I. Milk Fever

Milk fever (parturient paresis, hypocalcemia, paresis puerperalis, parturient apoplexy) is a non-febrile disease of adult dairy cows in which acute calcium (Ca) deficiency causes progressive neuromuscular dysfunction with flaccid paralysis, circulatory collapse, and depression of consciousness.

Milk Fever Occurrence

Milk fever is one of the most common metabolic diseases of dairy cattle. About 6% of US dairy cattle are affected annually. Estimates of the incidence of milk fever in dairy cattle have not changed appreciably over the last 35 years. Annual incidence rate of clinical milk fever within herds may vary from 2% to 60%. The cost of a single case of milk fever is about $300.

Subclinical hypocalcemia (depressed blood calcium concentrations but without clinical signs) affects about 50% of older (greater than second lactation) dairy cattle. Subclinical hypocalcemia may lead to decreased dry matter intake after calving, increased risk of secondary disease conditions, decreased milk production, and decreased fertility later in lactation.

Breed, age, and milk production level are important risk factors for milk fever in dairy cattle. Jerseys and Guernseys are the most susceptible to milk fever; Holsteins and Brown Swiss are moderately susceptible; and Aryshires and Milking Shorthorns are the least susceptible. Breed predilections may be explained in part by higher calcium content in the colostrum and by higher milk production per unit of body weight in the more susceptible breeds. Jersey cattle may also have fewer vitamin D receptors than Holstein cattle. The incidence of milk fever generally increases with parity and with higher levels of milk production regardless of breed. First lactation dairy cattle almost never develop milk fever because they produce less colostrum and because they have the ability to quickly mobilize calcium from their actively growing skeleton.

Milk Fever Etiology and Pathogenesis

Milk fever is caused by hypocalcemia that occurs as an animal's complex mechanism for maintaining calcium homeostasis fails during a sudden and severe calcium outflow. Any decrease in ionized blood calcium concentration causes the parathyroid glands to secrete parathyroid hormone (PTH). Within minutes, PTH increases renal reabsorption of calcium from the glomerular filtrate. If the perturbation in blood calcium is small (less than 1 g Ca/day), blood calcium returns to normal and PTH secretion returns to baseline levels. If the calcium drain from the extracellular pool is large, continued PTH secretion stimulates resorption of calcium stored in bone. This calcium comes from both the dissolved calcium in solution within the bones as well as from calcium released by osteoclastic activity on the organic bone collagen matrix.

Calcium exiting the extracellular fluid must ultimately be replaced by dietary calcium. Calcium is absorbed across the intestine and forestomachs by both vitamin D dependent and vitamin D independent means. Vitamin D independent absorption of calcium is primarily by passive diffusion. Vitamin D dependent absorption is by active transport; it occurs when dietary calcium is low or when calcium demand is very high.

Vitamin D, whether ingested or produced during ultraviolet irradiation of the skin, enters the blood and is converted in the liver to 25-hydroxyvitamin D. The activity of the renal enzyme responsible for converting 25-hydroxyvitamin D to the steroid hormone 1,25-dihydroxyvitamin D (1,25-[OH]2D) is stimulated by and tightly regulated by PTH. The most important function of 1,25-(OH)2D is its ability to stimulate active transport of dietary calcium across the intestinal epithelium.

Sudden calcium outflow occurs most commonly at the time of the initiation of lactation, when the animal's calcium requirement increases dramatically in a period of just a few hours. Calcium demand for dairy cattle prior to colostrum production includes endogenous fecal loss of 6 to 10 g Ca/day, urinary loss of 0.25 to 1.0 g Ca/day, and fetal skeleton calcification needs of up to 10 g Ca/day by the end of gestation. Colostrum production far exceeds the total of these demands, since colostrum contains about 2.0 to 2.3 g Ca/L, or about 20 to 30 g Ca/day.
In dairy cows managed for high milk production, calcium demands are at their nadir just prior to parturition. Calcium demands by the fetal skeleton are low relative to the amount of calcium needed to produce milk in late lactation. Thus, bone calcium resorption mechanisms become quiescent and intestinal calcium absorption mechanisms are passive at this time. Diets typically fed to these animals at this time exceed their calcium requirements, so that the calcium demands for maintenance of body tissues and the developing fetal skeleton can be met almost entirely by non-vitamin D dependent absorption of calcium across the intestine.

An animal's ability to adapt to hypocalcemia is influenced by a number of factors. An important determinant of milk fever risk is the acid-base status of the animal at the time of parturition. Metabolic alkalosis impairs the physiological activity of PTH so that bone resorption and production of 1,25-(OH)2D is impaired, thus reducing the animal's ability to successfully adjust to increased calcium demands. Evidence suggests that metabolic alkalosis induces conformational changes in the PTH receptor, which prevents PTH from tightly binding to it. Cows fed diets that are relatively high in potassium or sodium are in a relative state of metabolic alkalosis, which increases the likelihood that they will develop milk fever.

A second cause of hypocalcemia is hypomagnesemia. Low blood magnesium can reduce PTH secretion from the parathyroid glands and also can alter the responsiveness of tissues to PTH. High dietary potassium reduces ruminal magnesium absorption in addition to causing metabolic alkalosis.

**Milk Fever - Clinical Presentation**

The clinical effects of hypocalcemia in dairy cows are broad, since calcium serves many critical physiological functions. For example, calcium is required for release of the neurotransmitter acetylcholine at the neuromuscular junction. Impaired acetylcholine release effectively blocks transmission of nerve impulses through the junction and on to muscle fibers, leading to flaccid paralysis. Hypocalcemia also hinders calcium-dependent actin-myosin interactions, which directly decreases muscle contractility and enhances the clinical presentation of flaccid paralysis. Finally, hypocalcemia inhibits contractility of smooth and cardiac muscle, causing a variety of additional clinical signs in affected animals.

Some hypocalcemic animals show signs of hyperesthesia and tetany, especially during the early phase of hypocalcemia. This occurs because calcium assists in stabilizing membranes in peripheral nerves and muscle fibers. Thus, hypocalcemia may initially speed impulse conduction or even allow spontaneous impulse production in peripheral nerves and muscle fibers. Animals initially affected with hyperesthesia and tetany often later lapse into flaccid paralysis as the hypocalcemia worsens and neuromuscular junctions become completely blocked. Whether tetany or flaccid paralysis is seen also depends on the relative concentrations of magnesium and calcium. Magnesium competitively inhibits calcium at the myoneural junction. High magnesium concentration at the junction promotes flaccid paralysis. Low magnesium at the junction promotes tetany, as long as the hypocalcemia is not severe.

Approximately 75% of all cases of milk fever in dairy cattle occur within 24 hours of calving. An additional 12% occur 24 to 48 hours after calving. Some cases (about 6%) occur at the time of delivery and cause dystocia because hypocalcemia inhibits uterine contractility. About 7% of all hypocalcemias in dairy cattle do not occur around calving. Such cases are termed non-parturient hypocalcemia rather than milk fever.

Clinical signs of milk fever in dairy cattle may be divided for convenience into three stages. Stage I milk fever represents early clinical signs without recumbency. It may go unnoticed because its signs are subtle and generally last less than one hour. Affected cattle are typically excitable, nervous, hypersensitive, anorectic, and weak. They may shift their weight frequently and shuffle their hind feet. Physical examination during Stage I milk fever often reveals tachycardia and slight hyperthermia due to increased muscular activity.

Stage II milk fever in dairy cattle is characterized by sternal recumbency due to flaccid paralysis. Instead of being hypersensitive and tetanic, affected cows are now depressed and paralyzed. An affected cow may turn her head into her flank or extend her head. Her neck may curve into an "S" shape when extended due to disproportionate tone in the neck musculature. The affected cow may also exhibit fine muscle tremors, particularly in the triceps muscles.

Physical examination during Stage II usually reveals rapid heart rate and decreased intensity of heart sounds due to reduced cardiac muscle contractility. Reduced stroke volume, decreased cardiac output, and lowered arterial blood pressure are also present as cardiac contractility fails. Heart rate increases in an attempt to
compensate for these deficiencies. However, peripheral perfusion remains inadequate and the extremities of affected cows feel cold upon palpation. Inadequate perfusion may also depress consciousness. Affected cows usually have lowered rectal temperature (96°F to 100°F). However, during hot weather some cows with milk fever may be hyperthermic, especially if they are dark-colored and laying in direct sunlight. Impaired smooth muscle function due to hypocalcemia leads to clinical signs such as gastrointestinal atony, mild bloat, constipation, and loss of the anal reflex. Pupils may be dilated and unresponsive to light due to atony of the dilator pupillae muscle. Clinical signs of Stage II generally last from one to twelve hours.

Dairy cows in Stage III milk fever are laterally recumbent and progressively lose consciousness to the point of coma. They are often severely bloated in this stage as a result of lateral recumbency combined with profound gastrointestinal atony. Cardiac output becomes severely compromised, heart sounds may be nearly inaudible, and heart rate increases to 120 beats or more per minute. Cows in Stage III milk fever do not survive for more than a few hours without treatment.

Even seemingly uncomplicated cases of clinical milk fever or unobserved cases of subclinical hypocalcemia may be associated with important secondary problems. For example, milk production is reduced by about 14% in the lactation following a case of clinical milk fever. Milk fever is also associated with increased risk for retained fetal membranes, presumably due to loss of calcium-dependent uterine contractions, which aid in separation and expulsion of the fetal membranes. Immune suppression following the severe stress of milk fever may also contribute to the higher risk for retained fetal membranes. Cows affected with milk fever are also at higher risk for ketosis or displaced abomasum later in lactation. Risk of these diseases may be increased due to stress and anorexia at the time of the clinical episode of milk fever, or may be related to subclinical hypocalcemia that persists into lactation.

About 7% of all cases of milk fever in dairy cattle are non-parturient. In these cases, the stimulus for hypocalcemia must necessarily be something other than sudden calcium outflow associated with the onset of lactation. Subclinical hypomagnesemia may be the most important trigger for non-parturient hypocalcemias, because of the critical functions of magnesium in calcium homeostasis. Additionally, any cause of severe stress or feed deprivation may be sufficient to cause a sudden calcium outflow, lack of calcium uptake, and non-parturient hypocalcemia. Specific disease conditions that may trigger non-parturient hypocalcemia include ruminal acidosis, alkaline digestive disturbances (such as urea toxicity or protein overload), oxalate toxicity, toxic infections, heat stroke (or any cause of severe alkalosis), and increased estrogen concentrations due to estrus or ingestion of plant estrogens.

**Milk Fever Clinical Pathology**

Milk fever is confirmed by low calcium concentration in the blood. Clinical signs may begin as total blood calcium values fall below 7.5 mg/dl; however, clinical signs are only modestly correlated with blood calcium concentrations. For example, more than half of all mature dairy cows will have total blood calcium concentrations below 7.5 mg/dl following calving without any evidence of clinical signs. Animals in Stage I milk fever typically have mild hypocalcemia (5.5 to 7.5 mg/dl Ca). Some animals are able to remain standing with total calcium concentrations as low as 5.0 mg/dl, although most become recumbent before this level is reached. Animals in Stage II milk fever typically have total calcium concentrations of 3.5 to 6.5 mg/dl, and calcium may be as low as 1.0 mg/dl in animals with Stage III milk fever.

Blood ionized calcium concentration expresses the actual amount of metabolically active (ionized) calcium in the bloodstream and is therefore the most accurate method of diagnosing hypocalcemia. Total blood calcium determinations include calcium that is protein-bound or complexed and therefore cannot affect on neuromuscular function. Unfortunately, ionized calcium determinations are expensive, are not available in most laboratories, and require special handling of the blood sample. When acid-base balance and protein metabolism are not disturbed (as is typically the case in uncomplicated cases of milk fever), total blood calcium is highly correlated to ionized calcium and serves as an acceptable diagnostic test.

Blood concentrations of phosphorus are typically lowered to 3 mg/dl or less in cases of milk fever. This is explained by phosphorus loss in milk, PTH secretion causing renal tubular excretion of phosphorus, and ruminal pooling of phosphorus from salivary buffers during ruminal atony. Hypophosphatemia usually resolves spontaneously following correction of the hypocalcemia.
Blood magnesium concentration generally increases slightly during milk fever because PTH stimulates renal tubular reabsorption of magnesium. Blood magnesium concentrations below 1.8 mg/dl may contribute to the development of hypocalcemia and suggest that either the animal is not receiving enough dietary magnesium or that the magnesium provided in the diet is not sufficiently bioavailable.

Blood cortisol concentrations are often dramatically elevated in animals with milk fever. Excessive cortisol causes immunosuppression in periparturient animals and may in part explain the increased susceptibility cows with milk fever to infectious diseases such as mastitis. It may also account for the exaggerated stress leukogram (neutrophilia and relative lymphopenia) seen in the white blood cell count of animals with milk fever. Hyperglycemia is also evident during milk fever and is the result of an inability of the pancreatic B-cells to secrete insulin when extracellular calcium is low.

Laboratory confirmation of the diagnosis of milk fever is often not necessary, since response to treatment is a useful and commonly used diagnostic method. Most cases of milk fever respond rapidly to a single parenteral treatment with calcium salts. It is good practice to collect a blood sample prior to initial treatment of cases of milk fever. If the animal does not respond to initial treatment, then an accurate diagnosis can be made from the pre-treatment blood sample. Post-treatment samples are of very limited value in diagnosing milk fever because of the temporal influence of calcium administration.

It is important to rule out other possible causes of recumbency in parturient animals before initiating calcium treatment. Important differential diagnoses for clinical milk fever include toxemia from mastitis or metritis; physical injury such as pelvic fracture, obturator paralysis, leg bone fracture, ruptured gastrocnemius tendon, or "downer cow syndrome" due to pressure necrosis; hypomagnesemia; fat cow syndrome, or pregnancy toxemia. These disorders are discussed in other lectures.

Milk fever must be diagnosed ante-mortem, since there are no gross lesions or histological changes in affected animals at necropsy. Urine obtained from the bladder will have very low calcium concentration, but this alone is not sufficient evidence to make a diagnosis. Post-mortem blood samples cannot be used to assess calcium status.

**Milk Fever Treatment**

Milk fever should always be treated as promptly as possible, particularly if the animal is already recumbent. Severe and irreversible muscle damage (“compartment syndrome”) may occur during paresis in cows laying on hard surfaces. Stage I cases of milk fever may be treated with either oral calcium supplements or intravenous calcium salts. Animals in Stage II or III require immediate treatment with intravenous calcium salts. Animals affected with milk fever do not usually recover spontaneously, and 75% of all cases will eventually die if left untreated.

Standard intravenous treatment for cattle affected with milk fever is 500 ml of a 23% calcium gluconate solution. This treatment provides 10.8 g Ca. Calcium borogluconate may also be an effective source of calcium for intravenous treatment. Intravenous calcium should always be administered slowly to prevent sudden cardiac arrest due to hypercalcemia. At least 12 minutes should be allowed to inject intravenous calcium (8 to 12 g dose) into cattle.

A precise calculation of the dose of calcium salts necessary to correct milk fever cannot be made because of the dynamic nature of calcium metabolism. The immediate total body calcium deficit in a dairy cow with milk fever is about 6 g, so a standard dose of 500 ml of 23% calcium gluconate (10.8 g Ca) is adequate. Many veterinarians and dairy producers insist that a second bottle is necessary for many cows. However, much or all of the calcium in the second bottle will be excreted in the urine. Cows that get up only after a second bottle is given IV were able to rise only because more time elapsed after blood calcium concentrations were restored, not because of the extra calcium given. Just one bottle raises blood calcium above 15 to 22 mg/dl.

A very undesirable side effect of IV calcium is the extreme hypercalcemia it induces. This hypercalcemia effectively shuts off PTH secretion, triggers calcitonin release, and reduces the renal threshold for calcium reabsorption in the kidney. This sets the cow up for a hypocalcemic relapse 12 to 18 hours later. Cows given two bottles of calcium IV for milk fever have a higher relapse rate than cows just given one bottle.
Approximately 60% of recumbent animals affected with uncomplicated milk fever will get up within 30 minutes after a single intravenous treatment with calcium salts. Another 15% can be expected to rise within the next two hours. Pre-partum cases of hypocalcemia respond less favorably than parturient cases because weight of the fetus and placenta remains, making it difficult for the animal to rise.

Animals with unresponsive cases of milk fever should be re-evaluated and re-treated at about 12-hour intervals until they recover, die, or are salvaged. Calcium therapy in recumbent animals may be continued for up to three successive treatments; however, beyond this point calcium treatment is usually unrewarding. About 10% of dairy cows with milk fever will stay recumbent for over 24 hours but will eventually recover. Unfortunately, about 15% of milk fever cases in dairy cows will either die or eventually be salvaged because they are never able to rise. Most of these cases of milk fever are complicated by musculo-skeletal problems.

Cases of Stage I milk fever are best treated by administering calcium via a slowly absorbed route. Oral or subcutaneous calcium treatment is preferred over IV treatment for Stage I cases, since both provide enough calcium to correct the hypocalcemia without causing a large spike in blood Ca.

Subcutaneously administered calcium is gradually absorbed over a period of several hours. Rate of subcutaneous calcium absorption depends on the degree of peripheral perfusion and may therefore be ineffective in dehydrated animals. Solutions containing glucose should never be given subcutaneously, since glucose can only be actively absorbed into cells (a problem in the subcutaneous space, with its low cellular activity) and because glucose easily supports bacterial growth. Common complications of subcutaneous glucose administration in dairy cows are tissue destruction, abscess formation, and/or sloughing at the site of injection.

Calcium provided by oral dosing is also gradually absorbed. A variety of oral calcium salt preparations are available. They typically contain between 25 and 100 g Ca in the form of calcium chloride or calcium propionate. They work by rapidly raising calcium in the intestine to such a high concentration that a small amount is passively absorbed. For example, about 4 g Ca will be absorbed and enter the bloodstream of a cow given an oral solution containing 50 g of calcium chloride. Calcium chloride also rapidly causes a compensated metabolic acidosis, which improves the animal's own calcium homeostatic mechanisms via improved tissue responsiveness to PTH. However, high or repeated doses of calcium chloride can cause uncompensated metabolic acidosis. Calcium chloride is also irritating and may cause transient ulcers in the mouth, esophagus, rumen, and abomasum of some cows. Calcium propionate is less irritating to the cow and in high doses is nearly as effective as calcium chloride in supporting blood calcium concentrations. The propionate contained in calcium propionate can be converted to glucose and used as an energy source. Care must be taken during administration of any oral calcium supplement to avoid laceration of the pharyngeal region or aspiration of the solution. Thinner liquid drenches, while absorbed faster, pose a greater risk for aspiration than do the thicker
gels. Administration of supplemental calcium in bolus form (Bovikalc®, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO) appears to be the safest and most convenient form of oral calcium administration.

![Effect of Sub-Q Ca on Blood Ca](image)

Typical doses of oral calcium supplements will increase blood calcium concentrations 1 to 3 mg/dl within 30 minutes of administration. Blood calcium levels return to baseline values by six to twelve hours post-treatment. Oral calcium supplements are an effective and practical route of calcium administration for cases of Stage I milk fever. They have been used to successfully treat recumbent cases of milk fever; however, the risk of allowing a cow to remain recumbent any longer than necessary precludes their use for this purpose.

About 25 to 40% of dairy cows with milk fever that respond favorably to initial intravenous calcium therapy will relapse into hypocalcemia within 12 to 48 hours. Animals with pre-partum milk fever have an even greater relapse rate. Older cows are at greater risk for a hypocalcemic relapse because of their impaired bone responsiveness and generally higher milk production. Incidence of hypocalcemic relapses in dairy cattle may be reduced to only 5 to 10% of the total cases by administration of an additional 500 ml of 23% calcium gluconate subcutaneously or a dose of oral calcium at the time of initial treatment with intravenous calcium.

Table 1 (below) summarizes correct and incorrect treatment options for various forms of hypocalcemia.

**Table 1.** Rational calcium therapy for different hypocalcemic conditions in dairy cows.

<table>
<thead>
<tr>
<th>Hypocalcemic Condition</th>
<th>Preferred Treatment</th>
<th>Poor Treatment Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical milk fever, recumbent (Stage II or Stage III)</td>
<td>500 cc 23% calcium gluconate given slowly IV (~11 g Ca)</td>
<td>IV glucose more than 12 g Ca IV</td>
</tr>
<tr>
<td>Prevention of relapses after IV treatment of clinical milk fever</td>
<td>Oral calcium bolus (43g of Ca from CaCl₂ and CaSO₄), or oral CaCl₂ gel (~50 g Ca), or ~1 lb calcium propionate pumped with ~5 gallons warm water, or oral or 500 cc 23% calcium gluconate sub-cutaneously</td>
<td>Subcutaneous glucose</td>
</tr>
<tr>
<td>Clinical milk fever, standing (Stage I)</td>
<td>Oral calcium bolus, or oral calcium gel (as described above)</td>
<td>Oral Ca propionate (absorbed too slowly)</td>
</tr>
<tr>
<td>Supportive treatment for any off-feed cow in early lactation</td>
<td>Oral calcium bolus, or oral Ca propionate drench (as above)</td>
<td>Oral CaCl₂ gel (too irritating for non-critical uses)</td>
</tr>
<tr>
<td>Milk fever prevention (only for cows &gt;2nd or 3rd lact)</td>
<td>Oral calcium bolus, or oral Ca propionate drench (as above)</td>
<td>IV Ca (great risk for hypocalcemia 12 to 18 hours later)</td>
</tr>
</tbody>
</table>
Milk Fever Prevention

Feeding cows a calcium deficient diet before calving reduces the risk for milk fever by stimulating PTH secretion prior to calving. This activates bone osteoclasts, stimulates bone calcium resorption, and activates renal tubules to resorb urinary calcium and begin producing 1,25-(OH)2D. Thus, at the onset of lactation all calcium homeostatic mechanisms are active and effective. However, in practice it is difficult to formulate a diet that is truly calcium deficient. Modest reductions in dietary calcium result in modest reduction in the risk for milk fever.

The effect of a diet on an animal's acid-base balance is more important in controlling milk fever than calcium intake. Diets fed prior to parturition that evoke an acidic response in the animal will tend to prevent milk fever, while diets that evoke an alkaline response will tend to cause milk fever. Metabolic alkalosis (often caused by high dietary potassium) is a potent cause of milk fever because it impairs tissue responsiveness to PTH. Metabolic acidosis, on the other hand, allows tight binding of PTH to its receptors and full expression of the calcitropic effects of PTH.

The potential of a diet to cause either alkalosis or acidosis can be estimated by calculating its dietary cation-anion difference (DCAD). Several methods of calculating DCAD have been utilized. The most commonly used equation in dairy nutrition is DCAD (meq) = (Na + K) - (Cl + S). Low DCAD diets cause metabolic acidosis and reduce the risk of milk fever. A diet can have a low DCAD because it is low in cations, high in anions, or a combination of both. Anion sources include anionic salts (any mineral salt high in Cl and S relative to Na and K) and mineral acids (hydrochloric or sulfuric acids). Mixtures of chloride and sulfate anionic salts are often used for milk fever prevention. Chlorides are more potent systemic acidifiers, but they also appear to depress dry matter intake more than sulfates. Examples of chloride anionic salts are MgCl2, CaCl2, and NH4Cl. Examples of sulfate anionic salts are MgSO4, CaSO4, and (NH4)2SO4. Hydrochloric acid supplementation is another approach to adding anions to pre-fresh cow diets. The HCl is commercially mixed with a carrier (usually about 2 lbs/cow/day). Do not attempt to use liquid HCl on the farm - it is too dangerous to handle without special safety equipment. Optimal acidification generally occurs when anions are added to achieve a final DCAD between 0 to -100 meq/kg of dry matter. Low DCAD diets have the potential to decrease dry matter intake in pre-fresh cows. As a result, they should only be used in herds with excellent feeding management and high-quality, palatable feeds.

Monitoring urinary pH after feeding supplemental anions may be a direct and useful approach to establishing the optimal dose of anions within a dairy herd. An advantage of this approach (over relying on calculated DCAD alone) is that it is accounts for inaccuracies in mineral analyses and for unexpected changes in forage mineral content. Mean urinary pH can be evaluated by obtaining urine from a group of at least eight animals near parturition. When acidification is optimal, mean urinary pH values will be about 6.8 to 7.2. Mean urinary pH values below 6.0 indicate over-acidification and suggest that the dose of anions could be reduced. Conversely, urinary pH values over 7.2 reflect inadequate acidification and suggest that more anions are needed. Because there may be significant variations in urinary pH related to time after feeding, most accurate results will be obtained by collecting urine samples at a standard time, preferably within a few hours of feeding.

Addition of a cationic salt (such as sodium bicarbonate) to the dry cow diet increases DCAD and the risk of milk fever. Such salts should be avoided in diets of animals that are near parturition.

Prophylactic treatment of cows with intravenous and/or subcutaneous calcium gluconate immediately after calving may reduce the risk of milk fever. Intravenous calcium for this purpose is not recommended, because of the risk of a hypocalcemic relapse 12 to 18 hours later following the extremely high blood calcium peak and shutdown of the complex mechanisms to support blood calcium concentrations. Oral calcium supplements are a better choice for preventing milk fever. Treatment with four doses of an oral calcium supplement (given prior to calving, at calving, 12 hours post-calving, and 24 hours post-calving) reduces the risk of clinical and subclinical milk fever in dairy cows by about half. This protocol works best when at least one dose of oral calcium can be administered prior to calving.
II. Ketosis

Types of Ketosis

Ketosis is defined as increased levels of circulating ketones (beta-hydroxybutyrate or BHBA, acetoacetate, and/or acetone) caused by incomplete oxidation mobilized body fat during periods of negative energy balance. Circulating ketone bodies further depress appetite and may contribute to a downward spiral of increasing ketosis. About 30% of dairy cows are affected with ketosis sometime in early lactation; however, most cases are not diagnosed and respond spontaneously. About 3% of dairy cows exhibit clinical signs and are diagnosed and treated for ketosis. The ability to diagnose ketosis varies considerably from farm to farm. Failure to recognize and treat ketosis impairs cow health and performance.

Ketosis can be divided into 4 major types:

1. Primary ketosis: this is a disease of high producing dairy cattle in early lactation.
2. Secondary ketosis: this form of ketosis also occurs in lactating dairy cattle but is secondary to a disease process that affects appetite more than milk production.
3. Undernutritional ketosis: a rarer form of ketosis that occurs in extreme cases of poor nutrition and advanced cachexia. Ketosis is unlikely if the starvation is very gradual.
4. Pregnancy toxemia: this is a form of preparturient primary ketosis of adult cows or heifers that is commonly associated with twins. Beef cows in late pregnancy maintained on poor quality feed during the winter months are at particular risk but it can also be seen in dairy animals. It is the most common form of ketosis that is seen in sheep.

Primary Ketosis Overview

This is a spontaneous condition of dairy cattle during the first 6 weeks of lactation with the peak incidence occurring during the first 3 – 4 weeks. It occurs because high producing dairy cattle peak in milk production at about 4 weeks but dietary intake on a dry matter basis does not peak until about 8 weeks. Hence they are in a negative energy balance for at least the first 2 months of lactation. To offset the negative energy balance cattle mobilize fat and protein stores in the form of triglycerides and amino acids for gluconeogenesis. This form of ketosis is sometimes called Type I ketosis, because it shares some of the features of Type I diabetes, a related metabolic disorder.

Primary Ketosis Pathophysiology

Clinical ketosis in the dairy cow occurs when the demand for glucose by the mammary gland exceeds the energy made available through the diet and mobilization of adipose tissue stores. It should be remembered that negative energy balance is a normal state of affairs for the first few weeks of lactation and that a mild degree of ketosis (and ketonuria) is unavoidable and normal.

The products of fermentation by rumen microbes that are relevant from the perspective of energy metabolism are the volatile fatty acids propionate, acetate and butyrate. Propionate enters the TCA cycle directly, whereas butyrate and acetate first have to be metabolized to acetyl Co-A before they can enter the TCA cycle. Acetyl Co-A can either enter the TCA cycle or else be converted into the ketone bodies acetone, acetoacetate or BHBA. Butyrate and acetate are therefore considered to be ketogenic volatile fatty acids. In order for acetyl Co-A to enter the TCA cycle it has to be combined with oxaloacetate, which can only be generated via gluconeogenesis. The principle gluconeogenic precursors for oxaloacetate are propionate (from the rumen) and lactate and pyruvate from the anaerobic metabolism of glucose. Ketosis can be thought of as a condition that results from inadequate oxaloacetate availability with subsequent build-up of acetyl Co-A which is directed towards formation of ketone bodies. The lactating dairy cow tends to prioritize lactose production from lactate and propionate in the mammary gland therefore reducing supplies of oxaloacetate and forcing production of ketone bodies. The inevitable mobilization of adipose reserves into free fatty acids and glycerol exacerbates the problem because free fatty acids can only enter the TCA cycle via acetyl Co-A. The excess free fatty acids if not used in the TCA cycle will be reesterified into triglycerides and become predominantly stored in the liver, predisposing to hepatic lipidosis.
Primary Ketosis Clinical Signs

Non-specific signs of diminished appetite, reduced rumen motility with a normal TPR are typically seen with primary ketosis. Milk production is typically reduced less than with some other post-parturient diseases. Affected cattle often maintain a better appetite for hay than for silage or grains. Occasionally pica is observed.

Sweet smelling breath - some people can smell ketone bodies but do not rely on being able to do this! At best this test for ketosis is only 50% sensitive.

Nervous ketosis – acute, bizarre neurologic signs that vary from circling, through blindness to mania and convulsions.

Primary Ketosis Diagnosis

Ketonuria and keton lactia. A variety of cow-side tests are available for the demonstration of either ketonuria or keton lactia. Multistix™ can be dipped in a urine sample or the mid-stream urine flow from a suspect cow and they have reagents for not only ketones but also for blood, protein, bilirubin, glucose and pH. There are also Ketostix™ reagent strips that test for ketones only. Powder (modified Rothera’s reagent) and tablets (Acetest™) that give a color change with keton lactia are available for testing milk. Evaluation of milk ketones is actually a more accurate indicator of blood ketones than urine ketones. The Acetest tablets when used with a milk sample and the Rothera’s reagent powder have the advantage of testing for both acetone and acetoacetate, whereas the urine dipstick only tests for acetoacetate.

Milk or serum BHBA quantitation. Blood BHBA concentration is considered the gold standard for ketosis diagnosis (above 14.4 mg/dl or 1400 uM BHBA is considered diagnostic for ketosis). BHBA is more stable than the other two ketone bodies in serum or plasma, and many veterinary diagnostic laboratories do BHBA analyses. There is a milk BHBA test available (Keto-Test™ strips) that have about the same accuracy as urine ketone strips. The best cow side ketosis test is a hand-held meter and BHBA test strip that uses a drop of whole blood (Precision-Xtra™, Abbott Laboratories). This system has substantially better sensitivity than the urine or milk tests.

Primary Ketosis Treatment

Dextrose 50%. 500 ml of a 50% solution generally results in clinical improvement, but is associated with frequent relapses when used as the only therapy. The very large amount of glucose in this treatment (250 g) may contribute to the relapses. A reduced dose of IV glucose (e.g., 250 ml of a 50% solution) makes more sense pharmacologically and might make it easier for the cow to maintain glucose homeostasis.

Glucocorticoids. Dexamethasone (10-25 mg IV or IM) is indicated for its gluconeogenic, appetite stimulant and negative effect on milk production. Isoflupredone acetate (Predef®) is used by many farmers and practitioners. If used, be sure to follow label indications. This glucocorticoid also has mineralocorticoid effects and may contribute to urinary mineral loss. This can be particularly critical for potassium, as these cows are already anorectic and may already have marginal potassium status (see the discussion on hypokalemia later in these notes).

Glucogenic precursors. The most commonly administered product is propylene glycol, although calcium propionate or glycerol are good alternatives. Propylene glycol should be limited to 4 to 8 oz per os bid; higher doses may irritate the rumen mucosa and harm rumen microorganisms (although this is controversial). Do not administer oral propylene glycol for more than 3-5 consecutive days, particularly if there is significant rumen hypomotility. It appears to have a much broader safety margin when rumen motility is near normal.

Nervous ketosis. These animals may need tranquilization prior to treatment with products such as acepromazine, xylazine or chloral hydrate. The latter is an old fashioned therapy for nervous ketosis (30 g per os initially, followed by 7 g per os bid) that provides both sedation and a glucogenic precursor.

B vitamins. Multivitamin preparations that contain vitamin B12 are frequently administered intravenously (usually in addition to IV dextrose). Vitamin B12 is an essential cofactor in the metabolism of propionate for energy production in the Krebs cycle.
Secondary Ketosis Overview

The successful resolution of ketosis caused by a reduced appetite secondary to a separate primary condition relies on the successful treatment of the original disease. The majority of secondary ketosis cases occur during early lactation and are the result of other common post parturient diseases of dairy cattle such as metritis, mastitis and displaced abomasum. Successful treatment of the primary condition often results in disappearance of the ketonuria within 24 – 48 hours. Concurrent treatment of the ketosis, whilst not necessary, will often result in more rapid clinical improvement and return to production. If you decide to treat the secondary ketosis be cognizant of the primary condition when deciding what agents to use; for example, do not use abortifacent steroids if the animal is pregnant, do not administer propylene glycol for several days to a cow with complete ruminal atony due to peritonitis, etc.

Undemutritional Ketosis Overview

Prevention of this form of ketosis is entirely preferable to treatment. As a rule, therapy for starving animals with advanced cachexia is unrewarding, regardless of whether or not they have ketosis. For more details on starvation (protein-energy malnutrition) in ruminants, see the beef cattle nutrition lecture notes in these handouts.

Pregnancy Toxemia

Both heifers and adult cattle carrying twins are at risk for developing pre-parturient ketosis, particularly if their level of nutrition is inadequate. Severe systemic disease in late gestation can also cause pre-parturient ketosis in cattle carrying either singletons or twins. Treatment will depend upon the relative value of the calf/calves compared to the dam. In situations where the priority is to save the dam’s life, then the pregnancy should be terminated (by the intramuscular injection of 25 mg of dexamethasone and 25 mg of PGF2α). In situations where the calf or calves are the priority then give a guarded to poor prognosis and provide aggressive supportive treatment with IV dextrose, force feeding with energy rich feeds such as alfalfa meal and rumen by pass fats, glucogenic precursors and improved nutrition if the latter is an issue. Induction of parturition and/or elective caesarean at the earliest possible point for fetal viability should be considered.

Chronic Primary Ketosis Overview and Clinical Signs

Chronic ketosis may occur in dairy cattle who are genetically superior for milk production. It is characterized by intermittent and recurrent primary ketosis during the first 60 days of lactation. It is uncommon in first calf heifers. Affected animals may be over conditioned at parturition but this is not always the case. The final pathophysiology is the same as that for spontaneous primary ketosis (i.e., incomplete oxidation of fatty acids), but is often caused by underlying fatty liver. Fatty infiltration of the liver may have occurred in the weeks just before calving, but without evidence of ketosis because the cow was not yet under production stress. Fatty liver may also have occurred soon after calving, particularly if the cow had another disease around calving or experienced stress from over-crowding or moves from one pen to another. Whatever the cause of the fatty liver, it results in impaired gluconeogenesis by hepatic tissues and leaves the cow at very high risk for ketosis.

Chronic ketosis is sometimes called Type II ketosis because its association with Type II diabetes, a related metabolic condition. It is possible that cows with Type II ketosis had insulin resistance at the time they were developing a fatty liver. However, insulin resistance is not evident by the time the cow becomes ketotic.

Clinical signs with chronic ketosis are similar to those seen with spontaneous primary ketosis (with partial anorexia, mild depression and ketonuria); however, they occur earlier in lactation (starting as early as about 4 days in milk) and respond poorly to treatment. Milk production will be mildly diminished. With recurrent episodes considerable weight loss may be seen (losses of 1.5 to 2 units of body condition score are possible). Advanced, chronic cases may exhibit weakness and recumbency.

Chronic Primary Ketosis Treatment

Initial cases are treated identically to spontaneous primary ketosis, but with recurrent episodes more aggressive treatment is indicated. Often the producer will have already treated with conventional therapies (steroids, oral propylene glycol and 500 ml of 50% dextrose) but will be frustrated by the recurrence. Because these cows have an underlying fatty liver, they cannot make all of the glucose they need. Patience is useful – if
the cow can be kept alive, the fatty liver will eventually resolve and ketosis will subside. The recovery process is aided by the cow’s own normal decline in energy demands for milk production after about the third week of lactation.

If affected cows are particularly valuable, they may be referred to a hospital. In this setting, they can be force-fed with a combination of alfalfa gruel and oral electrolytes containing potassium at least twice daily for 3 to 4 days. An example recipe is 1 to 2 lbs alfalfa meal and 40 grams of potassium chloride mixed in 2 gallons of warm water.

Best results in hospitalized cows are obtained by giving continuous infusions of intravenous dextrose and polyionic fluids. An example is a constant intravenous infusion containing 5-10% dextrose with 20-40 mEq/L of potassium chloride added. If the cow is hypokalemic, a cheaper alternative for providing supplemental potassium is to give 100 g feed grade potassium chloride orally once a day. This is usually done as part of an oral drench similar to the one described above.

Reducing milk production (e.g., incomplete milk out) may also help cows with chronic ketosis recover. However, incomplete milk-out predisposes the cow to mastitis. Thus, this treatment is usually reserved for difficult cases.

Fat Cow Syndrome Overview

The fat cow syndrome is a persistently ketotic condition of dairy cows in the first days to weeks of lactation that are associated with over conditioning during the dry period. It can be seen as both a herd problem where overfeeding of springing heifers or dry cows results in over conditioning or obesity at the time of parturition or else as a sporadic problem in an individual cow. Some affected cows are embryo transfer donor cows that have been flushed repeatedly and have consequently gone for extended periods between lactations. Others are animals with reproductive problems that finally conceived, but have been dry for an excessively long time period.

You should consider spontaneous primary ketosis, chronic primary ketosis with chronic fat mobilization and the fat cow syndrome as a spectrum of disease with increasing severity. The fat cow syndrome results from excessive energy intake during the dry period. This leads to fat deposition in liver, muscle and the abdominal cavity. Fat within muscle reduces potential amino acid storage for future gluconeogenesis, and fat within the abdomen reduces the potential rumen volume and hence feed intake. With the increased energy demands of lactation, there will be increased peripheral lipolysis with a subsequent increased demand on the liver for both storage and use of triglycerides as well as export of triglycerides as very low density lipoproteins (VLDL). When the rate of VLDL export and fatty acid oxidation by the liver is exceeded by the rate of hepatic triglyceride formation then further hepatic lipidosis will occur. When intracytoplasmic lipid reaches greater than 40% of the hepatocyte on a volume for volume basis then this is considered severe hepatic lipidosis.

Fat Cow Syndrome Clinical Signs

Anorexia that can vary from moderate to complete feed refusal. Obesity or over-conditioning will often be present early in the disease but with prolonged anorexia animals may be in poor body condition. Affected individuals frequently develop other common periparturient diseases of dairy cattle - particularly milk fever, retained placenta, metritis and abomasal displacements.

Persistent and refractory ketosis. Frequently moderate to severe ketosis will be evident from just a few days after parturition. Some severely affected cows will develop fulminant liver failure, or overwhelming sepsis (aided by their poor immune function caused by the fatty liver).

Fat Cow Syndrome Treatment

Consider constant dextrose infusions and other aggressive measures for the persistent ketosis (force feeding, polyionic fluids, steroids, oral glucogenic precursors). Add a potassium source if the cow has been ketotic and off feed for three days or more. Aggressively treat all concurrent diseases, such as hypocalcaemia, metritis or surgical conditions of the abomasum.
Beware of overzealous and repeated use of steroids and propylene glycol, particularly by the producer, for the refractory ketosis. For high producing individuals consider limiting production by reducing milking frequency and/or completeness of milkout.

**Fat Cow Syndrome Prognosis**

The prognosis for this condition is poor to grave, depending on the degree of obesity and the time lag to detection and treatment. Intensive treatment of individually valuable animals is occasionally rewarding. Cows with this condition tend to either slowly deteriorate with persistent, refractory ketosis over several days to weeks, finally becoming recumbent with complete inanition or else succumb to septic conditions such as metritis or mastitis during early lactation. If the cow stays alive past about 50 days in milk she will probably survive.

**Ketosis Prevention**

Proper energy nutrition before and after calving is the key factor in preventing ketosis and fatty liver. Adequate energy in the time period just prior to calving, when dry matter intake is depressed, is especially important. Body condition loss just prior to calving strongly predisposes cows to fatty liver and ketosis. This may be triggered by frequently moving cows from pen to pen as they approach calving.

Excessive body condition score entering the dry period and/or excessive body condition score gain during the dry period (greater than about 1/4 unit of body condition score) are predisposing factors to ketosis and fatty liver. Fat cows are at greater risk for ketosis and fatty liver because of decreased dry matter intake in early lactation.

Care must be taken to assure that early lactation cows receive enough dietary energy to prevent problems with primary (underfeeding) ketosis. While most component-fed herds tend to overfeed concentrates in early lactation and cause rumen acidosis, a few do restrict concentrate feeding so severely as to cause primary ketosis. Limited access to forages and/or poor quality forages in early lactation can also contribute to primary ketosis. Useful rules are to keep early lactation cows slightly hungry for concentrates but never without access to the highest quality forages available on the farm.

TMR-fed herds with post-fresh groups sometimes dramatically increase dietary protein (>19%) and simultaneously decrease energy (<.76 Mcal/lb NEL) in an effort to prevent ruminal acidosis and yet still support good milk production. This combination may increase the risk of ketosis in the herd.

Some herds have persistent ketosis problems, which are related to feeding ketogenic silages. Hay silages that are chopped too wet (insufficient wilting or direct-cut silages) tend to favor growth of *Clostridium sp.* bacteria, which ferment some carbohydrates to butyric acid instead of the desirable lactic acid. If absorbed, dietary butyric acid is converted into BHBA and causes ketosis.

Ketogenic silages are easy to recognize because of the distinctive odor of butyric acid and protein degradation products of clostridial fermentation. A silage fermentation analysis can confirm the presence of and the amount of butyric acid present in the silage. Silages containing butyric acid should not be fed to pre- or post-fresh cows if at all possible. In any case, the rate of butyric acid feeding should not exceed about 50 g/cow/day. Harvesting practices must then be put into place to prevent ensiling overly wet forages. This requires adequate wilting time in the field after cutting and prompt covering of bunker silos if it rains during the filling and packing process.

Feed additives have limited benefits in preventing ketosis. Rumen-protected choline (a B vitamin that improves fat export from the liver) and niacin (also a B-vitamin – reduces mobilization of body fat) are two common feed additives that may be used to help prevent ketosis. Don’t expect miracles from these, or any other feed additives.

**III. Hypokalemia**

**Hypokalemia Overview**

Hypokalemia should be anticipated with any condition that causes inappetance in dairy cattle. There are no homeostatic endocrine mechanisms controlling blood potassium levels, such as those existing for calcium. Thus, cattle are reliant on dietary intake to maintain serum/plasma potassium within normal ranges. Mild to moderate
Hypokalemia (serum potassium 2.5 – 3.5 mEq/L; normal range 3.8 – 5.5 mEq/L) should be anticipated with all of the common post parturient diseases that negatively impact feed intake. However, mild to moderate hypokalemia tends to be asymptomatic and clinical signs of neuromuscular weakness – initial muscle fasciculations, trembling, followed by recumbency and eventually death, only tend to be seen with severe hypokalemia when serum potassium falls below 2.2 mEq/L.

Unfortunately many of the commonly used treatments for ketosis have the tendency to exacerbate hypokalemia by promoting intracellular potassium shifting. Any therapeutic intervention that causes hyperglycemia such as intravenous dextrose, oral glucogenic precursors such as propylene glycol, and glucocorticoids, will result in insulin release and resultant intracellular movement of potassium. A specific syndrome of severe hypokalemia, muscle weakness and recumbency has been associated with the repeated use of the glucocorticoid isofluprednone acetate (Predef®). Part of the explanation for the severe hypokalemia observed in cattle receiving multiple doses of this drug may lie in its partial mineralocorticoid effect, with resultant increased renal potassium losses. By comparison dexamethasone has no mineralocorticoid effect, and is therefore the glucocorticoid of choice for the treatment of uncomplicated ketosis. Metabolic alkalosis, the commonest acid base disturbance in cattle (particularly if anorectic), will exacerbate hypokalemia by further promoting intracellular potassium shifting.

**Hypokalemia Treatment**

*Mild hypokalemia (2.5 – 3.5 mEq/L)*: it is important to correct the inciting primary condition, returning the cow to a normal appetite and feed intake. Specific therapeutic attention to mild hypokalemia is not critical but can take the form of potassium added to oral or intravenous fluids. Oral potassium can be added to orogastric fluids at the level of 1 to 4 ounces sid to bid. If the intravenous route is chosen then supplemental potassium chloride can be added to fluids to a final concentration of 40 mEq/L. When administering potassium-containing fluids be careful to never exceed a final administration rate of 0.5 mEq/kg/hr.

*Severe hypokalemia (< 2.2 mEq/L)*: cattle with such severe hypokalemia are recumbent and often unable to support the weight of their heads, carrying a guarded to poor prognosis. Aggressive supplemental potassium administration in the form of 0.5 lb of feed grade potassium chloride bid for 2-3 treatments may be needed, to restore potassium levels to normal in these cattle. Concurrent intravenous potassium supplementation, if practically possible, can also be done as outlined above but does not appear to make as significant effect on these individuals as does oral supplementation. The best gauge to the success of therapy will be whether or not the cow stands within a 24 to 48 hour period, cattle that remain recumbent after this are at great risk for the development of ischemic myopathy and are unlikely to survive.

Because cattle are so reliant on feed intake for extracellular potassium, it is appropriate to consider low level oral potassium supplementation (e.g., 4 ounces KCl orally once a day) whenever a cow has been off feed for an extended period of time, or is receiving treatments that are likely to cause intracellular potassium shifting.

**IV. Hypomagnesemia**

**Hypomagnesemia Overview**

Hypomagnesemia (aka ‘grass staggers, wheat staggers, oat staggers, winter tetany and milk tetany’) is an acute, frequently life threatening, neurologic condition of cattle of both sexes. It is more common in beef cattle than dairy, and can be seen in cattle of almost any age. It is most commonly seen in spring calving beef cows on lush pasture in the early spring or summer. In the southern United States it can be seen all year round on cool season pasture grasses.

**Hypomagnesemia Clinical Signs**

The initial clinical signs are similar to those reported for milk fever, with affected cattle showing mild signs of anorexia, separation from the herd and hyperexcitability. Ear twitching, muscle fasciculations and hyperesthesia around the head will quickly progress to more severe whole body tremors, ataxia and recumbency with seizure activity. Some animals in the early stages can be quite maniacal and aggressive.
Hyperthermia (up to 106-107°F) frequently occurs as a result of strenuous muscle activity. Tachycardia will also be present. Opisthotonus and potentially violent clonic convulsions will rapidly progress to death, usually due to respiratory failure, if the condition is untreated.

Hypomagnesemia Etiology

There is no endocrine control of magnesium absorption, storage or excretion. Magnesium is stored within teeth and bone but these ‘pools’ are not particularly labile, so ruminants are essentially reliant on dietary intake for circulating magnesium. Significant magnesium loss occurs in lactating cattle through milk and pastures that are low in available magnesium (wheat, barley and oats pastures for example) or those that incite significant osmotic diarrhea (lush spring grass pasture) may precipitate clinical hypomagnesemia.

Winter tetany is described as a condition of pastured beef cattle under conditions of poor husbandry. A combination of climatologic stress and poor nutrition contributes to clinically significant hypomagnesemia in this situation. Clinical hypomagnesemia has also been reported in young calves fed magnesium deficient milk replacers; however, this is a rare situation.

Hypomagnesemia Clinical Pathology

The emergency nature of this condition and its requirement for prompt treatment makes it a clinical diagnosis. Serum magnesium measurement will often reveal low magnesium of less than 1.2 mg/dl. Occasionally clinical cases have normal serum magnesium, but CSF magnesium levels have been demonstrated to be reliably low (<1.5 mg/dl) in all cases. Urine magnesium is also depressed due to reduced urinary fractional excretion.

Hypomagnesemia Treatment

Magnesium should be administered parenterally, however remember the cardiotoxicity of magnesium salts and their potential to cause respiratory failure. If the animal is seizing, tranquilization will be necessary not only to treat the animal but also to prevent persistent, severe hyperthermia and self-trauma.

Magnesium can often be given intravenously in the form of proprietary milk fever treatments that contain both calcium and magnesium (Norcalciphos®, CalDex No. 2®). 250 ml of 20% magnesium sulfate solution subcutaneously will allow for slow equilibration with circulating levels, but this may be too slow for severe cases. Magnesium salts (sulfate, chloride or hydroxide) can be given orally or by enema, but this is can be technically challenging in a seizing adult beef cow.

Hypomagnesemia Prevention

Grass tetany is caused by diets that are low in magnesium and/or high in potassium. Lush, succulent grass pastures in the spring often fit this nutritional profile, although some diets fed to confined cows may also have this problem. Prevention of grass tetany is usually not challenging, as it requires only adequate supplementation of magnesium in the diet. If grazing herds consume some concentrates, it is not difficult to supplement those concentrates with adequate magnesium. It is difficult to deliver supplemental magnesium to cattle on pasture that are not receiving supplemental concentrates.

Hypomagnesemia may also be related to excessively high dietary potassium relative to magnesium. Potassium inhibits magnesium absorption in the rumen. Ideal K:Mg ratio for pre-fresh dry cows is less than 4:1. Some areas (e.g., north central Wisconsin) have soil types that tend to lead to high potassium/low magnesium forages. In these situations, it may be necessary to increase dietary magnesium concentrations to .40% or higher by adding extra magnesium oxide to the diet.

V. Hypophosphatemia

Hypophosphatemia Overview

Most cases of clinical milk fever have some degree of hypophosphatemia with the hypocalcemia. This hypophosphatemia occurs because elevations in PTH cause phosphorus loss via saliva and urine. Ruminal atony also contributes to hypophosphatemia because salivary phosphorus pools in the rumen. Normal blood
phosphorus concentrations are usually restored when the hypocalcemia is corrected with supplemental calcium alone – supplemental phosphorus is not typically required. Restoring normocalcemia halts the PTH secretion and phosphorus loss and increases gastro-intestinal motility, which allows for intestinal absorption of salivary phosphorus that pools in the rumen.

Some cows are unable to restore normal blood phosphorus concentrations, even after blood calcium has been corrected and stabilized. Reasons for this are unknown. Persistent hypophosphatemia may play a role in some relapsed milk fever cows, but this is uncertain. Many practitioners include intravenous and/or oral phosphorous supplementation as part of their therapy for repeat cases of milk fever but there is little evidence to support this. If attempted, hypophosphatemia may be corrected by intravenous administration of an available source of phosphorus (e.g., 30 g of sodium monophosphate in 300 ml distilled water) or by oral phosphorus supplementation (e.g., .5 kg of sodium monophosphate in about 2 gallons of warm water).

IV solutions containing multiple electrolytes often use a hypophosphite source of phosphorus. Unfortunately, hypophosphites are biologically unavailable to the cow and are of no value whatsoever in treating hypophosphatemia. Phosphate solutions do provide biologically available phosphorus; however, they usually cause precipitation when added to solutions that contain calcium or magnesium.

There is no specific nutritional prevention for hypophosphatemia. The best actions are to prevent hypocalcemia and to make sure that there is adequate phosphorus in the pre- and post-fresh diets (this is rarely a problem). The sensitivity and specificity of serum phosphorous measurements as an indicator of whole body phosphorous status are poor, so do not rely on blood tests to determine phosphorus adequacy.

Primary hypophosphatemia has been associated with post parturient hemoglobinuria in lactating dairy cattle, although this appears to be predominantly a disease problem in the Southern Hemisphere. It is unclear why hemoglobinuria is not a consistent feature of hypophosphatemia – other factors are probably involved. Affected cattle are typically within 6 weeks of parturition and develop progressive signs of tachycardia, tachypnea and weakness due to anemia from intravascular hemolysis. Urine will be dark red to black depending on the severity.