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# Hypomagnesemia Tetany in Cattle

**Alsaftli Zelal***

*Hama University, Agricultural Faculty, Animal Production Department, Hama, Syria*

***Corresponding author:** Dr. Alsaftli Zelal, Agricultural Faculty, Animal Production Department, Hama University, 3 Alastoai, homs, Hama, Syrian Arab Republic, Tel: 963946656403; E-mail: zelalsaftli@gmail.com

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**Abstract**

Grass tetany, sometimes called grass staggers or hypomagnesemia, can be a serious problem in Syria with cattle grazing small grain or ryegrass pastures. hypomagnesemia tetany has been known under a variety of names, including magnesium tetany, lactation tetany and grass staggers, but most of these terms have been discarded because the disease is not always associated with lactation or with grazing animals.

The exact cause of hypomagnesemia tetany in ruminant animals is a dietary deficiency of magnesium that may be a contributory factor. Some research workers consider the condition to be caused by a cation-anion imbalance in the diet, and Some research workers believe that high intake of the element (K & Na) may interfere with the absorption and metabolism of magnesium in the animal, which may be an important factor in the etiology of hypomagnesemia tetany.

Although the exact cause of hypomagnesemia is still uncertain, the primary factor would appear to be inadequate absorption of magnesium from the digestive tract. A high degree of success in preventing hypomagnesemia may be obtained by increasing the magnesium intake. This can be effected by feeding with magnesium rich mineral mixtures or, alternatively, by increasing the magnesium content of pasture by the application of magnesium fertilizers.

**Keywords:** Cattle; Grass tetany; Hypomagnesemia; Magnesium

**Abbreviations:** DM: Dry Matter; Mg: Magnesium; K: Potassium; Na: Sodium; Ca: Calcium; P: Phosphor; SCFA: Short Chain Fatty Acids; CSF: Cerebrospinal Fluid; PD: Potential Difference; CNS: Central Nervous System; ECS: Extracellular Space; TRPM7: Transient Receptor Potential Melastatin Subtype 7

## Introduction

Grazing animals on pasture can be an integral part of an effective feeding regime for cattle and other livestock. Grazing reduces valuable labor time and cost for the farmer because no harvesting is needed and provides exercise for the animal; however, as with other feeding programs, it does not come without risk [1].

Grass tetany occurs in ruminants grazing early spring grasses, while winter tetany occurs in ruminants consuming cereal forages such as wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), and rye (*Secale cereale* L.). A concern when livestock are allowed to graze on pasture is grass tetany. Grass tetany is typically found in ruminant animals, with lactating cows being the most susceptible [1]. Grass tetany generally becomes a problem when the diets of cattle are changed from winter stockpiles (silages) to rapidly growing, lush, spring grasses [2]. Testing may indicate high levels of potassium (K) and nitrogen (N) and low levels of magnesium (Mg), calcium (Ca), and sodium (Na) in the soil [3].

Incidences of grass tetany are seasonal and more common when the weather is cool and rainy. Pastures prone to cause grass tetany include, but are not limited to, a wide variety of warm season grasses such as orchard grass, perennial rye grass, tall fescue, timothy, and brome grass. When grazed, small grains such as wheat, barley, oats, and rye can also cause grass tetany. Lastly, grass tetany can occur in livestock that are wintered on low Mg grass hay or corn stovers [1]. Throughout the word, there are several types of hypomagnesemia tetany syndromes, which can be diagnosed according to the age of cows affected and the etiologic factors inducing the fatal nervous disorder. In beef herds, cows older than 6 years, if they are over fat at calving (body condition score 4 to 5 on 1 to 5 scale), and lose live weight (up to 1 kg/day) during lactation are more commonly affected with grass tetany than younger cows. Younger cows, two- and three year old may also be affected in herds with more complex types of grass tetany syndromes associated with low magnesium and high potassium intakes, and low sodium and phosphorus nutrition [4].

Determination which factors are likely to be important in reducing magnesium absorption in dairy at a specific location enables recommendation of cost-effective management strategies to prevent hypomagnesemia tetany. Hypomagnesemia tetany also occurs in younger calves fed several months on whole milk or milk-replacer diets, which provide inadequate magnesium for their requirements for maintenance and growth.

## Magnesium

The fact that magnesium (Mg) is an essential mineral for life was for the first time described in animals by Leroy [5]. It is the second most prevalent intracellular cation after potassium and the fourth most abundant cation in the body. Magnesium fulfills many physiological functions [6], with one of the best studied being the activation of enzymes. Intracellular magnesium is important for several enzymes that regulate the metabolism, and although the extracellular concentration is only 1% of the total magnesium in the

body, magnesium plays a key role as an extracellular ion for nerve transmission. Plasma magnesium, just like calcium, is also found in ionised form, protein-bound and in complexes, with the ionized magnesium being the most active form. It has ability to form chelates with important intracellular anionic-ligands, especially ATP, and its ability to compete with calcium for binding sites on proteins and membranes [7].

Mg is a constituent of bones (approximately 60 to 70% of the total body magnesium is present in the skeleton), 30-40% is distributed in the soft tissues and only about 1% can be found in the extracellular space [8,9] have reported that the total content of Mg within the body calves:

Mg (g)=0.655x-3.5g : x=body weight in kg

The normal level of magnesium in plasma for cows is in the range of 0.75-1.00 mmol/l or 1.8-2.4 mg/dl [10]. The cow is almost solely dependent on a constant dietary uptake of the mineral since magnesium metabolism is not regulated by specific hormones [8]. In a 500 kg dry cows weighing 500 kg have a daily dietary requirement of 1.2 g magnesium/kg DM. For cows in lactation with a milk production of ~30 kg/day the requirement increases to 2.0 g/kg DM [11].

Milk contains about 0.12-0.15 g magnesium /kg and a high yielding cow may lose around 3-4 g through milk per day. Colostrum contains about 0.4 g magnesium/kg [10]. Because the amount of magnesium in the extra cellular fluid equals the amount excreted in 17 kg of milk (0.15 g/kg 4% milk; [8], milk production in high lactating animals can quickly deplete the extracellular pool of magnesium, resulting in hypomagnesaemia if not rapidly replaced [12].

The level of minerals in forages varies according to properties of the soil, level and type of fertiliser applied to the crop, botanical composition, and maturity of the plant [13]. Generally, forages contain high levels of potassium, fairly high levels of calcium and lower levels of magnesium and phosphorus. The mineral composition of these varies; cereals are usually rich in phosphorus, oil seed residues are rich in phosphorus and potassium, and sugar beet products are rich in calcium and potassium. In several dairy cow diets, inorganic mineral supplements are added to fulfil the dietary demands of the cow.

| | | |
|---|---|---|
| **Endogenous loss (Inevitable loss)** | 3 mg Mg/kg Live weight | Mature pregnant beef cows fed a dry semi purified diet required 8.5, 7.0 and 9.0 g Mg/d to maintain the blood serum Mg level at 20 mg/L at 155, 200 and 255 d gestation, respectively |
| | 0.45 g Mg/kg gain | |
| | 0.12 g Mg/kg milk | |
| **Pregnancy Daily increment** | | |
| **-early in concepts** | 0.12 g Mg/d | these cows then required 21, 22 and 18 g Mg/d during early, mid and late lactation to maintain the blood-serum Mg level at 20 mg/L, respectively |
| **-mid** | 0.21 g Mg/d | |
| **-late** | 0.33 g Mg/d | |

**Table 1:** The amounts of Mg associated with the urinary and fecal endogenous loss, growth, pregnancy and lactation in cattle.

Limestone, calcium or magnesium phosphate, sodium chloride and magnesium oxide are common sources of minerals included in concentrate mixtures and mineral supplements and, in addition, sodium chloride is often fed at appetite [14] summarized the absolute amounts of Mg needed for various production functions in cattle (Table 1). The data were developed from balance studies, isotope experiments and slaughter data.

## Etiology

It is hypothesized that grass tetany (also called hypomagnesaemia tetany, lactation tetany, grass staggers, winter tetany, or wheat pasture poisoning) is caused by a deficiency of Mg in the blood; however, not all animals with hypomagnesaemia will develop grass tetany [15]. The classic clinical signs of hypomagnesemia in cows characterized by ataxia, recumbency, neuromuscular irritability, convulsions, and finally tetanic muscle spasms were known before [16] was termed "grass tetany" because the symptoms developed in the affected animals when they were first allowed to graze on fresh green grass in the spring, also he was confirmed the relationship between the clinical symptoms and hypomagnesemia. However, the Mg concentration in blood shows some variation (Table 2), and the observed nervous disturbances do not correlate with the blood Mg concentration [17]. Symptoms of magnesium deficit may not appear until serum magnesium level is less than 0.9 $mmol \cdot l^{-1}$. The severity of symptoms may not correlate with serum magnesium levels. Nevertheless, a low blood Mg concentration is a precondition of the clinical symptoms, which are probably produced in two steps: a) hypomagnesemia and b) impaired function of the central nervous system (CNS) [18]. Classic tetany was primarily observed after a few days once cows had been let out onto pasture in the spring. Older animals (third or more pregnancy) are more susceptible to grass tetany and hypomagnesemia is not related with parturition as is milk fever [9]. The predominant reason of the pathogenesis of hypomagnesemia is the small amount of Mg of 3-4 g which is present in the extracellular fluid, and which depends on an undisturbed ratio between influx > efflux. As above-mentioned, hypomagnesemia can be present without intake magnesium deficiency [19] and even happens after a change of diet when the diet is iso-magnesemic [20] or despite of the increase of Mg intake from 16 g/d to 23 g/d [21]. On the other hand, the Mg absorption (influx) from the diet was reduced. Storry et al. [22] estimated the Mg available from bone in cattle to be about 0.5 g/d, which is small in comparison to the 2.4 g Mg required per d for the production of 20 liter milk. Furthermore, Mg in the extracellular fluid is challenged by transport of Mg into milk (12 mg/l). The Mg demands for synthesis of milk decreases the blood Mg concentration, and Baker et al. [23] have submitted that the speed fall of blood Mg encourages the onset of clinical symptom. Reduced influx at identical efflux leads to hypomagnesemia and cannot be remunerated by Mg mobilization from the large pools in bone or soft tissue [9] or only to a negligible small extent [22].

| Mg Status | Blood Mg ($mmol \cdot l^{-1}$, mg/100 ml) |
|---|---|
| Normal Mg | 0.9 -1.2 (2.19 -2.92) |
| Uncertainty | 0.8 -0.9 (1.95 -2.19) |
| Suspicion of hypomagnesemia | 0.7 -0.8 (1.70 -1.95) |
| Hypomagnesemia | <0.7 (<1.70) |

**Table 2:** Status of Mg metabolism and blood Mg concentration.

Hypomagnesemia was originally suggested to be caused by the uncontrolled activation of muscles by impaired synaptic transmission at the motoric end plate [24]. This hypothesis was not supported in the

experiments of Todd and Horvath [25], and it is unlikely that the involuntary activation of muscles occurs originally in the periphery. Discuss the possible involvement of the central nervous system Conducted by Chutkow and Meyers [26] when they found that Mg-deficient rats were caused decreased Mg concentrations in the cerebrospinal fluid (CSF). The hypothesis of the decreased Mg concentration in CSF as a reason for clinical signs such as ataxia and tetany was tested by Meyer [27] found that Hypomagnesemia occurs in ruminant animals when the Mg concentration of the cerebrospinal fluid (CSF) falls below approximately 0.66 mmol/l. Normally the concentration of Mg in CSF is higher than that of plasma [28] confirmed that the CSF concentration in grazing dairy cows was a significantly reduced in clinically affected (0.51 mmol Mg/l) than in non-tetanic animals (0.73 mmol/l), despite the plasma Mg concentrations being similar (0.20 mmol Mg/l v. 0.15 mmol Mg/l respectively). In a later experiment in sheep, [29] were able to induce episodes of tetany by perfusion of the ventriculolumbar space with synthetic CSF containing, 0.25 mmol Mg/l, and could stop these tetanic episodes by perfusion with fluid of normal Mg concentration (1.00 mmol/l) and they have observed, in addition to diminished Mg, lower Ca concentrations in the CSF in sheep or calves with episodes of tetany.

From these field and experimental observations, it is clear that the clinical symptoms of Hypomagnesemia tetany are caused by a reduction in the CSF Mg concentration and it is thus important to understand the processes that contribute to low CSF Mg levels. Mg is a well-known modulator and physiological antagonists of $Ca2^{+}$-induced transmitter release at synapses [30], and low Mg in the CSF might facilitate $Ca2^{+}$-dependent transmitter release and the excitation of central nervous system neurons that, amongst others, activate muscles.

Magnesium is a nutrient required for all animals, but it is especially critical for ruminants. A physiological deficiency of Mg results in hypomagnesemia tetany. Typically, only female ruminants are affected, and the disturbance usually occurs during the early stages of lactation. There are many factors influencing magnesium absorption and metabolism in ruminants. The following factors need to be considered to ensure optimum utilization of Mg.

## Potassium and sodium

Several studies have demonstrated that ruminants consuming diets with high concentrations of potassium experience a significant reduction in magnesium absorption from the gastrointestinal tract. According to Sjollema [16] the composition of tetany-prone grass, which exhibited high concentrations of K and nitrogen, low concentrations of Na, and moderate levels of Mg. Hence, simple Mg deficiency seemed unlikely to be the main reason for hypomagnesemia tetany, and this disease "does not arise by inadequate intake of Mg" [19]. It also happens after a change of diet from forage and concentrate to young grass when the diet is isomagnesemic [20], and a decrease of blood Mg was even observed in cows despite an increase of Mg intake from 16 g/d to 23 g/d [21]. Nowadays, dietary factors are well known to interfere with Mg absorption, and the changes of grass composition reported by Sjollema [16] have a physiological background on Mg transport in the gut. These contradictory observations are nowadays not surprising as long as Mg influx is larger than efflux including the excretion of surplus in urine, blood Mg varies within the physiological level despite lower influx, even when the influx is reduced by high K intake [31] have indicated that the potential difference (PD) between blood and rumen contents might also affect Mg absorption. The (PD)-dependent magnesium absorption is therefore also called potassium-sensitive. The extent of the negative effect of potassium on magnesium absorption depends on the ruminal concentration of magnesium and it has been shown that supplemental magnesium can counteract the inhibitory effect of high levels of dietary potassium [32,33]. The effect of K appears to be dose dependent [34]. A dose response curve between K intake and Mg digestibility has shown that an increase of K between 1-3% of DM firmly reduces Mg digestibility, with minor effects overhead this concentration. In agreement with this conclusion are the results in cows of Schonewille et al. [35]. The authors have not found a correlation between Mg digestibility and K content of the diet within the range of 29 g (2.9%) to 44 g (4.4%) K/kg DM. Notably, Martens [36] have observed, in studies with heifers, that the absorption of Mg from the temporarily isolated rumen dramatically declines between 25 and 75 $mmol \cdot l^{-1}$ K concentration in the artificial rumen fluid, whereas 100 and 120 $mmol \cdot l^{-1}$ K do not further depress Mg absorption.

In 2004, Weiss collected magnesium digestibility data from 8 different feeding experiments by using lactating cows, where apparent magnesium digestibility had been measured using total collection of feces and urine. The cows were fed varying feed stuff and the mean apparent digestibility for magnesium was 0.18 (ranging from -0.04 to 0.33) and found that magnesium digestibility decreased linearly with 0.075 units for every 1% increase in dietary potassium. An addition of 18 g magnesium per day should be provided to lactating dairy for every percentage increase in dietary potassium above 1% DM to maintain the amount of digestible magnesium at the same level as with 1% potassium [37].

Feeding high levels of potassium generally has depressed blood serum magnesium in ruminants, as a result of reduced magnesium absorption [38]. The main effect of potassium is on pre-intestinal magnesium absorption [31] reported that magnesium infused into the omasum or abomasum was completely recovered at the duodenum, but 36% to 61% of magnesium infused into the rumen was not recovered at the duodenum. Correspondingly, it has been shown that ruminal infusion of potassium in sheep resulted in a large decrease in magnesium absorption, but infusing potassium into the abomasum or ileum had no effect, also indicated the reduction in the net absorption rate of Mg might be a result of the increased potential difference (PD) between blood and rumen fluid. These results further indicate that magnesium absorption may be more sensitive to potassium at low ruminal magnesium concentrations and that the negative effect of potassium can be overcome by increasing magnesium intake.

Magnesium is transported across the ruminal mucosa by an active sodium-linked process [39]. The risk of the disturbed Mg absorption during Na deficiency can easily be tested from a measurement of saliva flow and the load of K to the rumen. At Na deficiency, salivary concentrations of potassium increase to more than 100 $mmol \cdot l^{-1}$ and a daily flow rate increase to 200 l/d in high producing cows lead to a total influx of K of some 780 g/d K, which is equal to a dry matter intake (DMI) of 26 kg with 3% K in the DM. Hence, severe Na deficiency is a significant risk for reduced Mg absorption, because the flow of K into the rumen was increased by increasing K intake. Danger of Na deficiency often overlooked, because it is not always easy to detect and overt clinical symptoms of it are missing. Besides the large Na pool in the rumen at 200 g Na can be mobilized and can cover deficiency for a long time [40]. However, when K concentration in the rumen fluid increases (at high K intake), the Na absorption stimulates from the rumen which lead to markedly reduced in this ruminal Na

buffer capacity [41]. In addition, the absorbed Na cannot be stored and is rapidly excreted via urine [42]. Care et al. [32] showed that in sheep the K:Na ratio affects the absorption of Mg from a solution placed in a rumen pouch. A high K:Na ratio significantly depresses the rate of absorption which is related to the PD across the rumen wall (blood positive) compared with a solution with a low K:Na ratio. It would thus seem likely that the K:Na ratio in the diet is important in influencing the rate of absorption of Mg from the reticulo-rumen, especially at low concentrations of soluble Mg in the rumen fluid [43].

Fast-growing spring grass has been found to be low in sodium that do not cover the requirement of grazing ruminants [44], particularly lactating cows [45]. These factors have a strong influence on magnesium absorption by the rumen epithelium. In young spring grass, extremely low concentrations of sodium and high levels of potassium leads to sodium deficiency, a decreased Na:K ratio in the rumen, and consequently an increased level of potassium in ruminal fluid, which further exacerbates the imbalance by decreasing the absorption of magnesium from the rumen [8]. This result is a consistent with the observation which confirms the presence negative correlation between Na content of grass (Na deficiency-the author) and the emergence of symptoms of tetany [46]. Finally, adding NaCl into feed cows could be prevented grass tetany [47].

## Nitrogen and ammonia

Many experiments have been carried to determine the effect of Ammonia on Mg absorption which has offered contradictory results. Two reactions have been reported: the inhibition of Mg absorption and no effect on Mg digestibility by high ruminal ammonia. Sjollema [16] confirmed that there is correlation between high concentration of crude protein and incidence of grass tetany [48]. Several assumptions for the relation between ammonia and tetany have been discussed as the toxicity of ammonia [49], formation of the complex magnesium-ammonium-phosphate [50], or disturbed Mg absorption by ammonia [19].

Indeed, Mg absorption decreases when the ruminal $NH4^+$ concentrations increase suddenly and acutely. After an intraluminal application of large amounts of ammonium acetate in cows, Head and Rook [19] observed a decrease of blood Mg concentration and urinary Mg excretion. Many studies results established that the absorption of Mg from the temporarily isolated rumen was severely reduced with increasing $NH4^+$ concentrations from 0-40 $mmol.l^{-1}$ [36]. This decrease agrees with the observation of Care et al. [32] in studies with a rumen pouch in sheep. Mg absorption was decreased by ammonia in acute experiments, and this effect was additive to the known depression of K. But it is inconsistent with the findings of [51] who had not noticed any effect for high protein intake or high ruminal $NH4^+$ concentration on apparent Mg digestibility or urinary Mg excretion in conventional balance studies.

This contradiction in the assumptions and conclusions which may be due to the difference in the research methodology and the experiments methods used, as a conduct the experiment after a pre-feeding period of two or three weeks [51] or with ruminal $NH4^+$ concentration being raised very slowly [52]. These observations led to the hypothesis that an acute increase of ruminal $NH4^+$ reduces Mg absorption and that chronic elevation of ruminal $NH4^+$ induces adaptation to this fermentation product. [8] has found that Fermentation products, $NH4^+$ and short chain fatty acids (SCFA), influence Mg absorption, but the possible meaning regarding the pathogenesis of hypomagnesemia is not quite clear, however, a sudden increase of ruminal $NH4^+$ should be avoided, because high $NH4^+$ concentrations transiently reduce Mg absorption.

## Ruminal pH

EDTA possess chelating properties and have been related to decreased Mg transport, so it is expected that there is in solution in ruminal fluid as an ion [53]. The solubility of Mg in the rumen is ranging from 34% to 77% that may vary depending on diet [54], and size of supplemented magnesium oxide [55]. Ultrafilterable Mg in rumen liquor decreases from 6.0 to <0.5 $mmol.l^{-1}$ in cows as rumen pH increase from 5.6 to 7.2 $mmol.l^{-1}$ lower on grass than on hay with concentrate diets for a given pH [21]. In sheep, rumen solubility of Mg decreases from 80% to 20%, approximately, when pH is increased in vitro from 5 to 7 [56]. However, rumen pH markedly influences the solubility of Mg as a major determinant factor [56]. The concentration of Mg in ultracentrifuge rumen fluid was negatively correlated with pH, which was significantly higher at all times on the grass diets. This relation was also detected in the apparent availability of Mg. The proportion of absorbed Mg excreted in urine was significantly influenced by diet [43]. The solubility of Mg in ruminal fluid decreases abruptly when rumen pH is >6.0. Thus, at higher pH values, the soluble Mg concentration becomes unrelated to the pH [56]. But several studies found that both a higher [43] and lower pH [21] is one of etiology of grass tetany in sheep or cows grazing spring pasture. Thus, its possible role is unclear. However, There is a close and negative relationship between rumen pH and Mg absorption before the duodenum [57] and ruminal K (Na:K ratio) plus pH and Mg availability [43]. The reduced solubility of Mg in rumen content at higher pH values might be the reason for a potential effect of ruminal pH on Mg digestibility [50]. A fundamental relationship cannot be inferred from these studies, but they obviously indicate the significance of pH and Mg solubility in the rumen relating to Mg absorption. Besides, the putative Mg channel (TRPM7) exhibits a strong relationship to pH and is activated a pH of <7.0 in patch clamp studies [58].

## Fermentable carbohydrates (FC)

Metson et al. [59] has suggested a decline content of FC in the tetany-prone grass to be able to decrease Mg availability, and vice versa, the soaking of grazing dairy cattle with a starch solution increased blood Mg concentration [60] and the apparent digestibility of Mg [61,62] but did not constantly improve Mg absorption [63]. In the rumen fluid, the addition of FC causes (a) an increase in availability of short chain fatty acids (SCFA), (b) a lower rumen pH [62], which (c) increases Mg solubility [53], (d) a fall in NH4+ concentration, and (e) an increase in the number & size of papillae of rumen papilla and the absorptive surface area of rumen papilla [64] and hence the absorptive area for Mg [65]. Therefore, role of the addition of FC in improvement of apparent Mg digestibility is not surprising, but the underlying mechanisms cannot be deduced from conventional balance studies because of the simultaneous changes of parameters mentioned above. The accurate mechanism of the stimulation of Mg transport by short chain fatty acids or $HCO3^-/CO_2$ is unclear [66], but the PD-independent Mg transport is probably improved, because the depressive effect of K can be compensated by the addition of FC [67].

### Animal breeds

Animal breed has influence on digestibility of Mg in cows [68], so that true digestibility of Mg in Angus cows was higher than Hereford [69], and results have shown that Mg absorption from the rumen of sheep of different breeds exhibit differences [70]. Greene et al. [68] have found that Mg absorption is greater in Brahman than in Jersey, Holstein, and Hereford cows.

### Vitamin D

Factors controlling magnesium absorption are not well understood. Studies suggest a role for parathyroid hormone (PTH) in regulating magnesium absorption, but the role of vitamin D and its active metabolite 1,25-dihydroxyvitamin D is more controversial. PTH and Vitamin D3 are two major regulators of Ca metabolism. PTH being a major stimulator of vitamin D3 synthesis in the kidney while vitamin D exerts negative feedback on PTH secretion which together with PTH represent the signal cascade for the regulation of blood Ca by increased absorption from the intestine, decreased excretion via urine, and by bone formation or resorption [71]. Interactions between PTH and calcitriol and Mg were confirmed by [72,73], but the results are, in some cases, contradictory.

## Clinical Signs

Incidences of grass tetany can be characterized as acute, sub-acute, or chronic. In acute cases, the animals are generally found dead. If the animal is discovered alive, clinical signs may include excitability, twitching, ear flicking, aggressiveness, abnormal gait, vocalization, convulsions, and froth from the mouth and nose. Their body temperature begins to rise and their heart beats louder and faster. Death generally occurs within 1 h of the onset of symptoms [74]. In sub-acute cases, animals remain standing and signs develop over a period of a few days and include abnormal gait, excessive blinking, decreased feed intake, weight loss, and decreased milk production. The sub-acute form, if not treated, can also result in death. Lastly, in the chronic form of grass tetany, animals may exhibit unthriftiness, weight loss, and decreased milk production [75].

## Diagnosing Grass Tetany

The diagnosis of grass tetany is difficult because the cow usually dies before any determination can be made. Immediately before clinical signs are seen, serum Mg levels will be low. As symptoms progress, serum Mg levels may rise to near normal levels. A better diagnostic method is the measurement of urinary Mg because the kidneys will begin storing magnesium when serum Mg levels become insufficient [1].

Grass tetany is sometimes mistaken for other metabolic disorders in cattle. Because of its symptoms, hypomagnesaemia can be misdiagnosed as ketosis or milk fever; however, animals that are deficient in Ca will generally appear sluggish, whereas Mg deficient animals will exhibit excitability [76].

Samples from live cows are poor predictors of clinical hypomagnesaemia. Serum magnesium usually lies in the range 0.74-1.44 mmol/L (normal magnesium reference range Regional Laboratory Services Benalla) although Parkinson et al. [77] regards the normal range as between 0.6 and 1.1 mmol/L. Not all cows with serum Mg below 0.74 mmol/L show clinical signs. Radostits et al. [78] note some cows with serum magnesium as low as 0.16 mmol/L fail to show clinical signs, but signs of tetany usually occur when serum Mg falls below 0.5 mmol/L [78] or 0.4 mmol/L [77]. The latter suggest supplementation of cows with a mean serum Mg concentration below 0.63 mmol/L will usually prevent clinical grass tetany in the herd.

The diagnosis of subclinical hypomagnesaemia can be made by measuring total concentration of plasma magnesium, where 0.74 mM has been suggested to be a cut-off point [79]. However, some authors suggest that total magnesium in plasma is not always decreased at magnesium deficiency, and that the ionised magnesium level in plasma provides a more accurate measure of the magnesium status [80]. Urine sampling and the determination of magnesium concentration has been suggested as a simple way of determining magnesium status in cows [79], and has been shown to be linearly related to magnesium uptake [8]. The cut-off point for urinary magnesium excretion indicating sufficient magnesium supply has been set at 2.5 g per day [45,81] or 0.1 g per litre [79]. Mustering and handling of cattle for collection of blood or urine samples may precipitate grass tetany in susceptible cows, and may be impractical when many cows in the mob have young calves at foot. In human medicine, subclinical hypomagnesaemia is associated with diabetes, metabolic syndrome and cardiovascular disease [82,83], and may also have a negative impact on the ability to cope with hypocalcaemia, since adequate magnesium level is important for both the excretion of parathyroid hormone [84] and the tissue responsiveness to parathyroid hormone [85].

Hypomagnesaemia commonly occurs as a result of impaired magnesium absorption, and may be exacerbated if the animal is stressed, e.g. due to weather conditions or transportation. Magnesium transport between the extracellular and intracellular compartment is affected by stress [86], e.g. adrenaline, decrease plasma magnesium level. Increases in insulin levels in plasma are also associated with decreases in the concentration of plasma magnesium, and the rapid change in plasma magnesium level has been suggested to be caused by movements of magnesium ions from the plasma to the cells [87]. Clinical hypomagnesaemia, in contrast to milk fever, also occurs in beef cows and, as it is associated with dietary factors and sometimes external stressors, it may affect several cows in a herd at the same time [88].

Hypomagnesaemia is stressful syndrome resulted in exhaustion and disturbance in glutathione redox cycle and antioxidant because Mg is important Co-factor for many enzymes of normal healthy life chemical reactions and major factors for defense against oxidant radicals [89].

## Treatment Options

Treatment of grass tetany involves removal from the pasture and increasing blood serum levels of Mg. A treatment method that has been suggested by the USDA is a dose of 200 ml of a 50% solution of magnesium sulfate, injected subcutaneously. The injection will increase the level of Mg in the blood rapidly in only 15 minutes. Another method is an intravenous injection of calcium-magnesium gluconate; however, it is recommended that an injection of chloral hydrate or magnesium sulfate be given intravenously prior to treatment to calm the animal. Intravenous injections of these solutions must be given slowly by a trained person to prevent cardiac arrest. Heart and respiratory rates should be monitored closely during treatment. After serum Mg levels are increased, the animal should be continued on a diet high in Mg to prevent relapse. Also, approximately 30 grams of Mg sulfate should be given daily. Cows that have grass tetany are more likely to get it again later in the season or in future years [15]. Rapid

treatment to restore blood magnesium is essential. However, Oral treatment with 100 gm Causmag or Epsom salts are highly effective methods of supplying additional magnesium, and should also be given as relapses can occur after a few hours, and start feeding the cow hay and Causmag as soon as possible after she recovers to improve magnesium absorption from the rumen [90].

Some factors may predispose cattle to developing grass tetany. They include the age of the cow, breed, amount of milk being produced, time of calving, and stress. As cows age, the level of Mg and other minerals that are absorbed through the rumen are decreased [91]. In addition to age, researchers have determined that Angus and Angus crosses are more susceptible then other breeds because they are naturally poor absorbers of Mg. Host factors, such as decreased feed intake, a magnesium deficient diet, lactation, and altered absorption, lead to the depletion of intracellular magnesium levels and, eventually, serum magnesium [8,92,93].

Also, because minerals and nutrients are removed through the production of milk, high producers are susceptible to hypomagnesaemia and grass tetany. In addition, the time in which cows calve is important because grass tetany generally occurs in the early spring months. If a cow is placed on pasture during this time and has recently calved, it places the cow (and calf if she is nursing) at greater risk. Lastly, stress (both environmental and physiological) predisposes animals to a variety of conditions by impugning immune function and increasing susceptibility to disease [3].

## Prevention and Management Options

Prevention is the key to successfully handling this condition, as therapy is oftentimes not rewarding. Prevention of hypomagnesemia should be aimed at 2 major goals: continuous provision of adequate levels of magnesium in the diet and maximizing absorption of this essential mineral. Possible choices of supplemental salts include magnesium carbonate, magnesium sulfate, and magnesium chloride, but magnesium oxide (MgO) tends to be the most common choice, based on economics, palatability, and fewer laxative effects than the other options [94].

These measures are especially important when moving from normal winter rations to a young spring grass pasture, and in lactating cows [88], and the Nor For recommendations are to use feedstuff during the dry period that have a lower contents of potassium than 25 g/kg DM to reduce the risk of interfering with magnesium absorption [95].

Prevention can be accomplished several ways. One method to minimize risk is to delay turnout until the forage is more mature and is past the rapid growth stage (at least 6 inches tall). Delaying turnout also will reduce early-season grazing pressure on range and pastures, allowing soil moisture to be used efficiently to produce as much grass as possible for later in the grazing season [96].

Grass tetany is easily preventable. Analysis of forage should be performed prior to grazing dairy cattle if there is a history of grass tetany in the animals or on the pasture. Potassium is mostly located in the intracellularly compartments, playing a synergistic role with sodium in cellular activity. Measuring the mineral components of plant leaves would seem to be the best way to measure imminent danger periods. However, this creates two challenges [97]. Challenge 1-The change from safe to potential hazard occurs rapidly over a number of days. Sampling and analysis usually takes about a week so by the time the results of the analysis are received often the danger period is past. Challenge 2-Results from plant analysis must be converted to a form that can be used in the $K^+/(Ca^{++} + Mg^{++})$ grass tetany hazard ratio K/(Ca+Mg) ratios of plant species ranged between 0.63 (Lasiurus Sindicus) to 0.95 (Cencherus Ciliaris). It is recommended that K/ (Ca +Mg) ratio of forages should be below 2.20 [98]. The K/ (Ca+Mg) ratios over 2.20 may cause grass tetany in especially cool seasons. K/(Ca+Mg) ratios of all species were found below 2.20.

Example calculation: Say a plant has 3% $K^+$, 0.2% $Ca^{++}$ and 0.2% $Mg^{++}$, which would represent a typical young grass in post drought conditions. 3% $K^+$=30 g $K^+$/kg dry matter, divided by its atomic weight (39.0983 g/mole), =0.767 moles $K^+$/kg dry matter. $K^+$ has a valence of 1 so=0.767 eq K/kg dry matter. Similarly 0.2% $ca^{++}$=2 g $ca^{++}$/kg dry matter divided by its atomic weight (40.078 g/mole),=0.05 moles $ca^{++}$/kg dry matter multiply by valence of 2=0.1 eq $ca^{++}$/kg dry matter. Similarly Mg 0.2% $Mg^{++}$=2 g $Mg^{++}$/kg dry matter divided by its atomic weight (24.305 g/mole)=0.082 moles $Mg^{++}$/kg dry matter multiply by valence of 2=0.165 eq/kg dry matter.

Now to our grass tetany hazard ratio: K/(Mg+Ca)=(0.767/(0.1+0.165))=2.89 which is a worry as it is >2.2. This method must be used for accurate plant leaf hazard determination for grass tetany.

Based on the previous example: Say a plant has 3% K+, 0.2% Ca++ and 0.2% Mg++, Now to our grass tetany hazard ratio: (3which is a worry as it is >2.2. This method must be used for accurate plant leaf hazard determination for grass tetany.

Soil tests can be carried out prior to crops/grasses being grazed and the danger evaluated prior to animals grazing that area. The soil tests are usually in milliequivalents per 100 g which need no complex conversions (conyers. M-pers. com. 2002). Simply, the soil tests in milliequivalents can be put straight into the K/(Mg + Ca) ratio and then compared to range K/(Mg + Ca) soil risk (>0.09 Dangerous, 0.08-0.09 Hazardous, 0.07-0.08 Critical, 0.06-0.07 Marginal, <0.08 Safe) [97].

If possible, fertilizers that are high in nitrogen and potassium should be avoided. When cattle consume forage high in nitrogen, a substantial amount of ammonia is produced in the rumen. If there is a large amount of ammonia present, dietary Mg may be converted to the unfavourable, insoluble hydroxide form. This lowers the availability of Mg in the blood and tissues [1]. Cows depend on a frequent supply of magnesium from the feed since mobilization of magnesium from the bone is not very efficient [99]. Check the calcium (C) to phosphorus (P) ratio (2:1 is optimum), and energy intake (maintenance or above is desired) of the animal. Grass tetany may be less likely to occur when these factors are near optimum [100].

Fertilizers that may be applied to raise Mg levels of the soil include dolomitic or high Mg limestone, which contains 12-13% of actual Mg [101]. Dolomitic limestone is generally used when the soil pH is low. If the soil has a high pH, pastures can be dusted with a mixture of fertilizer containing magnesium oxide (MgO) [76]. Dusting the pasture with MgO is an effective method of increasing levels of Mg in the soil and subsequently, the animal; however, the solution is not very palatable. Filley [102] suggests mixing MgO with dry molasses to make it more appealing to cattle. Magnesium does not have to be added to the pasture, but can be supplemented directly into the diets of cattle, also in the form of MgO. Magnesium oxide is most effective when diluted (300 g/L of water), added to hay, and fed at a rate of 1 bale/10 cows [103].

Salt-mineral mixes and molasses licks or blocks are the most common methods that are successful. Molasses used in California often contains a large percentage of beet molasses, which is relatively high in Mg. Some of the molasses supplements are excellent sources of Mg and aid in the prevention of Grass Tetany. Some molasses supplements contain urea, which breaks down to $NH4^+$ in the rumen and will increase the risk of Grass Tetany. Make certain the molasses supplement you but will help your situation, not make it worse [104]. Magnesium oxide can also be mixed with salt and fed directly to cattle ad libitum. The salt increases the palatability of MgO as well as increases the sodium level in the blood. Suggested mixture is 75% salt to 25% MgO [1]. It has been shown that the balance of these two minerals may also help to increase the absorption of magnesium through the rumen [105]. Magnesium can also be added to drinking water in the form of magnesium sulfate (Epsom salts) at a rate of 3.0 g/L. Magnesium sulfate is also not very palatable and water intake needs to be monitored to ensure that dehydration does not occur. Also, if too much magnesium sulfate is consumed, the animal may develop scours [3].

New advances in plant development have led to the production of a variety of tall fescue grass that is high in Mg (HiMag). The plants are also free of endophytes which can decrease weight gain and cause reproductive problems in cattle. It was found that the HiMag variety contained 22% more Mg than normal endophyte-free varieties of tall fescue (Au Triumph, Kentucky-31, Martin, and Mozark) as well as 18.5% more Ca and 9% more P. When calculating the risk of this forage causing grass tetany, the tetany ratio was 1.34 (>2.2 is considered a high-risk level for developing grass tetany). The other varieties averaged 1.65, which was still below the threshold for causing grass tetany [106].

Perhaps the easiest method of prevention is simply not grazing lactating or high risk cows on grass tetany “hazard” pastures and reserving the land for other livestock such as steers or dry cows. Instead, legume hay or high-legume pastures would provide a safer alternative for these animals. Not only is it safer for the cow, but because legumes are more digestible than grasses, it is likely that lactating cows will produce more milk (6-10 lb) when grazed on a legume stand. Another incentive is that when managed correctly, a legume pasture will produce just as much forage as a grass stand [101].

## Conclusion

Grass tetany is a serious, yet preventable disease caused by severely low levels of Mg in the blood. It can strike cattle at an alarmingly fast rate (acute form), which makes detection and treatment often difficult. Because of its rapid onset and its ability to cause death, it is best to try, and prevent grass tetany, rather than treat it. Prevention involves either raising levels of Mg in the forage when cows are on pasture or feeding Mg supplements as part of a ration. With a good management program and regular forage testing when grazing lactating dairy cows, grass tetany and other diseases caused by mineral diseases can easily be prevented.

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