflating resuscitation bags. Anesth Analg 1975;54:133-8.
6. Carden E, Bernstein M. Investigation of the nine most commonly used resuscitator bags. JAMA 1970;212:589-92.
7. Longnecker DE, Murphy FL. Introduction to anesthesia. 9th ed. Philadelphia: WB: Saunders; 1997. p.257.