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Fluid Therapy for the Food Animal Practitioner
D. Michael Rings, DVM MS

Water is the most essential of all nutrients. It plays a vital role in many chemical reactions in the body and accounts for the majority of the body's weight. While depriving an animal of food (starvation) will result in death after weeks, loss of water can cause death within a few days. Therefore, hydration of the patient is of paramount concern to the veterinarian or person responsible for care-giving. Dehydration can also result in derangements of electrolyte concentrations and acid-base status of the patient.

Assessment of the food animal patient

The decision to give fluid is based on the clinician's determination of the degree of dehydration. In an ambulatory or field situation, assessment of laboratory parameters such as hematocrit and total plasma protein are not immediately available and the clinician must use physical findings to determine hydration. Tenting of the skin for > 2 seconds is the first detectable degree of dehydration and is said to represent 4% dehydration. Tenting between 2-4 seconds represents 6-8% water loss and > 4 seconds is approaching 10% loss. The assessor should bear in mind that acute losses of >12% are often accompanied by death. The skin of the lower eyelid is preferred over that of the neck because of better correlation with laboratory evaluations (PCV, TPP) of hydration (i.e. the neck has less elasticity). The position of the globe (eye) within the boney orbit is a valuable tool as well. In a normally fleshed and hydrated patient, the globe will extend to or slightly beyond the boney rim. Acute fluid losses tend to cause shrinkage in the retrobulbar tissues, leading to the globe's retraction within the orbit. If the lower lid is pulled down until the lid is even with the rim, the space between the lid and the globe should be < 0.5 cm.(the lacrimal lake). When this space is greater, the patient is either chronically malnourished (loss of retrobulbar fat) or dehydrated. In conditions of acute dehydration as is seen in cattle with abomasal volvulus or high intestinal obstructions or in calves with severe scours, the eyes may appear to be having a race toward the center of the head!

In young nursing calves, the animal's ability to stand and suckle are also helpful parameters in deciding the route of fluid administration to use. Calves having the ability to stand and maintaining a strong suckle are good candidates for oral rehydration therapy (ORT) whereas recumbent or weak calves which will not suckle are likely in need of intravenous fluids.

Oral Replacement Therapy (ORT)

Fluid administration remains a problem for most food animal practitioners; not so much from the point of knowing the appropriate fluid to use but rather how to administer the fluid in an economic fashion and by an effective route. Logistics, therefore, are the biggest problem. In haul-in practices or clinics with animal pens, the idea of iv fluid administration is not out of the question because someone is on the premises to monitor the delivery. In the field, iv fluids are occasionally given but only to the extent that the veterinarian has the time to baby-sit the animal and frequently the volume given is insufficient to correct the problem. Oral rehydration has the advantage of being a means of delivering large volumes of fluid over a short period of time (minutes) at a cheap price. However, for oral fluids to be effective the animal must not be severely dehydrated (>7-8%). As the total body water shrinks, the body compensates by contracting the vascular system, shunting blood away from non-essential organs. Oral fluids must make it to the small intestine to be absorbed systemically. Hypoperfusion of the GI viscera means that fluid within the bowel lumen can be only slowly absorbed and will not be adequate to make up this level of deficit.

Additionally, ORT is not an effective route for patients having severe ileus or disease conditions that slow emptying of the abomasum and/or forestomachs due to the sequestration of fluid proximal to the site of absorption. Thus, the cow with an abomasal volvulus will not benefit from oral fluid preoperatively but could benefit post correction and the calf with severe scours may not be adequately perfusing the bowel to absorb the fluids.

One of the most consistent signs of disease in cattle is anorexia. Hypokalemia is likely to develop because cattle store little potassium in the body but continue to lose it in urine and feces. The more profound the anorexia, the greater the prospect for hypokalemia. The most common clinical sign of hypokalemia, i.e. skeletal muscle weakness, is often observe d in sick cattle. Isotonic mixtures containing sodium chloride and potassium chloride can be offered safely to most sick cattle to accommodate this condition. Oral fluids to the adult ruminant should be delivered in the isotonic range (280-300 mOsm/L) to enhance their movement and absorption. Some formulations for oral ruminant fluids are listed in table 1.

Scouring calves are often energy deficient as well as dehydrated and the idea of supplementing glucose (as is available in many commercial oral scours treatments) seems appropriate, yet at the same time giving a hypertonic fluid would seem to contribute to the diarrhea by drawing water into the gut. In calves, hypertonic solutions have been shown to delay abomasal emptying into the duodenum. While this may appear to be counterproductive to rehydrating the patient, the delayed emptying of Glucose-rich solutions in the range of 400-600 mOsm/L will prevent overwhelming the intestine with fluid and better allow the calf to utilize a greater percentage of the glucose for energy. In secretory diarrheas (ETEC), oral fluids containing glucose and sodium enhance the movement of water across the cell (the glucose and sodium are actively transported and water is passively dragged along), however, in malabsorptive conditions (ie. cryptosporidiosis and giardiasis) the glucose-sodium mechanism will not enhance water movement. Therefore, selection of oral fluids should be based on the anticipated cause of the diarrhea. (Would want to avoid high glucose solutions if they can't be utilized...would only act osmotically to worsen the diarrhea)

Intravenous Fluids

As mentioned earlier, the major drawbacks to IV fluids are their expense and the difficulty in maintaining a patent catheter system. While I don't pretend to have a fool-proof catheter system, there are a few tips that may improve your success: 1) select catheters which maintain there internal lumen if bent. Polyethylene tubing, a cheap, readily available catheter material, once bent will not regain its lumen size; therefore, delivery rate is slowed or halted and blood will clot along the lumen wall. Intrafusor catheters also tend to kink and develop holes as well as migrate out of the vein. *Over the hub* catheters of material such as Silastic and Teflon appear to be good long_term catheters. Catheter length need be no greater than 3-5", even for the largest animal. The longer the catheter, the greater the turbulence and whipping motion at the free end as blood flows by. It is this motion which traumatizes the vein's endothelial lining and predisposes the animal for phlebitis. Additionally, exceptionally long catheter will go into the right heart and can go through the tricuspid valve. Experimentally, closure of the AV valve around even the most sterilely placed catheter will cause fibrin deposition and, ultimately, endocarditis.

Securing the catheter in place prevents migration out of the vein and minimizes phlebitis at the entry site due to movement. Several methods work well in cattle including super glue, tunnelling and the chinese finger-locking suture. Super glue is a fast, effective means of holding the catheter in place for several days. The obvious drawbacks are you can get the glue on your fingers and removal of the catheter will remove some of the patient's skin. Tunneling the catheter by oversewing the skin above and below the catheter protects it from movement and the external environment. The chinese fingerlock suture pattern is a little more intricate that either of the other methods but will hold the catheter fast.

Large carboys and coiled extension tubing make the delivery of large volumes of intravenous fluids less complicated. Nalgene containers[1] work nice because they are almost unbreakable, hold 3-5 gallons of fluid and can be sterilize by both heat and gas if necessary. Adaptation from the spigot to appropriate tubing is not difficult or expensive. Although many of the patients receiving IV fluids are relatively immobile, hopefully, most will improve on treatment and may feel good enough to move around in the pen. With straight tubing and simplexes, the tubing must frequently be adjusted in length to prevent the animal from a) becoming tangles in the redundant tubing or b) walking away from the tubing and disconnecting the fluid. The use of coiled tubing as an extension alleviates this problem. We use a coiled tube[2] as the extension which, in its coiled state is 11" long, but can stretch to 8'. This allows some freedom to the animal and eliminates the necessity of having someone constantly watching the fluid delivery.

The selection of the appropriate IV fluid, like that of oral fluids, is based on the veterinarian's diagnosis. Knowing the physiology of a condition allows the veterinarian to anticipate acid-base and electrolyte disturbances. In the young animal, especially, marked changes in blood pH occur. Blood gas machine have not become standard ambulatory fare

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so again, physical parameters need to be used to estimate the animal's base deficit. A simple chart, constructed on work done by Whitlock and Tasker, provides a helpful guide for this purpose. This has been reproduced in table 2.

Diarrhea is likely to produce a metabolic acidosis due to loss of bicarbonate in the stool. Additionally, as the acidosis progresses, [H+] move into the cell in exchange for potassium. The worse the acidosis, the greater the movement of K+ into the vascular system. Elevated potassium can cause cardiac conduction disturbances which may be fatal. Atrial standstill has been documented in calves due to hyperkalemia (Weldon, Moise and Rehbun 1992). Knowing this, calves getting intravenous treatments need to receive base (buffer) containing fluids to correct the acidosis. A commercially prepared solution of lactated Ringers is often given as a standard. One problem here: lactate must be converted to bicarbonate in the liver before it is an effective buffer. As has been mentioned, dehydration will under perfuse the abdominal viscera, including the liver. This means that the conversion of lactate → bicarbonate will be slow and may not be able to manage the metabolic acidosis. Acetate and pyruvate, usually in the forms of sodium acetate and sodium pyruvate, are converted more efficiently that lactate but would not be the fluid of choice for a patient with a blood pH < 7.2 (normal is 7.37-7.43). Calves which fit into the last 2 categories of table 2 probably have pHs less that 7.2 and need an immediate source of base. This is sodium bicarbonate. Isotonic solutions of sodium bicarbonate contain 50 grams $NaHCO_3$/gallon water. This supplies 600 mEq HCO_3 and 600 mEq Na+. Using the table it is possible to estimate the base deficit and make the fluids accordingly. Also, with diarrhetic neonates the opportunity for hypoglycemia is great and the supplementation of fluids with glucose will save some calves.

The question has been asked many times: What about the use of hypertonic saline? Five and 7% hypertonic sodium chloride solutions have been investigated for several years. Administration of these solutions will improve the systemic circulation and raise the blood concentrations of Na+ and Cl- temporarily. Hypertonic solutions are useful as an initial fluid, basically given as a bolus, to the flat-out, almost dead calf. They will improve cardiac performance for 30-60 minutes, thus giving you time to start other, more appropriate fluids. A rule of thumb which has worked well for me is give 5 ml/lb of 5% NaCl to the patient over 5 minutes (The Rule of 5). This means that a reasonably size calf (~ 100 lb) would receive 1-500 ml 5% saline bag over 5 minutes. At the end of this administration, assess the patient and start the fluids to correct the dehydration and pH and electrolyte derangements.

Some practitioners have been concerned that the high sodium loads, given all at once, may produce sodium toxicity (neurologic signs) in the CSF. This question has been addressed directly and no evidence of ↑ Na+ in the CSF has been seen. Hypertonic saline has been shown to be most effective in support of blood pressure, especially following blood loss, with a less satisfactory role in the endotoxic cow (Constable, Muir, Schmall and Hoffsis). Hypertonic saline has also been given to mildly dehydrated cows to purposely raise the blood osmolality with the expectation that this will cause the animal to drink and rehydrate herself. Most of this is testimonial gibberish, however, there is a reason to believe so again, physical parameters need to be used to estimate the animal's base deficit. A simple chart, constructed on work done by Whitlock and Tasker, provides a helpful guide for this purpose. This has been reproduced in table 2.

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There are fewer conditions causing metabolic acidosis in the adult. The best example would be grain overload or D-lactic acidosis. Many conditions which would most likely cause an acidosis in another species, toxemia ie. toxic metritis and toxic mastitis, have at least an equal chance to cause alkalosis. Ileus induced by these conditions causes the sequestration of HCl (abomasum) which is more profound than the acidosis cause by the cells' shifts to anaerobic metabolism. If the diagnosis is dehydration and the underlying cause has not been determined, I would recommend Ringer's solution as the fluid of choice. It is better to err on the safe side than to make a condition worse. The cow's ability to compensate for a metabolic acidosis is far superior than it is for an alkalosis. Cattle with a bicarbonate value of 12-15 mEq/L (a deviation from normal 24-28 mEq/l) would probably still be standing because respiratory compensation (in the form of blowing off CO_2) will prevent much movement in blood pH. Conversely, a bicarbonate level > 40 mEq/L will be seen in a severely ill animal, the compensatory mechanism being retention of CO2 (hypoventilation) and the formation of carbonic acid. It is difficult to elevate the pCO_2 beyond 50 torr without significant lung disease.

Knowing now what fluid we would choose for a particular problem, we are still faced with the cost of the product. Five liter bags of sterile IV fluid are approximately $16. When we start figuring volumes of IV fluid for an adult cow, we usually start at 5 gallons (18.5 liters) and go up from there. Commercial IV fluid cost per day to a 1000# patient receiving only maintenance levels (30 mL/lb/day) would amount to 6 5-liter bags, for a cost of $96. If you run fluids at 2 X maintenance as would be given in most dehydrated cows, the cost is almost $200/day! That takes the SUPER COW to warrant this level of expense. Additionally, no large animal practitioner wants to carry large volumes of fluid in their practice vehicle; too much added weight and takes up too much room. I have always wanted to offer my clients the best I can, at a cost which will keep him in business and make me a profit. A $200/day I feel I doing my client a disservice to spend that amount of money. A satisfactory (but also non-sterile) means of giving IV fluid involves making up your own fluids. The formulas for Ringer's, lactated Ringer's, saline, isotonic bicarbonate, isotonic KCl, and 5% dextrose are given in Table 3. The actual cost for the electrolyte to make up one gallon / 3.7 liters of Ringer's is less than $1. Reagent grade (>99% purity) chemicals can be purchase from chemical supply houses such as Sigma Chemical. Premeasured packets can also be purchased commercially at a reasonable cost.[3] Instead of using sterile fluids, distilled water can be substituted at a cost of $.60-.80/gallon. Therefore, your hard cost per gallon are less than $2. Additionally, it isn't necessary to carry large volumes of fluids with you. Simply carry packets of premeasured chemicals (ex. 1 packet will the NaCl, KCl, $CaCl_2$ needed for 1 gallon of Ringer's) which can be added to 1 gallon distilled water and start the patient going. Additional packets can be dispensed based on the amount of fluid you want to have given. The client can purchase additional distilled water from grocery stores and

[3]. Edlaw Pharmaceuticals Inc. Farmingdale, NY 11735 (1-800-454-6888)

quick stops and be left responsible for the additional fluids being given. Carboys and extension sets can be loaned/rented to the client.

You'll note in Table 3 that all of the formulas deal with gram measurements. I have yet to find a grams scale or balance beam in a large animal office, so the idea of making up your own fluids seems less attractive. Yet, if we can't keep our fluids cheap (RE: homemade), the client will refuse treatment and we will do less that we are capable. Dr. Bob Streeter and myself felt that there had to be a practical solution to this, and through the use of household items (a measuring spoon set), we have developed the handyman's guide to formulating fluids. Table 4 contains the level teaspoon and tablespoon weights of most of the common chemicals used in fluid therapy.

Table 1. Oral Rehydration Fluids

For the alkalotic animal

150 grams NaCl
30 grams KCl
QS to 5 gallons with water

supplies 127 mEq/l Na+, 19 mEq/L K+ and 146 mEq/L Cl-

For the acidotic animal

100 grams NaCl
100 grams $NaHCO_3$
30 grams KCl
QS to 5 gallons with water

supplies 60 mEq/L HCO_3, 145 mEq/L Na+, 19 mEq/L K+, 104 meq/l Cl

Asiatic Formula

13.9 grams NaCl
14.4 grams $NaHCO_3$
3.0 grams KCl
86.4 grams Glucose
QS to 1 gallon with water

supplies 40 mEq/L HCO_3, 100 mEq/l Na+, 70 mEq/L Cl

Table 2. Estimating base excess or loss for correction of acid-base disturbances

FLUID RUMEN	[VERY SCANT FECES]	+4 DEHYDR	+20 B.E.
SPLASHY RUMEN	[SCANT FECES]	+	3

		DEHYDR +15 B.E.
MODERATE DISTENSION	[SCANT]	+ 2 DEHYDR +10 B.E.
DOUGHY RUMEN	[FIRM FECES]	+1 DEHYDR +5 B.E.
NORMAL	-----NORMAL----------------	
SLIGHT DIARRHEA		+1 DEHYDR -5 B.E.
MILD DIARRHEA		+2 DEHYDR -10 B.E.
MODERATE DIARRHEA		+3 DEHYDR -15 B.E.
SEVERE DIARRHEA		+4 DEHYDR -20 B.E.

Table 3. Intravenous Fluids

For the treatment of acidotic conditions

1. " 5:4:1"
   - 5 g NaCl
   - 4 g $NaHCO_3$
   - 1 g KCl
   - QS to 1 liter

   a. supplies 48 mEq/L HCO_3

2. Isotonic Bicarbonate Solution

   50 g $NaHCO_3$ QS to 1 gal. with distilled water

   a. supplies 600 mEq HCO_3/gal. OR 162 mEq/L

3. Lactated Ringer's Solution

24 g NaCl	120 g NaCl
1.2 g KCl	6 g KCl
0.8 g $CaCl_2$	4.0 g $CaCl_2$
20 cc Na lactate	100 cc Na lactate
QS to 1 gal	QS to 5 gal

a. supplies the equivalent of 28 mEq/L HCO_3

b. will not be sufficient to correct severe acidosis or in markedly dehydrated animal

c. should not mix bicarb solutions with lactated

Ringer's due to pp't formation

For the treatment of alkalotic conditions

1. Saline (0.9%)
   36 g. NaCl
   QS to 1 gal. with distilled water

2. Ringer's Solution

34 g NaCl	170 g NaCl
1.2 g KCl	6.0 g KCl
1.3 g CaCl2	6.5 g CaCl2
QS to 1 gal.	QS to 5 gal.

Miscellaneous Solutions

1. Isotonic Dextrose (5%)
   200 g dextrose QS to 4 liters with distilled water

2. Isotonic Potassium Chloride Solution
   40 g KCl QS to 1 gallon with distilled water
   a. supplies 556 mEq K+ per gallon
   b. extrapolations from human medicine suggest that K+ not be given at a rate > 0.5 mEq/kg/hr

Table 4. Close approximations useful for concocting fluids without the use of a balance beam scale

Compound	teaspoon (G)	tablespoon (G)	isotonic sol'n
sodium chloride	6.4	19	0.9%
sodium bicarbonate	5.5	16	1.25%
potassium chloride	6.0	18	1.1%
calcium chloride	4.1	12.2	
ammonium chloride	4.0	12	
dextrose	3.0	10	5.0%