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Comparação da FiO_2 Fornecida por Sete Modelos de Sistema Balão-Máscara Auto-inflável*

Comparison of the FiO_2 Delivered by Seven Models of the Self-Inflating Bag-Mask System

Armando Carlos Franco de Godoy[1], Ronan José Vieira[2]

RESUMO

Godoy ACF, Vieira RJ — Comparação da FiO_2 Fornecida por Sete Modelos de Sistema Balão-Máscara Auto-inflável.

***JUSTIFICATIVA E OBJETIVOS**: Devido ao fato dos reanimadores com sistema balão-máscara auto-infláveis fabricados e/ou comercializados no Brasil serem amplamente disponíveis e utilizados em serviços de saúde extra e intra-hospitalares, este estudo teve o objetivo de determinar as frações de O_2 ofertadas por sete reanimadores recebendo diferentes fluxo de O_2.*

***MÉTODO**: Sete reanimadores com sistema balão-máscara auto-infláveis foram testados na Unidade Respiratória do HC/UNICAMP. Um fluxômetro de O_2 de parede foi conectado ao reanimador que recebia fluxo de O_2 de 1, 5, 10 e 15 $L.min^{-1}$, sendo estes conectados a um pulmão-teste. Os reanimadores que têm a capacidade de se conectar um reservatório de O_2 foram testados com e sem esse acessório. Foram efetuadas 20 medidas consecutivas e determinada a média.*

***RESULTADOS:** Apenas um reanimador apresentou oferta de fração de O_2 pouco abaixo do limite mínimo preconizado (0,80), quando utilizado com o reservatório de O_2. Sem esse dispositivo acoplado todos os reanimadores atingiram o limite mínimo de fração de O_2 preconizada (0,40). Os reanimadores que não apresentam a possibilidade de acoplar o reservatório de O_2 apresentaram maior oferta de O_2 em relação aos outros reanimadores.*

***CONCLUSÕES**: Todos os reanimadores que possuem a opção de acoplagem do reservatório de O_2 forneceram maior concentração de O_2 com esse acessório. Os reanimadores que não têm possibilidade de acoplar o reservatório de O_2 apresentaram maior oferta de O_2 em relação aos outros que podem ser acoplados ao reservatório quando usados sem esse acessório.*

Unitermos: EQUIPAMENTOS: Ventilador.

SUMMARY

Godoy ACF, Vieira RJ — Comparison of the FiO_2 Provided by Seven Models of Self-Inflating Bag-Mask Systems.

***BACKGROUND AND OBJECTIVES:** Since resuscitators with self-inflating bag-mask systems manufactured and/or commercialized in Brazil are widely available and used in health services, both out- and intra-hospitals, the objective of this study was to determine the O_2 fractions delivered by seven resuscitators receiving different O_2 flows.*

***METHODS:** Seven resuscitators with self-inflating bag-mask systems were tested at the Respiratory Unit of the HC/UNICAMP. A wall O_2 flowmeter was connected to the resuscitator that received an O_2 flow of 1, 5, 10, and 15 $L.min^{-1}$ and those were connected to a test lung. Resuscitators capable of being connected to an O_2 reservoir were tested with and without this accessory. Twenty consecutive measurements were performed and the mean determined.*

***RESULTS:** Only one resuscitator delivered and O_2 fraction slightly below the accepted limit (0.80) when used with the O_2 reservoir. Without this device, all resuscitators achieved the minimal limit of O_2 fraction (0.40). Resuscitators not capable of being connected to an O_2 reservoir delivered a higher O_2.*

***CONCLUSIONS:** All resuscitators capable of being connected to an O_2 reservoir delivered a higher O_2 concentration when connected to this device. Resuscitators that do not have this capability delivered a higher O_2 concentration than the ones that could be connected to this device but are used without it.*

Key words: EQUIPMENT: Ventilator.

INTRODUÇÃO

Os reanimadores com sistema balão-máscara auto-infláveis (SBMAI) são aparelhos utilizados com a finalidade de ventilar pacientes com necessidade de suporte ventilatório em situações tais como transporte extra e intra-hospitalar e reanimação cardiopulmonar [1]. Os SBMAI podem ser divididos em duas partes: unidade compressível e conector ao paciente e em alguns modelos existe a opção de ser acoplar um reservatório de O_2 (Figura 1). A unidade compressível é a parte a ser comprimida pelo operador com a finalidade de

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apreensão das mãos do operador, presença ou não de válvulas que limitam pressão no conector ao paciente e do tipo de material, *design* e tamanho da unidade compressível [2,5,16]. Assim, nessa pesquisa cada aparelho ofertou livremente o volume corrente que seu *design* permitia.

Na pesquisa adaptou-se ao sistema do teste um tubo T com válvula direcional (Figura 2: 5, 6) com a finalidade de eliminar o ar ejetado do pulmão-teste para o ambiente, não permitindo o possível retorno do O_2 para o interior da unidade compressível, caso o SBMAI apresentasse falha de vedação na válvula do paciente. A ocorrência dessa falha de vedação poderia acarretar falso aumento da FiO_2 ofertada pelo SBMAI. Apesar de parecer pertinente a função desse mecanismo de vazão do ar ejetado, não se encontrou na literatura trabalhos que utilizaram esse artifício. Diversos autores utilizaram um orifício localizado entre o SBMAI e o pulmão-teste [2,12-15]. Assim, quando a unidade compressível era comprimida, concomitantemente esse furo era tapado com o dedo do pesquisador e quando a unidade compressível do SBMAI era descomprimida esse furo era destapado.

Durante a realização do teste de FiO_2 a frequência respiratória foi mantida em 12 incursões por minuto com uma ou duas mãos, por ser este o modo mais empregado com mais frequência durante as ventilações com SBMAI [17].

A FiO_2 ofertada pelos SBMAI foi influenciada pelo fluxo de O_2 e a direção deste à unidade compressível, além da utilização ou não do reservatório de O_2.

Todos os SBMAI têm a opção de acoplagem do reservatório de O_2, Oxigel® modelo B, Missouri®, CE Reanimadores® e Protec® vinil forneceram maior FiO_2 quando esse acessório estava conectado a unidade compressível, e o CE Reanimadores® ofertou FiO_2 um pouco abaixo do limite mínimo de 0,80 preconizado pela ISO, 1997 [10], e ASTM, 1999 [11], isto é, 0,75 (0,6).

Todos os SBMAI que possuem acoplagem para o reservatório de O_2, quando testados sem esse acessório, atingiram FiO_2 de 0,40 ou mais, quando recebiam fluxo de O_2 a partir de 10 $L.min^{-1}$. Quando não se utilizou o reservatório de O_2 as FiO_2 ofertadas pelos SBMAI foram menores, pois o oxigênio ofertado ao reanimador é dissipado no ar ambiente próximo à unidade compressível (Figura 1), sendo parcialmente aspirado pelo reanimador. Os reanimadores que não têm a possibilidade de acoplar o reservatório de O_2 possuem maior oferta de O_2 em relação aos outros reanimadores em todos os fluxos de O_2.

Comparison of The FiO_2 Delivered by Seven Models of the Self-Inflating Bag-Mask System

Armando Carlos Franco de Godoy, M.D.; Ronan José Vieira, M.D.

INTRODUCTION

Resuscitators with self-inflating bag-mask systems are used to ventilate patients who need ventilatory support in situations such as extra- and intra-hospital transportation and cardiopulmonary reanimation [1]. Those devices can be divided in two parts: compressible unit and patient connector, but some models have the option to be connected to an O_2 reservoir (Figure 1). The compressible unit is the segment of the device that is supposed to be compressed by the operator to deliver a volume of air to the patient and, in the back, one

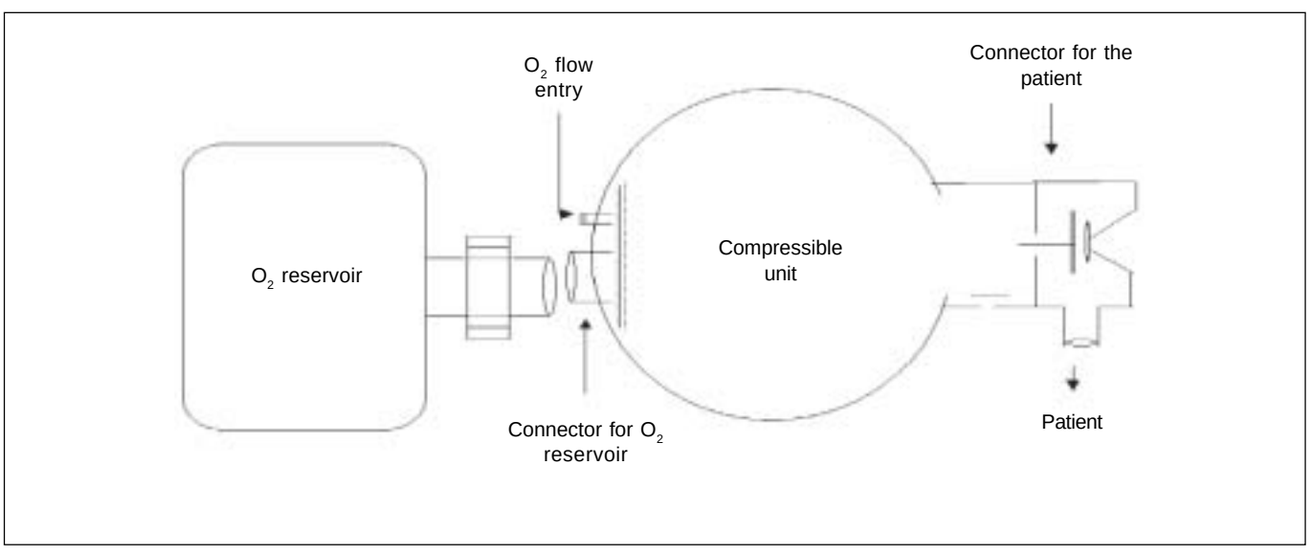

Figure 1 – Schematic Drawing of the Basic Components of Manual Resuscitators.

might find the connection for the O_2 reservoir and entrance of the O_2 flow. The connector to the patient is where the face mask or endotracheal tube is attached.

Several studies have demonstrated that different models of self-inflating bag-mask systems [1-3] might show differences in the fraction of O_2 delivered (FiO_2), since it is influenced by the shape and type of material of the compressible unit[4], tidal volume delivered [3], the use or lack of the O_2 reservoir [1], and flow of O_2 delivered to the compressible unit [2-5], among others.

The objective of this study was to determine the FiO_2 of seven different brands of self-inflating bag-mask systems manufactured or commercialized in Brazil when they received O_2 at 1, 5, 10, and 15 $L.min^{-1}$, were manipulated with both hands at 12 breaths per minute with or without O_2 reservoir.

METHODS

The data was collected at the Respiratory Unit of the Hospital de Clínicas da Universidade Estadual de Campinas – Unicamp, from January to March 2007.

The material used in the study included: a Vent Aid TTL-49504 Michigan Instruments test lung, a Newport Medical Instruments OM-100 O_2 analyzer, a BD wall O_2 flowmeter, an Oxigel 953 flowmeter, and a Bird T-tube with directional valve. The seven self-inflating bag-mask systems used could be classified into two groups, one group in which an O_2 reservoir could be attached: Oxigel® model B, CE Reanimadores®, Protec® vinyl, and Missouri®; and those that could not be connected to an O_2 reservoir: Oxigel model A®, Axmed®, and Narcosul®.

To test the FiO_2 (Figure 2), the wall O_2 flowmeter was connected to another flowmeter which was connected to the port of O_2 entry in the device. The connector to the patient was coupled to the O_2 analyzer, which was connected to the T-tube with a directional valve leading the flow to the surrounding environment, and a T-tube was connected to the test lung.

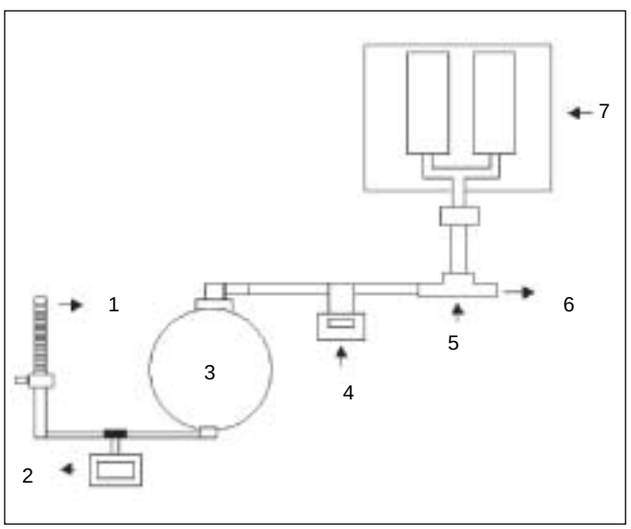

Figure 2 – Schematic Drawing of the FiO_2 Test. 1) wall O_2 flowmeter; 2) flowmeter; 3) self-inflating bag-mask system; 4) FiO_2 analyzer; 5) T-tube with directional valve; 6) T-tube air exit; 7) test lung.

The test lung was ventilated by the device, with one or both hands, 12 incursions per minute, receiving flows of O_2 of 1, 5, 10, and 15 $L.min^{-1}$. Systems that allowed the connection of O_2 reservoirs were tested with and without it. After two minutes of ventilation with each flow, the FiO_2 delivered by each device on the O_2 flowmeter connected to the system was recorded. During the study, the test lung remained with a resistance of 20 $cmH_2O.L^{-1}.sec^{-1}$ and a complacency of 0.05 L. cmH_2O^{-1}, the self-inflating bag-mask systems were operated by the same person, and the flows of O_2 delivered to the RAMI were measured and controlled by the devices of the system.

Twenty consecutive measurements of the FiO_2 were recorded for each flow in each brand of the self-inflating bag-mask system and the person who recorded the data did not know the objective and methodological procedure of the study. The program BioEstat 3.0 for Windows was used for the statistical analysis using means and standard deviation.

RESULTS

Figure 3 shows the FiO_2 delivered by the seven different brands of systems manufactured or commercialized in Brazil when they received a flow of O_2 1, 5, 10, and 15 $L.min^{-1}$, were manipulated with both hands with a frequency of 12 incursions per minute, and with and without an O_2 reservoir.

DISCUSSION

The Guidelines of the European Resuscitation Council 2000 on Advanced Adult Life Suppport, 2000 [6] and the Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, 2000 [7] emphasize that it is essential to administer oxygen at the highest concentration possible during resuscitation maneuvers, stating that high oxygen concentrations are toxic only when administered for a prolonged period. Some authors consider that the FiO_2 delivered is the most important parameter to be considered regarding its performance.

Since most of the time hospitalized patients who need self-inflating bag-mask systems are already receiving supplemental oxygen, the ideal resuscitator should deliver FiO_2 as closer to 1.0 as possible [2,9].

ISO 1997 [10] and ASTM 1999 [11] recommend that those systems should delivered a FiO_2 of at least 0.40 without an O_2 reservoir and 0.80 with this accessory, receiving a maximal O_2 flow of 15 $L.min^{-1}$ [2,8].

Contrary to other authors who stipulated a fixed tidal volume of 600 mL[12-15], in the present study a fixed tidal volume was not stipulated because in daily practice one cannot maintain it unchanged since it depends on the size and compression force of the operator's hand, presence or absence of pres-

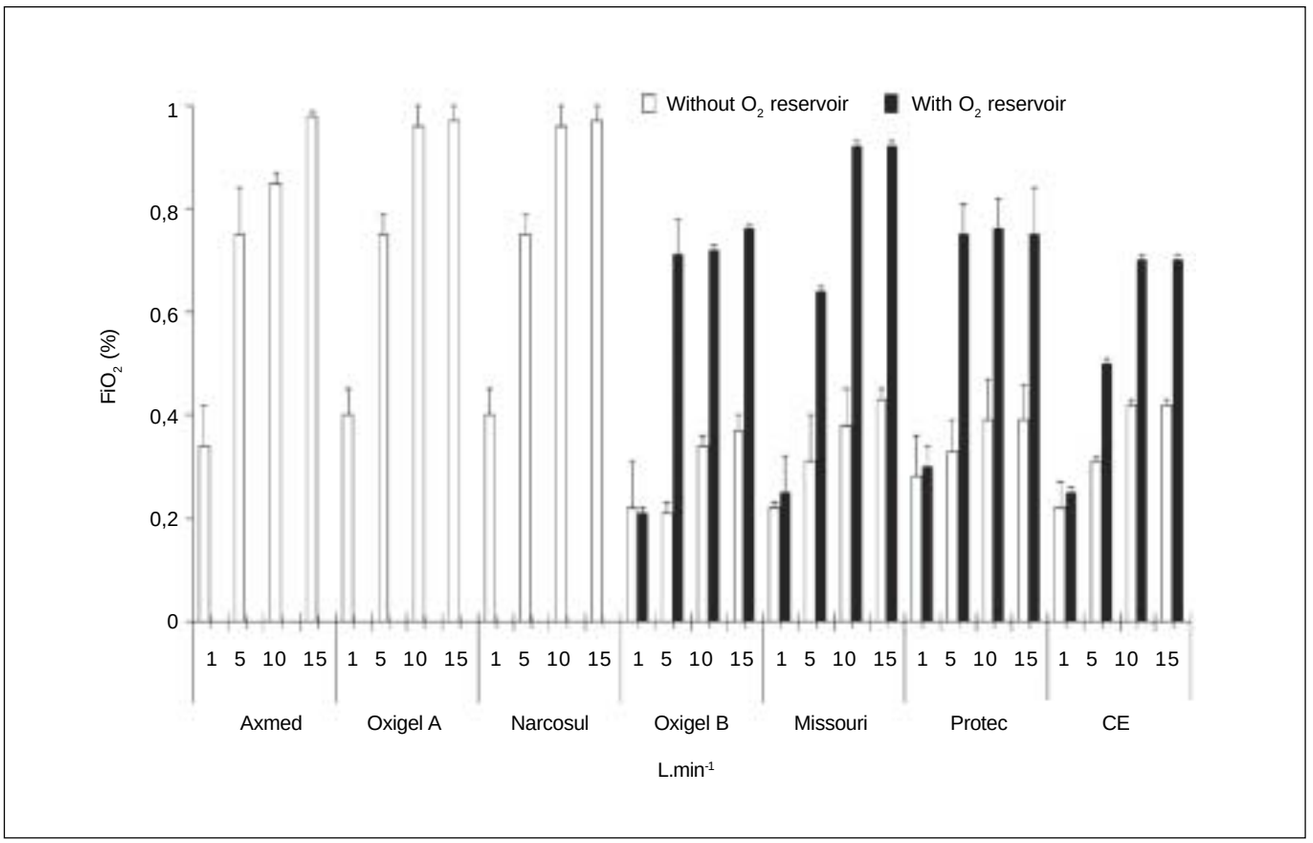

Figure 3 – Means and Standard Deviations of the FiO_2 Delivered by the Self-Inflating Bag-Mask Systems with and without de O_2 Reservoir.

sure-limiting valves at the connector to the patient, and the type of material, design, and size of the compressible unit [2,5,16]. Thus, each device delivered the tidal volume that its design allowed.

In the present study, the test system was adapted with a T-tube with directional valve (Figure 2: 5, 6) to eliminate the air ejected from the test lung to the environment preventing, therefore, return of the O_2 to the compressible unit in case of failure of the seal of the patient's valve. Failure of the seal could lead to a false increase in the FiO_2 delivered by the equipment. Although the function of this mechanism for ejection of the air is pertinent, we did not find studies using it in the literature. Several authors used a hole between the self-inflating bag-mask system and the test lung [2,12-15]; therefore, whenever the compressible unit was squeezed, this hole was simultaneously closed by the finger of the operator, and when the compressible unit return to its normal size the hole was uncovered.

During the FiO_2 test, the respiratory rate was maintained at 12 incursions per minute with one or both hands, since this is how ventilation with those devices is done more often[17].

The FiO_2 delivered was influenced by the flow of O_2 and its dislocation to the compressible unit and the use, or lack, of the O_2 reservoir.

All self-inflating bag-mask systems that could be connected to an O_2 reservoir, Oxigel model B®, Missouri®, CE Renimadores®, and Protec® vinyl, delivered a higher FiO_2 when this accessory was connected to the compressible unit, but CE Reanimadores® delivered a FiO_2 slightly below the minimal limit of 0,80 recommended by ISO, 1997 [10] and ASTM, 1999 [11], i.e., 0.74 (0.6).

All self-inflating bag-mask systems that could be connected to an O_2 reservoir delivered a FiO_2 of 0.40 or more with an O_2 flow of at least 10 $L.min^{-1}$ when used without his accessory. When the O_2 reservoir was not used, the FiO_2 delivered was lower because the oxygen that reaches the resuscitator is dissolved in the room air near the compressible unit (Figure 1) and it is partially aspirated by the resuscitator. Devices in which an O_2 reservoir could not be attached to, delivered higher amounts of O_2 than the other resuscitators in all O_2 flows.

REFERÊNCIAS – *REFERENCES*

01. Barnes TA, McGarry WP — Evaluation of ten disposable manual resuscitators. Respir Care, 1990;35:960-968.
02. Mazzolini DG, Marshall NA — Evaluation of 16 adult disposable manual resuscitators. Respir Care, 2004;49:1509-1514.

03. Carter BG, Fairbank B, Tibballs J et al. — Oxygen delivery using self-inflating resuscitation bags. Pediatr Crit Care Med, 2005;6: 125-128.
04. Boidin MP, Mooi B, Erdmann W — Controlled administration of oxygen with self inflating resuscitation bags. Acta Anaesthesiol Belg, 1980;31:157-165.
05. Nam SH, Kim KJ, Nam YT et al. — The changes in delivered oxygen fractions using laerdal resuscitator bag with different types of reservoir. Yonsei Med J, 2001;42:242-246.
06. Guidelines of the European Resuscitation Council 2000 on Advanced Adult Life Support — A statement of the Advanced Life Support Working Group as approved by the Executive Committee of the European Resuscitation Council. Anaesthesist, 2002;51:293-298.
07. American Heart Association — Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 7: The era of reperfusion: section 1: Acute coronary syndromes (acute myocardial infarction). Circulation, 2000; 102 (Suppl 8):I172-I203.
08. Tibballs J, Carter B, Whittington N — A disadvantage of self-inflating resuscitation bags. Anaesth Intensive Care, 2000; 28:587.
09. Maxwell LJ, Ellis ER — The effect on expiratory flow rate of maintaining bag compression during manual hyperinflation. Aust J Physiother, 2004;50:47-49.
10. International Organization for Standardization. International Standard ISO 8382: 1988(E). Resuscitators intended for use with humans. New York, American National Standards Institute, 1988. Disponível em: <http://www.iso.org>. Acessado em 21 de setembro de 2004.
11. American Society for Testing and Materials — Standard specification for performance and safety requirements for resuscitators intended for use with humans F-920–85. Philadelphia, Am Soc Testing & Materials, 1993.
12. Barnes TA, Potash R — Evaluation of five adults disposable operator-powered resuscitators. Respir Care, 1989;34:254-261.
13. Barnes TA, Stockwell DL — Evaluation of ten manual resuscitators across an operational temperature range of -18 degrees C to 50 degrees C. Respir Care, 1991;36:161-172.
14. Barnes TA, Catino ME, Burns EC et al. — Comparison of an oxygen-powered flow-limited resuscitator to manual ventilation with an adult 1,000-mL self-inflating bag. Respir Care, 2005;50: 1445-1450.
15. Zecha-Stallinger A, Wenzel V, Wagner-Berger HG et al. — A strategy to optimize the performance of the mouth-to-bag resuscitator using small tidal volumes: effects on lung and gastric ventilation in a bench model of an unprotected airway. Resuscitation, 2004;61:69-74.
16. Bennett S, Finer NN, Rich W et al. — A comparison of three neonatal resuscitation devices. Resuscitation, 2005;67:113-118.
17. Turki M, Young MP, Wagers SS et al — Peak pressures during manual ventilation. Respir Care, 2005;50:340-344.

RESUMEN

Godoy ACF, Vieira RJ — Comparación de la FiO_2 Suministrada por Siete Modelos de Sistema Balón-Máscara Autoinflable.

JUSTIFICATIVA Y OBJETIVOS*: Debido al hecho de que los reanimadores con sistema balón -máscara autoinflables fabricados y/o comercializados en Brasil están ampliamente al alcance y que son utilizados en servicios de salud extra e intrahospitalarios, este estudio tuvo el objetivo de determinar las fracciones de O_2 ofertadas por siete reanimadores recibiendo diferentes flujos de O_2.*

MÉTODO*: Siete reanimadores con sistema balón-máscara autoinflables fueron probados en la Unidad Respiratoria del HC/UNICAMP. Un fluxómetro de O_2 de pared fue conectado al reanimador que recibía flujo de O_2 de 1, 5, 10 y 15 $L.min^{-1}$, siendo que ellos se conectaron a un pulmón test. Los reanimadores que poseen la capacidad de conectarse a un reservorio de O_2 se probaron con y sin ese accesorio. Se efectuaron 20 medidas consecutivas y se determinó el promedio.*

RESULTADOS: *Apenas un reanimador presentó oferta de fracción de O_2 poco por debajo del límite mínimo preconizado (0,80), cuando se usó con el reservorio de O_2. Sin ese dispositivo acoplado, todos los reanimadores alcanzaron el límite mínimo de fracción de O_2 preconizada (0,40). Los reanimadores que no presentaron la posibilidad de acoplar el reservorio de O_2 presentaron una mayor oferta de O_2 con relación a los otros reanimadores.*

CONCLUSIONES*: Todos los reanimadores que poseen la opción de acoplamiento del reservorio de O_2, suministraron una mayor concentración de O_2 con ese accesorio. Los reanimadores que no tienen la posibilidad de acoplar el reservorio de O_2 presentaron una mayor oferta de O_2 con relación a los otros que sí pueden ser acoplados al reservorio cuando se usan sin ese accesorio.*