Study on intravenous fluid therapy using a clinical scoring system as an index for the treatment of suckling calves

Summary of Doctoral Thesis

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Introduction

Calf diarrhea is one of the most common causes of death in beef and dairy cattle. Fluid therapy is generally used in the treatment of diarrhea. Diarrhea can be caused by various factors that lead to the suppression of water absorption within the small intestine, resulting in the secretion of sodium (Na), chlorine (Cl), bicarbonate ions, and water into the intestinal lumen. This excess colonic secretion with respect to water absorption causes watery diarrhea. In calf diarrhea, reduced peripheral circulation causes a slight increase in the intracellular fluid volume and a significant decrease in the extracellular fluid volume. Thus, in order to prevent mortality from diarrhea in suckling calves, it is critical to maintain sufficient extracellular fluid volume. This can be achieved by appropriate oral or intravenous fluid therapy.

Fluid therapy is aimed to 1) restore the circulating plasma volume and 2) improve the depressive state by correcting metabolic acidosis. Since farm animal clinical veterinarians typically visit farms to provide care on site, the need for treatment is often determined based on the findings from general physical examination of the calves performed on site rather than laboratory biochemical findings. Fluid therapy is indicated for suckling calves if they show the following signs of significant dehydration, particularly of reduced circulating plasma volume: severe depression, debilitation, lethargy and astasia, lack of suckling for over 24 hours, and a rectal temperature of below 38°C. These physical changes are often assessed based on the experiences of clinical veterinarians. Instead, the need for fluid therapy should be determined based on a more objective method such as the clinical scoring system developed by Kasari and Garcia.

Chapter 1

In this Chapter, we describe the development of an objective method to determine the level of dehydration and acidosis in suckling calves based on findings from physical examinations. For the purpose of assessing the degree of calf diarrhea, we referred to the clinical scoring system commonly known as the "depression scoring system" developed by Kasari and Naylor. However, since this scoring system was developed specifically for Charolais and Simmental breeds, little was known as to whether it was also applicable in the Japanese Black breed. Thus, the aims of this Chapter were to 1) examine whether the depression scoring system developed by Kasari et al. was also applicable in accurately assessing the level of acid-base imbalance due to diarrhea in Japanese Black calves, and, if applicable, 2) establish the threshold levels for the scoring system. We demonstrated that the Kasari depression score was significantly correlated with the known biochemical indicators of dehydration (hematocrit (Hct), total protein (TP), potassium (K) concentration, phosphorus (iP) concentration) in the Japanese Black and its crossbreed calves with diarrhea, and that a Kasari score of >10 indicated that the ranges of these biochemical indicators were above the reference values. In other words, a Kasari depression score of >10 suggests that the calves have elevated levels of Hct and TP and are therefore dehydrated; in such cases, intravenous fluid therapy should be performed to achieve rehydration. Similarly, a Kasari depression score of >5 should be used as a criterion to determine the need for oral rehydration solution as it indicates an elevated serum urea nitrogen with respect to the reference level. The Kasari depression score was also effective in the assessment of acid-base imbalance in the Japanese Black and its crossbreed calves. Specifically, a Kasari depression score of ≥6.5 corresponded to severe metabolic acidosis, which was defined as a base excess (BE) = -10 mM. Collectively, these findings suggest that the depression scoring system, which was originally validated in Charolais and Simmental breeds, is also effective in accurately assessing the degree of dehydration and acidosis in the Japanese Black and its crossbreed calves. These findings led to the following conclusion:

> In the treatment of calf diarrhea, a depression score of >10 indicates the need for intravenous fluid therapy to treat dehydration and a depression score of >6.5 indicates the need for sodium bicarbonate to treat metabolic acidosis.

Chapter 2

In Chapter 1, we demonstrated that a Kasari depression score of ≥6.5 indicates severe metabolic acidosis (BE<-10 mM) in the Japanese Black and its crossbreed calves with diarrhea, suggesting the need for treatment with sodium bicarbonate. Sodium bicarbonate is highly effective in the treatment of metabolic acidosis since it directly neutralizes protons that are generated in the process of metabolic acidosis. However, sodium bicarbonate should be used with caution as rapid and excess infusion of sodium bicarbonate can cause a dramatic increase in the effective osmotic pressure of extracellular fluid, and elevate the risks of paradoxical cerebrospinal fluid acidosis, brain hemorrhage, and intracellular hypoxia. In humans, intravenous infusion of sodium bicarbonate is only recommended as an emergency option if the pH of the extracellular fluid is less than the intracellular pH (pH=7.2); if the pH of the extracellular fluid is above 7.2, it is safer to correct the acid-base imbalance with precursors of bicarbonate ions such as lactate ions or acetate ions. Thus, in this Chapter, we examined whether a commercially available acetate Ringer’s solution is superior to lactated Ringer’s solution in correcting the acid-base imbalance for the treatment of mild metabolic acidosis in calves. In order to address this, I created a model of mild metabolic acidosis induced by insufficient intake of a milk replacer, and used this model of mild acidemia to compare the effects of the following commercially available isotonic electrolyte solutions in correcting acid-base imbalance: isotonic saline solution (ISS), DL-lactate Ringer's (DLR) solution, L-lactate Ringer's (LR) solution, and acetate Ringer's (AR) solution. Notably, a limited level of D-lactate dehydrogenase is present in calves. Thus, the degree of alkalinization by DLR, which consists of 14 mM D-lactate and 14 mM L-lactate, is expected to be lower than that induced by LR which consists of 28 mM L-lactate. In this study, we also demonstrated that DLR was not effective in correcting acid-base imbalance in calves with experimentally-induced metabolic acidosis. Even though LR may be more effective than DLR in correcting acid-base imbalance, it is only effective in the later stage of fluid therapy when hepatic blood flow is sufficiently restored since LR is primarily metabolized in the liver. In comparison, the BE concentration that results from the metabolism of acetate ions does not depend solely on the hepatic metabolism. Thus, as expected, I demonstrated that AR was the most effective in achieving correction of acid-base imbalance. These findings led to the following conclusion:

Since acetate ions are metabolized in the muscles as well as in the liver to induce alkalization, AR solution is more effective than DLR or LR in the treatment of mild metabolic acidosis in calves.

Chapter 3

Farm animal clinical veterinarians typically provide care on site at farms, and have limited time, money, and labor as they handle livestock. Thus, it is challenging for them to perform fluid therapy with sufficient fluid replacement in adult cattle. The use of 7.2% hypertonic saline solution (HSS) is conventional for adult cattle and is effective in shock resuscitation. However, it is considered risky in calves as it rapidly increases the circulating plasma volume due to the difference in osmolarity. Intravenous infusion of HSS elevates the plasma osmolarity by 25-30 mOsm/L, which results in the difference in osmolarity between plasma and the intracellular fluid. In order to reduce this difference, intracellular fluid and interstitial fluid enter into the vessels and increase the overall circulating plasma volume. In ruminant animals, this “correction of osmotic pressure” is not restricted to the intracellular space; rather, some rumen fluid also perfuses into the vessels with intracellular and interstitial fluid via the rumen wall. Although there have been discussions, there is no consensus as to how this rapid fluid transfer and resulting increase in circulating plasma volume affects calves that do not have full cardiovascular, renal, and urinary systems. Notably, calves with underdeveloped rumen are unable to store and use fluid from drinking water like adult cattle. Although there have been studies to discuss the use of HSS in the treatment of calves with severe dehydration due to diarrhea, the number of studies that demonstrated its efficacy is limited. In all studies, HSS was administered with other substances such as high-molecular weight colloids (hypertonic saline dextran (HSD), 2,400 mOsm/L, HSS + 6% dextran 40) or with oral rehydration solution. Thus, in this Chapter, we examined the potential application of HSS in the treatment of calf diarrhea by determining the effect of 2.16% HSS in calves with diarrhea and hypernatremia. In this study, 2.16% HSS was prepared by mixing 250 mL of 7.2% HSS to 1L of saline and was infused intravenously to calves with diarrhea and hypernatremia. Among the 13 calves that were treated, 1 died subsequently while the remaining 12 showed improvements in diarrhea-induced hypernatremia. These findings led to the following conclusion:

With appropriate caution to potassium dynamics, 2.16% HSS can be highly effective in the treatment of dehydration and hypernatremia in calf diarrhea.

Summary

In summary, this study demonstrated that, in the treatment of calf diarrhea, it is critical to select the appropriate types of fluid therapy to achieve rapid recovery. In order to do so, one must assess various clinical changes on site in a timely manner. Since farm animal clinical veterinarians typically visit farms to provide care on site, it would be challenging to make clinical decisions based on the results of laboratory testing in routine practice. As alternatives, various methods, such as the scoring system used in the present study, as well as portable blood testing equipment, and simplified blood glucometer, may be used. Data obtained from these tests may be combined with other variables such as the body temperature, heartrate, respiration rate, and other information. The study suggests that such a comprehensive approach for clinical decision is the most effective in selecting the appropriate types of fluid therapy needed to achieve cure.