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Magnesium Deficiency and Cardiac Dysrhythmia

9.1. Electrocardiographic Changes of Experimental Magnesium Deficiency

In the early subacute magnesium-deficiency study of Kruse et al. (1932), convulsions were produced in 86% of the rats by the 18th day, with death occurring after one or more convulsions in 93%. Tachycardia was manifest during the preconvulsive period, and bradycardia with marked arrhythmia just before the convulsions started. Greenberg and Tufts (1938) confirmed these findings, and showed additionally that ECGs, taken while the rats were unconscious from the convulsive seizures, revealed a sinoauricular block, with occasional skipped and ventricular beats. Of 10 rats with less severe magnesium deficiency, such that despite manifest nervousness only one developed convulsions, seven survived long enough to have ECGs recorded the day before sacrifice on day 62. These rats exhibited little change in heart rates (which were slightly slower than were those of control rats on the same diet to which magnesium had been added) but had lengthened P-R intervals. Five of the seven surviving deficient rats had additional ECG abnormalities: Three had numerous extrasystoles, two had abnormally high takeoff of the ST segment in lead III, one with partial heart block and one with auricular extrasystoles.

Production of magnesium deficiency (average serum magnesium = 0.4 mEq/liter) in young dogs, with a diet similar to that used by Kruse et al. (1932), produced no significant difference from control heart rate (Syllm-Rapoport et al., 1962). There was a highly significant shortening of the atrioventricular conduction time (P-Q interval) and of the intraventricular conduction time (QRS in Lead II). There was some prolongation of the electrical systole (QT interval). There was an increased incidence of negative T waves in leads I, II, and III that was statistically significant in lead III. The voltage of the negative T waves in leads I, II, and III was statistically significant in lead III. The voltage of the negative T waves in leads I and II was almost half that of controls. Striking inversion of the T waves was
seen in several of the deficient animals. Comparably severe magnesium deficiency, produced with a semisynthetic diet, and that produced severe hypomagnesemia (< 0.5 mEq/liter), but no significant effect on serum potassium or calcium), and that caused arterial and multifocal myocardial lesions, was also associated with ECG abnormalities (Wener et al., 1964). These dogs developed sinus tachycardia, but little difference from control PR, QT, or QRS intervals. There was frequent occurrence, as in the previous group of dogs, of T-wave abnormalities: flattened or inverted T waves, especially in leads III, aVL, and V. They also had consistent RST-segment depression.

Subacute magnesium deficiency for three months in puppies that resulted in irritability and occasional convulsions also resulted in marked sinus tachycardia, peaking of the T waves, and ST-segment depression (Vitale et al., 1961). These dogs also became more susceptible to digitalis toxicity. These investigators pointed out the relationship of these ECG changes to the magnesium-induced shift in potassium. Although the magnesium-deficient dogs also developed hypokalemia, Vitale et al. (1961) referred to the loss of intracellular potassium that results from magnesium-deficient interference with mitochondrial enzymatic activity. They speculated that there might be a relatively greater decrease in intracellular than plasma potassium with a relative hyperkalemia. In support of this premise, was the peaked T wave of their magnesium-deficient dogs that resembled that seen in hyperkalemia. Ono (1962) confirmed these findings with young dogs maintained for four months on the same diet as used by Vitale and his co-workers (1961). He, too, found peaking of the T waves, especially in lead VR, when the serum magnesium levels decreased to 0.7 mEq/liter, with concomitant falls in serum potassium. Depression of the ST segment in limb or chest lead appeared with serum magnesium levels below 0.8 mEq/liter. The P-R interval increased slightly as the hypokalemia worsened. The Q-T interval remained almost normal. There were also occasional premature contractions. Comparable changes were produced by magnesium deficiency in monkeys (Vitale et al., 1963), except for bradycardia and elevated ST segment in severely deficient monkeys. The peaking of the T waves and the ST segment changes were comparable to those seen in hyperkalemia, even though the animals had hypokalemia. This group then tested their original postulate that there might be a local relative hyperkalemia (of the extracellular/intracellular potassium concentration) in the magnesium-deficient heart (Seta et al., 1965, 1966). Rats fed diets low in both magnesium and potassium had substantial reductions in myocardial potassium and magnesium levels. Rats on a low magnesium, adequate potassium intake had almost normal serum potassium level, but markedly subnormal myocardial potassium (Seta et al., 1965), supporting the premise that the hyperkalemia-like ECG of relatively early magnesium deficiency reflects local relative hyperkalemia. Electrocardiographic changes were observed at two-week intervals: T-wave peaking developed within two weeks of instituting the magnesium-deficient diet (best seen in the left precordial unipolar lead). QRS widening and tachycardia were additional early changes (Seta et al., 1966). ST segment depression, ventricular premature beats, and bigeminal rhythm were also seen in some of the dogs. The ECG changes of dogs deficient in both magnesium and potassium resembled those of potassium deficiency, but the terminal T-wave inversion was more marked. The P-