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Available in: http://www.redalyc.org/articulo.oa?id=289029240036

Acta Scientiae Veterinariae,
ISSN (Printed Version): 1678-0345
ActaSciVet@ufrgs.br
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Brasil
Cardiorespiratory Dynamics of Sedated Pigs Submitted to Different Inspired Oxygen Fractions under Controlled Mechanical Ventilation*

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ABSTRACT

Background: Individuals submitted to situations of deep sedation have a marked decrease in their ventilatory capacity. The provision of adequate ventilation and oxygenation in critically ill patients submitted to sedation in intensive therapy has been the subject of special care. In such cases, exposure to low inspired oxygen fractions (FIO2) is a factor that can influence alveolar perfusion and respiratory performance. The aim of this study is to evaluate the effects of three inspired oxygen fractions (80%, 60% or 40%) on the cardiorespiratory dynamics of pigs submitted to mechanical ventilation by intermittent positive pressure in deep sedation with propofol-remifentanil.

Material, Methods & Results: Twenty crossbred pigs weighing between 17 and 25 kg and aged between 60 and 90 days were used. Each animal was submitted to deep sedation for 2h in randomly assigned FIO2 (80%, 60% or 40%). Scores such as heart and respiratory rate, blood pressure, respirometry (PaO2, P(A-a)O2, PIP, Vmin), physiological dead space, pulmonary shunt and blood gas analysis (pH, PaO2, PaCO2, HCO3) were observed, evaluated and compared. Patients were evaluated after sedation was induced with propofol (12 mg.kg⁻¹) and remifentanil (0.5 mcg.kg⁻¹.min⁻¹). To maintain the level of sedation we used propofol (an average of 18 mg.kg⁻¹.h⁻¹) and remifentanil (0.5 mcg.kg⁻¹.min⁻¹). Intubation was preceded after the onset of sedation to mechanical ventilation - volume-cycled, intermittent positive pressure. Patients received a tidal volume of 10 mL.kg⁻¹ and an I:E ratio of 1:2, positive end-expiratory pressure of 4 cmH₂O with three inspired oxygen fractions. Patients’ respiratory rate was adjusted so as to maintain end-tidal carbon dioxide pressure between 35 and 45 mmHg. Data were subjected to analysis of variance for repeated measures followed by a Tukey test. Patients receiving a 40% oxygen concentration showed an average heart rate higher than the others. Shunt levels presented by animals exposed to higher oxygen fractions were significantly higher than in animals that received lower concentrations. However, the 60% fraction presented shunt levels almost two times higher than FIO2 0.4. We found statistical differences between inspired fractions, this proportion is not maintained in the difference of alveolar-arterial pressure, proving the inefficiency of the transport of oxygen by the alveolar-capillary barrier. The changes triggered by high fractions of oxygen will lead to the formation of shunts. This was the case with patients exposed to an 80% oxygen fraction, in which shunt levels were supraphysiological. Analyzing the results we conclude and recommend the use of FIO2 0.4, which both optimizes gas exchange with less lung damage and seems to provide hemodynamic stability.

Discussion: The alveolar oxygen pressure was calculated; one can see and understand how the deficiency in tissue perfusion and oxygenation happens, in conflict with high concentrations present in alveoli. Lower levels of oxygen in the alveoli are more effective in promoting the passage of the molecule into the bloodstream, reflecting optimal blood pressures. There are significant differences between inspired fractions, this proportion is not maintained in the difference of alveolar-arterial pressure, proving the inefficiency of the transport of oxygen by the alveolar-capillary barrier. The changes triggered by high fractions of oxygen will lead to the formation of shunts. This was the case with patients exposed to an 80% oxygen fraction, in which shunt levels were supraphysiological. Analyzing the results we conclude and recommend the use of FIO2 0.4, which both optimizes gas exchange with less lung damage and seems to provide hemodynamic stability.

Keywords: inspired oxygen fractions, mechanical ventilation, swine, propofol.
INTRODUCTION

Individuals submitted to situations of deep sedation have a marked decrease in their ventilatory capacity, especially when kept on spontaneous breathing [16]. Mechanical ventilation emerges as an important alternative to help correct depressant effects triggered by sedation. However, it must be carefully chosen, because it produces some effects which include significant changes in cardiovascular function due when it generates positive intrathoracic pressure [10].

Supraphysiological levels of O₂ significantly reduce the coronary blood supply in ischemic areas [21]. It is also known that the hemodynamic changes caused by hyperoxia range from reduced heart rate and cardiac output to increased blood pressure by systemic vasoconstriction [2,14]. This vasoconstriction ultimately impairs oxygen delivery to tissues and lungs. The subject treated with excess O₂ will suffer with the formation of atelectasis and pulmonary inflammatory processes [7,17,28].

The use of low concentrations of O₂ from pre-oxygenation to ventilation of the patient during surgery is recommended in order to avoid situations of low lung ventilation/perfusion ratio [1]. Many other studies recommend the use of an inspired oxygen fraction ranging from 30 to 50%. These concentrations, well below 100%, provide a good ventilation/perfusion ratio and keep the patient’s oxygenation at optimal levels with adequate pulmonary function [11,20,22].

This study aims to evaluate the cardiorespiratory changes in pigs sedated with propofol-remifentanil association and submitted to mechanical ventilation ventilation by intermittent positive pressure in three inspired oxygen fractions (FIO₂): 80%, 60% or 40%.

MATERIAL AND METHODS

Animals

Twenty crossbred pigs (Sus scrofa domestica) from the Faculdade de Veterinária (FaVet), Universidade Federal do Rio Grande do Sul (UFRGS) [School of Veterinary Medicine, Federal University of Rio Grande do Sul] were used in this study. We verified whether animals were in perfect health with body mass between 17 and 25 kg. At 90 days of age the animals were sent to the Unit of Animal Experimentation of Hospital de Clínicas de Porto Alegre (HCPA). The animals were kept at the unit under similar conditions for two days for adaptation. The animals were fed “growth” feed and water was provided ad libitum.

All procedures were performed in accordance to UFRGS guidelines for animal experimentation and Brazilian Federal Law 11.794/08, which establishes procedures for the scientific use of animals and regulates the registration of experimentation centers.

Preparation of animals

The pigs remained in the sedation room for about one hour adapting to the environment. They were then sedated using isoflurane in 100% oxygen with a universal vaporizer through an anesthesia face mask. After complete sedation and unresponsiveness to external stimuli, equipment placement was initiated. An aseptic percutaneous puncture was performed in the marginal ear vein (22 g intravenous catheter) for maintenance of fluid, and the medial plantar artery (22 g intravenous catheter) provided access for blood gas analysis and measurements of invasive pressure. The trial started thirty min after the recuperation of the animals, when the gas analyzer of the multiparameter monitor indicated the absence of isoflurane exhaled by the respiratory system and pigs were completely responsive.

Sedation and monitoring of animals

The patients were evaluated after sedation was induced with propofol (12 mg.kg⁻¹) and remifentanil (1 mcg.kg⁻¹). In order to maintain the level of sedation we used propofol (an average of 18 mg.kg⁻¹.h⁻¹) and remifentanil (0.5 mcg.kg⁻¹.min⁻¹) in a continuous infusion pump. Sedation control was agreed as follows: absence of palpebral reflex, eyes in dorsal-ventral rotation, and patients were kept in a bispectral range between 65 and 75. Monitoring was performed using a consciousness monitor (BIS). The dose of propofol varied according to the changes in the levels of consciousness of patients.

After the onset of sedation patients were intubated for mechanical ventilation. After exposure of the glottis, lidocaine spray was instilled and patients were intubated with a No. 6 Magill type endotracheal tube, with cuffs. At this point mechanical ventilation began with volume-cycled intermittent positive pressure. Patients were submitted to a tidal volume of 10 mL.kg⁻¹ and an I:E ratio of 1:2 and positive end-expiratory pressure (PEEP) of 4 cmH₂O. Patients’ respiratory rate was adjusted so as to maintain end-tidal carbon dioxide pressure (E₉CO₂)
between 35 and 45 mmHg. All data collected and used as parameters for respirometry and gas analysis were obtained through a multiparameter monitor.

For a period of 10 min after induction the patients were stabilized. During this time the sensors were set and ventilators were adjusted so that data collection could begin. During the experiment the animals were kept in fluid therapy with Ringer Lactate via marginal ear vein at a rate of infusion of 3 mL.kg⁻¹.h⁻¹.

Immediately after induction heart rate (HR), respiratory rate (RR) and electrocardiography (EKG) sensors were positioned to observe the tension of carbon dioxide at the end of expiration, and to verify oxygen saturation in hemoglobin and esophageal temperature - monitored constantly by multiparameter monitor. Minimum allowed body temperature was 37°C, and patients were kept constantly warm with heated mattresses and an air-conditioned environment.

Invasive blood pressure was obtained by connecting the catheter attached to the medial plantar artery to the sensor/transducer, and then to the pressure module of the multiparameter monitor. Systolic, diastolic and mean blood pressures were measured.

Arterial blood gas analysis was performed at the Laboratory of Clinical Pathology, HCPA. Arterial blood was collected from the medial plantar artery using heparinized syringes and immediately sent to the laboratory for blood gas meter analysis, which provided pH values, arterial pressure of CO₂ (PaCO₂), arterial pressure of O₂ (PaO₂) and bicarbonate levels.

**Experimental design**

The experiment was conducted with three groups of pigs, totaling 20 animals. Each group was submitted to the methodology described above, except for three different FIO₂: group FIO₂ 80% (six animals); group FIO₂ 60% (eight animals); group FIO₂ 40% (six animals).

Ventilatory parameters such as peak pressure, airway resistance and lung compliance were obtained in addition to the data described previously. Other data were calculated using the following equations [3]:

\[
\text{Alveolar Partial Pressure of Oxygen (PAO}_2) = FIO_2 \times (Pb-PH_2O)-(PaCO_2/0.8)
\]

\[
\text{Arterial Alveolar Gradient (P(A-a)O}_2 = \text{PAO}_2 - \text{PaO}_2
\]

\[
\text{Physiological Dead Space (VD/VT) = (PaCO}_2 - ETCO_2)/\text{PaCO}_2
\]

\[
\text{Physiological Right to Left Shunt (QS/QT) = [P(A-a)O}_2 \times 0.003] / [4+P(A-a)O}_2 \times 0.003]
\]

**Statistical analysis**

The methodology used to achieve the objectives included descriptive analysis by means and standard deviation and inferential statistics, performing a hypothesis test with a 5% significance level. Data were subjected to analysis of variance for repeated measures followed by a Tukey test. Analyses were performed using the SPSS statistical program (SPSS - Statistical Package for Social Science - version 16.0 / SPSS Inc. - IBM Company, Chicago, EUA).

**RESULTS**

Table 1 presents the collected data related to cardiovascular parameters mean and standard deviation during five different moments in time.

However, t₀ presented heart rate values slightly above the others in all inspired fractions (FI's), it was not significant. We found no significant differences between the fractions of oxygen through statistical analysis. A perceptive, but not statistically significant difference is the fact that patients submitted to a 40% oxygen concentration showed an average heart rate higher than the others.

The blood pressure collected means presented values within the normal range, but in a lower limit to the physiological reference value for the species, yet with no significant differences [9,12].

For the evaluation of respiratory dynamics, Table 2 presents collected data regarding the parameters in mean and standard deviation of the five points in time.

For the tested species, pH levels remained within acceptable physiological limits however slightly elevated, but there are neither discrepancies nor statistical differences [6,9]. As arterial CO₂ levels were normal, there are indications, through changes in pH levels, of metabolic alkalosis. Also in relation to acid-base status, another blood gasometrical reference value subject to control - bicarbonate - remained within the normal range and between different FIO₂, also showing no significant
differences [6,9]. PaCO₂ levels remained stable during the trial. There were no differences between FI’s and also between time points. Similar pressures of exhaled CO₂ also confirmed these values.

The first distortions were found in the analysis of oxygen pressures in arterial blood with development of supraphysiological levels of O₂ blood pressure. After alveolar pressure of oxygen calculated, there were significant differences between the FI’s - alveolar O₂ levels were proportionately higher in the 80% fraction when compared to the 60% fraction. On the same note, the proportion was higher in the 60% fraction than in the 40% fraction. This proportion is not maintained in the difference of alveolar-arterial pressure.

Shunt levels presented by animals exposed to higher oxygen fractions were significantly higher than in animals that received lower concentrations. However, the 60% fraction presented shunt levels almost two times higher than FIO₂ 0.4. Figures on physiological dead space were very close to zero or negative in most cases, with no statistically significant differences and distant from the physiological values [9].

It was observed in the minute volume a tendency of FIO₂ 0.8 providing lower gas volumes to patients. Although the analyzed results show a trend, there was no statistically significant difference between the data. Peak pressure shows the difference between the FIO₂ 0.8, which is lower compared to the others.

Table 1. Mean values ± standard deviation of ventilatory parameters of pigs sedated for two hours in mechanical ventilation with volume-controlled intermittent positive pressure in three different inspired oxygen fractions (FIO₂ 0.8, FIO₂ 0.6 e FIO₂ 0.4).

<table>
<thead>
<tr>
<th>FIO₂</th>
<th>t₀</th>
<th>t₃₀</th>
<th>t₆₀</th>
<th>t₉₀</th>
<th>t₁₂₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>102±27</td>
<td>88±25</td>
<td>83±14</td>
<td>88±24</td>
<td>89±21</td>
</tr>
<tr>
<td>0.6</td>
<td>100±37</td>
<td>88±16</td>
<td>87±21</td>
<td>85±23</td>
<td>85±23</td>
</tr>
<tr>
<td>0.4</td>
<td>117±18</td>
<td>103±16</td>
<td>100±16</td>
<td>99±12</td>
<td>104±37</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>83±11</td>
<td>75±7</td>
<td>75±9</td>
<td>77.0±11</td>
<td>83±11</td>
</tr>
<tr>
<td>0.6</td>
<td>84±13</td>
<td>85±15</td>
<td>83±15</td>
<td>81±14</td>
<td>82±13</td>
</tr>
<tr>
<td>0.4</td>
<td>77±8</td>
<td>79±7</td>
<td>78±6</td>
<td>79±5</td>
<td>79±9</td>
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<tr>
<td>SBP (mmHg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>120±23</td>
<td>118±18</td>
<td>119±17</td>
<td>118±23</td>
<td>124±23</td>
</tr>
<tr>
<td>0.6</td>
<td>120±16</td>
<td>123±17</td>
<td>123±20</td>
<td>121±15</td>
<td>123±12</td>
</tr>
<tr>
<td>0.4</td>
<td>108±16</td>
<td>115±9</td>
<td>115±8</td>
<td>115±9</td>
<td>116±11</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>62±10</td>
<td>54±5</td>
<td>55±9</td>
<td>56±8</td>
<td>62±9</td>
</tr>
<tr>
<td>0.6</td>
<td>63±12</td>
<td>65±12</td>
<td>64±13</td>
<td>62.0±13</td>
<td>63.1±13</td>
</tr>
<tr>
<td>0.4</td>
<td>59±6</td>
<td>59±5</td>
<td>58±3</td>
<td>60±4</td>
<td>59±9</td>
</tr>
</tbody>
</table>

HR (bpm): heart rate (beats per minute); MAP: mean arterial pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure.

**DISCUSSION**

No significant differences were founded between the applied fractions of oxygen and hemodynamic parameters as Nunes et al. [18], in which anesthetic doses of propofol were used in patients with spontaneous ventilation. Although, it is reported that high concentrations of oxygen - in awake dogs - result in increased cardiac output with decreased HR [2,14]. In propofol-anesthetized dogs the effects of two FIO₂ levels in mechanical ventilation do not alter arterial blood pressure [12]. When hemodynamic parameters obtained in the experiment were compared with others studies we noticed that all the means were slightly lower, but within the acceptable range of physiological parameters of the species [5,18].

Patients submitted to a 40% oxygen concentration showed an average heart rate that was higher than the others. This may indicate that lower FIO₂ maintain patients’ hemodynamic stability [14]. However, such data could have been better confirmed if our FIO₂ 0.4 sample group were larger. Changes in the cardiovascular system are expected in response to mechanical ventilation techniques and to changes in intrathoracic pressure, as artificial respiration is responsible for decreased venous return and consequent reduction in cardiac output and blood pressure. Always aggravated by anesthesia, such changes were not detected in our study, probably because the animals were healthy, with low levels of sedation and under constant and adequate tissue oxygenation [8].
Table 2. Mean values ± SD (standard deviation) of ventilatory parameters of pigs sedated for two hours in mechanical ventilation with volume-controlled intermittent positive pressure in three different inspired oxygen fractions (FIO₂ 0.8, FIO₂ 0.6 e FIO₂ 0.4).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FiO₂</th>
<th>t₀</th>
<th>t₃₀</th>
<th>t₆₀</th>
<th>t₉₀</th>
<th>t₁₂₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.8</td>
<td>7.510±0.115</td>
<td>7.537±0.035</td>
<td>7.546±0.037</td>
<td>7.518±0.046</td>
<td>7.529±0.045</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>7.494±0.046</td>
<td>7.543±0.030</td>
<td>7.540±0.018</td>
<td>7.534±0.027</td>
<td>7.528±0.023</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>7.518±0.046</td>
<td>7.536±0.017</td>
<td>7.530±0.032</td>
<td>7.521±0.024</td>
<td>7.508±0.092</td>
</tr>
<tr>
<td>HCO₃ (mmol/L)</td>
<td>0.8</td>
<td>31±3.0</td>
<td>33±2.2</td>
<td>33.2±2.2</td>
<td>33±2.3</td>
<td>32.9±3.0</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>32±1.7</td>
<td>32±1.4</td>
<td>32.1±1.7</td>
<td>31.7±1.7</td>
<td>31.2±1.7</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>32±2.9</td>
<td>32±2.9</td>
<td>32.2±2.3</td>
<td>31.7±2.5</td>
<td>30.0±7.9</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>0.8</td>
<td>41±12.9</td>
<td>39.9±3.9</td>
<td>39.2±1</td>
<td>41±4</td>
<td>40±4</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>43±5.5</td>
<td>37.9±2.9</td>
<td>38.2±2</td>
<td>39±2</td>
<td>40.2±2</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>42±4.4</td>
<td>39.0±3.8</td>
<td>38.3±3.5</td>
<td>40±2</td>
<td>42±10</td>
</tr>
<tr>
<td>PaO₂ (mmHg)*</td>
<td>0.8</td>
<td>342±62</td>
<td>341±78</td>
<td>379±32</td>
<td>370±28</td>
<td>379±40</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>275±21</td>
<td>277±15</td>
<td>284±19</td>
<td>268±21</td>
<td>278±7</td>
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<tr>
<td></td>
<td>0.4</td>
<td>180±24</td>
<td>176±19</td>
<td>181±21</td>
<td>187±11</td>
<td>172±34</td>
</tr>
<tr>
<td>PAO₂ (mmHg)*</td>
<td>0.8</td>
<td>518±16</td>
<td>520±5</td>
<td>521±2</td>
<td>518±5</td>
<td>519±5</td>
</tr>
<tr>
<td></td>
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<td>373±6</td>
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<td>377±2</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>231±5</td>
<td>236±4</td>
<td>236±4</td>
<td>234±3</td>
<td>232±13</td>
</tr>
<tr>
<td>P(A-a)O₂ (mmHg)*</td>
<td>0.8</td>
<td>176±49</td>
<td>179±75</td>
<td>142±32</td>
<td>147±29</td>
<td>141±41</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>98±19</td>
<td>103±16</td>
<td>95±20</td>
<td>110±21</td>
<td>99±7</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>51±25</td>
<td>60±15</td>
<td>55±21</td>
<td>47±10</td>
<td>59±22</td>
</tr>
<tr>
<td>QS/QT (%)</td>
<td>0.8</td>
<td>11.6±2.8</td>
<td>11.7±4.3</td>
<td>9.6±2</td>
<td>9.9±1.7</td>
<td>9.5±2.5</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>68±1.3</td>
<td>72±1</td>
<td>66.5±1.3</td>
<td>7.7±1.4</td>
<td>6.9±0.5</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>37±1.7</td>
<td>43.3±1</td>
<td>40.5±1.5</td>
<td>3.4±0.7</td>
<td>4.3±1.5</td>
</tr>
<tr>
<td>Vₚ/Vₜ (%)</td>
<td>0.8</td>
<td>-9±8</td>
<td>-3.9±6</td>
<td>-5.4</td>
<td>-1.2±5</td>
<td>-3±6</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>-4±8</td>
<td>-5.0±8</td>
<td>-6.5</td>
<td>-2.6</td>
<td>-5.8</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.2±12</td>
<td>-7±6</td>
<td>-8.4</td>
<td>-6.8</td>
<td>-2.14</td>
</tr>
<tr>
<td>Vₘₙ (mL)</td>
<td>0.8</td>
<td>5698±1117</td>
<td>5398±1186</td>
<td>5388±884</td>
<td>5463±1011</td>
<td>5601±1002</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>5816±969</td>
<td>6315±1098</td>
<td>6202±1121</td>
<td>6061±808</td>
<td>5952±1274</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>5645±1506</td>
<td>6193±679</td>
<td>6445±854</td>
<td>6563±1083</td>
<td>6758±1144</td>
</tr>
<tr>
<td>PPI (cmH₂O)**</td>
<td>0.8</td>
<td>12.5±2.1</td>
<td>11±1.3</td>
<td>10.3±1</td>
<td>10.8±1</td>
<td>11.3±1.5</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>14±1.8</td>
<td>12.7±1.6</td>
<td>13.2±2.3</td>
<td>12.6±2</td>
<td>13.8±2.3</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>14.5±1.5</td>
<td>12.8±0.7</td>
<td>13.1±1.5</td>
<td>13.5±1.8</td>
<td>14.3±2.6</td>
</tr>
</tbody>
</table>

HCO₃: bicarbonate; PaCO₂: partial arterial pressure of CO₂; PaO₂: partial arterial pressure of O₂; PAO₂: partial alveolar pressure of O₂; P(A-a)O₂: alveolar-arterial pressure gradient of O₂; Qs/Qt: right-left physiological shunt fraction; Vₚ/Vₜ: physiological dead space ratio; Vₘₙ: minute volume; PPI - peak airway pressure. *P < 0.001 and **P > 0.005 for ANOVA. a, b, c Groups followed by the same letter do not differ significantly by Tukey test.
Scientific Articles have shown that differences are found in human patients. In this case the patients underwent anesthetic - not sedative - doses of the drug, causing a major collapse of the cardiovascular system. Otherwise, this study used lower doses of propofol in combination with remifentanil, which resulted in lower threshold values, but within the standards for swine. The combination of propofol-remifentanil may lead to a decrease in blood pressure due to central depression with decreased sympathetic response and a negative inotropic effect [4,26].

Blood gas analysis is a test that can be extremely useful when one needs to evaluate respiratory effectiveness and its impact on acid-base balance. Altered pH values can often equal ventilatory problems. Physiological pH levels of pigs were higher when compared to those humans and other pets [4]. Variation in pH and metabolic alkalosis were probably caused by maintenance/fluid therapy with crystalloid solution of ringer’s lactate administered to patients during sedation. This option was chosen precisely because it is used to counter acidosis [13].

Reduced respiratory center activity and hypoventilation could occur by the action of anesthetics used, but the adverse effects were canceled by adequate ventilation. Mechanical ventilation is used to minimize changes in the blood concentration of CO₂ [5]. This analysis can be made based on adequate and stable levels of PaCO₂ maintained during the trial. Such values were also confirmed by similar pressures of exhaled CO₂, confirming the adequate gas exchange and pulmonary perfusion. FI’s did not influence the circulating levels of CO₂ in which patients receiving lower concentrations of oxygen maintained better lung function that allowed an optimized ventilation/perfusion ratio [5,16].

With higher oxygen concentrations, in the short term those changes are not harmful to individuals. However, exposure for long periods can predispose patients to hemodynamic alterations, problems in pulmonary perfusion and gas exchange. In some cases it might develop into an infectious processes [27]. PaO₂ levels depend on the FIO₂, ventilation and the relationship between ventilation/perfusion [5].

After alveolar pressure of oxygen were calculated it was possible to see and understood how deficient tissue perfusion and oxygenation happen, in a stark contrast to high concentrations in the alveoli. Lower levels of oxygen in the alveoli are, proportionally speaking, more effective in promoting the passage of the O₂ molecule into the bloodstream, reflecting optimal blood pressures. While there are significant differences between FI’s this proportion is not maintained in the difference of alveolar-arterial pressure, proving the inefficiency of the transport of oxygen by the alveolar-capillary barrier [15,17].

The changes triggered by high fractions of oxygen will lead to the formation of shunts. They were within acceptable physiological limits [9]. High levels of shunts may promote complications and even delay the recovery of patients in ICUs. This was the case of patients exposed to an oxygen fraction of 80%, in which shunt levels were supraphysiological [25].

Physiological dead space values are important because they reflect the adequate ventilation/perfusion ratio and are good indicators for the sedation of patients. Values below zero are found infrequently and do not necessarily mean problems [23,24]. Patients under the stress of exercise, pregnant women and children usually present these values, resulting from a lower functional residual capacity of the respiratory system. This would be acceptable in our case because our animals were young [24]. It is interesting to report that Nunn & Hill [19] found values similar to the ones presented in our research in patients receiving high tidal volumes at low respiratory rate. Shankar et al. [24] mentioned that with the use of PEEP in ventilation there is a greater possibility of alveolar expansion/emptying, resulting in higher fractions of expired CO₂ and thus the absence of physiological dead space.

FIO₂ 0.8 provides lower gas volumes to patients, probably because of higher gas concentrations. The peak pressure shows the difference between the FIO₂ 0.8, which is lower compared to the others because of the same reasons: the fact that patients receive lower Vmin [16,25].

CONCLUSION

According to the results previously obtained we noticed that differences between FI’s and arterial oxygen levels were as expected. Because of possibility to developing a greater percentage of shunt, FIO₂ 0.8 was not appropriate and should be used with care for long periods. It is worth noting that the use of a 40% oxygen fraction can bring many respiratory and hemodynamic benefits to the patient. However, further studies on this fraction are necessary, especially for longer periods.
SOURCES AND MANUFACTURERS
1Forane - Cristália Produtos Químicos Farmacêuticos Ltda, Itapira, SP, Brazil.
2Safelet ETFE - Nipro Medical Ltda, Sorocaba, SP, Brazil.
3S/5 Monitor (MCAiOx, Spirometry and Invasive Pressure Module) - Datex-Ohmeda Inc., Finland.
4Propovan - Cristália Produtos Químicos Farmacêuticos Ltda, Itapira, SP, Brazil.
5Ultiva - GlaxoSmithkline do Brasil Ltda, Rio de Janeiro, RJ, Brazil.
6Infusomat - Laboratórios B. Braun S.A, São Gonçalo, RJ, Brazil.
7BIS Monitor - Aspect Medical Systems Inc., Natick, MA, USA.
8Xylestesin - Cristália Produtos Químicos Farmacêuticos Ltda, Itapira, SP, Brazil.
9Origami - K. Takaoka Industria e Comércio Ltda, São Paulo, SP, Brazil.
10Lactated ringer's solution- Baxter Hospitalar Ltda, São Paulo, SP, Brazil.
11BIS Monitor - Aspect Medical Systems Inc., Natick, MA, USA.
12Statistical Package for Social Science version 16.0 - SPSS Inc., IBM Company, Chicago, IL, USA.

Funding. This work was supported by Fundo de Incentivo à Pesquisa e Eventos (FIPE - HCPA), Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (FAPERGS) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil

Ethical approval. This study was approved by the Institutional Research Ethics Committee CEUA-HCPA (Porto Alegre, RS, Brazil) and is registered under the number 086189.

Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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