Calcium and Magnesium Physiology and Nutrition in Relation to the Prevention of Milk Fever and Tetany (Dietary Management of Macrominerals in Preventing Disease)

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KEYWORDS

• Calcium • Magnesium • Hypocalcemia • Hypomagnesemia • Milk fever • Tetany • Adaptation • Prevention

KEY POINTS

- Calcium and magnesium play similar and distinct roles in physiology as divalent cations in extracellular or intracellular compartments, respectively. As nutrients they are differently regulated, but still share enough common characteristics to be best understood together. Dairy cows may suffer events of hypocalcemia and hypomagnesemia, commonly known as milk fever and tetany.
- Milk fever is a nonnutritional, nondegenerative production disease, characterized by hypocalcemia at parturition as a consequence of a sudden increase in Ca demand and an unavoidable delay in Ca metabolism adaptation.
- Tetany is due to impaired Mg absorption from the rumen that cannot be compensated by absorptive or excretory adaptation, resulting in a net nutritional shortage of Mg, culminating in hypomagnesemia.
- Gastrointestinal and renal transepithelial transport mechanisms of Ca and Mg play key roles in the etiology of milk fever and tetany. Prevention strategies require triggering activation of Ca gastrointestinal absorption and avoiding factors limiting ruminal Mg absorption.

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- Milk fever prevention strategies have focused on adaptation of Ca metabolism by challenging Ca balance weeks before parturition, either by reducing nutritional Ca availability or by inducing hypercalciuria with a lower dietary cation-anion difference. Oral Ca supply at calving can be complementary to adaptation strategies, whereas the standard use of intravenous Ca infusions may be detrimental. Assurance of high Mg supply is a prerequisite to preventing milk fever.
- Prevention of tetany should focus on supporting nutritional Mg supply by avoiding low Mg intakes, high K intakes, insufficient Na supply, and sudden dietary changes, especially those affecting rumen ammonia concentrations.

INTRODUCTION

Calcium and Magnesium Homeostasis, a Priority at Cellular and Animal Levels

Calcium (Ca) and Magnesium (Mg) are nutritionally essential minerals that present obvious elemental similarities given their proximity in the periodic table. This proximity confers sometimes analogous and at other times complementary roles in biology, the most evident being that Ca is the divalent extracellular cation while Mg is the intracellular one. Many cell functions need to be preserved by accurate regulation of these cations, and this is in both cases achieved by regulation of gastrointestinal absorption, renal reabsorption, and exchange with bone tissue.[1]

At both the animal and cellular levels, Ca is precisely controlled. Cells maintain very low ionic Ca by the expression of membrane Ca channels and complexation with proteins.[2] In the extracellular compartments, Ca is kept at constant levels to help cellular Ca regulation to sustain physiologic functions for which Ca is required, while managing Ca reserves and its skeletal function. An adult cow contains about 10 kg of Ca, of which 98% is in its bones, the rest being in the extracellular compartments.

Magnesium takes part in many functions such as activation of enzymes,[3] modulation of channels,[4] and bone formation.[5] A dairy cow with a body weight of 700 kg has a total amount of Mg of some 450 to 500 g. Most of the Mg is found in bones (60%–70%), the rest being located in intracellular spaces. Only about 1% is found in the extracellular space including the blood.

HYPOCALCEMIA AND HYPOMAGNESEMIA IN DAIRY COWS

Despite the importance of homeostatic control of these minerals, dairy cows often suffer from production diseases based on events of Ca and Mg dyshomeostasis. Causes and consequences of these negative fluctuations in blood Ca and Mg concentrations are different, but they share some fundamental characteristics and are better understood together.

Hypocalcemia

Breeding dairy cattle for production has generated milk yields severalfold greater than requirements of the offspring, which creates a unique physiologic condition, a discontinuity between Ca utilization for fetal growth and milk production.[6] Parturition requires redirection of Ca transfer from cow-to-calf to cow-to-mammary-gland, which nondairy cattle breeds and other mammals seem to cope with without problems. Dairy cows suffer from a very large and sudden increase of Ca clearance from their blood, and for this reason most of them develop some degree of hypocalcemia.