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**UNIVERSIDADE ESTADUAL PAULISTA
“JÚLIO DE MESQUITA FILHO”
FACULDADE DE MEDICINA**

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**Efeito do aumento do diâmetro da sonda endotraqueal na
mecânica pulmonar e na hemogasometria arterial de gatos
anestesiados sob ventilação controlada por volume ou
ventilação controlada por pressão**

Tese apresentada à Faculdade de Medicina,
Universidade Estadual Paulista “Júlio de
Mesquita Filho”, Câmpus de Botucatu, para
obtenção do título de Doutor em
Anestesiologia.

Orientador: Prof. Dr. Francisco José Teixeira Neto

Botucatu
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Tese (doutorado) - Universidade Estadual Paulista (UNESP), Faculdade de Medicina, Botucatu

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1. Gatos. 2. Respiração artificial. 3. Ventilação Pulmonar.

Palavras-chave: Gatos domésticos; Pressão de pico; Pressão de platô; Resistência das vias aéreas.

Dedicatória

"Aos meus pais e à minha irmã, por sempre acreditarem em mim. À minha avó e à minha tia, que já partiram, e de quem não pude me despedir adequadamente. As verei em um lugar melhor."

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Epígrafe

"If you're going to try, go all the way; otherwise, don't even start"

Charles Bukowski

Capítulo 1

RESUMO

OSPINA, DA. **Efeito de um aumento de 50% no diâmetro interno da sonda endotraqueal na mecânica pulmonar em gatos anestesiados sob ventilação controlada por volume com uma pausa inspiratória prolongada.** Botucatu, 2024. 19p. Tese (Doutorado) – Faculdade de Medicina de Botucatu, Universidade Estadual Paulista, Botucatu.

Objetivo– Avaliar o efeito do aumento do diâmetro interno da sonda endotraqueal de 3,0 mm ($SE_{(3,0)}$) para 4,5 mm ($SE_{(4,5)}$) no gradiente entre a pressão de pico (P_{pico}) e a pressão de platô (P_{plat}) registrada durante a ventilação controlada por volume (VCV) com uma pausa inspiratória prolongada em gatos.

Delimitação experimental– Estudo experimental prospectivo.

Animais– Dez gatos hígidos (peso ideal: $4,22 \pm 0,39$ kg).

Material e Método– Após a administração de propofol, uma sonda endotraqueal ($SE_{(3,0)}$) foi inserida para a manutenção da anestesia com isoflurano (fração inspirada de oxigênio: 0,4). O gradiente $P_{pico} - P_{plat}$ registrado durante a VCV (volume corrente: 12 ml/kg) com uma pausa inspiratória $> 0,5$ seg foi usado como um índice estimativo da resistência das vias aéreas (R_{aw}). A P_{pico} , P_{plat} , gradiente $P_{pico} - P_{plat}$, complacência quase-estática (C_{qstat}) e a hemogasometria arterial foram mensurados após 10–15 minutos de estabilidade da profundidade anestésica/ausência de assincronia paciente-ventilador com a $SE_{(3,0)}$. Os animais foram reintubados com uma $SE_{(4,5)}$ e repetiu-se o mesmo protocolo. Empregou-se o teste t pareado ou o teste de Wilcoxon para comparação das variáveis obtidas com diferentes sondas endotraqueais ($p < 0,05$ considerado significativo).

Resultados– À medida que o diâmetro interno da sonda endotraqueal foi aumentado de 3,0 para 4,5 mm, a P_{pico} [mediana (valor mínimo e máximo)] diminuiu de 8 (6–10) cmH₂O para 7 (6–8) cmH₂O ($p < 0,0039$); enquanto a P_{plat} não apresentou alterações [6 (5–7) e 6 (5–7)] ($p > 0,99$). O aumento no diâmetro interno da sonda reduziu o gradiente $P_{pico} - P_{plat}$ de 2–3 mmHg para 1 mmHg em todos os gatos ($p = 0,0039$). A C_{qstat} e a hemogasometria arterial não foram alterados pela mudança no diâmetro interno da sonda endotraqueal.

Conclusões e relevância clínica– O gradiente $P_{pico} - P_{plat}$ é útil para detectar aumentos na R_{aw} causados por uma sonda endotraqueal estreita durante a VCV com uma pausa inspiratória $> 0,5$ seg. Em gatos com peso ideal próximo a 4 kg, o emprego de uma sonda com 4,5 mm pode ser preferível a uma sonda de 3,0 mm porque reduz a sonda de maior diâmetro reduz a P_{pico} durante a VCV.

Palavras-chave Gatos domésticos, pressão de pico, pressão de platô, resistência das vias aéreas

ABSTRACT

OSPINA, DA. **Effects of a 50% increase in endotracheal tube internal diameter on pulmonary mechanics recorded during volume-controlled ventilation with a prolonged inspiratory pause in cats.** Botucatu, 2023. 19p. Thesis (PhD) – São Paulo State University, School of Medicine, Botucatu.

Objective To evaluate the effects of increase in endotracheal tube internal diameter $ET_{\text{tube(ID)}}$ from 3.0 mm ($ET_{\text{tube(3.0)}}$) to 4.5 mm ($ET_{\text{tube(4.5)}}$) on the gradient between peak inspiratory pressure (P_{peak}) and plateau pressure (P_{plat}) recorded during volume-controlled ventilation (VCV) with a prolonged inspiratory pause in cats.

Study design Prospective, experimental study.

Animal population Ten healthy cats [ideal body weight (IBW): 4.22 ± 0.39 kg].

Methods After propofol administration, an $ET_{\text{tube(3.0)}}$ was placed for maintenance of anesthesia with isoflurane (inspired oxygen fraction: 0.4). The $P_{\text{peak}} - P_{\text{plat}}$ gradient recorded during VCV (tidal volume: 12 mL kg^{-1}) with an inspiratory pause > 0.5 sec was used as a surrogate index of airway resistance (R_{aw}). P_{peak} , P_{plat} , $P_{\text{peak}} - P_{\text{plat}}$ gradient, quasistatic compliance (C_{qstat}), and arterial blood gases were measured after 10–15 min of stable depth of anesthesia/absence of patient-ventilator asynchrony with the $ET_{\text{tube(3.0)}}$. Animals were reintubated with an $ET_{\text{tube(4.5)}}$ and the same protocol was repeated. A paired t test or a Wilcoxon test compared data with different $ET_{\text{tube(ID)}}$ ($p < 0.05$ considered significant).

Results As the $ET_{\text{tube(ID)}}$ was increased from 3.0 to 4.5 mm, P_{peak} [median (range)] decreased from 8 (6–10) cmH_2O to 7 (6–8) cmH_2O ($p < 0.0039$); while P_{plat} did not change [6 (5–7) and 6 (5–7)] ($p > 0.99$). The increase in $ET_{\text{tube(ID)}}$ reduced the $P_{\text{peak}} - P_{\text{plat}}$ gradient from 2–3 cmH_2O to 1 cmH_2O in all cats ($p = 0.0039$). C_{qstat} , and arterial blood gases were unaltered by the change in $ET_{\text{tube(ID)}}$.

Conclusions and clinical relevance The $P_{\text{peak}} - P_{\text{plat}}$ gradient is useful to detect increases in R_{aw} caused by a narrow endotracheal tube during VCV with an inspiratory pause > 0.5 sec. In cats with an IBW close to 4 kg, an $ET_{\text{tube(4.5)}}$ can be favored in relation to an $ET_{\text{tube(3.0)}}$ because it lowers P_{peak} .

Keywords Airway resistance, domestic cats, peak airway pressure, plateau pressure

Introduction

The internal diameter of the endotracheal tube significantly contributes to total airway resistance (R_{aw}) in neonatal/pediatric human patients (Jarreau et al. 1999; Oca et al. 2002). According to the Ohm's law, resistance to gas flow through an endotracheal tube result in a pressure drop (ΔP) from one end to another end of the tube at a given flow rate (Mitchell & Jones 2005; Lumb & Thomas 2021):

$$\text{Resistance to gas flow} = \frac{\Delta P}{\text{Flow rate}}$$

If the gas flow follows a laminar pattern, resistance can be calculated by combining the Ohm's law with the Hagen-Poiseuille equation (Mitchell & Jones 2005; Lumb & Thomas 2021):

$$\text{Resistance to gas flow} = \frac{8 \times \text{gas viscosity} \times \text{length of tube}}{\pi \times (\text{radius of the tube})^4}$$

From the equation above, besides gas viscosity, an increase in the length of the tube and a reduction in its ID/radius will increase resistance to gas flow (Mitchell & Jones 2005; Lumb & Thomas 2021). The endotracheal tube internal diameter ($ET_{\text{tube(ID)}}$) is of critical importance in neonatal/pediatric human patients, where seemingly small reductions in endotracheal tube size may cause a major impact on R_{aw} (Oca et al. 2002). By applying the equation above, if an adult cat is intubated with a 3.0 mm internal diameter endotracheal tube ($ET_{\text{tube(3.0)}}$) instead of a 4.5 mm internal diameter endotracheal tube ($ET_{\text{tube(4.5)}}$) of the same length, resistance to gas flow will increase by approximately 5 times with the narrower endotracheal tube.

In patients who are breathing spontaneously an increase in total R_{aw} caused by a narrow endotracheal tube negatively impacts respiratory function by increasing the work of breathing (Lumb & Tomas 2021). In animals receiving volume-controlled ventilation (VCV) with a constant inspiratory flow an increase in R_{aw} is expected to increase peak airway pressure (P_{peak}) (Kaczka et al. 2019). However, an increase P_{peak} measured at the end of a constant inspiratory flow during VCV reflects not only the energy spent to overcome the frictional resistance imposed by the airways (R_{aw}), but also the viscoelastic properties of the respiratory

system (Barberis et al. 2003; Henderson & Sheel 2012). If a pause in inspiratory flow of at least 0.5 seconds is added after the target tidal volume (V_T) is achieved during VCV, the plateau pressure (P_{plat}) measured at the end of the zero flow period may reflect only the energy spent to overcome the viscoelastic properties of the respiratory system (Barberis et al. 2003; Henderson & Sheel 2012). Therefore, an increase in gradient between P_{peak} and P_{plat} in VCV mode with a prolonged inspiratory pause will be the result of an increase in total R_{aw} (Barberis et al. 2003; Henderson & Sheel 2012; Kaczka et al. 2019).

Because cats are prone to laryngospasm upon induction of anesthesia, some clinicians may favor the use of narrower endotracheal tubes to facilitate intubation, especially if the arytenoids are not fully relaxed/abducted. The hypothesis of the present study was that the gradient between P_{peak} and P_{plat} recorded during VCV with a relatively long inspiratory pause (> 0.5 seconds) would allow to detect a decrease in R_{aw} caused by a 50% increase in $ET_{tube(ID)}$ (from 3.0 mm to 4.5 mm), and the use of a larger endotracheal tube size would be beneficial because it would reduce P_{peak} in anesthetized cats receiving VCV.

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