Saving the Valuable Calf

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In spite of the best calf-raising management techniques in beef and dairy operations, some calves will still get sick. Many, if not most calves are not of sufficient value to warrant intensive or expensive therapy. Occasionally, affected calves are very valuable and owners want the best possible intensive therapy. I will discuss two situations which are life-threatening and offer suggestions for the management of each. These situations are colostrum deprivation and the technique of total intravenous feeding to manage debilitated calves.

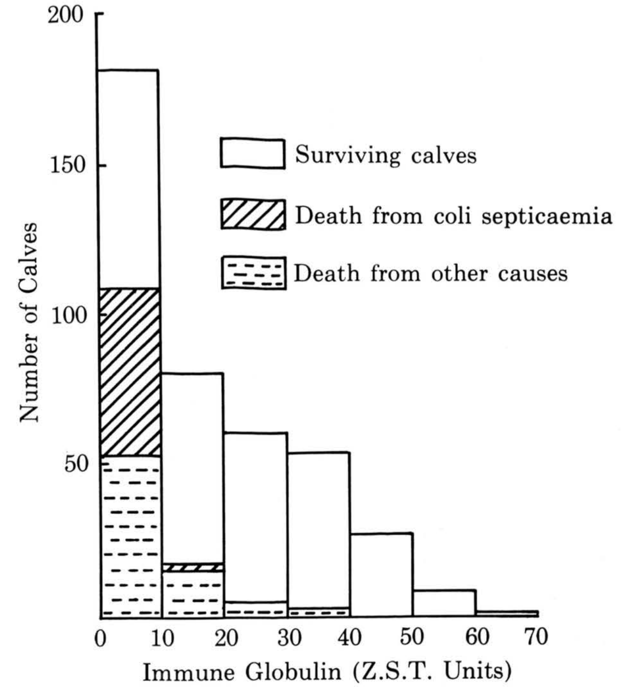
The Colostrum-Deprived Calf

Occasionally a valuable calf will not receive colostrum during the first 18-24 hours. First-calf heifers may not own their calves, or calves may crawl away from cows and not be found for several hours. These calves may first ingest colostrum at a time when immunoglobulin absorption is inefficient. Then too, some calves that ingest colostrum early enough do not absorb immunoglobulin because the colostrum had low globulin content or for other unidentified reasons (25). It has been demonstrated that practically no IgG or IgM is absorbed after 24 hours (2). It has been equally well demonstrated that colostrum-deprived calves have a poor chance of survival (17,9,16) (Fig. 1).

Since immunoglobulin is so crucial in protecting the calf from septicemia, it is important to be able to assess a calf's serum immunoglobulin content. The history by itself may be reliable enough to make this determination. First, one can determine the total plasma protein. The normal total plasma protein of the colostrum-fed calf is equal to or greater than 6 gm/dl. Calves that are colostrum-deprived have a total plasma protein of 4.7 gm/dl. or less (19). If calves are normally hydrated and have less, the protein most likely deficient is globulin. The determination is not as accurate as other methods in estimating immunoglobulin content, but it is sufficient to assess the overall immune status (20).

To estimate the total plasma protein, a microhematocrit tube is filled with an unclotted blood sample. After centrifugation the hematocrit can be read to estimate hydration. Then the tube is broken at the junction of cells and plasma. A drop of plasma is placed in the chamber of a refractometer. A direct reading is made.

Protein electrophoresis offers a more accurate means of measuring plasma proteins. Results are expressed in gm/dl. of each class of serum protein, including gamma globulin. Gamma globulin concentrations of calves that nurse globulin-rich colostrum within 2 hours have serum gamma globulin concentrations of about 2 gm/dl. Calves that are colostrum-deprived have essentially no gamma globulin present (2). Calves with less than about 1 gm/dl. of globulin are probably inadequately protected. Since the gamma fraction is composed primarily of IgG, this test offers an excellent measure of immune status.



The relationship between serum immune globulin concentration and neonatal calves.
Figure 1. From A. D. McEwan, et al. (17).

IgM migrates in the B globulin peak and is especially important in preventing colisepticemia (6). Since immunoglobulins are apparently not selectively absorbed, inadequate gamma globulin content indicates a total immunoglobulin deficiency.

The zinc sulfate or sodium sulfite precipitation tests offer simple and accurate means of estimating serum immunoglobulin content (17,20). The test is conducted by putting 0.1 ml of serum with 6 ml of test reagent in a test tube. Gamma globulin is precipitated to form an opaque appearance. The more gamma globulin present, the heavier the precipitate that forms. If newsprint cannot be read through the solution in the test tube, adequate immunoglobulin is present (Fig. 2).

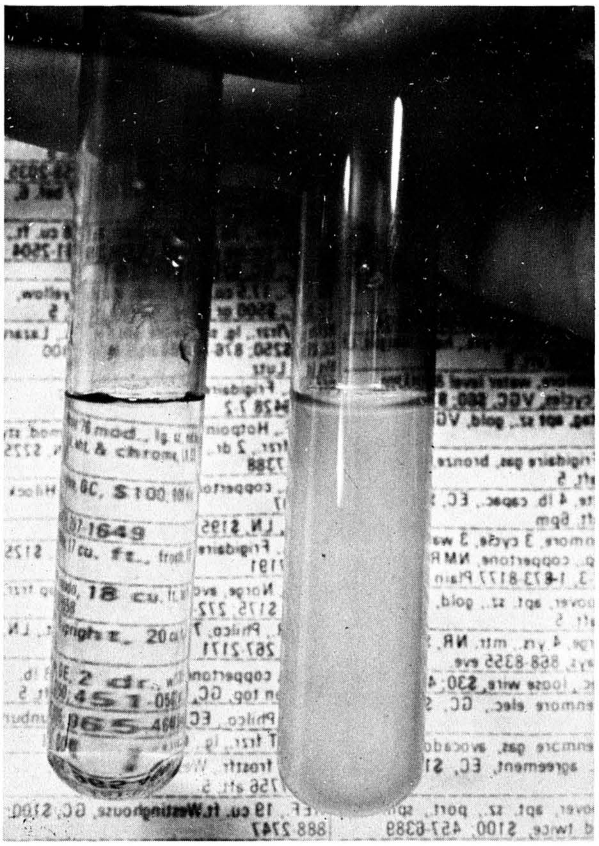


Figure 2. The zinc sulfate turbidity test showing one tube with no turbidity (no gamma globulin) and one tube with heavy precipitate. Newsprint cannot be read through the tube.

Radial immunodiffusion offers the definitive measure of immune status. Each class of immunoglobulin IgG, IgM, IgA, can be quantitated individually by this method. This method is less practical and not necessary for most purposes.

Once the calf is found to be deficient in immunoglobulins, the question of how to provide protection to the calf remains. There is no adequate bovine gamma globulin concentrate available commercially. The hyperimmune serum products are not sufficiently concentrated to serve the purpose at recommended doses. The only way to administer an adequate amount of gamma globulin to a gamma globulin-deficient calf is to give bovine plasma, serum, or whole blood. If plasma or serum is to be given, a centrifuge with the capacity to spin down liter volumes of blood is required. The dose can be calculated as follows (Fig. 3).

45 kg calf 8% b.w. = blood vol.
45 x .08 = 3.60 kg or l blood
Hct. = 30% 3.6 kg x .7 = 2.52 l serum

Cow has about 2 gm gamma globulin per 100 ml

Want calf to have about 2 gm gamma globulin per 100 ml

So give calf about 1 serum or plasma volume: 2-3 l

Figure 3.

It is apparent that it is no small task to obtain and administer 2 to 3 liters of plasma or serum. If plasma is chosen, the entire calculated dose can be given as rapidly as a 14-gauge needle will allow.

If whole blood must be given, approximately 3-4 liters are required. It should be given slowly over a period of several hours to prevent overloading of the vascular system. Since transfused red blood cells have a half-life of about 48 hours, the massive destruction of these cells could pose a threat. I would suggest that up to 2 liters of blood be given intravenously over about 2-4 hours, and the remainder given the following day. The subcutaneous and intraperitoneal routes can also be used for a portion of the dose. Immunologic reactions are not expected during the first transfusion. Repeated transfusions 1-2 weeks later may result in anaphylaxis, however. Because the rational dose is so high, plasma is much preferred to whole blood.

Intravenous Feeding

Enteric colibacillosis and other causes of neonatal diarrhea frequently persist for several days. Numerous authors have presented excellent recommendations on the treatment and management of neonatal diarrhea of calves (13,21). These authors emphasize 1) fluid therapy (23,6), 2) correction of acidosis, and 3) correction of electrolyte imbalances as the primary goals of treatment (7). The most critically ill calves are given intravenous fluids to reestablish hydration and combat shock. Glucose and bicarbonate are added to correct acidosis and hypoglycemia and facilitate movement of potassium into cells (14,13).

Calves less dehydrated are treated orally with homemade or commercially available solutions containing electrolytes, glucose and in some cases, amino acids. These solutions are formulated to utilize carrier protein mechanisms in the intestinal mucosa to enhance the absorption of water. It has been shown that the glucose-sodium carrier mechanism remains intact in calves with colibacillosis.

Most clinicians recommend that milk be removed from the diet of calves (especially dairy) with diarrhea during the first 24-48 hours (13,22). The electrolyte solutions previously mentioned are given in place of milk during this period. Most manufacturers recommend that glucose electrolyte solutions not be given as the sole nutrient source for more than 48 hours. This recommendation is made because even though the solutions contain glucose and amino acids, they fall far short of meeting the nutritional requirements of calves. In fact, they provide about 1/6 of the energy requirements (13). The energy obtained from glucose in most intravenous fluids likewise does not meet requirements. Glucose and amino acids are given orally primarily to stimulate water absorption and any nutritional value obtained is merely an added benefit.

This means that while the diarrheic calf is being treated by this method, he is in a negative energy balance. Fortunately, the overwhelming majority of calves respond to this therapy within 2-3 days and are reintroduced successfully to milk. The short period of negative energy balance is of no consequence.

Problems with this scheme can arise however, in the small number of calves that have diarrhea that persists for more than 2-3 days. By the previously outlined therapy, we can control the big killers of calves: dehydration, acidosis, electrolyte imbalance, hypoglycemia, and keep calves alive for longer periods of time. We do not have equally effective means of correcting the diarrhea, but rather allow it to correct in time on its own. Calves which live for about one week with persistent diarrhea often suffer from malnutrition or starvation. Nutritional support is often the limiting factor in determining survival. Most causes of neonatal diarrhea such as enterotoxic *E. coli*, corona and roto virus, result in minor structural changes which are fully capable of regeneration and recovery. If calves could be kept alive in a good nutritional state long enough, perhaps more would recover.

Milk reintroduced to the calf with persistent diarrhea after 2-3 days of electrolyte therapy is usually of little nutritional benefit and worsens diarrhea in my experience. There is no evidence to indicate how efficiently a diarrheic calf can utilize milk as a nutrient source.

Calves in this condition would stand to benefit from improved nutrition if it could be delivered without requiring the gastrointestinal tract. Indeed, improved nutrition could help body defenses and overcome the underlying cause of disease. It was with this goal in mind that we began to investigate total intravenous feeding (hyperalimentation) in calves.

Total intravenous feeding is a technique which has been employed in human medicine for several years (4,8,18,24,27,28,5). The technique is used mainly in patients who need nutritional support because of serious gastrointestinal disease, and is particularly useful in infants. More recently it has been employed successfully in veterinary medicine (3,10,11).

The principles of the technique are that glucose levels given at an absolutely constant rate can be completely utilized by the patient to meet energy requirements. The protein requirements can be met with amino acids if enough glucose is given concurrently so that amino acids are not needed as an energy source. To accomplish this, the solution must provide about 100-150 calories per gram of nitrogen in order to spare the protein for anabolism (11). Since most cases will require relatively short-term (1-2 weeks) feeding, attention is given primarily to major nutrient requirements: water, energy and protein. Electrolytes, minerals and fat-soluble vitamins are less critical. The solution must be then formulated so that the protein, energy, caloric-to-protein ratio and water requirements are met.

The nutrient requirements of a calf can be estimated as follows:

50 kcal/kg b.w./day maintenance (21)
3 kcal/gm desired weight gain
.45 gm Nitrogen/kg b.w./day
20-25 ml H_2O/lb. b.w./day

Using a 45 kg (100 lb.) calf as an example:

H_2O = 25 ml/100 lb. = 2500 ml
Calories = 50 cal. x 45 kg = 2250 cal.
Nitrogen = 0.45 gm x 45 kg = 20.25 gm

The most critical and difficult nutrients to obtain are amino acids. Many of the amino acid products available in veterinary medicine have minsicule amounts of protein. For this or any other purpose, the most concentrated solutions should be used. This usually is a 5% protein hydrolysate. We have used Aminosol (Abbott Laboratories) in our experimental and clinical patients. This product contains 750 ml of solution with 170 calories from glucose and 37.5 gm protein (6.5-7.0 nitrogen). We added 400 ml of 50% glucose to the Aminosol to provide an additional 680 calories. The mixed solution then contains 1150 ml containing about 850 calories and 6 gm nitrogen with a nitrogen-caloric ratio of 1:142 (11). The quantity given is then based on the nutrient requirement of the calf as follows:

Table 1
Comparison of Required and Supplied Nutrients

Nutrient	Maintenance requirements	Total trequirement for a 45-kg calf	Supplied in special fluid
Water	40-50 ml/kg	2,250 ml	2,500 ml
Energy	50 cal/kg	2,250 cal	2,207.5 cal
Nitrogen	0.6 g/kg	27 g	12.5 g

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It can be seen that the most difficult requirement to meet is protein. This is because of the unavailability of amino acid solutions in greater than 5% concentrations.

The intravenous catheter is a critical step in the success of the technique. The skin over the jugular should be clipped and prepared as for surgery. The catheter is inserted aseptically using sterile gloves. Several methods could be satisfactorily used to secure the catheter (1,29). We found that subcutaneous tunneling worked especially well for the long-term trials (26).

The choice of catheter material is also important. Catheters which cause the least tissue reaction are preferred. Catheters will also function longer if they are not prone to kink. Finally, the catheter should terminate in a large vessel such as the vena cava or right atrium. If hypertonic fluid is delivered into large vessels, there is a greater dilution and rapid mixing in blood and the detrimental effects on the vascular endothelium are not as great.

Catheters of polyvinyl chloride (epidural catheter, Becton-Dickinson) and silastic were considered satisfactory in regard to minimal tissue reaction and resistance to kinking. Polyethylene catheters were unsatisfactory.

During the mixing and delivery of these fluids, strict asepsis must be maintained. These are nutrient solutions capable of supporting bacterial growth and they will be delivered over extended periods of time at warm temperatures. Contaminated solutions could lead to catheter sepsis and septicemia.

A technique for administration of fluids for extended periods of time has been described (26). The major requirements for fluid delivery are that sterility can be maintained and that the rate of flow can be accurately and uniformly maintained. It is helpful to use expandable tubing which allows the calf maximum freedom and insures that he will not become tangled in the apparatus (Fig. 4). To accomplish accurate flow, electric pumps can be used. We have found that fluid can be satisfactorily dripped if a microdrip chamber which delivers 60 drops/ml is used (Venoset Microdrip, Abbott Laboratories, North Chicago, Ill.). The rate of flow through the chamber is regulated with a three-way stopcock (Pharmaseal Inc., Toa Alta, Puerto Rico). It is important that the required daily volume of fluid be delivered evenly over the 24-hour period of time. Utilization of these concentrated nutrients, particularly glucose, depends on adaptation by way of insulin, etc., to a constant influx. If the rate of flow varies to any great extent, the renal threshold will be exceeded and glucose diuresis results. When this occurs, not only is the nutrient lost, but dehydration could also result.

To test the validity of these concepts in calves, we selected 6 normal calves. Each calf received colostrum for the first 24-48 hours. They were then given the hyperalimentation fluid intravenously according to the calculated formula. During the feeding trials, no feed, water or bedding was available. The trials lasted for a mean of 12 days. While on intravenous feeding the calves remained vigorous, strong, hungry and very active. Their hydration and general health remained good. Bowel movements were normal for about 24 hours, then gradually diminished and were nearly absent by the end of the trials.

Numerous parameters were measured during the experiments including body weight, urine glucose, complete blood counts, total plasma protein, serum electrolytes, blood glucose, BUN, blood gases and blood ammonia. Necropsies were then performed to evaluate the effects of catheterization and examine any other detrimental effects.

Results indicated that body weight was maintained in most calves and one calf gained 2.3 kg. This is particularly significant since the initial weight was taken with a full gastrointestinal tract and the final weight was taken with an empty tract (Fig. 5). Plasma total protein decreased during the trials in all calves (Fig. 6). This was thought to indicate that protein requirements were not entirely met with the solutions given. No significant changes were noted in hemograms, serum sodium, potassium, chloride, calcium, phosphorus, magnesium, blood gases, serum ammonia and BUN. The serum glucose levels fluctuated considerably and depended entirely on the success of establishing uniform fluid delivery. Fluid delivery was started slowly and gradually increased over the first 24-36 hours to allow time for homeostatic mechanisms to adapt. Urine glucose levels were used to adjust flow rate.

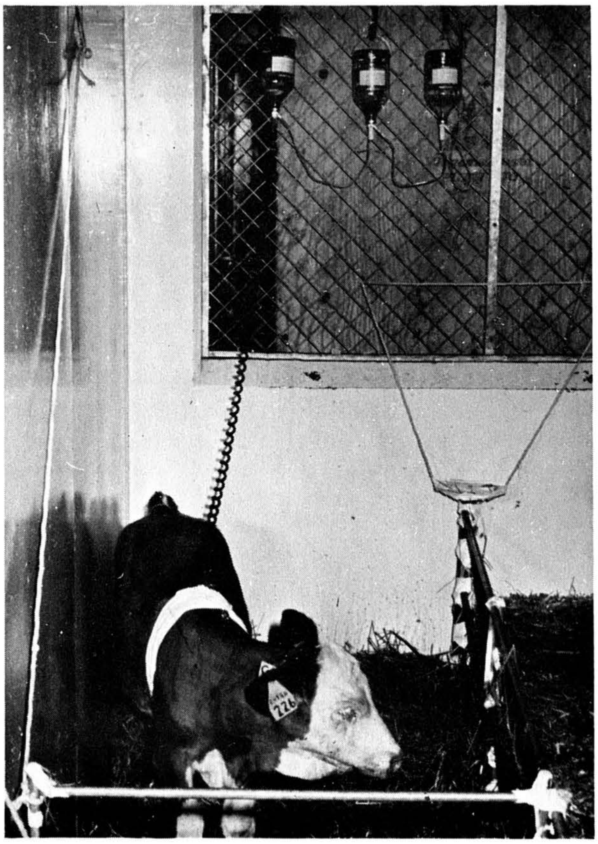
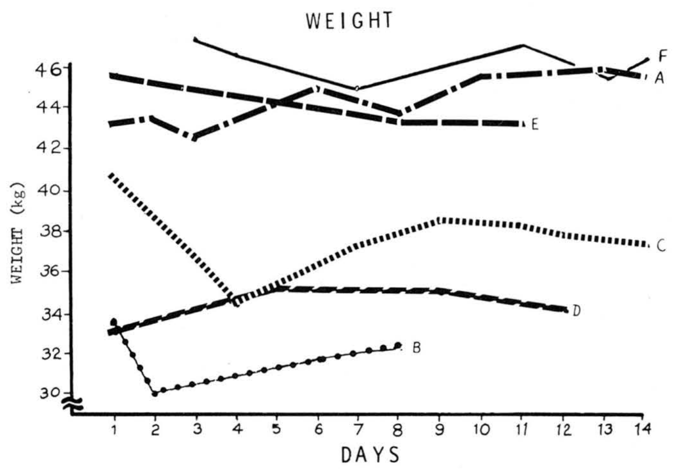


Figure 4. Hyperalimentation techniques. Calf being given intravenous fluids. Note the fluid delivery apparatus–calf is allowed maximal freedom.

Necropsies revealed no significant lesions other than those associated with the catheters. One calf had severe thrombosis of the jugular vein (Fig. 7) but the veins of the other calves were normal. The thrombosis could have resulted from catheter sepsis or from the irritant effects of hypertonic solutions administered in the vein. Problems may have been avoided had the catheter been inserted into the vena cava or right atrium. Most catheters had thin sheaths of fibrin on the surface which would probably remain attached to the vein once the catheter was removed.

Other complications encountered in man that have not been seen in calves include hyperosmotic coma, diuresis with dehydration, hypophosphatemia and hypersensitivity (18,24).

In treating debilitated or malnourished calves, the major effort should continue to be directed at management of the primary disease. This usually entails correcting dehydration, acidosis, electrolytic imbalances and controlling infectious processes. Intravenous nutrition does not have to meet the entire



—Weights of calves maintained on total intravenous feeding.

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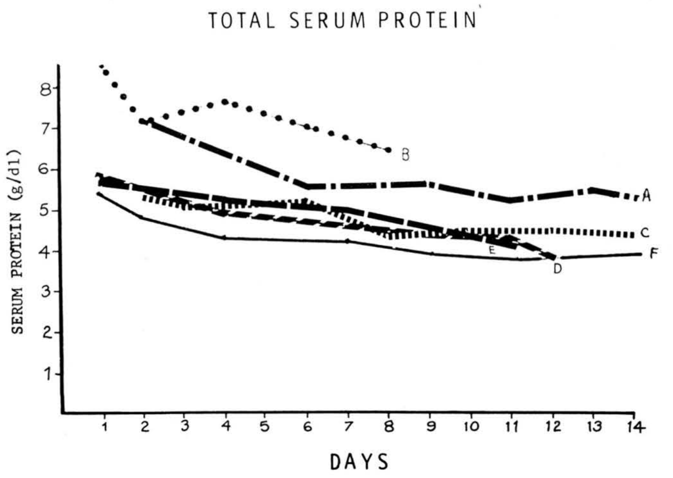

–Total serum protein of calves maintained on total intravenous feeding.

Figure 6. Reprinted with permission of the editor of JAVMA.

nutrient requirement to be beneficial. The diarrheic calf whose gut is maldigesting milk may be meeting only 10% of his nutritional requirements. Providing even 50% of his requirements intravenously would be an improvement. Also, intravenous feeding can be combined with the feeding of oral electrolyte solutions to advantage. In fact, it is probably beneficial to continue to provide some nutrients orally to prevent atrophy of the gut and to keep enzyme systems, particularly lactase, stimulated. It has been shown in some animals that total intravenous feeding results in a significantly reduced gut mass (12). In such animals, reintroduction to oral feeding could be difficult. A few calves which were on long-term total intravenous feeding were gradually and successfully reintroduced to milk. In others, diarrhea has reappeared when milk was reintroduced. It appears that milk should be gradually reintroduced to prevent complications.

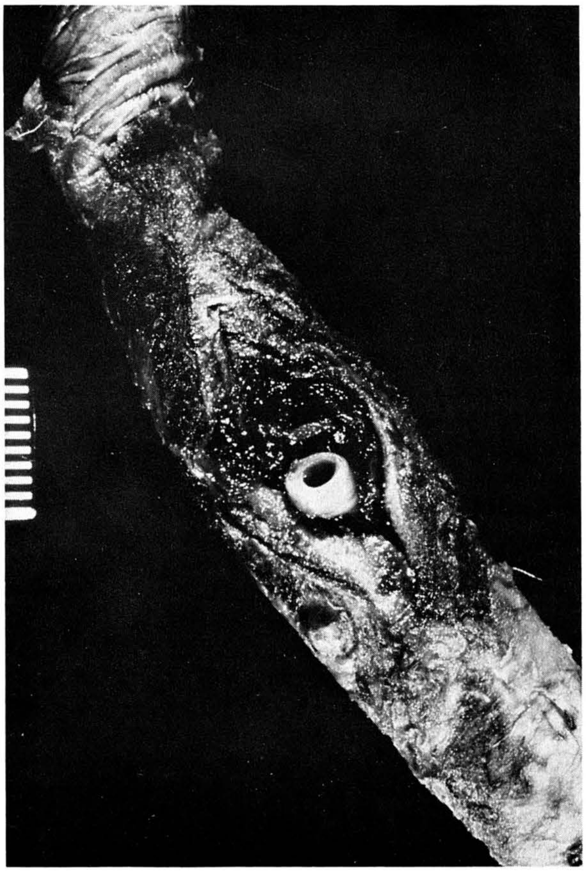

Figure 7. Thrombosis of jugular vein showing catheter in place. Thrombosis can be prevented by sterile technique in catheter placement, choosing non-reactive catheters and placing catheters so they terminate in large vessels such as the vena cava.

Numerous clinical patients have been treated with hyperalimentation. The majority were affected with neonatal diarrhea of over one-week duration. Others had bovine virus diarrhea (BVD) and atresia coli. In some cases, particularly the calf with BVD, remarkable improvement was seen. In others, no difference could be noted.

This technique is not a miracle cure which will save every patient. It certainly will not correct the primary etiology. Rather it should be viewed as a new dimension in supportive therapy.

The goal in hyperalimentation is to maintain the calf's life-support processes so that he can outlive his disease.

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