

NEW APPROACH TO ELECTROLYTE THERAPY

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Introduction

It has been recognized for many years that fluid and electrolyte administration is the mainstay of therapy of calf diarrhea, a fact that has stimulated the development of over 35 commercially available electrolyte formulas for this purpose. Calf scours usually occurs when a delicate balance between environmental factors, the calf and the etiologic agent is lost. Most outbreaks of diarrhea in calves are caused by more than 1 pathogenic agent, oftentimes representing a combination of bacteria, viruses, and/or parasitic agents.(1,2) The interaction between factors other than the infectious agent along with a combination of pathogenic organisms, many of which may have no specific effective therapy make treatment a challenge. In spite of these problems, calves with diarrhea, regardless of cause, frequently have consistent metabolic derangements. Diarrheic calves frequently have metabolic acidosis, intracellular potassium loss (sometimes in the face of serum hyperkalemia), hyperchloremia, and hypoglycemia. Calf scours is a wintertime disease in many parts of the country and can be the reason for an additional problem, hypothermia. The ideal electrolyte formula would be capable of rehydration, resolution of metabolic acidosis, replenish potassium losses, correct hypoglycemia and warm the calf. In addition, the fluid would attenuate the diarrhea, stimulate the calf's appetite, maintain weight gain and have some therapeutic efficacy against the etiologic agent. It would be convenient to mix, easy to administer, and could be mixed with milk or milk replacer.

In a Wisconsin survey of dairies with a 95% or greater survival rate of female calves(3), for 66.7%, administration of oral electrolyte solutions to scouring calves was standard practice. More producers (78.8%) immediately withdrew milk from the diet of scouring calves and, for most, milk was gradually reintroduced to the diet. In an early study at the University of Wisconsin, as many as 60% of calves with diarrhea for more than 5 days managed in this way were hypoglycemic and had hormonal changes consistent with acute or chronic starvation.(4) In a more recent study of calves with acute diarrhea managed by reduced milk intake fed and oral electrolyte feedings given twice daily, 55% of prefeeding blood samples showed them to be hypoglycemic. In pigs fasted for 2 days, there was increased tissue permeability, decreased electrolyte absorption and enhanced sodium and chloride secretion, suggesting a critical role of enteral nutrition in the maintenance of normal electrolyte transport across intestinal epithelium.(5) Persistence of diarrhea, recurrence of diarrhea with the reintroduction of milk to the diet, or progressive weight loss or ill-thrift in spite of resolution of diarrhea are notable complications of current practices. Is there a new approach to oral electrolyte therapy in calves with diarrhea? How does one choose amongst the 35-plus commercially available electrolyte solutions?

Correction of Dehydration

A 45 kg calf has a maintenance fluid requirement of 3.5 to 4.0 L daily. It is not uncommon for this size calf to lose 5 to 10% of its body weight with the onset of acute diarrhea. Common practice is to withdraw milk from the diet of this calf at the onset of diarrhea and to feed 2 L

of a commercial electrolyte solution two times daily. While the practice may meet maintenance fluid requirements for this calf, there is no fluid provided to correct the 2.25 to 4.5 L deficit due to dehydration. Calves with acute diarrhea should receive a minimum of one but frequently 2 extra 2 L feeding daily (total fluid intake of 7 to 8.5 L) to correct dehydration and meet maintenance fluid requirements.

Correction of Metabolic Acidosis and Electrolyte Disturbances

Calves with diarrhea frequently are acidemic, hypokalemic (total body deficit) and hyperchloremic. The oral electrolyte solutions differ in their ability to alkalinize calves with acidosis.(6,7,8) Previous studies have emphasized the importance of bicarbonate as the determinant of alkalinizing ability. It may be more likely that the concentrations of the strong ions, sodium, potassium, and chloride, in the electrolyte solution and subsequently in the gastrointestinal tract that determine the alkalinizing ability of the electrolyte solution.(9) Electrolyte solutions with a strong ion difference ((Na + K) - Cl) greater than plasma (approximately 45 mEq/L) will have a tendency to alkalinize. Ranking the strong ion difference (SID) of some of the commercial electrolyte solutions, products like Lifeguard[®], Lifeguard[®] HE, and Biolyte[®], have a larger SID than products like Resorb[®] and Ion Aid[®]:

Table 1. Strong ion difference (anion-cation balance) of selected commercial electrolyte solutions.

Oral Electrolyte Product	Strong Ion Difference ((Na + K) - Cl)
Scourlyte [®] (Schering)	30
Resorb [®] (SmithKline Beecham)	31.7
Formula 911 [™] (Advantech)	49
Hysorb [®] (Sanofi)	60
Isotone-A [®] (Vet-A-Mix)	60
Hydralyte [®] (Vet-A-Mix)	70
Lifeguard [®] (SmithKline Beecham)	80
Lifeguard [®] HE (SmithKline Beecham)	81
Biolyte [®] (Upjohn)	81

This ranking is consistent with published results comparing alkalinizing ability of electrolyte solutions(6,7,8), offering validity to the method of comparison. Electrolyte solutions with the greatest alkalinizing ability will have sodium concentrations similar to plasma combined with potassium concentrations greater than plasma potassium concentration. The same solutions will be the most effective in resolving the characteristic electrolyte disturbances due to diarrhea.

The inclusion of glycine in oral electrolyte solutions has been advocated because of its beneficial effect on fluid and electrolyte transport in the small intestine of diarrheic calves.(10) Several commercial electrolyte solutions contain glycine in the formulation (Hysorb[®], Lifeguard[®], Hydralyte[®], Resorb[®]).

Correction of Hypoglycemia and Provision of Energy Substrate

Diarrheic calves which do not receive sufficient caloric intake to meet maintenance requirements will be hypoglycemic, lose weight, and may die, particularly if they are housed in a cold environment. There are no oral electrolyte solutions currently available which meet the caloric needs for maintenance and growth of an average size (40 kg) calf and normal calves fed all but 2 hypertonic, energy dense electrolyte solutions had significant weight loss during therapy.(11,12) Hypertonic electrolyte solutions such as Biolyte[®], Hydralyte[®], and Lifeguard[®] H.E., come closest to providing approximately 80% of the maintenance caloric needs(12) or approximately 50% of the combined caloric requirement of a 40 kg calf for maintenance and growth. The hypertonic oral electrolyte solutions have been shown to have a beneficial effect on blood glucose concentration and have produced no adverse effects in calves with diarrhea which might be attributable to bacterial overgrowth in the intestinal tract or osmotic diarrhea.(13,14) It would seem that hypertonic oral electrolyte solutions should be selected for hypoglycemic, diarrheic calves.

Neonatal calves have little or no fat which can be mobilized for energy during periods of caloric deprivation. Calves that cannot mobilize fatty acids sufficiently may catabolize muscle protein for energy, increasing the risk of development of uremia and producing a calf that becomes progressively more unthrifty, even if the diarrhea is resolved. Depriving diarrheic calves milk, frequently the sole source of calories in calves less than a week of age, should be questioned unless substantial benefits in survival rate, treatment days or fecal consistency can be demonstrated. Milk deprivation not only withdraws a significant caloric input but reintroduction after milk-withdrawal is associated with exacerbation of diarrhea.(11) An early study(15) showed no benefit of milk deprivation in scouring calves and, in more recent studies(16,17), have shown beneficial effects of continued milk feeding during diarrhea.

In a study completed in our laboratory, calves with diarrhea maintained on a normal milk diet to which a hypertonic oral electrolyte solution was added, fecal consistency, weight gain and blood glucose concentrations were significantly greater than in calves with diarrhea fed oral electrolyte solution with a restricted milk diet. These results suggest that calves with diarrhea may be better managed by continued milk feeding with oral electrolyte solution supplementation.

Assimilation of oral glucose and milk in diarrheic calves may be enhanced by the addition of soluble dietary fiber to the diet.(18) In addition to enhancing energy homeostasis, there may be additional benefits of improved gastrointestinal transport times, maintenance of digestive enzyme activity, enterocyte proliferation and function, and normal bacterial flora.(17) Efficacy studies in diarrheic calves need to be done but work in other animal species and people shows substantial benefit. Some of the newer generation oral electrolyte solutions for calves have included fiber sources (Formula 911[™], ASAP[™]), but their efficacy remains to be established. Administration of fiber in oral electrolyte solutions may complicate mixing and make nursing of fluids through a nipple difficult.

Miscellaneous Factors

A number of electrolyte solutions have additional ingredients which are added to attenuate diarrhea by alteration of electrolyte and fluid shifts, adsorb toxins, or alter intestinal transport. The efficacy of such ingredients other than those referred to above have not been demonstrated in diarrheic calves and should not form the basis of selection of that product.

The role of reestablishing or enhancing the population of normal bacterial flora to enteric immunity seems attractive. The efficacy of probiotics has been suggested, though the mechanism

is unknown.(19) Benefits in diarrheic could be attributable to production of lactic acid by lactobacilli and streptococci which acidifies gastrointestinal pH. Hydrogen peroxide production by probiotic organisms could be detrimental to pathogenic organisms. Production of antibiotics by certain strains of lactobacilli and streptococci may adversely affect pathogenic organisms. Synthesis of digestive enzymes by probiotic organisms may improve digestive function. Synthesis of B-vitamins by probiotic organisms may be beneficial to the diarrheic calf. Finally, it may be that beneficial bacteria may competitively inhibit pathogens from attaching or colonizing areas of the gastrointestinal tract and aid in their exclusion, control or elimination.(19)

Most oral electrolyte solutions, particularly those containing bicarbonate, should not be mixed with milk because they will impair rennet clot formation in the abomasum and alter abomasal potentially alter abomasal emptying and gastrointestinal transport time. The effect of mixing electrolyte solutions with milk replacer has not been adequately tested and issues of abomasal clot formation are irrelevant. Some oral electrolyte solutions can be mixed with milk or milk replacer and may be preferred because of the convenience of a combined feeding. The author prefers that the oral electrolyte and milk or milk replacer feedings be separated because calves with diarrhea rarely nurse a large volume of fluid which would result when the 2 are mixed. Preference is given to having milk or milk replacer feedings occur when calves are willing to suckle. Forced feeding of electrolyte solution can be employed if the calf is unwilling to suckle the required volume with fewer side effects of placement in the rumen than milk.

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Summary

Oral electrolyte administration remains the mainstay of therapy of calf diarrhea. Solutions can effectively combat dehydration if they are administered in sufficient volume (6.5 to 8.5 L daily) alone or in combination with milk. Hypertonic oral electrolyte solutions are the most calorie dense of the oral electrolyte solutions and are superior to most isosmolar solutions in their ability to resolve metabolic acidosis and electrolyte derangements of the scouring calf. Continued milk feeding combined with administration of oral electrolyte solution for treatment of diarrhea can satisfactorily meet the calf's caloric requirements for maintenance and growth, increase weight gain, improve glucose homeostasis, and shorten the course of diarrhea. Provision of fiber and beneficial intestinal microflora in oral electrolyte solutions have potentially beneficial outcomes but remain to be tested in field studies.