Comparison of Commercial Isotonic Fluids Intravenously Administered to Rehydrate Fasted Bullocks

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ABSTRACT. Holstein bullocks were used in this study to compare the effectiveness of five commercial parenteral fluids (saline IS, Hartmann’s IH, 5%-glucose 5G, Ringers IR, and 1/2 Ringer’s and 2.5% glucose combination solutions RG) in correcting the disturbances associated with dehydration induced by fasting for 48 hr. These five commercial fluids (30 ml/kg) were given to bullocks with dehydration induced by fasting for 48 hr. Arterial and venous blood samples were taken before fasting, and at 0, 15, 30, 45, 60, 90, 120, 240, 360 min, and 24 hr after initiation of fluid administration. Fasting for 48 hr induced significant reductions in body weight and relative plasma volume (rPV), of approximately 7.72 and 21.93%, respectively. During the administration period, rPV showed a progressive increase from approximately 88.1% after fasting to 113.0% with no significantly differences between groups. A rapid decrease of rPV when fluid administration has been finished was observed in the 5G and RG groups. The results of the fluid administration trial showed that the 1/2 Ringer’s and 2.5% glucose combination solution inhibited the acidification of the blood, produced no change in the electrolyte balance of serum, and induced a proper reabsorption rate of glucose in the renals, and was therefore considered the best choice for the rehydration of adult cattle which have had no appetite for over 2 days. — KEY WORDS: bullock, fasting, intravenous fluid therapy, isotonic fluid.

The cost of commercial fluids for intravenous rehydration therapy for cattle is often too great to be economically feasible in practice [1]. Michell [6] pointed out five questions concerning fluid therapy: (1) what should be used, (2) where should it be administered, (3) how much and how often, (4) what are the risks, and (5) what is the specific aim of the treatment. Concerning the third question, it is preferable to administer too much rather than too little fluid, since any excess of water or electrolytes can be eliminated by the kidneys, provided that the animal has no renal failure. The determination of the fluid requirement is based on a clinical assessment of the degree of dehydration expressed as a loss of body weight [1]. For example, a 500 kg cattle suffering from 5% dehydration would require 25 l of fluid. However, it is doubtful that an adequate volume of replacement fluid is given to dehydrated animals in clinical practices.

Michell’s last question is the most important, and should be carefully considered. The specific aims of rehydration therapy are to repair (1) extracellular volume, (2) electrolyte balance (mainly sodium and potassium ion concentrations), (3) acid-base balance, (4) renal functions and (5) calorific balance [2, 6]. To perform safe and effective treatment, the choice of commercial fluid appropriate for the specific objectives and an understanding of the characteristics of physiological disturbances are indispensable.

The present study examined the effects of a 48 hr fast on bullocks and investigated the therapeutic value of five commercial fluids used to rehydrate them.

MATERIALS AND METHODS

Animals: Seven Holstein bullocks, 17 months old, were penned on wood chips. The daily feed was given in equal portions at 09:00 and 17:00 hr. The bullocks were fed on 10 kg of concentrate mixture and 1 kg of rice straw per day. Water and ammonium chloride mixture salt blocks (Cow-Stone: Nippon Zenyaku Kogyo Co., Ltd., Fukushima) were given ad libitum. In this study, the following isotonic commercial fluids were used: isotonic saline (IS), Hartmann’s (IH), 5%-glucose (5G), Ringer’s (IR) and 1/2 Ringer’s + 2.5% glucose combination fluid (RG) (Table 1, Nippon Zenyaku Kogyo Co., Ltd.). Crystalloid fluids are indicated by the groups labeled IS, IH, and IR. Three

Table 1. Comparison of commercial fluids employed in this study

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Na⁺ (mEq/l)</th>
<th>K⁺ (mEq/l)</th>
<th>Ca²⁺ (mEq/l)</th>
<th>Cl⁻ (mEq/l)</th>
<th>lactate (mg/dl)</th>
<th>glucose (mg/dl)</th>
<th>Osmolarity (mOsmol/l)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic saline (IS)</td>
<td>154</td>
<td>–</td>
<td>–</td>
<td>154</td>
<td>–</td>
<td>–</td>
<td>281.0</td>
<td>5.52</td>
</tr>
<tr>
<td>Hartmann’s solution (IH)</td>
<td>130</td>
<td>4</td>
<td>3.0</td>
<td>109</td>
<td>28</td>
<td>–</td>
<td>252.0</td>
<td>6.57</td>
</tr>
<tr>
<td>5%-glucose (5G)</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>284.0</td>
<td>3.79</td>
</tr>
<tr>
<td>Ringer’s solution (IR)</td>
<td>147</td>
<td>4</td>
<td>5.0</td>
<td>156</td>
<td>–</td>
<td>–</td>
<td>282.7</td>
<td>4.30</td>
</tr>
<tr>
<td>1/2 Ringer’s + 2.5% glucose (RG)</td>
<td>73.5</td>
<td>2</td>
<td>2.5</td>
<td>78</td>
<td>2</td>
<td>2.5</td>
<td>284.0</td>
<td>4.86</td>
</tr>
<tr>
<td>Plasma</td>
<td>135–144</td>
<td>3.9–5.6</td>
<td>2.6–3.2</td>
<td>93–104</td>
<td>22–26</td>
<td>0.045–0.075</td>
<td>279–298</td>
<td>7.421</td>
</tr>
</tbody>
</table>
animals were randomly assigned to each of the 5 groups. Each animal was fasted two or three times and received different fluids in turn. Animals were given at least a week to recover between experiments.

**Fasting:** Feed, salt blocks and water were withheld for 48 hr to induce dehydration for each experiment. Before and at the end of the fast, body weight, complete blood count, arterial gases, serum electrolytes and plasma glucose concentration were measured, and water deficiency was determined using body weight and hematocrit (Ht) values by Michell’s formula as follows [4]:

$$\text{water deficiency} = \frac{\text{BW}_{\text{pre}} \times 0.6 \times (1 - \text{Ht}_{\text{pre}} / \text{Ht}_{\text{break}})}{\text{BW}_{\text{pre}} \times 0.6 \times (1 - \text{Ht}_{\text{pre}} / \text{Ht}_{\text{break}})}$$

where \(\text{BW}_{\text{pre}}\) and \(\text{Ht}_{\text{pre}}\) are body weight and Ht value before fasting, and \(\text{Ht}_{\text{break}}\) is the Ht value at the end of the fast.

**Comparison of isotonic fluids:** Approximately 1 hr before the administration of the isotonic fluids, a 14G i.v. catheter (I. V. catheter for animals; Nippon Zenyaku Kogyo Co., Ltd.) and a 22G i.v. catheter (Safeflet Cath, Nipro Co., Ltd., Osaka, Japan) were implanted percutaneously into the right jugular vein and ear artery (arteriae auricularis), respectively. The arterial catheter patency was maintained by flushing with a small volume of heparinized saline after use. The solutions were infused through an ordinary drip tube (15 drops equal 1 ml; Drip tube set for animal; Nippon Zenyaku Kogyo Co., Ltd.) [11] from the original 11 containers.

The start time of fluid administration was set up for the maximal speed as possible using the above equipment. The start time of fluid administration was designated as 0 min. Arterial and venous blood samples were taken before fasting, and at 0, 15, 30, 45, 60, 90, 120, 240, 360 min and 24 hr after the initiation of fluid administration. Arterial whole blood samples taken from the ear arteria were measured for blood gases by an automatic gas analyzer (248 pH/gas analyzer; Ciba-Corning Diagnostic Ltd. Essex, England). Venous blood samples were taken from the left jugular vein, and some samples were measured for complete blood count (white blood cell, WBC; red blood cell, RBC; Ht; and hemoglobin concentration, Hb) by a microcellcounter (Sysmex F-800 micro cellcounter; R. A. Systems Co., Nagano, Japan). The samples were then stored in heparin lithium coated tubes or micro cellcounter; R. A. Systems Co., Nagano, Japan). The plasma osmotic pressure was determined by a microcellcounter (Sysmex F-800 micro cellcounter; R. A. Systems Co., Nagano, Japan).

**Effect of fasting for 48 hr:** Dryness and chilliness of oral mucous membrane, sinking of eyes, and eyelid skin tenting of about 0.5 seconds were the main clinical signs following fasting. The loss of body weight and changes in rPV resulting from fasting for 48 hr are depicted in Fig. 1. Body weights before fasting (577.1 ± 15.7) differed significantly from those at the end of the fast (532.4 ± 12.6 kg, p<0.01). The average decrease of mean body weight was approximately 7.7%, with a range of 5.2 to 10.2%. Except for WBC, the complete blood count values increased significantly (p<0.05). The average decrease of rPV, calculated with the Hb and Ht determinations, was approximately 21.9%, ranging from 6.6 to 37.9%.

The calculated water deficiency was 44.7 ± 10.1. **Effect of administration of isotonic fluid:** A flow rate of
17.8 ± 1.9 ml/kg/hr for bullocks weighing 577.1 ± 15.7 kg was the average employed through a 14G i.v. catheter and drip tube. The an average time for the end of fluid administration in this study was 102 ± 10 min. No clinical side effects of fasting on rectal temperature, respiratory and heart rate were observed throughout the experimental period.

The rPV calculated from Hb and Ht values is shown in Fig. 2. During the administration period, no differences in rPV were observed between the groups, which showed a progressive increase from approximately 88.1 after fasting to 113.0%. The changes in rPV observed after the administration period were found to depend on whether the replacement fluid contained glucose. A rapid decrease of rPV when fluid administration had finished was observed in the 5G and RG groups (administered replacement fluid containing glucose). This was significantly different when compared with the IS, IH, and IR groups (replacement fluids containing crystalloid).

A progressive and significant decrease in arterial pH was observed in the IS and IR groups, as shown in Fig. 3. No significant changes were observed in arterial pH of the IH, 5G and RG groups during the experimental period. Sequential changes of arterial pH due to the administration of isotonic fluids. A progressive and significant decrease in arterial pH was observed in the IS and IR groups (given fluid containing high chloride). No significant changes in pH of the IH, 5G and RG groups were observed during the experiment period. The asterisk indicates p<0.05 by ANOVA.

Sequential changes of plasma osmotic pressure are shown in Fig. 4. The plasma osmotic pressure of the animals administered replacement fluid containing crystalloid maintained a high level from 0 min until 90 min, and after

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**Fig. 1.** Effect of body weight and relative plasma volume due to fasting. The 48 hr fasts caused an average decrease in mean body weight [A] and circulating plasma volume [B] of about 7.7 and 21.9%, respectively. Symbols identify individual animals in A and B.

**Fig. 2.** Sequential changes of rPV due to the administration of isotonic fluids. Increased rPV indicates plasma dilution. No significant differences between groups were observed until fluid administration had ceased. The asterisk indicates p<0.05 by ANOVA.

**Fig. 3.** Sequential changes of arterial pH due to the administration of isotonic fluids. A progressive and significant decrease in arterial pH was observed in the IS and IR groups (given fluid containing high chloride). No significant changes in pH of the IH, 5G and RG groups were observed during the experiment period. The asterisk indicates p<0.05 by ANOVA.

**Fig. 4.** Sequential changes of plasma osmotic pressure.
the administration period, this increased osmotic pressure decreased to the level observed before fasting. In contrast, the plasma osmotic pressure measured in animals given replacement fluid containing colloid was significantly decreased at 15 min and remained at a low level until 90 min after initiation of fluid administration (p<0.05). The changes in plasma osmotic pressure level of the 5G group were significantly lower than those observed in the RG group throughout the experimental period (p<0.05).

The serum sodium concentration changed concomitant with plasma osmotic pressure, as shown in Fig. 5A. No significant changes of sodium concentration were observed in the RG group during replacement of fluids. The serum sodium concentration of animals given replacement fluids containing crystalloid were maintained at the high levels induced by fasting from 0 min until 90 min after initiation of fluid administration. However, the serum sodium concentration in the 5G group was significantly decreased during the administration period (p<0.05). After the replacement of fluid, sodium levels of the groups given crystalloid fluids recovered to the levels observed before fasting. Figure 5B shows the sequential changes of serum chloride levels of bullocks. Significant increases in chloride concentrations were observed in the groups given crystalloid fluids until 90 min after initiation of fluid administration (IS; 118.0 ± 0.6, IH; 114.3 ± 3.1, and IR; 118.0 ± 2.5 mmol/l, respectively). The concentrations then recovered to the levels observed before the fast (p<0.05). In contrast, the serum chloride level decreased significantly until 90 min after initiation of administration in the 5G group (97.0 ± 4.58 mmol/l), and in the RG group, the level measured at 0 min of administration were maintained throughout the experimental period.

The serum calcium concentrations of the IS and 5G groups were reduced significantly concomitant with fluid administration until 90 min of administration (7.7 ± 0.1 and 7.7 ± 0.7 mg/dl, respectively, p<0.05). However, no changes due to fluid administration were observed in the RG group. In the RG group, no significant changes in
DISCUSSION

In the present study, the average decreases of body weight and circulating volume induced by fasting for 48 hr were about 7.72 and 21.93%, respectively. Corke [1] reported the clinical symptoms of fasting as a 7% decrease in body weight, eyelid skin tenting of about 0.5 second, and delayed capillaries refill. Dryness and chilliness of the oral mucous membranes were also observed in our study. The water deficiency calculated from the body weight and changes of Ht value was estimated to be 44.7 l, bullocks weighing an average 577.1 kg. For the hydration of the animals, 44.7 l of fluid with an additional 30 ml/kg B.W. for replacement of essential water losses [10, 12] during the period of replacement, i.e. approximately 62 l is recommended. Corke [1] suggested that it is preferable to administer too much rather than too little fluid for, provided the cattle do not have renal failure, any excess of water or electrolytes can be eliminated by the kidneys. However in practical applications of fluid therapy time, labor and expense of treatment severely limit replacement volume. Therefore we considered 30 ml/kg B.W. for essential water losses, was a suitable minimum volume for administration.

Although the appropriate volume can thus be determined, the choice of fluid remains in question.

It is necessary to analyze the electrolyte data of fasting animals to specify the aim of fluid therapy. Sodium concentration is an important factor for tightly regulating plasma osmotic pressure [5]. When water loss arising from an intracellular fluid volume deficiency is combined with hypernatremia, the effect is severe [5]. In the present study, the increase of plasma osmotic pressure from 284.9 ± 2.4 to 306.6 ± 11.2 mOsmol/kg H2O was accompanied by hypernatremia in fasting bullocks. The replacement of intracellular fluid deficiency is important for cattle having no appetite over 2 days.

Roussel [7] observed that approximate 60% of sick cattle had pH values within reference ranges and had 10% decreased HCO3– concentrations. In our study, no changes in pH were observed during the fast. Therefore, alkalizing solutions are not beneficial for most sick cattle, and Hartmann’s solution, the standard fluid of choice in many small animal and equine hospitals, is not an appropriate fluid for adult cattle [7].

A flow rate of about 17.8 ± 1.9 ml/kg/hr for a bullock weighing 577.1 ± 15.7 kg was maximal using standard equipment for practical clinics in Japan (14G i.v. catheter and drip tube), but is much less than the flow rate recommended by Roussel for cattle [7]. Roussel suggested that a flow rate of 40 ml/kg/hr should not be exceeded, because up to 40 ml/kg/hr of isotonic saline could be administered to cattle without clinical side effects, but some animals develop significant elevations in central venous pressure at higher flow rates [7]. We therefore suggest that the maximal flow rate employed in standard equipment is a good choice for safely administrating fluid to cattle weighing over 300 kg.

The relative plasma volumes calculated from Hb and Ht values increased dramatically after initiation of fluid administration and no differences were observed between groups up to and including 90 min. Subsequently the decreases of rPV in the 5G and RG groups (given fluid containing glucose) were significantly greater than those in the groups given crystalloid fluids after the administration period. These results indicate that colloid fluid is advisable for dehydrated cattle, because with it the immediate replacement of an intracellular fluid deficiency can be achieved [9].

The arterial pH levels decreased significantly after the
fluid administration in the present IS and IR groups, but not in the IH, 5G, and RG groups. Sodium lactate, converted by the liver into sodium bicarbonate, contributes to the correction of metabolic acidosis due to shock or diarrhea [1], and is contained in IH fluids. It may be that the decrease in arterial pH was inhibited due to the effect of sodium bicarbonate originating from the metabolic by product of IH. Before the administration of replacement fluids, the fasted bullocks had high serum chloride concentrations. A progressive increase in the chloride level was also induced by the administration of crystalloid fluids. The IS and IR groups, with higher serum chloride concentrations were inclined to be more acidified by the intravenous administration of chloride than the groups with less serum chloride concentration [7]. These results suggest that it would be wise to avoid the administration of a fluid containing a high chloride concentration to rehydrate cattle with hypochloremia. The administration of IH might therefore inhibit acidification, but the authors do not recommend its administration because of its risk of hyperchloridemia. The administration of 5G, incurring the decrease of serum electrolytes concentration, is also not recommended, since although its glucose is available for energy supply, its net effect in replacement therapy is to deliver free water. The administration of 5G resulted in the dilution of serum electrolytes, an objectionable effect [7]. Therefore, RG, which inhibits acidification but induces no objectionable effect [7].

Calcium is necessary not only for skeletal muscle contraction and neuronal function, but also for the gastrointestinal smooth muscle function [7]. Calcium may be added to intravenous fluids. The IR, IH and RG solutions, we used in the present study contained 5, 3 and 2.5 mEq/l of calcium, respectively. However, no changes in serum calcium level due to administration of those fluids were found. The stabilizations of serum sodium and chloride levels and also of calcium concentration are reasons to recommend RG as a first choice for dehydration treatment.

It is well known that insulin is released from islets of Langerhans when blood glucose concentration rise above 110 mg/dl. The blood glucose concentrations in 5G and RG groups exceeded that level immediately after the initiation of fluid administration and reached peak levels (647.3 ± 70.9 and 361.7 ± 20.0 mg/dl, respectively) at the end of fluid administration. It is speculated that increases in blood insulin gave rise to a rebound phenomenon at 6 hr after the initiation of fluid administration. However, there were no clinical signs of hypoglycemia at that time.

The urine volumes of the groups given glucose were higher than those of the groups given crystalloids. This phenomenon may be caused by the reabsorption rate of glucose in the kidney. It was reported that the reabsorption rate of glucose in the kidney is approximate 0.5 g/kg/hr [7]. In that study, the flow rates of glucose contained in the 5G and RG solutions were about 1.0 and 0.5 g/kg/hr, respectively. Therefore, the total urine volume measured at intervals of 30 min in the 5G group at the 2.0–2.5 hr interval (2,390 ml/30 min) is greater in quantity more than those in the RG group at same time (1,515 ml/30 min). As a result, it might be necessary to pay heed to incidental hypoglycemia as a rebound from hyperglycemia, but the authors recommended intravenous fluid therapy employing a large amount of RG for the proper reabsorption rate of glucose in the kidney.

Fluid therapy is an extremely valuable adjunct to the treatment of cattle in many cases. However, it is doubtful whether sufficient fluid volume to meet the animal’s requirement is given in clinical practice. Our results suggest that a 1/2 Ringer’s and 2.5% glucose combination fluid is the best choice for rehydration therapy of dehydrated cattle without hypochloremia, and it should be administered at a volume of 30 ml/kg BW.

REFERENCES