Evaluation of peak inspiratory pressure and respiratory rate during ventilation of a preterm infant lung model with a self-inflating bag by paramedics of the Fire Department

Avaliação do pico de pressão e da frequência respiratória durante o uso de balão autoinflável por socorristas do Corpo de Bombeiros em um modelo de pulmão neonatal pré-termo

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ABSTRACT

Objective: To evaluate the peak inspiratory pressure and the ventilation rate obtained by paramedics of the Fire Department of Brasília, Brazil, when using a neonatal self-inflating bag on a preterm lung model.

Methods: Descriptive observational study including 31 volunteers, from 68 paramedics invited, who were components of two groups of the Fire Department's Continuous Training Program. For three minutes, the paramedics ventilated an analogical simulator of preterm infant lung using a neonatal self-inflating bag. The peak inspiratory pressure and the respiratory rate were captured by a pneumotachograph and a graphical monitor of ventilation. Data were recorded and analyzed.

Results: Mean peak pressures in cmH_2O for test lung were 14.6±8.2, being less than 20 in 77.4% of the analyzed pressure curves, more than 40 in 3.2%, and between 20 and 40cmH_2O in 19.4% of the curves. Mean ventilation rates were 38.3±10.3 cycles per minute, being less than 40 in 51.6% of the analyzed pressure curves, more than 60 in zero, and between 40 and 60 in 48.4%. In no occasion the pressure reached 60 cycles per minute.

Conclusions: The paramedics, most of the time, did not achieve the advised minimum level of ventilation pressure and ventilation rates recommended by international guidelines during ventilation of a neonatal lung model with a self-inflating bag.

Key-words: cardiopulmonary resuscitation; pulmonary ventilation; respiration, artificial; infant, premature.

RESUMO

Objetivo: Avaliar o pico de pressão inspiratória e a frequência ventilatória obtidos por socorristas do Corpo de Bombeiros com a utilização de balão autoinflável em modelo de pulmão neonatal pré-termo.

Métodos: Estudo observacional descritivo incluindo 31 voluntários dentre 68 socorristas convidados, componentes de duas turmas do Programa de Capacitação Continuada do Corpo de Bombeiros. Durante três minutos, os socorristas ventilaram um simulador analógico de pulmão neonatal pré-termo, utilizando balão autoinflável de tamanho neonatal. Foram captados os picos de pressão inspiratória e a frequência respiratória por meio de um pneumotacógrafo e um monitor gráfico de ventilação. Os dados eram gravados e posteriormente analisados.

Resultados: A média do pico de pressão foi de 14,6±8,2cmH_2O, sendo menor que 20 em 77,4% das vezes, maior que 40 em 3,2% das vezes, e entre 20 e 40cmH_2O em 19,4% das vezes. A média da frequência ventilatória foi de 38,3±10,3 ciclos por minuto, sendo menor que 40 em 51,6% das vezes e entre 40 e 60 ciclos por minuto em 48,4% das vezes; em nenhuma das vezes a pressão atingiu 60 ciclos por minuto.

Conclusões: Os socorristas, na maioria das vezes, não atingiram o nível mínimo desejado de pressão de ventilação e frequência respiratória recomendados em protocolos internacionais durante a ventilação pulmonar neonatal com o balão autoinflável.

Palavras-chave: ressuscitação cardiopulmonar; ventilação pulmonar; respiração artificial; prematuro.

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Recebido em: 25/3/2009
Aprovado em: 2/7/2009

Introduction

Prehospital emergence care is among the responsibilities of the Fire Departments. In the Brazilian Federal District, the Fire Department received 98,521 calls in 2007. More than half of them (53.3%) were prehospital emergency cases and, of these, 5.1% were related to pregnant and/or parturient women[1]. Occasionally, for some pregnant women, the delivery takes place before they reach the hospital. The firefighters who provide this type of care must be prepared to perform infant cardiopulmonary resuscitation, offering ventilation using a self-inflating bag, whenever necessary. These paramedics are trained by means of a specific course on prehospital care and provide care in this area.

The equipment most often used for manually assisted mechanical lung ventilation is the self-inflating bag[2]. Such equipment is used for respiratory resuscitation during cardiorespiratory arrest at emergence rooms, intensive care units (ICUs), surgery rooms, during transportation of patients with respiratory failure and those receiving chest physical therapy.

The manual of neonatal resuscitation of the American Academy of Pediatrics (AAP) and the American Heart Association (AHA) recommends that the ventilation rate for newborns is between 40 and 60 breaths per minute and that the peak inspiratory pressure (PIP) provided to preterm newborns is between 20 and 40cmH_2O[3]. Therefore, some models of self-inflating resuscitators are equipped with exhaust valves to prevent that the pressure applied by the operator surpasses the limits recommended in the literature. It is advisable that this valve relieves the pressure when the maximum value of 40cmH_2O±5 is reached[4].

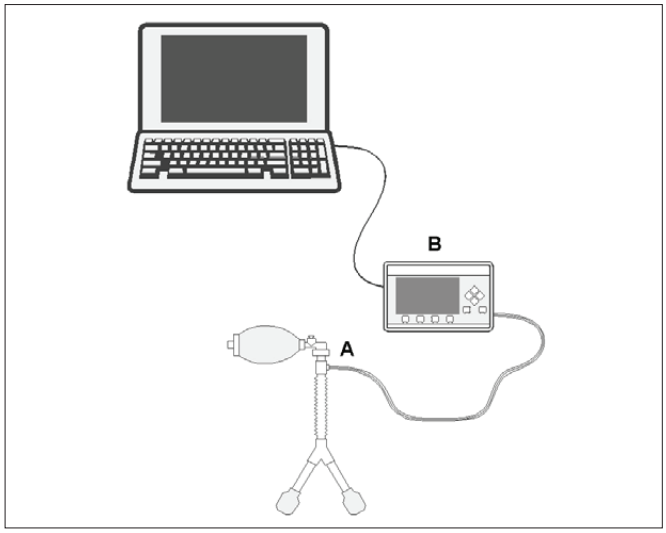


Figure 1 – Data collection scheme: (A) Pneumotachograph placed between the lung model and the self-inflating bag and (B) graphic ventilation monitor.

Resende *et al*, in 2006, found a wide variability regarding the respiratory rate (RR) and PIP applied by neonatologists during ventilation procedures using self-inflating bag in a neonatal lung model[5]. Such variation may be related to the following aspects: size of the reservoir, model equipped with pressure relief valve, performance of this valve, size of the operator's hands, use of one or both hands, time spent by the operator while applying pressure to the bag, characteristics of the mask used, adherence of the mask to the patient's face, as well as lung compliance[6-9].

In the clinical practice, the parameter used to estimate the ventilation pressure offered is the movement of thoracic expansion and/or the tactile perception of resistance to expansion[5]; however, both criteria are subjective and there is not a well-know relation of these parameters with adequate alveolar expansion[9], which makes it difficult to keep constant and adequate pressure during the resuscitation procedure. Ventilation, when provided at low pressures, may cause repeated cycles of alveolar collapse and reexpansion, generating atelectrauma and, when provided at high pressures, it may cause regional hyperdistension of the alveoli and airways, leading to barotrauma and volutrauma[10,11]. RR should also be monitored so that it remains within the parameters mentioned above, which usually is carried out by simply counting the number of breaths.

The objective of the present study was to assess the PIP and ventilation rate achieved by the paramedics of the Fire Department using a self-inflating bag in a preterm neonatal lung model.

Methods

This is a descriptive observational study using an analogical lung model especially designed for this type of research. A ventilation monitor and a computer were also used (Figure 1).

We invited 68 paramedics who were members of a group who took the 2008 Continuous Training Program of the 2nd Search and Rescue/Medical Emergency Unit of the Fire Department of the Brazilian Federal District. Of these, 31 paramedics accepted to participate in the study as volunteers,

which accounted for 9.5% of all firefighters in the Federal District (a total of 326). These paramedics had finished the training course just before data collection. All firefighters included in this study worked only as prehospital emergence paramedics and, in order to be able to perform their tasks, they took the Emergence and Urgent Care Course (CESU) offered by the Fire Department. Taking this course was a prerequirement for working as paramedics.

We used an analogical simulator of a preterm neonatal lung with lung compliance of 1.4mL/cmH_2O at a volume of 11mL. The adiabatic heating caused by the pressure variation was reduced by filling up the lung model with copper wires, thus decreasing the volume variation when there was pressure variation.

PIP and RR were assessed using a pneumotachograph (Intermed®, São Paulo, Brazil) placed between the lung model and the self-inflating bag (Figure 1A). The pneumotachograph collected the analogical sign of pressure and flow and forwarded it to a graphic ventilation monitor (Figure 1B) Tracer 5® (Intermed®, São Paulo, Brazil). The monitor transformed the analogical sign into a digital sign using transducers and processors.

Then, one paramedic at a time ventilated the lung model using a new Lifesaver® neonatal bag of 280mL (Hudson RCI®, Temecula, CA, USA) without a manometer. Ventilation was performed directly to the trachea of the lung model. Paramedics could carry out a brief test using the lung model some minutes before performing the ventilation procedure. However, they could not view the data displayed on the monitor. They could only see the lung model. Each paramedic was asked to perform the ventilation procedure, simulating as similarly as possible the actual neonatal resuscitation of a preterm infant. The data record occurred at the same time as the ventilation procedure of the lung model during the three minutes of continuous ventilation. Data were collected by a computer using the computer program Wintracer® (Intermed®, São Paulo, SP, Brazil). Although the data generated by Tracer® were continuously collected, the 20 central seconds of each minute were also recorded in the computer. Pressure curves were separately analyzed, and the maximum values of each curve were identified and entered into a spreadsheet. In order to collect the rate per minute, the cycles collected during the central 20 seconds of each minute were counted and added up, thus determining the RR.

Data collection was carried out just after the volunteers had completed the training course. Paramedics could not see the graphic curves displayed on the monitor, thus they were not led to correct their performance during data collection in case they realized they were doing something wrong.

The objectives of the study and how data would be disclosed were explained to all professionals who participated in this study. Thus, volunteers were asked to sign a written consent form when they accepted to participate in this project.

Paramedics completed a questionnaire including the following questions: How long have you been working for the Fire Department? How long have you been working as a paramedic? Have you ever performed ventilation in a newborn?

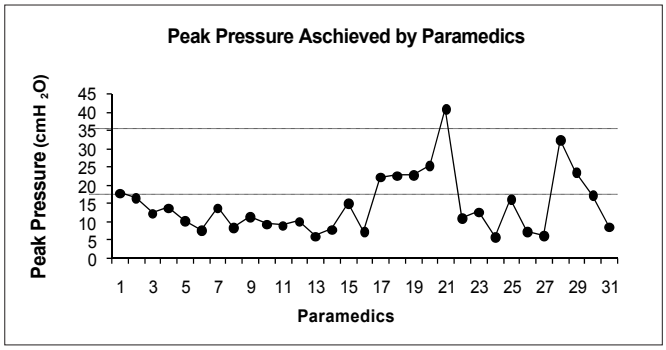
Data collection was carried out in the 2nd Search and Rescue/Medical Emergency Unit of the Fire Department of the Brazilian Federal District. Data were analyzed using the computer programs Excel 2003 and SPSS 13.0 for Windows. The Kolmogorov-Smirnov test was used to assess the normality of the data. The research project was approved by the Research Ethics Committee of Universidade Católica de Brasília.

Results

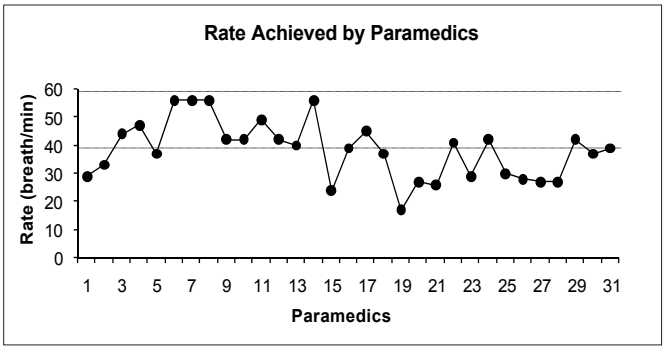
Data distribution was parametric; therefore, we used mean and standard deviation as measurements of central tendency and dispersion, respectively. We analyzed 1,186 curves provided by 31 participants. Graph 1 shows the variability of PIP achieved by the paramedics. The lowest PIP was 5.8cmH_2O and the highest PIP was 40.8cmH_2O; the mean PIP was 14.6±8.2cmH_2O. In 80.6% of the times, pressure values were not within the adequate range (between 20 and 40cmH_2O); in 77.4% of the times, pressure values were lower than 20cmH_2O; and in 3.2% of the times, pressure values were higher than 40cmH_2O. In 19.4% of the times, pressure values were within the adequate range.

With regard to ventilatory rate, Graph 2 shows the variability of the RR achieved by the paramedics. The lowest RR was 17 and the highest value was 56 cycles per minute. The mean ventilatory rate was 38.3±10.3 cycles per minute. In 51.6% of the times the ventilatory rate was lower than 40 cycles per minute and, in 48.4% of the times, the rate was between 40 and 60 cycles per minute. Ventilatory rate did not reach 60 cycles per minute.

The participants' mean time on the job was 13±5 years as firefighters and 10±4 as paramedics. Among the participants, 35.5% had already provided ventilation using a self-inflating



Graph 1 – Peak pressure reached by the 31 paramedics analyzed. Distribution of means of peak inspiratory pressure (the dashed lines show the range recommended by the American Academy of Pediatrics and the American Heart Association)



Graph 2 – Respiratory rate reached by the 31 paramedics analyzed. Distribution of means of respiratory rates (the dashed lines show the range recommended by the American Academy of Pediatrics and the American Heart Association)

bag to a newborn at least once, whereas 64.5% of them had never carried out this procedure.

Discussion

The variability of the pressure values found in the present study is not in agreement with those values found by Resende *et al* (2006). These authors found that of the pressure values reached by neonatologists and considered to be inadequate, half were lower than the recommended values and the other half was considered higher than the ideal values[5]. In the present study, among the paramedics who provided ventilation at inadequate pressure values, all of them applied pressures lower than the recommended value, except for one. This may suggest that physicians' had a higher level of confidence while paramedics were more cautious, since 64.5% of them had never carried out neonatal ventilation before in a real situation in spite of having been trained in this procedure.

As in the present study most paramedics did not reach the minimal recommended pressure value of 20cmH_2O, which is necessary for an efficient resuscitation, it is possible to assume that during a real situation there might be failure of cardiopulmonary resuscitation with risk of suffocation, resulting in hypoxia, which may damage the encephalon, leading to cerebral palsy[12]. It is also worth highlighting that low PIP ventilation in a preterm lung, whose surfactant deficiency tends to lead to alveolar collapse, causes atelectrauma[13-15]. Cyclical alveolar collapse alternated with inspiratory reopening of the alveoli could exacerbate the lung lesion[9], leading to respiratory distress syndrome[16] and causing the development of bronchopulmonary dysplasia at the long term[10]. It is worth mentioning that the self-inflating bag is not equipped with a device that provides positive end-expiratory pressure (PEEP), except for some models. The absence of this device in addition to the low PIP values may increase the vulnerability to alveolar collapse and to the other damages mentioned above[17].

With regard to RR, more than half of the paramedics ventilated at an inadequate rate and did not achieve the minimal recommended values[3]. Low RR causes a reduction in the minute ventilation, which is the result of multiplying the RR by the tidal volume (TV), with the possibility of intensifying hypoxia[18] in a real situation.

In the present study, we decided to use a neonatal artificial lung model because it is a practical method and this practice is in agreement with national and international studies[5,19,20]. Paramedics could not use the parameter of thoracic expansion. However, such resource is not completely reliable as it has been demonstrated by Baskett and Nolan[21], in spite of the fact that during a real resuscitation procedure, paramedics do not check only this parameter, using also the tactile sensation.

It is important to keep in mind that not only paramedics but also neonatologists could not ventilate this lung model applying adequate pressure values[5]. This may suggest that only practice does not ensure ventilation success; if this was true, neonatologists, who have the opportunity of ventilating newborns more often, should have shown a significantly better performance. We assumed that the difficulty lays in the type of manual ventilator: the self-inflating bag in the present study. It is important to highlight that there are manual ventilators that enable to define and view the pressure values while they are being used[17,19,22], and one of these devices was designed and patented in Brazil.

We concluded that the data collected in the present study demonstrated that paramedics did not reach the advisable levels of RR and PIP during lung ventilation using a self-inflating bag in a neonatal lung model.

Acknowledgements

The authors would like to thank Thiago Moraes Viana Bandeira for proofreading the Portuguese version of the manuscript.

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