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EFFECTS OF THE HIGH-FLOW MODIFIED TO-AND-FRO ANESTHESTIC SYSTEM ON BLOOD GAS AND RESPIRATORY RATE IN HALOTHANE ANESTHETIZED HORSES[1]

EFEITOS DO SISTEMA ANESTÉSICO DE ALTO FLUXO "TO-AND-FRO" MODIFICADO SOBRE OS GASES SANGÜÍNEOS E FREQÜÊNCIA RESPIRATÓRIA EM CAVALOS ANESTESIADOS COM HALOTANO

Cláudio Corrêa Natalini[2] Alexandre da Silva Polydoro[3]

SUMMARY

Ten healthy adult horses male or female, mean body weight of 424±44.1kg, were anesthetized with romifidine, tiletamine/zolazepam and halothane for 60 minutes using a modified to-and-fro rebreathing anesthetic system, added of 1 liter mechanical dead space. The gas flow rate was 10 liters oxygen/minute during all inhalation anesthetic time. Variables analyzed were arterial blood pH, carbon dioxide partial pressure ($PaC0_2$) and oxygen partial pressure ($Pa0_2$), and respiratory rate (RR). The horses were allowed to breath spontaneously, and were positioned in right lateral recumbency the arterial 0_2 values were significantly higher during halothane anesthesia when compared to the baseline values, and significantly lower after induction with tiletamine/zolazepam although arterial hypoxemia were not present. The arterial $PaC0_2$ values were significantly higher from baseline values during halothane anesthesia occurring arterial hypercapnia and mild respiratory acidosis. The arterial pH changes paralleled the changes in $PaC0_2$. Respiratory rate values were significantly lower during halothane anesthesia when compared to baseline values. All values remained within accepted range for lateral recumbent spontaneously breathing anesthetized horses.

Key words: *equine, horses, anesthesia, anaesthesia, halothane.*

RESUMO

Dez cavalos adultos e sadios machos ou fêmeas, com peso médio de 424±44,1kg, foram anestesiados com romifidina, tiletamina/zolazepam e halotano por 60 minutos, sendo utilizado um sistema anestésico reinalatório "to-and-fro" modificado pela adição de um litro de espaço morto mecânico. O fluxo de gás diluente foi de 10 litros de 0_2/minuto durante o período de anestesia com halotano. As variáveis estudadas no sangue arterial foram o pH, pressão parcial de dióxido de carbono ($PaC0_2$) e pressão parcial de oxigênio ($P0_2$) e freqüência respiratória (RR). Os cavalos foram mantidos sob respiração espontânea e posicionados em decúbito lateral direito. Os valores arteriais de oxigênio estiveram significativamente aumentados durante a anestesia com halotano quando comparados com os parâmetros basais da variável, e significativamente diminuidos durante a indução com tiletamina/zolazepam, embora sem a presença de hipoxemia arterial. Os valores arteriais dióxido de carbono foram significativamente maiores a partir dos parâmetros basais da variável em relação aos parâmetros obtidos dos 15 aos 60 minutos de anestesia com halotano, ocorrendo hipercapnia e discreta acidose respiratória. As alterações de pH arterial ocorreram paralelas as alterações no dióxido de carbono arterial. Os valores de freqüência respiratória estiveram significativamente reduzidos durante a anestesia com halotano, quando comparados com os valores basais. Os

[1]Projeto desenvolvido com auxílio do CNPq-DF e da FAPERGS-RS.

[2]Médico Veterinário, Professor Assistente, Departamento de Clínica de Pequenos Animais, UFSM, Santa Maria, RS.

[3]Médico Veterinário, Professor Adjunto, Centro de Ciências da Saúde, ULBRA. Rua Pe. Anchieta 66/301, 92110-050 Canoas, RS. Autor para correspondência.

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parâmetros obtidos das variáveis estudadas, permaneceram dentro dos limites considerados normais para cavalos anestesiados com halotano, em decúbito lateral e respirando espontaneamente.

Palavras-chave: *eqüinos, anestesia, halotano.*

INTRODUCTION

The anesthetic machine and breathing circuit for inhalation anesthesia delivers oxygen and anesthetic gases to the horse and remove carbon dioxide from the exhaled gases (BEDNARSKI, 1991). Halothane and isoflurane are the most commonly used inhalant anesthetic agents in horses. These agents are usually delivered in a semi-closed circly system or a valveless to-and-fro system using an out-of-the circuit vaporizer (BEDNARSKI, 1991, STEFFEY *et al.*, 1977).

In the horse, which is apparently predisposed to alveolar hypoventilation during inhalation anesthesia, it is suggested that adequate anesthetic apparatus design should be directed towards minimizing resistance and dead space and provididng maximal and efficient carbon dioxide elimination. Resistance to breathing imposed by large animal anesthetic machine may contribute to increase work of breathing and ventilatory depression in anesthetized large animals (ROBINSON, 1991).

The disadvantages of the to-and-fro breathing system are and excessive heat generated by the absorbent, however studies have shown no increase in the patients body temperature after 90 minutes of anesthesia, alkaline dust may be inhaled, relatively awkward to use, the soda lime nearest to the patient becomes expended first and increases mechanical dead space, and positioning the carbon dioxide absorption canister close to the patient head may be cumbersome (BEDNARSKI, 1991, RIEBOLD *et al.* (1995). Compared to a circle system, the to-and-fro anesthetic circuit is relatively simple and of rugged construction, easily disassembled for cleaning, easily transportable, and it is possible a relatively rapid change in anesthetic concentration for a given fresh gas flow (BEDNARSKI, 1991).

Canister size is most critical in the to-and-fro system because the carbon dioxide content of the system progressively increases with time owing to increase mechanical dead space (PURCHASE, 1965). Too large or too small a canister causes rapid increase in apparatus dead space of carbon dioxide absorption is not complete, respectively (DORSCH & DORSCH, 1984). The to-and-fro system may be used with an horizontal or vertical canister, filled with approximately nine pounds of soda lime, and it can be used either as a semi-closed system, the distinction between the two referring to the fresh gas flow rate (BEDNARSKI, 1991, RIEBOLD, *et al.*, 1995).

It has been described that using a semi-closed to-and-fro system with a vertical canister, oxygen-halothane anesthesia in horses, it is possible to carry out 120 minutes prolonged surgery without remarkable effects on blood gases and pH (STOLK & LAGERWEIJ, 1989). This study was designed to evaluate the effects of a to-and-fro modified system, adding one liter mechanical dead space, on blood gases and respiratory rate in oxygen-halothane anesthetized horses, during 60 minutes using time as a factor.

MATERIALS AND METHODS

Ten matures healthy horses (8 geldings and 2 mares), 9.8±2.5 years old, and weighting 424±44.1kg were used. Food was withheld for 12 hours beforre each study. Water was available at all time. Immediately before each anesthetic induction respiratory rate was recorded, and an arterial blood sample was collected from the carotid or facial artery for pH, carbon dioxide arterial partial pressure ($PaCO_2$), and oxygen arterial partial pressure ($Pa0_2$) baseline determination.

After sedation with intravenous (IV) romifidine[a] 0.08mg.kg^{-1}, a 20 gauge, 2 inch catheter[b] was percutaneuosly placed in the horse facial artery and a 14 gauge, 3.5 inch catheter[c] was introduced in the jugular vein, both sutured to the skin. Anesthetic induction was obtained with tiletamine/zolazepam[d] combination at 1.5mg.kg^{-1} IV, 15 minutes after sedation, and the horses positioned in right lateral recumbency.

After induction and tracheal intubation, each horse was connected to the anesthetic breathing circuit equipped with and halothane precision vaporizer[e]. The to-and-fro system was equipped with a horizontal nine pounds capacity soda lime canister and a 51cm x 5cm hose connection, adding one liter mechanical dead space to the circuit (Figure 1). Oxygen flow rate was 10 liters/minute. Anesthesia was maintained with 3V% halothane[f] for the first 20 minutes and 1.5V% to 2V% during the remaining 40 minutes of inhalation anesthesia. The horses were allowed to breath spontaneously.

Respiratory rate was determined by counting thoracic and abdominal excursions in one minute interval. Heparinized arterial blood samples were collected and refrigerated for pH and blood gas

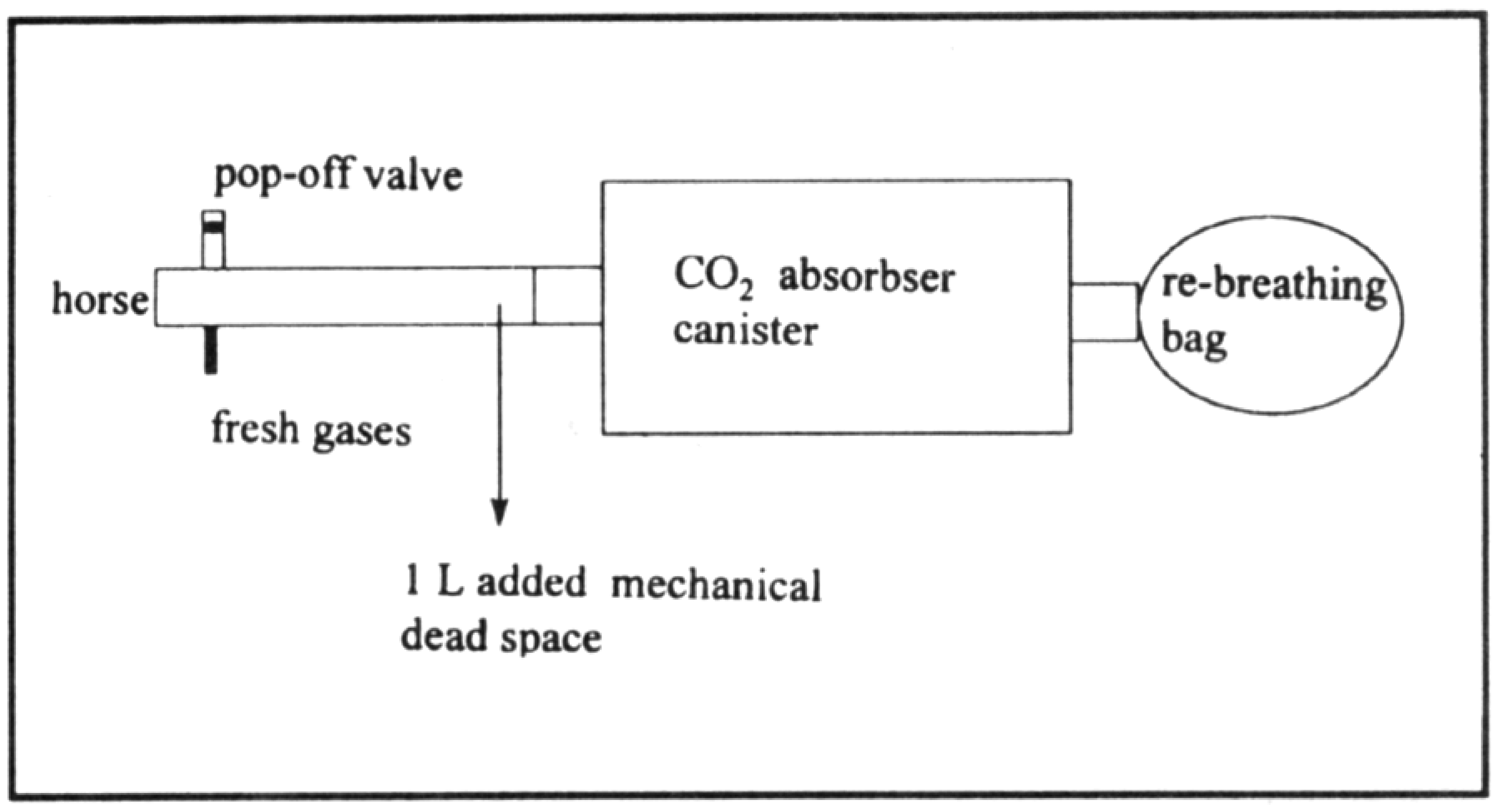

Figure 1 - Modified To-and-fro anesthetic system added of one liter mechanical dead space.

analysis. Time for data and blood sample collection were T0 (baseline), T1 (10 minutes after sedation), T2 (after anesthetic induction), T3 (15 minutes of halothane anesthesia), T4 (30 minutes of halothane anesthesia), T5 (45 minutes of halothane anesthesia), and T6 (60 minutes of halothane anesthesia).

Hypoxemia in this study was defined as a $Pa0_2$<60mm Hg during administration of 100% oxygen. This value was determined based on the shape of the oxyhemoglobin saturation curve, with values less than 60mm Hg resulting in rapid desaturation of hemoglobin.

Data are presented as mean ± standard deviation. One way repeated measure analysis of variance was used on one factor (time) and seven levels, for comparison. Bonferroni's method was used to isolate group or groups that differ from the others ($p<0.05$).

RESULTS

After romifidine administration all horses became heavily sedated showing classics signs of the alpha-2-adrenoceptor agonist as indifference to their surroundings, dropping head, and lower lip flaccid. After tiletamine/ zolazepam all horses became smoothly laterally recumbent and no central nervous system excitement or adverse effects were observed. All horses were easily intubated and positioned for the study. It was possible to maintain halothane anesthesia in all horses with vaporizer concentration between 1.5V% to 2.0V%. All recoveries were considered normal. Anesthetic apparatus design has permitted an easy connection of the patient to the to-and-fro system.

The response variables parameters (mean± standard deviation) and statistical analysis are presented in Table 1. After anesthetic induction it was observed a non-significant $Pa0_2$ reduction from the baseline value without arterial hypoxemia ($Pa0_2$<60mm Hg). After institute oxygen-halothane anesthesia the $Pa0_2$ values were increased significantly. The $PaC0_2$ values were increased progressively from baseline with significance from 15 to 60 minutes of halothane anesthesia. The pH values changed parallel to $PaC0_2$, becoming significant after romifidine sedation. Respiratory rate decreased significantly after sedation and increased significantly after induction. During anesthetic period respiratory rate values were not significantly different from sedation.

DISCUSSIÓN AND CONCLUSION

For most efficient absorption of the carbon dioxide, the canister of the to-and-fro system should provide space between the granules equivalent to or greater than the animal's tidal volume, when filled with nine pounds of soda lime (THURMON & BENSON, 1981; RIEBOLD, 1995). We have been using an horizontal, nine pounds canister, which should provide enough space to contain one tidal volume of an adult horse. due to canister placement to close to the animal when in use, heat produced by the exothermic chemical reaction of soda lime and $C0_2$ in the presence of water does not have time to dissipate before gases are re-breathed (THURMON & BENSON, 1981). Although it was not an intention in this study to measure the temperature inside the system, it is probable that the extension we have used

Table 1 - Blood gases and respiratory rate (mean ± Std Dev) in horses subjected to halothane anesthesia with an added one liter mechanical dead space To-and-Fro System.

Study Time	$Pa0_2$ (mm Hg)	$PaC0_2$ (mm Hg)	pH	Respiration (breaths/min)
Baseline	105.8±15.74 ^{b}	38.4±3.39 ^{b}	7.44±0.04 ^{a}	21.22±7.63 ^{a}
10min romifidine	98.6±12.74 ^{b}	39.1±3.24 ^{b}	7.43±0.06 ^{a}	12.11±4.54 ^{b}
Induction	74.1±6.62 ^{b}	42.6±3.34 ^{b}	7.39±0.05 ^{b}	22.11±7.32 ^{a}
15 min halothane	229.7±57.74 ^{a}	52.3±8.59 ^{a}	7.34±0.04 ^{bc}	9.78±3.38 ^{b}
30 min halothane	207.3±57.03 ^{a}	56.1±9.04 ^{a}	7.33±0.04 ^{c}	7.78±2.49 ^{b}
45 min halothane	175.4±49.02 ^{a}	56.8±11.73 ^{a}	7.32±0.05 ^{c}	8.33±2.69 ^{b}
60 min halothane	191.0±76.03 ^{a}	57.9±9.83 ^{a}	7.32±0.04 ^{c}	9.33±2.24 ^{b}

a, b, c; Significant differences between time are present when letters are different ($p<0.05$).

to connect the patient to the apparatus aided to dissipate heat produced.

The to-and-fro system is most commonly used as a semi-closed method. With this method, the flow rates of 0_2 and anesthetic vapor will be greater than the animal's metabolic requirements. Using the system on a 500kg horse, the 0_2 flow meter should be set to deliver 6 to 8 liters per minute, and halothane vaporizer adjusted to provide 3 to 4 volumes per cent. The 0_2 flow rate and halothane percentage should be maintained until surgical anesthesia is induced, at which time the 0_2 flow rate reduced to 3 to 4 liters per minute and the anesthetic vapor concentration reduced to 2 to 2,5 volumes per cent (THURMON & BENSON, 1981). Results of our study confirm that and initial high 0_2 flow rate (10 liters per minute) promote rapid induction to a medium anesthetic plane. We have maintained the 10 liters per minute 0_2 flow rate during the anesthetic period and reduced the halothane concentration from 3 to 1.5 or 2.0 volume per cent. With a 10 liters per minute flow rate and a gas inlet adjacent to the exhaust valve, the expired gases were diluted in the added mechanical dead space, preventing the excess of $C0_2$ build-up in the system.

Arterial hypercapnia during inhalation anesthesia in spontaneously breathing, clinically normal horses is produced by a combination of pharmacological depression of the respiratory center by anesthetic drugs and recumbency, with more dramatic effects induced by dorsal recumbency than lateral recumbency (HALL ***et al.***, 1968). Impairment of pulmonary function can occur in horses positioned in lateral recumbency (HORNOF ***et al.***, 1986). One study found that during spontaneously ventilation, horses in lateral recumbency anesthetized with halothane developed hypercarbia ($PaC0_2$ = 50 to 60mm Hg), each horse was connected to a large animal circle breathing circuit (DAY ***et al.***, 1995). In our study, $PaC0_2$ increased significantly from baseline to 15 minutes of halothane anesthesia (T3), although there was no significant increase within one hour of inhalation anesthesia. Our study investigating the to-and-fro system added of one liter mechanical dead space, confirm that a 10 liters per minute 0_2 flow rate, maintain $PaC0_2$ within acceptable limits in laterally recumbent halothane anesthetized horses during 60 minutes.

Causes of arterial hypoxemia in general anesthetized horses are hypoventilation, alveolar-capillary membrane diffusion impairment, low inspired oxygen concentration, mismatching of pulmonary ventilation and perfusion, intrapulmonary shunt and decrease cardiac output (MUIR & HUBBELL, 1991). Controversy exists concerning the clinical definition of hypoxemia. A $Pa0_2$>200mm Hg has been reported as a goal during the maintenance of inhalation anesthesia in horses (MUIR & HUBBELL, 1991). Significant decrease in $Pa0_2$ were not observed in our horses, although during the maintenance phase of anesthesia, $Pa0_2$ values were bellow 200mm Hg throughout 45 to 60 minutes of halothane. It can be explained because halothane anesthesia tends to reduce cardiac output, decreasing pulmonary blood flow, with consequent decrease in oxygen uptake. Arterial hypoxemia ($Pa0_2$<60mm Hg) was not observed in our study.

Our results showed that pH decreased as $PaC0_2$ increased. In dogs, changes in pH produce hemodynamic variations (WEXELS ***et al.***, 1985). As hemodynamic variables were not measured, we can not ascertain that the increased pH determined cardiovascular changes.

Depression of the respiratory center usually occurs throughout general anesthesia in horses, with more dramatic effects induced by dorsal than lateral recumbency (DAY ***et al.***, 1995; HALL ***et al.***, 1968). During severe hypercapnia horses under general anesthesia do attempt to breath spontaneously between ventilador-delivered breaths, although horses do not breath spontaneously during moderate hypercapnia when ventilated mechanically (WAGNER ***et al.***, 1990). In our study, respiratory rate decreased significantly throughout anesthetic period, which can be related to the anesthetic drugs used, and to lack in response to respiratory stimulation from elevated $PaC0_2$.

In conclusion, our study confirms that one liter mechanical dead space added to a large animal to-and-fro system do not produce severe blood gas imbalance in laterally recumbent halothane anesthetized adult horses, when a 10 liters per minute 0_2 flow rate is used during 60 minutes.

SOURCES AND MANUFACTURERS

a - Sedivet, Boehringer de Angeli Química e Farmacêutica Ltda. Itapecerica da Serra, SP.
b - Insyte, Becton and Dickinson Vascular Access - Sandy, Utah - EUA.
c - Intracath, Deseret Medical Inc. - Becton and Dickinson Company - Sandy, Utah - EUA.
d - Zoletil, Virbac do Brasil Ind. e Com. Ltda. São Paulo, SP.
e - Vaporizador HB 4.2, HB Metalúrgica Ind. e Com. Ltda. São Paulo, SP.
f - Halotano, Cristália Produtos Químicos e Farmacêuticos Ltda. Itapira, SP.

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