EFFECT OF ORAL POTASSIUM AND SODIUM CHLORIDE ON PLASMA COMPOSITION OF CATTLE: A GRASS TETANY RELATED STUDY

K. C. SCOTTO, V. R. BOHMAN AND A. L. LESPERANCE
University of Nevada, Reno 89507

MANY factors have been implicated in the etiology of grass tetany including hypomagnesemia, hypocalcemia, class of animal, stage of production and various dietary factors. Hypomagnesemia has been the most consistent clinical symptom. Elevated levels of dietary potassium (K) (Kunkel, Burns and Camp, 1953; Ward, 1966a) and nitrogen (Redmond, 1950; Metson et al., 1966) have lowered plasma magnesium (Mg). Studies by Burt and Thomas (1961), Burau and Stout (1965) and Stout, Brownell and Burau (1967) have suggested a possible role of plant organic acids (namely citric and trans-aconitic) in the development of the tetany syndrome. An experimental tetany resembling grass tetany has been induced by Bohman et al. (1969) by the oral administration of trans-aconitic or citric acid plus potassium chloride (KCl). This tetany responded to intravenous treatment with calcium (Ca)—Mg gluconate.

The purpose of this study was to measure at various intervals the effect of KCl and sodium chloride (NaCl) on plasma citric acid and certain cations associated with grass tetany. Since splenectomized cattle failed to respond to intravenous Ca-Mg gluconate when tetany was induced in earlier studies (Bohman et al., 1969), a second objective was to ascertain if the blood composition of these animals differed from intact cattle under similar conditions related to tetany.

Experimental Procedure

Experiment I. Eight yearling cattle of mixed breeding averaging 221 kg, live weight, were allocated to 2 blocks of a 4 x 4 latin square design. Splenectomized cattle were used in one block and intact animals in the other. The time interval between treatment periods was 1 to 2 weeks. Each animal received 53 g citric acid and either 0, 40, 80 or 160 g KCl per 100 kg body weight. Treatment sequences were allotted randomly. The citric acid and KCl were suspended in water and administered once each period within a minute via stomach tube immediately after the initial blood sample was taken.

Serial blood samples were taken initially (prior to drench) and at 1/2, 1, 2, 4, 8 and 24 hr. after administration of the drench. Blood samples were obtained by venipuncture of the right jugular. Blood was drawn into 50 ml heparinized centrifuge tubes which were then tightly capped and cooled to 40°C. After the 24-hr. bleeding interval, all blood samples for a particular experimental period were centrifuged. The plasma was transferred into 25 ml pyrex test tubes and immediately frozen for laboratory analysis. Studies with both blocks were conducted at the same time.

Plasma samples were analyzed for citric acid, Ca, Mg, K and sodium (Na). Plasma citric acid was determined by a method of Natelson (1961) except 2 ml of plasma with proportionate amounts of reagents were used and the oil-bath step described in the clinical method was omitted. Plasma Ca was determined by the Clark-Collip modification of the Kramer-Tisdall method which involves precipitating the Ca as oxalate and titration with permanganate (Hawk, Oser and Summerson, 1954). Concentrations of Mg, K and Na in the plasma were determined by atomic absorption spectroscopy by the use of a Beckman DU spectrophotometer with an atomic absorption accessory.

Experiment II. Four intact animals averaging 242 kg were randomly assigned to a 4 x 4 latin square. Each animal received 53 g of citric acid per 100 kg body weight, as in the previous experiment, and either no salt, 80 g KCl, 63 g NaCl (to supply the number of cations equivalent to 80 g KCl) or 80 g KCl+63 g NaCl. Treatments were again administered once in water by drenching immediately after the initial blood sample.

Serial blood samples were obtained initially and at 10, 20, 30, 45, 60 and 120 min. after treatment and 24 hr. later. Handling of blood
Results and Discussion

Experiment I. Plasma citric acid increased after oral administration of the citric acid-KCl slurry and reached a peak at ½ hr. post-administration (figure 1). At that time the concentration of citric acid in the plasma was 22, 130, 192 and 233% greater than initial levels for the respective treatments of 0, 40, 80 and 160 g KCl per 100 kg body weight. All cattle receiving KCl had significantly (P< .05) higher levels of plasma citric acid than their controls. In addition the splenectomized animals had 33% more plasma citric acid than the intact animals at this time interval. Table 1 compares initial and ½-hr. levels of plasma citric acid for both blocks. The initial levels are well within the normal range cited by Blosser, Niedermier and Smith (1951) who determined the mean level of 4.55 mg/100 ml on 83 analyses of bovine plasma with a range of 1.92 to 6.85 mg/100 ml with no significant diurnal variation in blood serum citric acid.

The failure of splenectomized animals to respond to treatment earlier (Bohman, 1969) may have been caused by the relatively greater concentration of citric acid in their blood. If higher levels of plasma citric acid form chelates with Ca and Mg (Stout et al., 1967), then the hypothesis is a tenable one. It is possible that the additional citric acid present in the blood of splenectomized animals influences response to Ca-Mg gluconate by complexing Ca and Mg as these salts are infused. It should be noted, however, that the amount of organic acid administered earlier was 157 g/100 kg body weight as compared to 53 g/100 kg in this study. Apparently the levels of plasma citric acid were modified in some unknown manner by the spleen. High levels of organic acids in the blood may be an important contributing factor to hypomagnesemia or grass tetany under some conditions. Stout et al. (1967) have suggested that any plant with 1% or more of trans-aconitic acid is considered likely to produce tetany in cattle. The usual, concurrent high levels of K, accentuate this possibility by increasing the levels of plasma citric acid as well as lowering plasma Mg.

At 8 and 24 hr. plasma citric acid for all animals was within the normal range but cattle receiving 160 g KCl/100 kg had significantly (P<.05) lower levels than the controls (no KCl). Except for the ½ and 1-hr. bleedings, significant (P<.05) animal differences occurred. Irrespective of these differences, all animals responded similarly to the experimental treatments. Blosser et al. (1951) have

### Table 1. Effect of KCl on Plasma Citric Acid

<table>
<thead>
<tr>
<th>KCl g/100 kg</th>
<th>0</th>
<th>40</th>
<th>80</th>
<th>160</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Type of animal</td>
<td>mg/100 ml</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>Intact</td>
<td>3.22</td>
<td>3.56</td>
<td>2.97</td>
<td>2.98</td>
</tr>
<tr>
<td></td>
<td>Splenectomized</td>
<td>3.09</td>
<td>2.73</td>
<td>3.02</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>3.16</td>
<td>3.15</td>
<td>3.00</td>
<td>2.94</td>
</tr>
<tr>
<td>1/2 hour</td>
<td>Intact</td>
<td>3.67</td>
<td>6.45</td>
<td>6.97</td>
<td>8.34</td>
</tr>
<tr>
<td></td>
<td>Splenectomized</td>
<td>4.04</td>
<td>7.97</td>
<td>10.52</td>
<td>11.24</td>
</tr>
<tr>
<td></td>
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<td>3.86</td>
<td>7.21</td>
<td>7.45</td>
<td>9.79</td>
</tr>
<tr>
<td>% increased</td>
<td>Intact</td>
<td>14</td>
<td>74</td>
<td>135</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>Splenectomized</td>
<td>31</td>
<td>192</td>
<td>248</td>
<td>288</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>22</td>
<td>130</td>
<td>192</td>
<td>233</td>
</tr>
</tbody>
</table>

* Values within rows with different superscripts are significantly different (P<.05).
also shown that highly significant differences in plasma citric acid occurs between animals.

According to Kennedy (1968) citrate and trans-aconitate disappear rapidly from the rumen. Results from this study support this conclusion. The rate at which citric acid appears in the plasma in these experiments indicates rapid absorption of this material from the rumen. In addition, results of this study indicate a rapid turnover or metabolism of citric acid, since plasma citric acid levels at 4-hr. post-administration were similar regardless of the amount of KCl received.

Figure 2 shows the effect of oral KCl on plasma K for both blocks. A direct relationship exists between the amount of KCl administered and plasma K. The relative increase for K was not as great as that of citric acid. At ½-hr. the concentration of K in the plasma was -2, 6, 15 and 30% greater than the initial levels for the respective treatments of 0, 40, 80 and 160 g KCl/100 kg body weight. The two higher KCl levels were significantly (P<.05) greater than the lower levels. Potassium is readily absorbed from the rumen and omasum (Ward, 1966a). Results from this study again appear to verify that phenomenon; although, on the higher levels of KCl, plasma K was sustained at increased levels for longer periods of time. KCl was administered as a slurry and the longer interval of high plasma K may reflect the rate at which KCl went into solution within the rumen. In previous studies (Bohman et al., 1969) crystals of KCl were always noticed within the rumen upon autopsy of cattle that died from induced tetany.

Both Ward (1966a) and Pickering (1966) refer to the ability of the ruminant to metabolize great amounts of K in the diet, excreting the K primarily in the urine. Plasma values of K at 24-hr. post administration averaged 23.5 mg/100 ml compared to a pre-treatment average for all animals of 24.0 mg/100 ml. Generally relatively high levels of K loading can be tolerated with cattle because of their ability to rapidly excrete this element (Pickering, 1966).

The highest average level of plasma K determined in this study was 33.9 mg/100 ml which occurred in animals that received the greatest amounts of KCl. Plasma K of about 60 mg/100 ml was toxic (fatal) in a cow given KCl at the rate of 50 g/100 kg body weight (Ward, 1966b). Animals in the current study received three times the quantity given by Ward, but did not demonstrate such high levels of plasma K. Ward (1966b) indicates that the state of hydration of animals may be an important factor since rumen water rapidly equilibrates with extracellular body water, including the plasma. It is likely that the animal used by Ward was more dehydrated than those used in this study.

Oral KCl also increased (P<.05) plasma concentrations of Mg, Ca and Na (table 2) during early intervals post administration. Calcium increased (P<.01) by about 1 mg/100 ml of plasma at the ½ hr. interval in animals receiving 160 g KCl/100 kg, but 4 hr. after drenching, treatments had no effect on plasma Ca, Mg or Na. While KCl modified plasma Ca, this element remained within the normal range (9.2 to 11.1 mg/100 ml) cited...
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by Blosser et al. (1951). Hypocalcemia has been noted (Custer, 1959; Marshak, 1959) in other grass tetany related studies. The results of this trial are compatible with those of Bohman et al. (1969).

Cattle receiving high levels of KCl had higher levels (P<.05) of plasma Mg at 1 hr. and lower (P<.05) levels of plasma Mg at 8- and 24-hr. post administration, although plasma Mg in animals receiving 160 g KCl/100 kg body weight was not considered hypomagnesemic (1.7 mg/100 ml) (Rook and Storry, 1962). These results complement the findings of Kunkel et al. (1953) and De Groot (1962) who determined that high dietary K decreased serum Mg.

Plasma Mg may not be a true reflection of the Mg actually available to the animal. If high K intakes decrease availability of ingested Mg (De Groot, 1962), and if citric acid forms chelates with Mg (Stout et al., 1967), then actual plasma Mg values may be misleading. The method used for analysis of plasma Mg in this study does not differentiate between complexed or ionized magnesium.

Tetany was induced in one splenectomized animal which received 160 g KCl/100 kg body weight. A blood sample taken at the onset of tetany (about 20-min. post administration) contained 13.3 mg citric acid/100 ml as compared to an average for both blocks at ½ hr. post administration of 9.29 mg/100 ml. The high plasma citric acid in this animal approaches that reported by Camp, Dollahite and Schwartz (1968) of 13.5 mg/100 ml plasma in sheep given a lethal dose of potassium trans-aconitate. Potassium, Mg and Ca increased during tetany as compared to initial preadministrative levels; Na was somewhat depressed. Treatment with Ca-Mg gluconate increased plasma Ca and Mg at the ½ hr. interval as expected. Treatment of this animal was followed by dramatic recovery; the animal did not relapse into tetany as Bohman et al. (1969) had observed with other splenectomized animals (the data from this animal were not included in the statistical analyses).

Experiment II. Generally, plasma citric acid reached a peak 20 to 30 min. post-administration (figure 3). Both KCl and NaCl increased plasma citric acid, but NaCl does not exert as much influence as KCl. The combination of KCl and NaCl does not appreciably raise citric acid above that level reached with KCl only, but the effect persists longer. These data suggest that the salts (KCl or NaCl) are not specific in their effect on plasma citric acid.

In early intervals post-administration plasma K was depressed in the animals when no KCl was given (figure 4), similar to Experiment I, but to a greater extent. Plasma K peaked at 23.4 mg/100 ml in 10 min. in those animals receiving only KCl. Those receiving KCl and NaCl averaged 26.3 mg/100 ml plasma K at 45 minutes. Plasma K was significantly higher (P<.01) for all animals receiving this element during the first 2 hr. after administration than the other two groups. In 24 hr. plasma K values for all animals were similar.

Plasma Mg was higher (P<.05) in early post-administrative periods for those animals receiving KCl. For example, at 60 min. with no K, plasma Mg was 2.29 mg/100 ml; with K, 2.48. Other time intervals were similar. Although not statistically different (P>.05), plasma Mg was intermediate for the cattle receiving NaCl or NaCl+KCl. Plasma Mg values of all animals were similar at the 120-min.
interval. Animals receiving only citric acid had the highest plasma Mg (2.60 mg/100 ml) at 24 hr. while the concentration of Mg in the plasma of animals receiving the combination of KCl and NaCl was the lowest (2.28 mg/100 ml).

Except for 10-min. post-administration, Na showed no difference due to treatment. The difference observed at the above time interval probably has little biological significance. The role of Na in the grass tetany syndrome has yet to be delineated.

Summary

Citric acid (53 g/100 kg body weight) was administered to two blocks of animals, one splenectomized and one intact, with 0, 40, 80 or 160 g KCl/100 kg body weight in water by stomach tube. In a second study animals received either no salts, 80 g KCl, 63 g NaCl or both KCl and NaCl with citric acid administered as before. A latin square experimental design was used with both studies. Serial blood samples were taken and plasma citric acid, Mg, K, Ca and Na measured.

Plasma citric acid increased and generally reached a peak ½ hr. after drenching, regardless of the treatment; the increase was related directly to the amount of salt administered. Within 24 hr. plasma citric acid was within the normal range. Oral KCl and/or NaCl increased plasma Mg, Ca and Na in early periods post-administration. Plasma K was depressed in early intervals in those animals receiving no salt or only NaCl. All plasma constituents were normal in 24 hours. Splenectomized cattle had higher levels of plasma citric acid post-treatment than intact animals.

Literature Cited


