Enteral fluid therapy administered in continuous flow by naso-ruminal route using three maintenance electrolyte solutions: effects on physiological biomarkers and the hemogram of bovines

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Abstract: The aim of this study was to evaluate the effects of three enteral electrolyte solutions, each with different energy sources, administered as continuous flow on the physiological parameters and blood count of healthy Holstein heifers. Six Holstein heifers were used in a crossover design. All animals received all three treatments: solution with calcium propionate, 4g of NaCl, 0.5g of KCl, 0.3g of MgCl2, and 10g of calcium propionate diluted in 1000mL of water (measured osmolarity: 299mOsm/L); solution with glycerol, 4g of NaCl, 0.5g of KCl, 0.3g of MgCl2, 1g of calcium acetate, and 10mL of glycerol in 1000mL of water (measured osmolarity: 287mOsm/L); solution with propylene glycol, 4g of NaCl, 0.5g of KCl, 0.3g of MgCl2, 1g of calcium acetate, and 15mL of propylene glycol in 1000mL of water (measured osmolarity: 378mOsm/L). Physical evaluations and blood samples were collected immediately before the initiation of fluid therapy; at 3-hour intervals over the 12-hour period of fluid therapy, and 12 hours after the end of fluid therapy. Animals presented no signs of stress or discomfort. All solutions resulted in a significant decrease in erythrocyte concentration, hemoglobin concentration, and hematocrit, without affecting the leukogram. Enteral fluid therapy administered as continuous flow via the naso-ruminal route was well-tolerated by animals with minimal effects on animal welfare, even when administered for 12 hours. This technique is indicated as an alternative route for parenteral maintenance fluid therapy. Electrolyte solutions proposed here were able to significantly expand blood volume.

Key words: ruminants, polyionic solutions, physiologic parameters, volemia, hemogram.

Hidratação enteral via nasorrinal em fluxo contínuo utilizando três soluções eletrólíticas de manutenção: efeitos sobre os biomarcadores fisiológicos e o hemograma de bovinos

RESUMO: Objetivou-se avaliar os efeitos de três soluções eletrólíticas enterais de manutenção com diferentes fontes de energia administradas em bovinos adultos por via nasorruminal em fluxo contínuo sobre parâmetros fisiológicos e hematológicos. Foram utilizadas seis novilhas holandesas em um delineamento crossover. Os animais foram submetidos a três tratamentos: Solução contendo Propionato de cálcio - 4g de NaCl, 0.5g de KCl, 0.3g de MgCl2, e 10g de propionato de cálcio para cada 1000mL (Osmolaridade mensurada: 299mOsm/L); Solução contendo Glicerol - 4g de NaCl, 0.5g de KCl, 0.3g de MgCl2, 1g de acetato de cálcio e 10mL de glicerol para cada 1000mL (Osmolaridade mensurada: 287mOsm/L); Solução contendo Propilenoglicol - 4g de NaCl, 0.5g de KCl, 0.3g de MgCl2, 1g de acetato de cálcio e 15mL de propilenoglicol para cada 1000mL (Osmolaridade mensurada: 378mOsm/L). Foi realizado exame físico e coletada de sangue para os hemogramas imediatamente antes do início da hidratação e a cada três horas durante 12h de tratamento e mais uma colheita 12h após o final do período experimental, perfazendo seis colheitas ao total. Todas soluções promoveram ao longo das 12 horas de tratamento hidratação com redução nos valores de hemácias, concentração de hemoglobina e volume globular, sem, contudo, alterar o leucograma. A hidratação enteral em fluxo contínuo via nasorrinal, mostrou-se uma técnica bem tolerada pelos animais, como mínimos efeitos sobre o bem-estar, mesmo quando administrada por 12 horas, sendo, portanto, uma técnica indicada como uma opção à hidratação parenteral na terapia de manutenção de fluidos. As três soluções eletrólíticas aqui propostas são capazes de expandir significativamente a volemia.

Palavras-chave: ruminantes, soluções poliônicas, parâmetros fisiológicos, volemia, hemograma.

INTRODUCTION

The prevalence of hydroelectrolyte and acid-base disorders is common in variable bovine diseases; therefore, fluid therapy has become an indispensable part of the bariatric routine (RIBEIRO FILHO et al., 2013). In this way, accurate evaluation of dehydration and acid-base disorders is necessary for optimal hydroelectrolyte replacement.

In bovine medicine, fluid therapy is most commonly administered by intravenous and oro-ruminal routes (RIBEIRO FILHO et al., 2013). Due to the large volumes administered, professional

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supervision is required during fluid therapy, and the final cost of administration via the parenteral route is sometimes unviable (RIBEIRO FILHO et al., 2011). Consequently, this route of fluid therapy is only used under critical scenarios, such as hypovolemic shock.

Enteral fluid therapy, like the oro-ruminal route, allows a large volume of electrolyte fluid to be administered directly into the rumen in cases of mild and moderate dehydration (ROUSSEL, 2014), and is used careful in cases with motility disorder. Although, this technique is simple, when performed over several days, successive tube passages increase the risk of laryngeal and esophagus lesions. In addition, large volumes of fluid can cause some discomfort to the animal when administered quickly into the rumen.

An alternative method that has been used and studied in Brazil for more than 10 years, is enteral fluid therapy with continuous flow, using a naso-gastric or naso-ruminal tube with a small diameter. This technique has been used successfully in horses (AVANZA et al., 2009; RIBEIRO FILHO et al., 2012; RIBEIRO FILHO et al., 2015); owing to the small gastric capacity of this species, several doses or slow and continuous administration is required throughout the day.

In goats (ATOJI-HENRIQUE et al., 2012), calves (RIBEIRO FILHO et al., 2017), and bubaline calves (ERMITA et al., 2016) continuous flow via the naso-ruminal route has been tested and promising results have been reported. Some studies have already been performed in adult cattle (RIBEIRO FILHO et al., 2009; RIBEIRO FILHO et al., 2011; RIBEIRO FILHO et al., 2013); however, many questions remain unanswered, including osmolarity, the correct electrolyte composition, energy precursor, and infusion rate for these animals. This is because this technique is not widespread in this species, and animals need to remain in an individual stall during therapy.

One important characteristic of enteral fluid therapy is the possibility of creating new solutions with altered compositions that meet the needs of the animal and increase the therapeutic efficiency (RIBEIRO FILHO, 2011). When used in continuous flow, the deleterious effects described above are minimized, besides not preventing the animal from walking and laying inside the stall and feeding during fluid therapy.

According to CONSTABLE (2003), solutions for enteral use should contain sodium, potassium, chloride, calcium, phosphate, and a glycemic precursor, such as propionate. In addition, RIBEIRO FILHO et al. (2014) stated that by maintaining volemia and electrolyte balance, the solution should not cause any adverse events.

The objective of this study was to evaluate the effects of enteral fluid therapy administered as continuous flow by the naso-ruminal route with three enteral electrolyte solutions, containing different energy precursors, on the physiological biomarkers and the hemogram of clinically healthy cattle.

**MATERIALS AND METHODS**

This experiment included six healthy Holstein heifers from the flock of the Experimental Research and Extension Unit in Dairy Cattle of the Federal University of Viçosa (Unidade Experimental de Pesquisa e Extensão em Gado de Leite da Universidade Federal de Viçosa), aged 16 and 18 months and with a mean body weight of 300kg. Animals were adapted to the experimental environment for 10 days before the beginning of the study, during which they were restricted in an individual stall in a Tie Stall system. Animals were fed with corn silage as a balanced ration and water was provided ad libitum.

A crossover 6×3 design was adopted (six animals × three treatments) and all animals received all treatments. To avoid an overlap effect, there was a 7-day interval between treatments. The composition of the electrolyte solutions was as follows: Solution with calcium propionate solution (SEPCA), 4g of NaCl, 0.5g of KCl, 0.3g of MgCl₂ and 10g de calcium propionate in 1000mL of water (measured osmolarity: 299mOsm/L); glycerol solution (SEGLy), 4g of NaCl, 0.5g of KCl, 0.3g of MgCl₂, 1g of calcium acetate, and 10mL of glycerol in 1000mL of water (measured osmolarity: 287mOsm/L); and a solution with propylene glycol, 4g of NaCl, 0.5g of KCl, 0.3g of MgCl₂, 1g of calcium acetate, and 15mL of propylene glycol in 1000mL of water (measured osmolarity: 378mOsm/L).

A naso-ruminal tube with a small diameter (4mm diameter and 1.8m length) was used to administer fluid. The tube was attached to the halter and connected to a gallon with a 20L capacity with a spiral hydration system, set 1.5m above the head of the animal. The continuous flow rate was 15mL/kg/h, over 12 hours, and animals did not receive food or water during the hydration period.
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have decreased volemic effects, remaining longer enteral solutions (osmolarity > 320 mOsm/L) could be suggested by ANZA et al. (2009). Hypertonic solutions are absorbed quickly and in large amounts, as electrolyte solutions, as hypo or isotonic solutions are absorbed more slowly and in smaller quantities. Osmolarity is an important characteristic for the efficacy of an electrolyte solution, as hypo or isotonic solutions are absorbed quickly and in large amounts, while hypertonic solutions are absorbed more slowly and in smaller quantities. Over-stimulating gas production can result in discomfort and conditions such as a bloat. This kind of change accumulation inside the gut, causing discomfort or conditions such as a bloat. This kind of change was not observed in the present study, as described by RIBEIRO FILHO et al. (2013). The choice of energy precursor directly affects these findings, because calcium propionate, glycerol, and propylene glycol can be oxidized by the ruminal microbiota or absorbed in the integral form, not affecting the ruminal fermentation. This can result in gas production and accumulation inside the gut, causing discomfort or conditions such as a bloat. This kind of change was not observed in the present study, as there was no significant change in abdominal girth (P > 0.05) across the whole fluid therapy period under all treatments, corroborating the findings of RIBEIRO FILHO et al. (2013). The choice of energy precursor directly affects these findings, because calcium propionate, glycerol, and propylene glycol can be oxidized by the ruminal microbiota or absorbed in the integral form, not over-stimulating gas production. There was no variation in fecal humidity (P > 0.05) over time or between treatments. This result confirmed that the electrolyte solutions proposed were readily absorbed by the intestinal tract with minimal losses through feces. Osmolarity is an important characteristic for the efficacy of an electrolyte solution, as hypo or isotonic solutions are absorbed quickly and in large amounts, as suggested by AVANZA et al. (2009). Hypertonic enteral solutions (osmolarity > 320 mOsm/L) could have decreased volemic effects, remaining longer in the intestinal lumen, increasing the risk of osmotic diarrhea; however, this was not observed in the present study, even for the SEProp group with 378 mOsm/L, which was well tolerated by the animals.

The concentrations of red blood cells and hemoglobin (Table 2) decreased significantly after 6 hours of fluid therapy (T6h) with all treatments, and remained low over 12 hours of fluid therapy (T12h) in the SEGly and SEProp groups, returning to basal levels at 24 hours (T24h). These results confirmed that the solutions were well absorbed by the gastrointestinal tract and that the osmolarity of SEProp did not limit its use. The expansion capacity of the solutions (hemodilution) is demonstrated by the decreased hematocrit concentration (P < 0.05) observed following 3 hours of fluid therapy (T3h) in all groups. After being absorbed in the rumen and gut, the solutions dilute the solid components of the blood and proteins, explaining the results of this study, as described by RIBEIRO FILHO et al. (2011) and RIBEIRO FILHO et al. (2013). These findings showed that enteral fluid therapy was not observed in the present study, even for the SEProp group with 378 mOsm/L, which was well tolerated by the animals.

Table 1 - Mean ± standard deviation of the heart rate (HR – bpm), respiratory rate (RR – rpm), rectal temperature (RT – °C), ruminal movement (RM – cm) and feces humidity (FH – %) of heifers under enteral fluid therapy in continuous flow with three different electrolyte solutions.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Fluid therapy period</th>
<th>T0h</th>
<th>T3h</th>
<th>T6h</th>
<th>T9h</th>
<th>T12h</th>
<th>T24h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td></td>
<td>SEPCa</td>
<td>SEGly</td>
<td>SEProp</td>
<td>SEPCa</td>
<td>SEGly</td>
<td>SEProp</td>
</tr>
<tr>
<td>HR</td>
<td>70.2 ± 11.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>67.2 ± 22.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>71.5 ± 15.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>20.2 ± 6.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.0 ± 4.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.6 ± 0.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.7 ± 0.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>RR</td>
<td>21.0 ± 10.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.3 ± 6.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.4 ± 0.4&lt;sup&gt;bd&lt;/sup&gt;</td>
<td>38.5 ± 0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.7 ± 0.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.6 ± 0.3&lt;sup&gt;bd&lt;/sup&gt;</td>
<td>38.9 ± 0.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>RT</td>
<td>73.2 ± 15.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>176.2 ± 16.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.6 ± 10.7&lt;sup&gt;ah&lt;/sup&gt;</td>
<td>63.5 ± 11.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>19.7 ± 5.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.4 ± 0.3&lt;sup&gt;ad&lt;/sup&gt;</td>
<td>38.7 ± 0.3&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>RM</td>
<td>4.0 ± 0.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.2 ± 0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.7 ± 0.5&lt;sup&gt;ab&lt;/sup&gt;</td>
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<td>3.7 ± 0.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.7 ± 0.8&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>AG</td>
<td>66.5 ± 22.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>175.2 ± 15.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>178.2 ± 18.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>183.8 ± 20.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>183.2 ± 16.2&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>179.2 ± 17.1&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>FH</td>
<td>86.9 ± 2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>86.6 ± 2.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>86.5 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>86.5 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86.5 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86.5 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
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Means followed of lower case letters are different in the same line and capital letters are different in the same column (P < 0.05).
as continuous flow is an effective alternative to intravenous fluid therapy for adult cattle. All other parameters of the erythrogram remained unchanged and within the reference intervals for this species.

There were no changes in the leucogram profile throughout the experimental period or between treatments (Table 3). This result clearly shows that intubation with a naso-ruminal tube for 12 hours, and all experimental management, had no significant excitatory or stressful effects on the animals, which would result in relative polycythemia following the release of adrenaline (THRALL et al., 2012).

CONCLUSION

Enteral fluid therapy given as a continuous flow via the naso-ruminal route is well-tolerated by animals with minimal effects on welfare, even when administered for 12 hours, and is indicated as an alternative route for parenteral maintenance fluid therapy. The three electrolyte solutions proposed here are able to significantly expand blood volume.

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ACQUISITION SOURCES

a Sulfal Química Ltda., Belo Horizonte, MG, Brazil; b Adicel Ltda., Belo Horizonte, MG, Brazil; c Biobrotas Olequímica, Brotas, SP, Brazil; d Enterequi System, Viçosa, MG, Brazil; e Vacuteiner BD, Juiz de Fora, MG, Brazil; f HumanCount Plus, Belo Horizonte, MG, Brazil.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The project was previously approved for the Ethical Committee in the Use of Animals of the Universidade Federal de Viçosa (CEUA/UFV) with the protocol number 44/2017.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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