**Oxygen outflow delivered by manually operated self-inflating resuscitation bags in patients breathing spontaneously***

Fluxo de saída de oxigênio fornecido por reanimadores manuais com balão auto-inflável em pacientes com ventilação espontânea

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**Abstract**

**Objective:** To determine the oxygen outflow delivered by seven different models of manually operated self-inflating resuscitation bags (with and without an oxygen reservoir connected), which were tested using different oxygen supply rates without manipulating the bag, by simulating their use in patients breathing spontaneously. **Methods:** The oxygen outflow was measured using a wall oxygen flow meter and a flow meter/respirometer attached to the bag, together with another flow meter/respirometer attached to the patient connection port. The resuscitation bags that allow the connection of an oxygen reservoir were tested with and without this device. All resuscitation bags were tested using oxygen supply rates of 1, 5, 10, and 15 L/min. Statistical analyses were performed using analysis of variance and t-tests. **Results:** The resuscitation bags that allow the connection of an oxygen reservoir presented a greater oxygen outflow when this device was connected. All resuscitation bags delivered a greater oxygen outflow when receiving oxygen at a rate of 15 L/min. However, not all models delivered a sufficient oxygen outflow even when the two previous conditions were satisfied. **Conclusions:** Of the resuscitation bags studied, those that allow the connection of an oxygen reservoir must have this reservoir connected to the bag when used as a source of oxygen in nonintubated spontaneously breathing patients. All of the models studied should receive oxygen at a rate ≥ 15 L/min. It is not safe to use manually operated self-inflating resuscitation bags for this purpose without knowing their characteristics. **Keywords:** Oxygen/administration & dosage; Resuscitation; Equipment and supplies; Respiration; Intensive care.

**Resumo**

**Objetivo:** Determinar o fluxo de saída de oxigênio fornecido por sete modelos diferentes de reanimadores manuais com balão auto-inflável (com e sem reservatório de oxigênio acoplado), que foram testados utilizando-se diferentes fluxos de entrada de oxigênio sem manipular o balão, simulando o uso em pacientes com respiração espontânea. **Métodos:** O fluxo de saída de oxigênio foi medido utilizando-se um fluxômetro de oxigênio de parede e um fluxômetro/respirômetro conectados ao balão e outro fluxômetro/respirômetro conectado à porta de conexão do paciente. Os reanimadores que permitem o acoplamento de um reservatório de oxigênio foram testados com e sem esse reservatório. Todos os reanimadores foram testados utilizando-se fluxos de entrada de oxigênio de 1, 5, 10 e 15 L/min. Para a análise estatística utilizaram-se análise de variância e o teste t. **Resultados:** Os reanimadores que permitem o acoplamento de um reservatório de oxigênio apresentaram maior fluxo de saída de oxigênio quando esse dispositivo estava acoplado. Todos os reanimadores forneceram maior fluxo de saída de oxigênio quando receberam 15 L/min de oxigênio. Entretanto, nem todos os modelos testados forneceram fluxo de saída de oxigênio suficiente mesmo quando as duas condições anteriores foram atendidas. **Conclusões:** Dos reanimadores estudados, os que permitem o acoplamento de um reservatório de oxigênio devem obrigatoriamente estar com esse reservatório acoplado ao balão quando utilizados como fonte de oxigênio em pacientes não intubados com respiração espontânea. Todos os modelos estudados devem receber um fluxo de oxigênio ≥ 15 L/min. Não é seguro utilizar reanimadores manuais com balão auto-inflável para esse propósito sem conhecer suas características. **Descritores:** Oxigênio/administração & dosagem; Ressuscitação; Equipamento; Respiração; Cuidados intensivos.

**Introduction**

Manually operated self-inflating resuscitation bags are devices used to ventilate patients who require ventilatory support.¹⁻³ Usually during transport, these resuscitation bags are used to provide high oxygen concentrations to patients who make spontaneous breathing efforts. However, in some cases, manually operated self-inflating resuscita-
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operated self-inflating resuscitation bags can be connected to an oxygen reservoir that has a bag refill valve (Figure 1). This valve allows the aspiration of atmospheric air, mixing it with the oxygen inside the bag. The resulting mixture is then delivered to the patient. The oxygen reservoir has a pressure control system that opens if the oxygen supply rate is too high or if the bag remains idle.

Since different models of manually operated self-inflating resuscitation bags present different functional performances, and since we found no data on manually operated self-inflating resuscitation bags manufactured or marketed in Brazil, the aim of the present study was to determine the oxygen outflow delivered by seven different models of manually operated self-inflating resuscitation bags used in Brazil (with and without an oxygen reservoir connected), and which were tested using different oxygen supply rates without manipulating the bag, by simulating their use in patients breathing spontaneously.

Methods

The data were collected in the Respiratory Unit of the State University at Campinas Hospital das Clínicas from January of 2006 to January of 2007.

The materials used were as follows: one BD wall oxygen flow meter (Becton Dickinson, Franklin Lakes, NJ, USA); two flow meter/respirometers (953; Oxigel, São Paulo, Brazil); and seven models of manually operated self-inflating resuscitation bags used in Brazil, manufactured by Oxigel.

Figure 1 – Basic components of the manually operated self-inflating resuscitation bag and of the oxygen reservoir.
rates of 1, 5, 10, and 15 L/min without manipulating the bag. The resuscitation bags that allow the connection of an oxygen reservoir were tested with and without this reservoir. During the study, the oxygen supply rates were continuously monitored by the flow meters connected to the system.

An average of twenty consecutive tests were carried out on the seven manually operated self-inflating resuscitation bags, using oxygen supply rates of 1, 5, 10, and 15 L/min, in order to collate the data.

Statistical analyses were performed using the BioEstat 3.0 program, analysis of variance, and the t-test. Values of $p \leq 0.05$ were considered significant.

**Results**

Table 1 shows the means of the oxygen outflow delivered by the seven manually operated self-inflating resuscitation bags (with and without an oxygen reservoir connected) tested using oxygen supply rates of 1, 5, 10, and 15 L/min without manipulating the bag.

The percentage of oxygen delivered through the patient connection port was influenced by the presence of an oxygen reservoir connected to the resuscitation bag, the direction of the oxygen inflow into the bag, the rate of oxygen flow provided to the resuscitation bag, and the resuscitation bag design.

As can also be seen in Figure 2, the direction of the inflow into the bag follows three different patterns (parallel to the bag refill valve of the bag, perpendicular to the bag refill valve of the bag, and directly inside the bag), and there are three types of patient valves (disc valves, duck-bill valves, and semi-fixed disc valves).

As shown in Figure 3, in order to measure the oxygen outflow, a wall oxygen flow meter and a flow meter/respirometer were attached to the bag of the manually operated self-inflating resuscitation bag, and another flow meter/respirometer was attached to the patient connection port.

The seven manually operated self-inflating resuscitation bags were tested using oxygen supply
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Figure 3 - Test of oxygen outflow through the patient connection port without manipulating the bag. 1) Wall oxygen flow meter; 2) Flow meter/respirometer; 3) Manually operated self-inflating resuscitation bag; and 4) Flow meter/respirometer.

factured by Axmed delivered the least amount of oxygen outflow (Figure 2). This seems to be due to the fact that, for this resuscitation bag, the oxygen inflow comes from outside the bag, in a longitudinal direction, arriving directly to the bag refill valve (Figure 1). In addition, when receiving oxygen at a rate of 10–15 L/min, the Axmed resuscitation bag disk valve presented inspiratory/expiratory vibration, dividing the oxygen outflow, part of it to the exhalation port and the remainder to the patient connection port.

When the manually operated self-inflating resuscitation bags to which an oxygen reservoir can be connected (CE Reanimadores, Missouri, Oxigel model B, and ProtecSolutions) were used without this device, they did not begin to deliver an oxygen outflow through the patient connection port until the oxygen supply rate reached 10 L/min. It seems that a 10 L/min inflow was necessary to open the bag refill valve (Figure 1), directing the flow to the bag, and then to the patient connection port. The oxygen reservoir connected to these resuscitation bags prevented oxygen leakage from the oxygen reservoir socket (Figure 1), opening the refill valve along the oxygen passage to the bag and then to the patient connection port. However, the ProtecSolutions resuscitation bag, with no oxygen reservoir connected, did not deliver any oxygen outflow through the patient connection port at any of the oxygen supply rates tested. This is due to the flow direction being parallel to the bag refill valve, allowing all of the oxygen to leak from the reservoir socket, whereas in the other three manually operated

Table 1 - Oxygen outflow delivered by seven manually operated self-inflating resuscitation bags (with and without an oxygen reservoir connected) tested using oxygen supply rates of 1, 5, 10, and 15 L/min without manipulating the bag.

<table>
<thead>
<tr>
<th>Resuscitation Bag</th>
<th>Oxygen Supply Rate (L/min)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>-O₂R Oxigel B</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+O₂R</td>
<td>0</td>
<td>3.2 (0.3)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>-O₂R ProtecSolutions</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+O₂R</td>
<td>0</td>
<td>2.3 (0.2)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>-O₂R Missouri</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+O₂R</td>
<td>0</td>
<td>3.9 (0.4)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>-O₂R CE</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>+O₂R</td>
<td>0</td>
<td>3.2 (0.2)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>-O₂R Narcosul</td>
<td>0</td>
<td>2.1 (0.2)</td>
</tr>
<tr>
<td>+O₂R</td>
<td>0</td>
<td>5.4 (0.5)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>*O₂R Oxigel A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Axmed</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- O₂R = without oxygen reservoir connected; +O₂R = with oxygen reservoir connected; and *O₂R = oxygen reservoir not an option.
self-inflating resuscitation bags (CE Reanimadores, Missouri, and Oxigel model B), the flow direction is perpendicular to the bag refill valve, forcing it to open and allowing the oxygen to enter the bag, although some loss is still unavoidable.

All of the manually operated self-inflating resuscitation bags studied delivered a greater oxygen outflow through the patient connection port when receiving oxygen at a rate of 15 L/min.

**Discussion**

Only a single sample of each manually operated self-inflating resuscitation bag was tested. Therefore, although all of the samples were new and unused, this represents a limitation of this study.

However, the use of manually operated self-inflating resuscitation bags as sources of oxygen in nonintubated spontaneously breathing patients can be harmful to those who are hyperventilating due to metabolic acidosis, since the mask can impair ventilation, thereby increasing acidosis.

The results of this study show that, of the models of manually operated self-inflating resuscitation bags studied, those that offer the option of being connected to an oxygen reservoir delivered a greater oxygen outflow when this device was connected. Therefore, we suggest that all models that offer this option be operated with the oxygen reservoir connected to the bag when used as sources of oxygen in nonintubated spontaneously breathing patients. In addition, since all of the models studied delivered a greater oxygen outflow when the oxygen supply rate was ≥ 15 L/min, we recommend that this oxygen supply rate be used for all manually operated self-inflating resuscitation bags. Nevertheless, it should be noted that not all of the models tested delivered a sufficient oxygen outflow, even when the two previous recommendations were followed.

It is not safe to use manually operated self-inflating resuscitation bags to provide oxygen to patients who breathe spontaneously without knowing the characteristics of the resuscitation bags.

**References**