Motility of the Rumen and Abomasum During Hypocalcaemia

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ABSTRACT

The relationship between plasma calcium level and rumen motility in cows and sheep and abomasal motility in cows was investigated by inducing hypocalcaemia in seven cows and five sheep by the infusion of Na_2 EDTA over a period of approximately two hours. Rates and amplitudes of rumen and abomasal contractions were markedly reduced by the reduction of plasma calcium level to approximately 50% of normal. There were significant positive linear relationships ($P<0.05$) between rate and amplitude of rumen contractions in both sheep and cows over a plasma calcium range of 1-3 mmol/L. There was also a significant linear relationship ($P<0.05$) between plasma calcium and abomasal rate of contraction over the same range in cows, but the relationship with amplitude of abomasal contraction was not quite significant ($P<0.1>0.05$).

Key words: Rumen, abomasum, motility, cows, sheep, hypocalcaemia.

RÉSUMÉ

Cette expérience consistait à étudier la relation entre la teneur plasmatique en calcium et la motilité du rumen, tant chez des vaches que chez des moutons, et la motilité de la caillette, chez des vaches. On provoqua à cette fin une hypocalcémie, chez des vaches et des moutons, au moyen d'une infusion de Na_2EDTA qui dura environ deux heures. Le rythme et l'amplitude des contractions du rumen et de la caillette subirent une réduction marquée, lorsque la teneur du plasma en calcium s'établissait à environ 50% de la normale. On enregistra des relations linéaires positives significatives ($P<0,05$) entre le rythme et l'amplitude des contractions du rumen, tant chez les moutons que chez les vaches, lorsque le taux du calcium plasmatique variait de 1 à 3 mmol/L. À cette concentration, on constata aussi l'existence d'une relation linéaire significative ($P<0,05$) entre le taux de calcium plasmatique et le rythme des contractions de la caillette, chez la vache, mais la relation avec leur amplitude ne s'avéra pas aussi significative ($P<0,1>0,05$).

Mots clefs: rumen, caillette, motilité, vaches, moutons, hypocalcémie.

INTRODUCTION

Rumen tympany is a regularly occurring sign in natural hypocalcaemic syndromes in cows and ewes (2). Others (4, 11) have reported that rumen motility is reduced in hypocalcaemia induced by intravenous infusions of sodium oxalate solution or disodium ethylenediaminetetraacetate (Na_2 EDTA) solution. However, Moodie and Robertson (9) were unable to significantly alter total rumen movements per ten minutes in two cows by inducing hypocalcaemia with a sodium oxalate infusion over a period of 55-60 minutes. More recently, Huber *et al* (5) have related ruminal and abomasal motility in sheep to levels of serum diffusible calcium during hypocalcaemia induced by the infusion of Na_2EDTA solution. They found a highly significant positive correlation between serum diffusible calcium and changes in the amplitude of ruminal contractions. They also found that abomasal contractions were depressed but not eliminated when the serum diffusible calcium level was reduced sufficiently to cause the onset of clinical signs of hypocalcaemia. From their results, they postulated that rumen contractility is more sensitive to the effects of hypocalcaemia than abomasal contractility. Further observations on the effects of hypocalcaemia on rumen and abomasal contractility are presented in this paper.

MATERIALS AND METHODS

INDUCTION OF HYPOCALCAEMIA

Hypocalcaemia was induced in seven nonpregnant dairy cows and five Merino wethers by the constant infusion of a 4.7% (W/V) solution of Na_2EDTA (adjusted to pH 7 with NaOH) over a period of approximately 2 hours. Infusion flow rates were initially 600 mL/h and 60 mL/h, respectively, for cows and wethers, but were reduced appropriately when clinical signs of hypocalcaemia began to develop. Both cows and sheep were offered their normal feed (lucerne, hay or chaff) prior to the

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start of the experiment but were not offered any during the infusion period.

The cows were lightly restrained in their feeding stanchions during the experiments while the sheep were held in a wooden crate during the infusions and were prevented from becoming recumbent in the later stages of induction by means of broad support straps under the sternum and abdomen.

MEASUREMENT OF RUMEN AND ABOMASAL MOTILITY

Rumen motility was recorded via a 7.5 cm 18 gauge needle inserted directly into the dorsal sac of the rumen in the centre of the left paralumbar fossa. The needle was connected by nylon tubing[1] (1.9 mm I.D.) to a strain gauge transducer[2] which transmitted pressure change signals to a 2-channel recorder.[3] The transducer was connected to a peristaltic pump which provided a continuous flow of water through the transducer and cannula at approximately 4 mL/hour. The transducer was maintained at the same horizontal level as the rumen needle and pressures were calibrated with a mercury manometer. Recordings were made immediately prior to the induction of hypocalcaemia, just prior to the onset of recumbency due to hypocalcaemia and in some animals at one or two other occasions during the infusion of Na_2EDTA. In the wethers, a further recording was taken one hour after the end of the infusion, i.e. when plasma calcium levels were rising again.

Rate of rumen contractions was recorded as the mean number of primary contractions per minute measured from 120 mm of trace. Amplitude was measured as mm Hg from the mean of seven such contractions except where the number was less than seven in 120 mm of trace, in which case the total number in that length of trace was averaged.

Changes in abomasal motility (in the cows only) were similarly recorded using a transducer connected to a nylon catheter (I.D. 1.9 mm) which had been surgically implanted, at least two weeks prior to experimentation, into the greater curvature of the abomasum of each cow near the fundic-pyloric junction. Measurements of rates and amplitudes of abomasal contractions were carried out in a manner similar to those for rumen contractions, but, because their occurrence and sequences were sometimes erratic, measurements commenced with the first contractions occurring after the starting point on the trace for measurement of rumen contractions. Where compounded abomasal contractions occurred the amplitude of the initial peak only was recorded. A blood sample for plasma calcium estimation was collected into an evacuated tube containing lithium heparin[4] at the time of making each rumen and abomasal motility recording.

For control purposes, rumen and

TABLE 1. Mean Plasma Calcium Levels, and Rumen and Abomasal Recorded Contraction Amplitudes and Rates at the Start and End of the Induction of Hypocalcaemia by the Intravenous Infusion of 4.7% Na_2EDTA Solution

	Plasma calcium (mmol/L) (mean ± SD)	Amplitude (mm Hg) (mean ± SD)	Rate (contractions per minute) (mean ± SD)	n
Cows				
Rumen				
Start Na_2EDTA infusion	2.5 ± 0.22	14.7 ± 2.58	1.13 ± 0.309	7
End Na_2EDTA infusion	1.3 ± 0.23	8.9 ± 1.98	0.59 ± 0.177	7
Abomasum				
Start Na_2EDTA infusion	2.6 ± 0.21	31.7 ± 13.00	2.26 ± 0.689	5
End Na_2EDTA infusion	1.2 ± 0.26	16.5 ± 16.37	0.62 ± 0.804	5
Sheep				
Rumen				
Start NaEDTA infusion	2.52 ± 0.13	10.9 ± 2.08	1.10 ± 0.406	5
End Na_2EDTA infusion	1.22 ± 0.16	3.4 ± 1.74	0.32 ± 0.190	5
One hour after termination of Na_2EDTA infusion	1.62 ± 0.21	6.7 ± 2.34	0.48 ± 0.310[a]	4

[a]Mean increase not significant ($P>0.05$), all other mean changes significant ($P<0.05$)

There were significant ($p < 0.05$) linear regressions of rumen rate and amplitude (cows and sheep) and abomasal rate (cows) on plasma calcium level when the results of all the cows or sheep were pooled (Table II and Figs. 2, 3 and 4)

TABLE II. Regression Equations and Correlation Coefficients of Rumen and Abomasal Contraction Rates and Amplitudes on Plasma Calcium Level (X)

	Linear Regression Equation	Correlation Coefficient	P
Cows			
Rumen amplitude (19)[a]	$y = 5.29 + 3.68X$	0.67	<0.01
Rumen rate (19)	$y = 0.23 + 0.36X$	0.62	<0.01
Abomasal amplitude (15)	$y = 7.48 + 9.72X$	0.46	<0.1 >0.05
Abomasal rate (15)	$y = -0.05 + 0.88X$	0.57	< 0.05
Sheep			
Rumen amplitude (15)	$y = -3.18 + 5.56X$	0.84	<0.001
Rumen rate (15)	$y = -0.45 + 0.64X$	0.79	<0.001

[a]Figures in brackets are total number of observations

There were no significant changes in rumen and abomasal contraction rates and amplitudes over the three hours of the control saline infusion in any of the animals used

[1]Portex tubing, Boots Pure Drug Coy. (Aust.) Pty. Ltd.
[2]Transducer type 2BP.15 Mk. 5, Ether Engineering Ltd., Herts., England.
[3]"Both" recorder Type 100HT, Both Equipment Pty. Ltd., Adelaide, Australia.
[4]Vacutainers, Becton Dickinson Coy., Rutherford, New Jersey.

abomasal motilities were also measured in the same cows and sheep infused over three hours with 0.9% saline at the same volume rate as the Na_2EDTA.

ESTIMATION OF PLASMA CALCIUM LEVEL

Plasma calcium level was estimated by an EDTA titration method using a commercial kit.[5]

STATISTICAL ANALYSIS

Regressions of rumen and abomasal contraction amplitudes and rates on plasma calcium level were estimated separately by standard statistical methods (7). Significance of mean changes in amplitudes and rates between the normocalcaemic and hypocalcaemic states were tested using Student's t test (7).

RESULTS

The clinical signs observed during the inductions were typical of hypocalcaemia and, in cows, included swaying, restlessness, a "stilty stance" due to hyperextension of the hocks and finally, recumbency with head turned to flank. In the sheep the signs were less marked but included restlessness, grinding of the teeth, slight hyperextension of the hocks, pupillary dilation and eventual weakness causing the animal to rest on the support straps. Heart rates were not recorded in these experiments but in previous inductions of hypocalcaemia under similar conditions rates were found to increase significantly in six cows from 55 to 73 beats per minute but were found not to be significantly changed in a group of six sheep.

Mean amplitudes and rates of rumen and abomasum contractions before and after a 50% mean reduction in plasma calcium level are shown in Table I, while Fig. 1 shows typical tracings of changes in amplitudes and rates due to hypocalcaemia.

DISCUSSION

The results show there is a

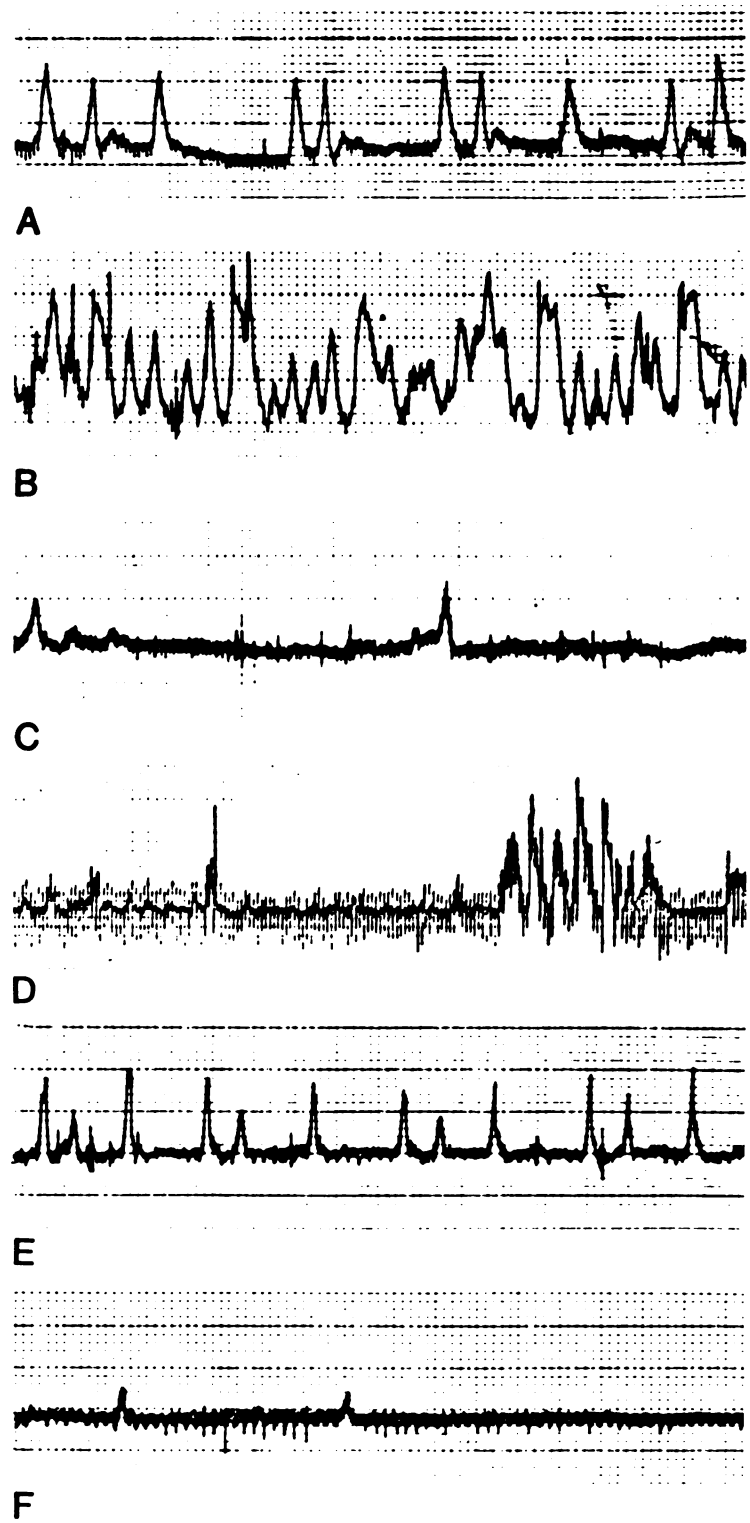

Fig. 1. A and B. Typical rumen and abomasal (respectively) pressure recordings prior to the induction of hypocalcaemia in one cow (10 mm deflection = 16 mm Hg). C and D. Typical rumen and abomasal (respectively) pressure recordings at the end of infusion of Na_2EDTA (hypocalcaemic state) — 10 mm deflection = 20 mm Hg (C) and 16 mm Hg (D) in the same cow as A and B.
E and F. Typical rumen pressure recordings in the rumen of one sheep prior to and at the end of the induction of hypocalcaemia respectively (10 mm deflection = 16 mm Hg). (1 small division = 1 mm) (paper speed = 0.2 mm/sec).

[5]Kit No. 64214, Harleco Co., Philadelphia, Pennsylvania.

highly significant correlation between plasma calcium level and amplitude and rate of rumen contractions in cows and sheep in the range of plasma calcium levels between 1 and 3 mmol/L. The correlation between rumen amplitude and plasma calcium in sheep is similar to that reported elsewhere (5). In the cows, there was also a significant correlation between plasma calcium level and the rate of abomasal contractions, but the correlation with recorded amplitude of contraction only approached significance ($P<0.1 >0.05$). This was due to the wide range of observed abomasal contraction amplitudes at plasma calcium levels of 1-1.3 mmol/L (Fig. 3). In the case of rumen amplitudes and rates, the results here show a linear relationship exists, at least down to a plasma calcium level of 1 mmol/L. Testing the curvilinear fit did not result in higher R^2 values in any of the sets of data in these experiments. Unfortunately, these animals were not treated with calcium solutions so that the behaviour of the relationship above a calcium level of 3 mmol/L could not be ascertained.

Rumen amplitude and rates of contraction had increased markedly in the present sheep experiments by the time plasma calcium had risen from the lowest point of 1.22 mmol/L to one of 1.62 mmol/L. Ramberg *et al* (11) found that ruminal and intestinal motility started to show an obvious diminution at around 1.62 mmol/L in cows in which hypocalcaemia was induced by Na_2EDTA infusion. It would appear that a plasma calcium concentration of 1.6-1.7 mmol/L is a critical one in respect to gut motility. However, the results here and those of Huber *et al* (5) suggest that there is a strong linear relationship between both amplitude and rate of contraction and plasma calcium level, at least between levels of 3 mmol/L and 1 mmol/L. Ramberg *et al* (11), however, were referring to clinically obvious diminution in motility and not to pressure recordings.

The mean decrease in amplitude and rate of abomasal contraction in the present experiments is proportionally similar to the decreases in rumen motility (Table I) when plasma calcium was reduced to a level consistent with that producing clinical signs. Thus the suggestion of Huber *et al* (5) that rumen contractility is more sensitive to hypocalcaemia than abomasal contractility is not supported by the present results. These authors postulated that because rumen contractions are solely dependent on extrinsic nerves, the earlier onset of rumen atony than abomasal atony, observed by them, was due to a failure of vagus-rumen neuromuscular transmission. Their data (from six sheep) also showed that rumen contraction amplitudes were above 10% of baseline even when serum diffusible calcium (ionized calcium plus non-protein-bound complexed calcium) was as low as 2.25 mg/dL. This latter figure would be equivalent to approximately 4.5 mg/dL or 1.12 mmol/L of EDTA titratable plasma calcium (ionised plus protein-bound calcium) (1).

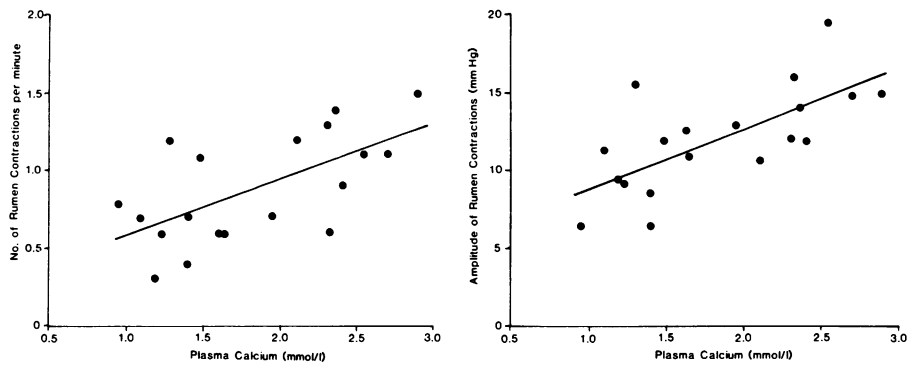

Fig. 2. Relationship between plasma calcium level and rumen contraction rates and amplitudes in seven cows.

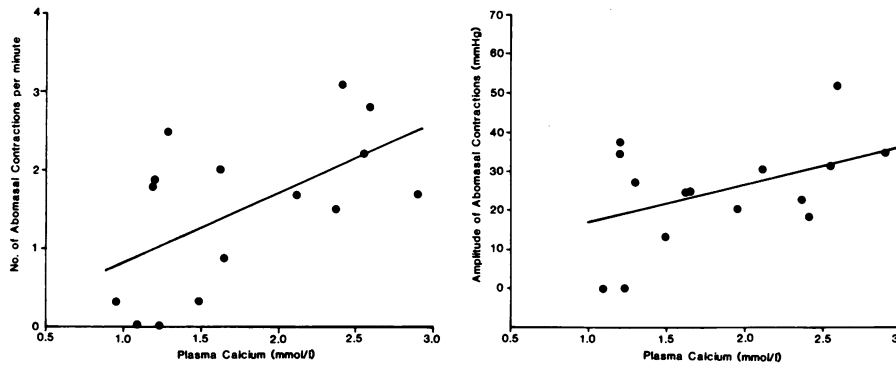

Fig. 3. Relationship between plasma calcium level and abomasal contraction rates and amplitudes in five cows.

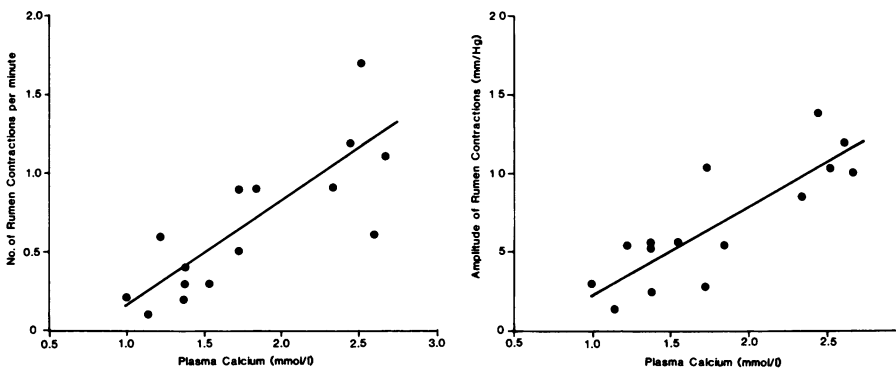

Fig. 4. Relationship between plasma calcium level and rumen contraction rates and amplitudes in five sheep.

In the present studies, complete atony occurred in the abomasum only, in two of the cows at plasma calcium levels of 1.00-1.25 mmol/L, but rumen contraction rates and amplitudes, although markedly reduced, were still present at this level in both cows and sheep. These observations tend to support the hypothesis that both rumen and abomasal motilities are similarly reduced in hypocalcaemia due to the general effects of a depression of levels of ionised calcium on smooth muscle contractility (3) and on neuromuscular transmission.

The reductions in amplitudes and rates of abomasal contractions observed in the cows is in accordance with the report of Poulsen and Jones (10) who found reduced abomasal emptying rates in EDTA induced hypocalcaemia in goats. Abomasal atony is thought to precede abomasal displacement and/or torsion and a role for hypocalcaemia in predisposing to these conditions has been suggested (6, 10). A subclinical hypocalcaemia with plasma calcium levels around 1.75 mmol/L certainly occurs in cows (8) and in such cases a notable diminution in rumen and abomasal motility would occur.

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