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# CEREBROSPINAL FLUID MAGNESIUM CONCENTRATIONS IN HYPOMAGNESAEMIC TETANY

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## SUMMARY

Plasma and cerebrospinal fluid (CSF) samples from field cases of grass tetany in dairy and beef cows indicate that the signs of tetany develop only in hypomagnesaemic cows that also have very low CSF magnesium levels. In dairy cows with experimentally induced hypomagnesaemic tetany, a steep fall in CSF magnesium concentration has been observed just prior to the appearance of tetany. In conscious sheep a tetanic syndrome has been produced by ventriculolumbar perfusion of the CSF space with synthetic CSF solutions of low magnesium concentration.

## INTRODUCTION

Although grass tetany is invariably associated with hypomagnesaemia, it is apparent that hypomagnesaemia by itself is not sufficient to produce tetany.

In sheep fed a synthetic and low-magnesium diet the onset of tetany has been correlated with a fall in cerebrospinal fluid (CSF) magnesium concentration subsequent to the production of hypomagnesaemia (Meyer and Scholz, 1972). This paper examines evidence for a similar correlation in cows with grass tetany and with experimentally induced hypomagnesaemic tetany. In addition, measurements are made of neuromuscular responses in conscious sheep to ventriculolumbar perfusions of different concentrations of magnesium.

## EXPERIMENTAL AND RESULTS

### NATURALLY OCCURRING GRASS TETANY

Blood and lumbar CSF samples were collected from some Taranaki dairy cows with clinical grass tetany and from others with severe hypomagnesaemia but displaying no nervous signs (Pauli and Allsop, 1974). Similar samples were taken from an Angus beef herd on an experimental farm near Rotorua. Magnesium and calcium concentrations of the plasma and CSF were measured by atomic absorption spectroscopy.

TABLE 1: MEAN (± SE) PLASMA AND CSF MAGNESIUM AND CALCIUM LEVELS FROM COWS WITH GRASS TETANY AND FROM HYPOMAGNESAEMIC COWS SHOWING NO SIGNS

| | | *Plasma* | | *CSF* | |
|---|---|---|---|---|---|
| | *No. of Cows* | *Magnesium (mg/100 ml)* | *Calcium (mg/100 ml)* | *Magnesium (mg/100 ml)* | *Calcium (mg/100 ml)* |
| *Dairy cows*: | | | | | |
| Tetanic | 12 | 0.47 ± 0.41 | 8.78 ± 1.58 | 1.23 ± 0.11 | 4.76 ± 0.22 |
| Not tetanic | 7 | 0.36 ± 0.09 | 9.55 ± 1.66 | 1.76 ± 0.18 | 4.78 ± 0.42 |
| Significance | | n.s. | n.s. | $P < 0.001$ | n.s. |
| *Beef cows*: | | | | | |
| Tetanic | 4 | 0.73 ± 0.23 | 5.12 ± 0.56 | 1.40 ± 0.16 | 4.10 ± 0.05 |
| Not tetanic | 7 | 0.32 ± 0.06 | 8.80 ± 0.97 | 1.81 ± 0.17 | 4.44 ± 0.53 |
| Significance | | $P < 0.01$ | $P < 0.001$ | $P < 0.01$ | n.s. |

The results are summarized in Table 1. Statistical analysis of the results for the dairy cows shows that, while the plasma magnesium levels were similar for both groups, the CSF magnesium was significantly lower in the clinically affected group. The plasma and CSF calcium levels were not significantly different. The tetanic beef cows also had significantly lower CSF magnesium concentrations than the unaffected group, while CSF calcium levels were similar. Plasma magnesium levels often increased during tetany as shown here. In contrast to dairy cows, the tetanic beef cows were severely hypocalcaemic.

## Experimental Hypomagnesaemic Tetany

Four lactating dairy cows were fed an artificial low-magnesium diet (0.34 mg Mg/g dry matter) based on that of Allsop and Rook (1972) with unwashed straw replacing both the washed straw and the cellulose, and sucrose replacing half of the starch. Daily feed intakes were of the order of 6 to 12 kg and milk yields were maintained. All the cows showed signs of convulsive tetany within 28 days of being introduced to the diet. One other cow, fed the same diet supplemented to 1.5 mg Mg/g dry matter for 30 days, showed no nervous signs.

The plasma magnesium concentrations of the cows fed the magnesium-deficient diet fell sharply to a mean level of 0.5 mg/100 ml within 7 days, and more slowly thereafter to as low as 0.1 mg/100 ml shortly before the onset of tetany (Table 2). Plasma magnesium levels increased during tetany.

TABLE 2: MAGNESIUM CONCENTRATIONS (mg/100 ml) OF PLASMA AND CSF FROM DAIRY COWS WITH EXPERIMENTALLY INDUCED HYPOMAGNESAEMIC TETANY

| *Cow No.* | *Sample* | *Initial Mg conc.* | *Mg conc. at times (h) before onset of tetany* 60-72 | 48-60 | 36-48 | 24-36 | 12-24 | 3-12 | *Mg conc. During Tetany* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Plasma | 1.94 | 0.23 | | 0.20 | | 0.23 | | 0.46 |
| | CSF | 2.14 | 1.52 | | | | | | 0.92 |
| 2 | Plasma | 2.50 | | 0.38 | | 0.22 | | 0.24 | 0.41 |
| | CSF | 2.21 | | 1.50 | | | | 1.20 | 1.12 |
| 3 | Plasma | 2.55 | 0.41 | 0.25 | | 0.19 | 0.10 | | 0.24 |
| | CSF | 2.11 | 1.72 | | | | 1.30 | | 1.05 |
| 4 | Plasma | 2.14 | | 0.33 | | 0.20 | | 0.13 | 0.25 |
| | CSF | 2.33 | | 1.78 | | | | 1.33 | 0.88 |

The CSF magnesium concentrations declined gradually from normal levels of about 2.2 mg/100 ml to about 1.6 mg/100 ml 2 to 3 days before tetany, and then fell more rapidly, reaching about 1 mg/100 ml during tetany.

The CSF calcium concentrations remained normal in all cows throughout the experimental periods. Plasma calcium concentrations fell from an average of 8.9 mg/100 ml on the days before tetany to a mean of 8.0 mg/100 ml during tetany.

### Ventriculolumbar CSF Perfusions

The experimental method outlined here will be described in detail elsewhere.

Mature, non-pregnant ewes were used. To perfuse the CSF space the sheep was restrained in a sling, and the lateral ventricle cannulated by passing a needle down a previously implanted guide. A lumbar puncture was then performed. Synthetic CSF was pumped into the lateral ventricle and 10 min fractions of the lumbar outflow were collected. The synthetic CSF solutions were prepared to contain normal concentrations of sodium, potassium, calcium, chloride, bicarbonate, phosphate and glucose, and were sterilized by filtration. The magnesium concentration was varied to produce three experimental solutions. The temperature, pH and pressure of the synthetic CSF were maintained within normal limits. At the beginning of each perfusion, all sheep used had normal plasma and CSF magnesium and calcium concentrations.

The results of 13 perfusions are summarized in Table 3. Four sheep perfused for up to 600 min with complete CSF solution (2.4 mg Mg/100 ml) showed no clinical signs. The outflow

TABLE 3: THE TIMES FOR THE PRODUCTION AND RESOLUTION OF SIGNS PRODUCED BY THE PERFUSION OF SYNTHETIC CSF SOLUTIONS CONTAINING VARIOUS CONCENTRATIONS OF MAGNESIUM

| *Mg conc. of Perfusion Solution (mg/100 ml)* | *Sheep No.* | *Time to Mild Signs (min)* | *Time to Severe Signs (min)* | *Time to No Signs (min)* | *Total Perfusion Time (min)* |
|---|---|---|---|---|---|
| 2.4 | 1[1] | — | — | — | 600 |
| | 1[1] | — | — | — | 600 |
| | 2 | — | — | — | 480 |
| | 3 | — | — | — | 600 |
| | 4 | — | — | — | 600 |
| 0.6 | 2 | 225 | — | 735 | 760 |
| | 3 | — | — | — | 720 |
| | 5 | — | — | — | 600 |
| | 6 | — | — | — | 370 |
| 0.0 | 1[1] | 270 | 570 | 730[2] | 670 |
| | 2[1] | 170 | 260 | 300[2] | 270 |
| | 3 | 150 | 280 | 350 | 430 |
| | 4 | 340 | 560 | 640 | 670 |

— No effect.
[1] Perfused at 1.5 ml/min, remainder all at 1.0 ml/min.
[2] Complete solution not perfused to resolve signs.

magnesium concentration remained normal throughout. Using the magnesium-free solution the first mild signs produced consisted of episodes of approximately 10 sec duration involving fine muscle tremors of the head and neck and tetanic extension of the neck and forelegs with some paddling of the forelegs (mean outflow magnesium concentration 0.39 mg/100 ml). During the intervals of 10 min or more between episodes the sheep appeared normal. The signs were considered severe when the episodes involved tetanic extension of the neck and all legs for periods greater than 10 sec and included violent paddling of the legs, the intervals between episodes being less than 10 min (mean outflow magnesium concentration 0.35 mg/100 ml). Perfusion with a solution containing 0.6 mg Mg/100 ml produced only mild signs in one of four sheep (mean outflow magnesium concentration 0.89 mg/100 ml). Perfusion with complete solution following the production of signs caused complete resolution of the signs by the time the outflow magnesium concentration had returned to normal. Plasma magnesium levels did not fall appreciably during the perfusions.

## DISCUSSION

The results from field cases of grass tetany in dairy and beef cows show that clinically affected and unaffected cows had a similar degree of hypomagnesaemia. However, the presence of tetanic signs was associated with lower CSF magnesium levels, although there were only limited data for beef cows. The relevance of the hypocalcaemia of tetanic beef animals is not clear. However, since this did not occur in dairy cows, it is unlikely that it is a prerequisite for the manifestation of signs. The CSF magnesium levels fell slowly in animals during the development of experimentally induced hypomagnesaemia, but steeply just prior to the onset of tetany. This steep fall may be associated with a further slight decrease in plasma magnesium concentration. However, as in field cases of grass tetany, the presence of clinical signs is much more closely associated with low CSF magnesium levels than with the degree of hypomagnesaemia. As in the dairy cows with grass tetany, there were only slightly lower plasma calcium levels at tetany.

Ventriculolumbar perfusions showed that the removal of magnesium from the CSF of conscious sheep can produce neuromuscular signs similar to those of hypomagnesaemic tetany. The effect is not the result of a large fall in plasma magnesium level but is probably produced by lowering the magnesium concentration of the interstitial fluid of the CNS which is separated from the CSF by a permeable barrier (Rall *et al.*, 1962).

The CSF magnesium concentrations induced in these experiments were lower than those observed in sheep with hypomagnesaemic tetany ( Meyer and Scholz, 1972); however, in those sheep the plasma magnesium concentrations were also low and the low CSF magnesium levels were probably of greater duration. It appears that the low CSF magnesium concentrations observed in cases of hypomagnesaemic tetany may be responsible for the nervous signs.

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