Diarrhea in the Calf
Part II: Secondary Changes and Treatment*

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There are three primary alterations in the body as a whole due to diarrhea: 1. Dehydration, 2. Acidosis, and 3. Electrolyte losses and imbalances. The initiating factors in the development and the magnitude of each in the acutely diarrheic neonatal calf have been discussed in Part I. This paper will briefly cover the effect that these alterations have on the body as a whole and their treatment. Only by knowing, understanding and taking into consideration these alterations and their effects on the diarrheic calf is a rational medical treatment possible.

In diarrheal dehydration the preferential loss of fluid from the blood (15), which causes a 50% decrease in plasma volume (27), causes an increased hematocrit, blood viscosity (4,27) and peripheral vasoconstriction (7,12,27) clinically evident by the cold extremities in the dehydrated diarrheic calf. The peripheral vasoconstriction is an attempt by the body to maintain an adequate blood flow to the vital organs, such as the heart and central nervous system by shunting the remaining blood to them. The decreased peripheral vascular perfusion causes a lack of oxygen to these tissues (5,12) and therefore an increased production of lactic acid (25) as this regularly follows anaerobic metabolism. Lactic acid is utilized almost exclusively by the liver, which due to diarrheal alterations may have a decreased lactate uptake (14,19,25). Blood lactic acid, therefore, increases due to both increased production and decreased utilization (3,17,33) adding to the already existing acidosis caused by the loss of bicarbonate in the feces (2,23).

Bicarbonate loss increases the body's H^+ concentration as can be seen from the following chemical reactions:

$$H_2O + CO_2 \longrightarrow H_2CO_3 \longrightarrow H^+ + HCO_3^- \downarrow \text{intestinal loss}$$

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Water and carbon dioxide combine, forming carbonic acid. Carbonic acid deionizes forming H^+ and HCO_3^-. As the HCO_3^- is lost across the intestinal mucosa more HCO_3^- and H^+ are produced. The continuing HCO_3^- drain pulls the reaction to the right. Since the H^+ remains in the body and the HCO_3^- does not the H^+ concentration increases, resulting in acidosis.

Acidosis, once it develops as a result of the diarrheal alterations, that is dehydration, electrolyte losses and increased H^+ production, is a primary factor in maintaining and worsening these alterations (12,25) particularly the potassium losses and imbalances. The decreasing intracellular pH is especially important in causing these potassium alterations (12,21,28) which develop in the following manner.

Normal electrolyte distribution in the body is a low intracellular sodium ion concentration and high extracellular concentration, whereas the reverse relationship is true for the potassium ion. Intracellular potassium is high and extracellular low. Hydrogen ion concentration is slightly higher in intracellular fluid than extracellular (35). Although the electrolytes are constantly exchanged across the cell membrane their concentration inside and outside the cell is quite constant. During diarrhea the extracellular hydrogen ion concentration increases as acidosis develops. As this occurs there is a tendency for these ions to move into the cell (35). Two possibilities exist, first that a negative ion accompany the positive hydrogen ion, second, that there is an exchange and a positive ion, potassium, leaves the cell as hydrogen enters. The second possibility predominates and there is both an intracellular

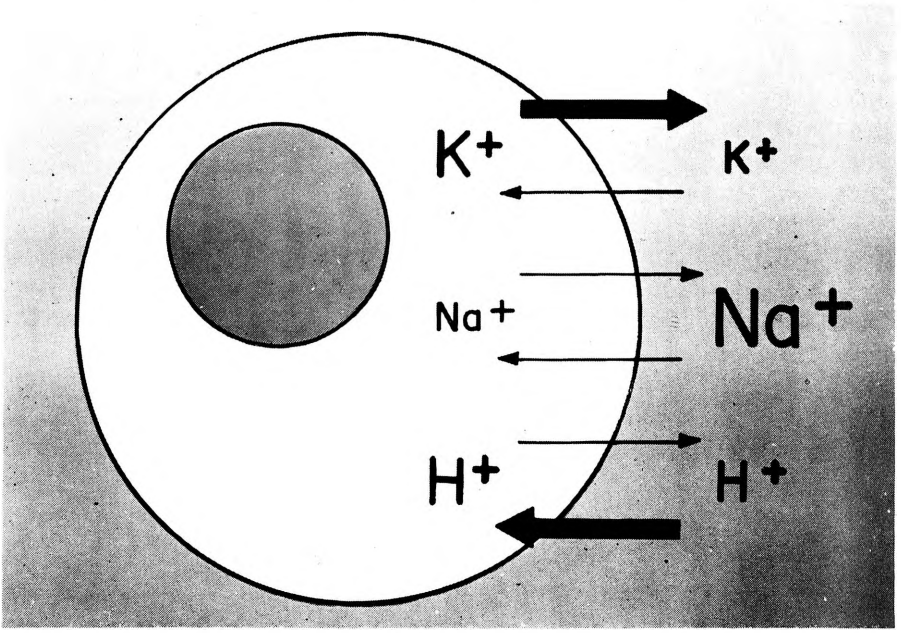

Figure 1: Ion movements as a result of diarrheal acidosis illustrating increased hydrogen ion movement into the cell causing increased potassium ion movement out.

accumulation of hydrogen ion and loss of potassium ion (Fig. 1) (12,21,28,34).

Potassium concentration becomes elevated in the extracellular fluids including the blood. Much of this potassium ion is lost in the feces and urine but its blood concentration is often increased throughout the course of diarrhea (11,15,34,36). Therefore, the normal potassium ratio across the cell membrane is changed as a result of these ion shifts (Fig. 2). This results in a decreased potassium concentration inside the cell (7,12,16) and an increased potassium concentration outside the cell (11,15,34,36) both changes causing the potassium concentration ratio across the cell membrane to become abnormal as illustrated in Figure 2.

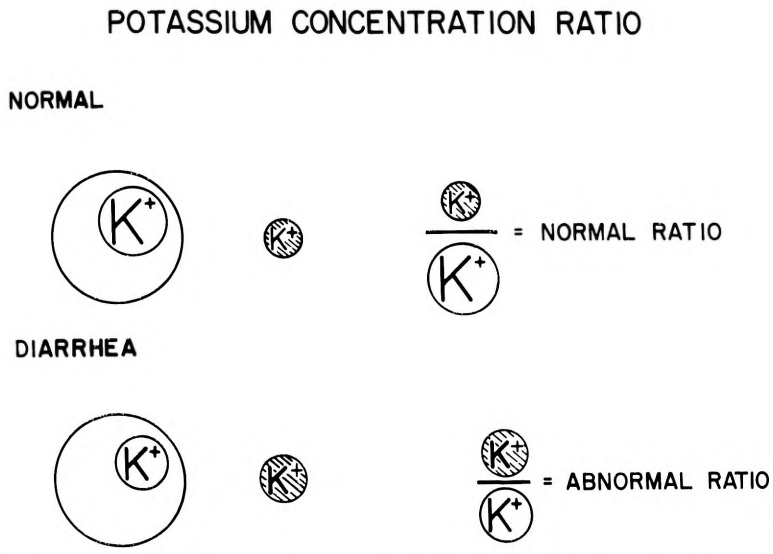

Figure 2: Transmembrane potassium concentration ratios normal versus diarrheic. In diarrhea the intracellular potassium concentration decreases and the extracellular increases both causing this ratio to become abnormal resulting in a decreased membrane potential.

The electrical potential across the cell membrane, which is necessary for the conduction of nerve impulses, skeletal and cardiac muscle contraction, etc., is largely determined by this transmembrane potassium concentration ratio (18). The effect that this altered ratio has is well illustrated clinically by abnormal electrocardiograms (15,16,30) and lethargy (24).

It is evident from the magnitude of fluid and electrolyte losses which have occurred that the use of antibacterial agents by themselves will be of little or no benefit to the calf. The one treatment that is essential is the replacement of these fluids, which raises three questions — what, how much and how? What and how much must be determined not by changes in plasma concentrations, as well illustrated by potassium whose plasma concentration increases in spite of large potassium losses from the body (22), but by the actual losses during

diarrhea determined by complete balance studies as described in Part I of this paper.

Treatment of the acidosis is particularly imperative (12,14,15). Lactate is commonly used to treat many forms of acidosis but to be effective it must be completely metabolized. In the diarrheic, acidotic, hypovolemic calf endogenous lactic acid contributes to the acidosis (3,10,17,33). Although endogenous lactic acid may play only a minor role in the acidosis its use would appear to be contraindicated in diarrheal therapy. Bicarbonate is the treatment of choice (33).

How to administer this fluid must be considered. Since intestinal absorption appears to be decreased during diarrhea (1,8,17) oral or rectal lavage would not be indicated. Subcutaneous therapy would seem to be an ideal route from several aspects. The large volume of fluid needed by the diarrheic calf can be easily and rapidly given in several locations. Subcutaneous absorption of large quantities of fluid normally occurs over a 6 to 8 hour period (32), therefore, treatment 2 to 3 times a day would appear to be equal in benefit to the much more difficult slow intravenous infusion. But the decreased blood flow to the subcutaneous tissues due to peripheral vasoconstriction will greatly delay absorption from subcutaneous areas (32), although this route may still be a possibility if peripheral vasoconstriction has not yet occurred or if blood volume has been restored by other therapy. The severity of peripheral vasoconstriction can be estimated by comparing the temperature of extremities to that of the rest of the body.

Intraperitoneal administration of the fluid may be another alternative. Again the large volume needed by the diarrheic calf may be easily and rapidly given by this route. Absorption normally occurs quite rapidly although this may also be altered in the diarrheic calf. Perhaps some combination of the subcutaneous and intraperitoneal routes would give satisfactory therapeutic results.

Slow intravenous infusion is from the calf's viewpoint, the most ideal route; from the veterinarians', the most non-ideal; and from the stockman's, impossible. We are all aware of the difficulties in catheterizing nearly collapsed veins in the severely dehydrated diarrheic calf and keeping it in the vein without constant supervision during slow intravenous infusion. Yet this route is ideal for several reasons. The problem with absorption encountered by the other routes is eliminated. A hypertonic solution may be given. That is a solution containing a greater concentration of particles or molecules than does the blood.

Since restoration of the greatly decreased blood volume is essential, an intravascular hypertonic solution is indicated. By giving a hypertonic solution intravenously, the blood osmolarity is increased above that in the other body fluid compartments. This results in the movement of water into the blood from these compartments which have not been as severely decreased by the diarrhea (27). The blood volume is therefore increased not only by the fluids given but by the contribution from the other fluid compartments in the body.

To replace the potassium lost during diarrhea it is necessary to give a solution high in potassium (22). The potassium loss is entirely from inside the cells (22) and must be replaced to the cells without increasing the extracellular concentration as such an increase would worsen the already altered transmembrane potassium ratio (Fig. 2). Glucose added to a fluid containing a high potassium concentration will enhance the movement of potassium into the cell (20). Therefore, we have found that a glucose containing, potentially toxic, high potassium solution can be given intravenously without increasing the extracellular potassium concentration. Glucose also serves as an energy source helping to nutritionally maintain the anorexic calf and return the blood glucose level to normal since hypoglycemia commonly occurs in this disease (34). To replace the electrolytes lost plus the added glucose in the volume of water actually lost by the diarrheic calf the solution has an osmolarity about 2.5 times that in the blood (22).

In conclusion:

I. Diarrheal dehydration
   - A. Results in
     1. a 50% decrease in plasma volume
   - B. Treatment
     1. 3-4 liters of fluid/day for the average size calf.
     2. hypertonic solution intravenously the best

II. Electrolyte losses and imbalances
   - A. Results in
     1. a decreased cellular membrane potential which causes:
        - (a) lethargy
        - (b) muscular weakness
        - (c) opisthotonus occasionally
        - (d) cardiotoxicity as evidenced by an abnormal EKG
     2. Acidosis
        - (a) due to fecal bicarbonate loss
   - B. Treatment
     1. replace electrolytes actually lost
     2. glucose to maintain the calf nutritionally and enhance potassium movement into the cell

III. Acidosis
   - A. Results in
     1. an increase and maintenance of the previous two alterations (dehydration and electrolyte losses)
     2. interferes with normal metabolic reactions dependent upon maintenance of a normal hydrogen ion concentration in the body
   - B. Treatment
     1. bicarbonate
     2. not lactate

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