Magnesium Disorders in Horses

Allison J. Stewart, BVSc (Hons), MS

KEYWORDS

• Hypomagnesemia • Hypermagnesemia • Calcium • Alkalosis
• Parathyroid hormone

Magnesium (Mg) is an essential macroelement that is required for cellular energy-dependent reactions involving ATP, including ion pump function, glycolysis and oxidative phosphorylation, and nucleic acid and protein synthesis. Mg has an important role in the regulation of calcium (Ca) channel function and therefore neurotransmitter release, neuronal excitation, skeletal muscle contraction, vasomotor tone, and cardiac excitability. Because of the importance of Mg in several physiologic processes, homeostatic mechanisms normally maintain intracellular and extracellular concentrations within narrow limits. Severe Mg deficiency results in neuromuscular disturbances, but such overt clinical signs are rarely documented in horses. In contrast, subclinical hypomagnesemia is common in critically ill humans and animals. Subclinical hypomagnesemia increases the severity of the systemic inflammatory response syndrome (SIRS); worsens the systemic response to endotoxins; and can lead to ileus, cardiac arrhythmias, refractory hypokalemia, and hypocalcemia.

CHEMISTRY

Mg concentrations in body fluids are reported as mEq/L, mg/dL, or mmol/L. Because the atomic weight of Mg is 24.3 and its valence is 2^+, 1 mEq (0.5 mmol) = 12.156 mg. The conversion factors are as follows:

mg/dL = mmol/L $\times$ 2.43
mmol/L = mg/dL $\times$ 0.411
mmol/L = mEq/L $\times$ 0.5
mg/dl = mEq/L

Dietary Mg levels are reported in g/kg of feed, in parts per million (ppm), which is expressed as mg/kg = g/kg $\times$ 1000 or as a percentage, by dividing by 10. Oral Mg is commonly available as magnesium oxide (MgO), MgO_x, which contains 60.25% elemental Mg. Magnesium carbonate ($MgCO_3$) and magnesium sulfate ($MgSO_4$) can also be fed. $MgSO_4$ for intravenous (IV) injection is commercially available as

Department of Clinical Science, John Thomas Vaughan Large Animal Teaching Hospital, College of Veterinary Medicine, Auburn University, 1500 Wire Road, Auburn, AL 36849, USA
E-mail address: stewaaj@auburn.edu

Vet Clin Equine 27 (2011) 149–163
doi:10.1016/j.cveq.2010.12.009 **vetequine.theclinics.com**
0749-0739/11/$ – see front matter

$MgSO_4 \cdot 7H_2O$ in a 50% solution. Although the $MgSO_4$ compound contains 20.2% elemental Mg, its solution contains only 9.9% elemental Mg. Each mL of 50% $MgSO_4 \cdot 7H_2O$ solution contains 99 mg (8 mEq = 4 mmol) of elemental Mg. The 50% solution (500 mg/mL = 4 mEq/mL) is hypertonic, with an osmolarity of 4000 mOsm/L and should be diluted to at least a 10% solution before IV administration.

MG DISTRIBUTION WITHIN THE BODY

Mg is the fourth most abundant cation in the mammalian body and the second most abundant intracellular cation after potassium. The body of domestic animals contains 0.05% Mg by weight, of which 60% is in bones, 38% is in soft tissues, and 1% to 2% is in extracellular fluids. Only 30% of the bone Mg is readily exchangeable and therefore available as a reservoir to maintain extracellular Mg concentrations. The remaining 70% of bone Mg has structural functions and is held within the hydroxyapatite lattice and released only during active bone resorption. Although most soft tissue Mg is in the intracellular compartment, intracellular and extracellular ionized Mg (Mg^{2+}) concentrations are similar, with only a very small transmembrane gradient compared with calcium ions (Ca^{2+}). Intracellular Mg^{2+} concentrations are variable, being proportional to the metabolic activity of the cell.

Less than 1% of the total body Mg is contained in the extracellular fluid, therefore serum Mg concentration may not adequately reflect the total body Mg stores. In equine serum, 30% of Mg is protein bound and 10% is complexed to weak acids, with the remaining 60% in the ionized form (Mg^{2+}).[1,2] Only the ionized form is biologically active, therefore it is preferable to measure the concentration of the ionized form in the serum rather than the total Mg (tMg) concentrations. Red blood cells contain approximately 3 times the concentration of Mg in serum; therefore hemolysis can elevate measured serum Mg concentrations.

The serum tMg concentration depends on the protein concentration, whereas the Mg^{2+} concentration depends on the acid-base status. Acidosis increases the Mg^{2+} concentration, whereas alkalosis reduces it. This property is clinically important when treating alkalotic conditions, such as exercise-associated metabolic alkalosis in endurance horses resulting from chloride loss, nasogastric reflux associated with small intestinal obstruction, or duodenitis/jejunitis and respiratory alkalosis associated with hyperventilation. Clinical signs of hypomagnesemia can develop because of low concentrations of Mg^{2+} despite normal tMg concentrations. Feeding an acidic diet with a low dietary cation-anion balance will increase the percentage of Mg^{2+}.[1]

PHYSIOLOGIC ROLE OF MG

Mg serves as an essential cofactor for more than 300 enzymatic reactions involving ATP, such as replication, transcription and translation of genetic information, and cellular energy metabolism reactions of glycolysis and oxidative phosphorylation.[3,4] Mg is necessary for membrane stabilization, nerve conduction, ion transportation, regulation of Ca channel activity, and normal functioning of the sodium-potassium–activated ATP (Na^+/K^+ ATPase) pump, which maintains the Na^+/K^+ gradient across all membranes as well as regulates the intracellular K^+ balance.[5] Ca ATPase and proton pumps also require Mg as a cofactor. Consequently, Mg plays an important role in excitable tissues. Defective function of ATPase pumps and ion channels may result in interference with the electrochemical gradient, alteration in resting membrane potential, and disturbances in repolarization, resulting in neuromuscular and cardiovascular abnormalities.[4,6–8] Mg's role in the regulation of movement of Ca into the