Original Communications

Renal Excretion of Lactate and Magnesium in Alcoholism

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The magnesium deficiency syndrome, consisting of tremor, athetoid movements of the extremities, mental aberrations and convulsions accompanied by decreased serum magnesium content has been described repeatedly in chronic alcoholism.1,2 Although the production of this deficiency is not entirely clear and is undoubtedly influenced by diet and gastrointestinal loss, of particular significance is the demonstration by McCollister, Flink and Lewis3 that the urinary excretion of magnesium is increased following ingestion of alcohol. This is in striking contrast to the marked conservation of magnesium occurring in normal subjects on magnesium-deficient diets.4 Barker, Elkinton and Clark,5 studying the renal excretion of magnesium in man, noted a marked increase in magnesium excretion following lactate infusion. They suggested that soluble magnesium complexes formed by chelation in the renal tubules might prevent reabsorption of magnesium during the diuresis of magnesium following lactate infusion.

Lieber and associates6 have demonstrated that the oxidation of alcohol is accompanied by elevations of blood lactate levels. These factors pertinent to a hypothetical explanation of magnesium deficiency in chronic alcoholism have then been established, namely, that alcohol oxidation results in elevated plasma lactate levels, and increased lactate concentration is associated with diuresis of magnesium. Kalbfleisch et al.7 studied this problem during infusion of alcohol for a brief period of time and, while noting increased magnesium excretion, were unable to detect changes in lactate blood levels or lactate excretion. Because the response to prolonged and continuous alcohol ingestion may differ from that seen during acute intravenous infusions further investigation of this problem seemed warranted.

It was the purpose of this study to evaluate the excretion of lactate and magnesium in (1)

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normal subjects during and following the ingestion of alcohol, (2) alcoholic subjects admitted in acute intoxication, (3) hospitalized chronic alcoholics after ingestion of alcohol, and (4) both normal and alcoholic subjects following the intravenous infusion of lactate.

### MATERIALS AND METHODS

Chronic alcoholic patients admitted during acute alcoholic intoxication to the psychiatric ward of the Douglas County Hospital were studied in the following manner. An initial blood sample was taken immediately after admission and analyzed for lactate content by the method of Barker and Summerson, for magnesium content by atomic absorption spectrophotometry and for ethanol content by the method of Conway. Similar determinations were made 2 and 4 hours later. A timed urine specimen collected from initial emptying of the bladder on admission to the next spontaneous micturition was measured and the lactate and magnesium content determined. In this laboratory normal values derived from healthy subjects subsisting on their usual diet are serum magnesium 1.92 ± 0.16 mg. per cent, plasma lactate 14.0 ± 2.9 mg. per cent, urinary lactate excretion average of 3 mg. per hour (range 0.4 to 7.3 mg.) and 24 hour urinary magnesium excretion average of 5.8 mg. (range 1 to 11 mg.).

Six normal volunteer housestaff members were studied during and following the ingestion of alcohol. After adequate hydration, the bladder was emptied and the urine passed during the next 2 hours was collected. Following this control period, the subjects ingested alcohol (in the form of 86 proof whiskey mixed with water) for the next 4 hours. A control blood sample was analyzed for lactate and magnesium content prior to the ethanol ingestion and at 2 and 4 hours thereafter. Urine specimens were collected at the 2 and 4 hour intervals and during an 8 hour period following. Approximately 250 ml. of whiskey was ingested by each subject during this period.

![Correlation of magnesium and lactate excretion](https://academic.oup.com/ajcn/article-abstract/18/4/231/4787489)

**Fig. 1.** Correlation of magnesium and lactate excretion. Hourly magnesium and lactate excretion in ten acutely intoxicated alcoholic subjects indicating highly significant correlation.

The alcohol ingestion experiments conducted on hospitalized chronic alcoholic patients consisted of obtaining a 2 hour control urine specimen, following which the subjects ingested 90 cc. of 86 proof whiskey, and collecting a urine specimen 2 hours later. The excretions of magnesium and lactate during each period were measured. Blood lactate and magnesium levels were determined prior to the ingestion of alcohol and at the end of 2 hours.

The lactate infusion experiments were conducted according to the procedure described by Soffer et al. After obtaining a 2 hour urine specimen as a
control, 75 mg. per kg. of sodium lactate in a 14 per cent solution was infused rapidly and a second 2 hour urine specimen obtained. Serum magnesium and lactate levels were measured prior to the infusion of lactate and at the end of 2 hours.

RESULTS

Experiment I: Magnesium and Lactate Excretion in Acutely Intoxicated Patients

The mean serum magnesium and plasma lactate values, the blood alcohol concentration and the mean excretion of magnesium and lactate were determined in ten acutely intoxicated patients. For the entire group the serum magnesium values were similar to those found in normal subjects whereas plasma lactate and lactate excretion were increased (Table I). When the patients were subdivided according to the plasma lactate level (Table II), the blood alcohol and serum magnesium values were comparable whereas the excretion of lactate and magnesium in those with elevated plasma lactate levels greatly exceeded that of the group with normal levels of plasma lactate. Within the entire group of ten subjects, there was a significant positive correlation between urinary magnesium and lactate with one exception (Fig. 1). This subject had a serum magnesium concentration of 1.3 mg. per cent, which is well below the normal value 1.9 ± 0.2 mg. per cent for this laboratory. The rate of disappearance of alcohol from the blood stream in the patients with normal and elevated plasma lactate levels appeared identical (Fig. 2). This may be taken as presumptive evidence that the rate of alcohol metabolism is not significantly altered by the level of plasma lactate. The plasma lactate level failed to show correlation with the level of blood alcohol. These data comparing blood alcohol and plasma lactate levels are shown in Figure 3, and indicate that these factors are independent in this group of patients.

Experiment II: Ingestion of Alcohol by Normal Subjects

The mean plasma lactate levels and serum magnesium concentrations during the control period and at the end of the first and second 2 hour periods of alcohol ingestion in the normal male subjects are shown in Figure 4. Both

![Graph of Blood Alcohol vs Time](attachment:attachment.png)

**Fig. 2.** Alcohol metabolism in intoxicated patients. Comparing mean decrease in blood alcohol concentration in intoxicated subjects with normal and elevated lactate levels.

![Graph of Serum Lactate vs Blood Alcohol](attachment:attachment.png)

**Fig. 3.** Correlation of blood alcohol and lactate levels in intoxication. Area designated by vertical lines indicate normal plasma lactate values.

![Graph of Plasma Lactate and Magnesium](attachment:attachment.png)

**Fig. 4.** Blood lactate and magnesium levels during alcohol ingestion. Mean levels of lactate and magnesium and alteration during alcohol ingestion in six normal subjects.
lactate and magnesium levels increased at the end of the first 2 hours and returned toward the control value at the end of the second period. Values for the urinary excretion of magnesium and lactate in normal subjects during the 2 hour control period, the 2 periods of alcohol ingestion, and an 8 hour recovery period immediately following the completion of the alcohol ingestion appear in Table III. Both magnesium and lactate excretion increased during the 4 hours in which alcohol was ingested. This information is given graphically in Figure 5 in which it can be seen that the increase in magnesium and lactate excretion at the 2 and 4 hour periods of alcohol ingestion was significantly greater than during the control or recovery periods. There was a correlation between the magnesium and lactate excretion throughout the entire period and the coefficient of correlation was strongly significant (Fig. 6). Serum zinc and urinary zinc excretion failed to show any significant alteration during the period of alcohol ingestion.

Experiment III: Ingestion of Alcohol by Hospitalized Patients with diagnosis of Chronic Alcoholism

Eight patients were studied. Control values for the urinary excretion of magnesium and lactate were determined during a 2 hour period following adequate hydration. The patients then ingested 90 cc. of 80 proof whiskey and the urinary excretion of magnesium and lactate was determined during the following 2 hour periods. Because of the lack of correlation between magnesium and lactate excretion noted in the acutely intoxicated subject with low serum magnesium levels, eight additional patients were studied: four known to have low serum magnesium levels and four with normal levels. The alterations in magnesium and lactate following alcohol ingestion in these two groups is shown in Figure 7. As with acute intoxication the subjects with normal serum magnesium levels showed an increase in both magnesium and lactate excretion. Those with a greatly depressed serum magnesium level did not show further increase in magnesium excretion although the increase in lactate excretion was much greater.

Experiment IV: Lactate Infusion in Alcoholic and Normal Subjects

Seven normal subjects and six hospitalized chronic alcoholics were given 75 mg. per kg. of sodium lactate intravenously. Urine collections were made for 2 hours prior to and 2 hours following the infusion. Plasma lactate and serum magnesium levels were determined immediately before infusion and 1 hour later. The alcoholic and normal subjects did not differ significantly as groups and the data for lactate and magnesium excretion are combined in Table IV. Although lactate excretion was appreciably increased, relatively little change was noted in magnesium excretion. The correlation of magnesium and lactate excretion noted following alcohol ingestion was not duplicated by lactate infusion in this experiment. The increase in the excretion of lactate was comparable following alcohol ingestion and lactate infusion.

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Table III

<table>
<thead>
<tr>
<th>Period</th>
<th>Magnesium (mg/hr.)</th>
<th>Lactate (mg/hr.)</th>
<th>Volume (ml/hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hr. control</td>
<td>5.85 ± 4.0</td>
<td>3.75 ± 4.6</td>
<td>78 ± 50</td>
</tr>
<tr>
<td>Alcohol ingestion</td>
<td>10.3 ± 4.8</td>
<td>8.85 ± 4.6</td>
<td>410 ± 240</td>
</tr>
<tr>
<td>First 2 hr. period</td>
<td>13.3 ± 3.0</td>
<td>6.67 ± 3.2</td>
<td>370 ± 151</td>
</tr>
<tr>
<td>Second 2 hr. period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery 8 hr. period</td>
<td>3.9 ± 2.4</td>
<td>3.32 ± 1.5</td>
<td>70 ± 19</td>
</tr>
</tbody>
</table>

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Fig. 5. Urinary magnesium and lactate excretion following alcohol ingestion. Ingestion of alcohol in six normal subjects resulted in these mean levels of lactate and magnesium excretion.
Lactate and Magnesium Excretion in Alcoholism

COMMENTS

Although analysis of these data, as they pertain to lactate and magnesium excretion, is complicated by the variability of the experimental procedure, certain conditions appear warranted.

In the acutely intoxicated alcoholic patient good correlation was found between lactate and magnesium excretion. Furthermore, the increased lactate excretion appeared to be clearly associated with increased plasma lactate concentration. Alcohol ingestion in normal subjects was accompanied by increased plasma lactate levels, lactate and magnesium excretion also increased and there was good correlation between the two. The influence of serum magnesium levels themselves on the correlation of lactate and magnesium excretion indicates, as might be expected, that at low serum magnesium levels, augmented lactate excretion is not accompanied by increases in magnesium excretion. Perhaps of greater significance is the inability of the kidney to conserve magnesium despite evidence of marked magnesium depletion.

The absence of a concomitant increase in magnesium excretion with that of lactate following lactate infusion clearly negates the hypothesis that the two are directly related. It is noteworthy that the hourly excretion of lactate

**TABLE IV**
Effect of Lactate Infusion on Magnesium and Lactate Excretion

<table>
<thead>
<tr>
<th>Data</th>
<th>Normal (7)</th>
<th>Alcoholic (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.80 (1.61−2.05)*</td>
<td>1.88 (1.25−2.23)</td>
</tr>
<tr>
<td>Lactate</td>
<td>9−14</td>
<td>26−31</td>
</tr>
<tr>
<td>Urinary excretion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.1 (0.1−4.72)</td>
<td>2.1 (1.9−3.7)</td>
</tr>
<tr>
<td>Lactate</td>
<td>5.6 (0.5−24.7)</td>
<td>6.6 (0.8−21.0)</td>
</tr>
<tr>
<td>Lactate infusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.8 (1.4−5.2)</td>
<td>4.9 (1.7−6.0)</td>
</tr>
<tr>
<td>Lactate</td>
<td>27.3 (6.0−51.0)</td>
<td>64.0 (6.0−213.0)</td>
</tr>
</tbody>
</table>

* These figures represent the range.

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**Fig. 6.** Correlation of magnesium and lactate excretion in normal subjects following alcohol ingestion.

**Fig. 7.** Effect of alcohol ingestion on magnesium and lactate excretion in chronic alcoholic patients. The failure of alcohol to augment magnesium excretion when serum magnesium levels are depressed is illustrated.
was greater than found in normal subjects following alcohol ingestion and is comparable to that occurring in acutely intoxicated alcoholics with elevated plasma lactate levels.

It thus appears probable that the metabolism of alcohol is commonly associated with increased lactate and magnesium excretion through processes which are independent or indirectly related.

The inability to correlate the blood level of alcohol with elevations of plasma lactate noted in the acutely intoxicated patients suggests that some factor, other than the metabolism of alcohol then occurring, is involved in producing the increase in plasma lactate. The thiamine deficiency, the incidence of which is known to be high in alcoholics, may be important in this regard.

SUMMARY

A series of experiments in normal and alcoholic subjects following alcohol ingestion and lactate infusion indicates that good correlation of lactate and magnesium excretion is found following alcohol ingestion when the serum magnesium level is normal. Marked depression of serum magnesium levels in the alcoholic appears to limit the magnesium excretion following alcohol ingestion although lactate excretion is increased. Lactate infusion produces little change in magnesium excretion but does produce increases in lactate excretion comparable to that following alcohol ingestion. It is concluded, therefore, that although elevated levels of plasma lactate and increased excretion of magnesium and lactate are commonly associated in alcoholism they are not directly related.

REFERENCES