Simultaneous mechanical ventilation of several patients with a single ventilator

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Abstract

Introduction: Simultaneous mechanical ventilation of several patients with a single ventilator might reduce the deficit of these devices for the care of patients with acute respiratory failure due to Covid-19. **Objective:** To communicate the results of a mechanical ventilation exercise with a ventilator in a lung simulator, and simultaneously in two and four. **Results:** No statistically significant differences were observed between programmed, recorded and measured positive end-expiratory pressure, mean airway pressure and peak pressure, except when simultaneously ventilating four lung simulators. **Conclusions:** Simultaneous mechanical ventilation should be implemented by medical personnel with experience in the procedure, be restricted to two patients and carried out in the intensive care unit.

KEY WORDS: Controlled mechanical ventilation. Acute respiratory insufficiency. COVID-19. Lung simulators.

Ventilación mecánica simultánea con un solo ventilador a varios pacientes

Resumen

Introducción: La ventilación mecánica simultánea a varios pacientes con un solo ventilador podría disminuir el déficit de esos dispositivos para atender a los enfermos con insuficiencia respiratoria aguda por Covid-19. **Objetivo:** Comunicar los resultados de un ejercicio de ventilación mecánica con un ventilador en un simulador de pulmón, y simultáneamente en dos y cuatro. **Resultados:** No se observaron diferencias estadísticamente significativas entre la presión positiva al final de la espiración, presión media de la vía aérea y presión pico programadas, registradas y medidas, excepto al ventilar simultáneamente cuatro simuladores de pulmón. **Conclusiones:** La ventilación mecánica simultánea debe ser instaurada por personal médico con experiencia en el procedimiento, restringirse a dos pacientes y ser realizada en la unidad de cuidados intensivos.

PALABRAS CLAVE: Ventilación mecánica controlada. Insuficiencia respiratoria aguda. COVID-19. Simuladores de pulmón.

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Date of reception: 20-03-2020
Date of acceptance: 13-04-2020
DOI: 10.24875/GMM.M20000379

Gac Med Mex. 2020;156:249-252
Contents available at PubMed
www.gacetamedicademexico.com

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Introduction

The use of mechanical ventilation in clinical practice and its immediate acceptance by the medical community revolutionized the treatment of the seriously ill and critical patient. The possibility of keeping alive and helping patients with acute respiratory failure became a reality and a common practice in hospital medicine.¹ This unprecedented therapeutic intervention was the scenario that allowed the description of acute respiratory distress syndrome (ARDS), the therapeutic benefit of the use of positive end-expiratory pressure (PEEP), alveolar recruitment and prone ventilation.¹⁻⁷

Since respiratory failure is always the first organic failure in the patient with multiple organ dysfunction syndrome, having enough ventilators is of paramount importance, particularly in ill-fated times such as those we are living in. Given the possibility that numerous patients experience acute respiratory failure in Mexico due to the Covid-19 pandemic, and the need to apply a protocol for massive mechanical ventilation to “victims” due to ventilator shortages, simultaneous ventilation of several patients with a single ventilator, especially those who share similar pathophysiological characteristics, can be a viable alternative.^{8,9} Although this procedure was proposed more than 20 years ago, it is currently feasible with pressure-controlled ventilation, by means of which peak pressure (Ppeak) and conduction pressure can be controlled, which allows ventilation with lung protection measures. The purpose of this paper is to communicate the results of a single-ventilator multiple mechanical ventilation exercise in lung simulators.

Method

The ventilator and circuits were connected to latex anesthesia breathing bags (lung simulator); dual limb adult breathing circuits were used (RT200 series, Fisher & Paykel Healthcare, Auckland, New Zealand); two pieces, assembled and connected to the inspiratory and expiratory valve, were used to connect one, two or four lung simulators (Fig. 1) to a single mechanical ventilator (AVEA®, CareFusion, San Diego, CA, USA) programmed in the pressure-control mode. To corroborate the measurements, a pressure and volume calibrator was available (VT305®, Fluke Biomedical, Cleveland, OH, USA).

Figure 1. Diagram of two and four lung simulators; in blue, inspiratory limbs of the circuit connected to the inspiratory valve;¹ in red, expiratory limbs of the circuit connected to the expiratory valve;² in green, the lung simulators.

The programmed values, those recorded by the ventilator and those measured by the calibrator were consecutively recorded in one, two and four lung simulators. The ventilator was then programmed in the pressure-control mode with PEEP rising from 0 cm H₂O, fraction of inspired oxygen at 40%, respiratory rate at 20 breaths per minute, inspiration:expiration ratio at 2:1. Each PEEP level was maintained for 10 minutes, in order to favor stability of the readings; the process was repeated until reaching a PEEP of 11 cm H₂O due to the limitations of the lung simulator.

Statistical analysis was carried out with measures of central tendency and dispersion for quantitative variables, frequency and percentage were recorded for categorical variables, and the Kolmogorov-Smirnov test was used for normality of the curve. Two-tailed Student's t-test and Pearson's correlation test were applied for normally distributed data; abnormally distributed data were analyzed with Mann-Whitney's U-test and the Spearman correlation test. Statistical significance was established with a p-value < 0.05. The statistical programs used were Social Science Statistics (<http://socscistatistics.com>) and STATA (StataCorp LLC, <http://stata.com/products/mac/>).

Results

No statistically significant differences were observed between programmed, recorded and measured PEEP, mean airway pressure and Ppeak, except when ventilating four lung simulators, a situation in which Ppeak was significantly lower in the lung simulators than in the ventilator (Table 1 and Figure 2).

Discussion

The described results demonstrate that programmed and obtained pressures were statistically equivalent when one or two lung simulators were ventilated; therefore, the system reliably transmitted the projected

Table 1. Comparison of airway pressure and volume

	One lung Mean (SD)	Two lungs Mean (SD)	Four lungs Mean (SD)
Pressure (cm H ₂ O)			
Programmed PEEP <i>versus</i> ventilator PEEP	6.9 (3.21) <i>versus</i> 5.2 (3.21) p = 0.9203	5.2 (3.32) <i>versus</i> 5.7 (3.30) p = 0.4894	5.5 (3.50) <i>versus</i> 5.9 (3.23) p = 0.6584
Programmed PEEP <i>versus</i> measured PEEP	6.9 (3.21) <i>versus</i> 5.0 (3.19) p = 0.9326	5.2 (3.32) <i>versus</i> 4.7 (3.23) p = 0.5887	5.5 (3.50) <i>versus</i> 4.2 (3.14) p = 0.1134
Ventilator PEEP <i>versus</i> measured PEEP	5.2 (3.21) <i>versus</i> 5.0 (3.19) p = 0.8520	5.7 (3.30) <i>versus</i> 4.7 (3.23) p = 0.2159	5.9 (3.23) <i>versus</i> 4.2 (3.14) p = 0.0358
Ventilator P _{maw} <i>versus</i> measured P _{maw}	9.4 (3.43) <i>versus</i> 9.6 (3.42) p = 0.8711	9.7 (3.27) <i>versus</i> 9.0 (3.19) p = 0.3492	10.1 (3.41) <i>versus</i> 8.9 (3.30) p = 0.1193
Ventilator P _{peak} <i>versus</i> measured P _{peak}	21.2 (3.14) <i>versus</i> 20.8 (3.08) p = 0.8054	22.7 (3.22) <i>versus</i> 21.5 (3.14) p = 0.1328	26.3 (3.68) <i>versus</i> 24.4 (3.58) p = 0.0309
Volume (mm)			
Ventilator volume <i>versus</i> measured volume	163.1 (18.14) <i>versus</i> 146.6 (17.10) p < 0.0001	174.9 (20.64) <i>versus</i> 160.0 (18.54) p < 0.0001	221.3 (3.88) <i>versus</i> 205.3 (4.67) p < 0.0001

PEEP = positive end-expiratory pressure, P_{maw} = mean airway pressure, P_{peak} = peak pressure, SD = standard deviation.

Figure 2. Ventilator and lung pressures distribution. PEEP = positive end-expiration pressure, P_{maw} = mean airway pressure, P_{peak} = peak pressure.

values. Simultaneous mechanical ventilation of multiple patients with a single device has the potential to double the access to mechanical ventilation until more supplies (ventilators) are received or the number of patients requiring them decreases.

Conclusions

Owing to the complexity of the connections and monitoring, the modality of simultaneous ventilation with a single ventilator should be applied by medical personnel with experience in the procedure, be restricted to two patients and carried out in the intensive care unit, where continuous monitoring is available, in addition to requiring ethical analysis and approval by health authorities.

Conflicts of interest

Dr. Gorordo Delsol reports receiving fees from Pfizer México and Merck, which are unrelated to the presented investigation. The rest of the authors declare that they have no conflicts of interest.

Funding

The authors did not receive any sponsoring to carry out this article.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments were performed on humans or animals for this research.

Confidentiality of data. The authors declare that no patient data appear in this article.

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