Changes in the feed intake, pH and osmolality of rumen fluid, and the position of the abomasum of eight dairy cows during a diet-induced left displacement of the abomasum

S. C. L. VAN WINDEN, C. R. BRATTINGA, K. E. MÜLLER, J. TH. SCHONEWILLE, J. P. T. M. NOORDHUIZEN, A. C. BEYNEN

During the last six weeks of the dry period, eight Holstein-Friesian cows were fed a restricted amount of grass silage; after calving, a mixture of maize silage and concentrates was offered in a feeding regimen designed to induce a displacement of the abomasum. In the first month after calving, the cows were monitored for the following variables: feed intake and composition, milk production, the position of the abomasum, and the pH and osmolality of the rumen contents. In five of the eight cows, a left displacement of the abomasum occurred between four and 21 days after calving in the absence of other diseases. The displacement was temporary, lasting between five and 36 consecutive hours and one or two days in two of the cows (floaters), and for three or more days in the other three. Before these three cows developed the displacement, their abomasum was 4·3 to 7·9 cm higher, its contents had a higher mean osmolality (+19·2 mosmol/kg), and the ratio of roughage to concentrates in their feed was lower (–0·87) than in the three cows that did not develop clinical signs of a displaced abomasum. There were no significant differences in these variables between the floaters and the healthy cows.

Veterinary Record (2004) **154,** 501-504

S. C. L. Van Winden, DVM, MSc, PhD,
K. E. Müller, DVM, PhD,
J. P. T. M. Noordhuizen, DVM, PhD,
Department of Farm Animal Health,
J. Th. Schonewille, BSc, PhD,
A. C. Beynen, MSc, PhD,
Department of Nutrition, Faculty of Veterinary Medicine, Utrecht University, Yalelaan 7, 3584 CL Utrecht, The Netherlands
C. R. Brattinga, DVM, MSc,
Department of Animal Sciences, Animal Husbandry Group, Wageningen University, PO Box 338, 6700 AH Wageningen, The Netherlands

A DISPLACEMENT of the abomasum, usually to the left side, most often occurs during the first month after calving, predominantly in Jersey, Guernsey and Holstein-Friesian cows (Constable and others 1992, Stengärde and Pehrson 2002). The condition is associated with a high level of rapidly fermentable components in the ration supplied after calving (Martens 2000), a small roughage mat in the rumen (Goff and Horst 1997), an energy-dense feed provided before calving (Coppock 1974) and a low feed intake after calving (Dirksen 1962, Østergaard and Gröhn 2000). Conditions which commonly affect high-producing cows in early lactation, such as a severe negative energy balance, hypocalcaemia and infectious diseases, have been shown to be risk factors for the development of a displaced abomasum (Massey and others 1993, Heuer and others 1999). In dairy cows, the estimated average incidence of the condition is 5 per cent, but it can range from 0 to 20 per cent on different farms (Kane 1983, Dawson and others 1992, Jacobsen 1995).

The aim of this study was to induce a displaced abomasum and to evaluate the changes in feed intake, the ratio of roughage to concentrate in the cows' voluntarily ingested feed, the position of the abomasum, and the pH and osmolality of the rumen contents before it developed. It has recently been shown that even in apparently healthy cows the position of the abomasum changes after calving (Van Winden and others 2002), and it was expected that larger changes would occur in cows that develop the condition. Eight dry pregnant cows were fed a dietary regimen designed to induce a displaced abomasum, modified from that used by Coppock and others (1972), and differences in the selected variables were evaluated between the cows that did or did not develop a clinical displaced abomasum.

MATERIALS AND METHODS

Animals and nutrition

The study took place under the supervision and with approval of the Ethical Review Committee of Animal Experimentation of the Faculty of Veterinary Medicine, Utrecht University in the Netherlands. Eight multiparous Holstein-Friesian cows were used; they weighed between 612 and 723 kg six weeks before calving. The cows were housed on stands with sawdust bedding. During the last six weeks of the dry period, they were fed individually according to the Dutch recommendations for energy requirements (Centraal Veevoeder Bureau 1998) and received 53 MJ NE$_l$/day. The ration consisted of 7·7 kg dry matter (DM) of grass silage which was given once daily at 10.00.

Immediately after they calved they were offered 5 kg DM of a mixture of concentrates for two hours; after the leftover concentrates were removed and weighed, they were provided with 10 kg DM of maize silage to which they had access until 08.00 the next day. During the following days they were fed increasing amounts of concentrates, with a maximum of 13·5 kg DM/day, between 10.00 and 13.00, and between 13.00 and 08.00 the next day they were provided with maize silage ad libitum; before the next supply of concentrates at 10.00 the animals had no access to feed.

The leftover quantities of both the mixture of concentrates and the maize silage were weighed and recorded, and their daily feed intake of each was calculated. Details of the feeding regimen are shown in Table 1. The cows were milked at 12.00 and 24.00 and their yield at each milking was recorded.

Clinical examination

Each day at 08.00, 11.00, 13.00, 15.00 and 17.00 the cows were examined for the presence of a left or right displaced abomasum. If the abomasum was found to be displaced at 17.00 the cow was re-examined at 23.00. The examination was made by percussion auscultation in an attempt to evoke the characteristic 'steelband' sound on the left or right side of the cow. Any suspected displaced abomasum was confirmed by an ultrasonographic survey (Winter and Hofmann 1996).

A visual check for mastitis was made on the first milk of each milking period. The involution of the uterus was checked each week by rectal palpation and a vaginal discharge was used as a criterion to diagnose endometritis. If a cows was suspected of having milk fever, a blood sample was collected to determine blood calcium concentration.

TABLE 1: Quantities of maize silage and concentrates supplied to each cow during the postpartum period (kg dry matter [DM])

Days postpartum	Rape seed* (extracted)	Soybean meal*† (extracted)	Sugar beet pulp* (dehydrated)	Maize silage‡
1	0·9	3·2	0·9	10
2	0·9	4·5	1·8	10
3	0·9	4·5	2·7	10
4	0·9	4·5	3·6	10
5	0·9	4·5	4·5	10
6	0·9	4·5	5·4	10
7	0·9	4·5	6·3	3·1§
8	0·9	4·5	7·2	3·1§
9	0·9	4·5	8·1	15
10-11	0·9	4·5	8·1	15
12-15	0·9	4·5	8·1	3·9§
16-28	0·9	4·5	8·1	15

* Offered from 10.00 to 13.00
† 39 per cent rumen undegradable protein
‡ Offered from 13.00 to 08.00; composition: 33·5 per cent DM, 67 g crude protein/kg DM, 210 g crude fibre/kg DM; 39 g crude ash/kg DM
§ 50 per cent of the individually measured DM intake of maize on days 6 and 11 was supplied – the reported amount is an average

TABLE 2: Overall average values of the variables measured in the three groups of cows

Dependent variable	Healthy	Floater†	Displaced abomasum†
Milk production (kg/day)[c]	32·6	37·6	30·6
Total DM intake (kg/day)[c]	13·7	14·1	12·0
Ratio of roughage to concentrates (kg DM:kg DM)[q]	0·94	1·17	0·07**
Osmolality of rumen contents (mosmol/kg)[l]	266·8	265·4	286·0**
pH of rumen contents[q]	6·50	6·47	6·27
CR position (cm)[q]	21·1	18·5	29·0*
CD position (cm)[q]	18·1	15·3	22·4**
AL (cm)[q]	27·5	27·8	33·5**

* $P<0.05$, ** $P<0.1$ compared with the healthy cows
† Data for the floater cows and the cows with a displaced abomasum are related to the periods during which measurements were made
[c] Cubic time effect, [q] Quadratic time effect, [l] Linear time effect.
DM Dry matter, CR position Distance from the ventral midline to the abomasal margin in the cranial part of the abomasum, CD position Distance from the ventral midline to the abomasal margin in the caudal part of the abomasum, AL Length of the abomasum in the ventral midline

Position of the abomasum

The position of the abomasum was determined daily by the ultrasound technique described by Braun and others (1997). The left ventral abdominal wall was clipped and smeared with transducer gel. A Pie Medical 100 device with a 5 MHz transducer was used to make a transabdominal ultrasonographic examination between 16.00 and 17.00 each day. The extension of the abomasum from the ventral midline to the left in the cranial and caudal regions was measured, and the length of abomasum in the ventral midline was also measured (Braun and others 1997, Van Winden and others 2002).

Measurements

The intake of maize silage and concentrates by each cow was measured daily, and the combined intake of silage and concentrates was used to calculate its total daily DM intake. The ratio of roughage to concentrates in the total DM intake is related to the occurrence of displaced abomasum (Shaver 1997) and it was therefore calculated.

Samples of rumen fluid were obtained daily at 13.00 with a metal oesophageal probe. As the samples could have been contaminated with saliva, only easily obtained samples were used. Immediately after collection, the pH of the rumen juice was measured in duplicate using a calibrated pH meter (Radiometer 51; Radiometer). The rumen fluid was centrifuged at 12,100 *g* and the supernatant was stored at –20°C for up to six weeks before it was analysed. When all the rumen fluid samples had been collected, the samples were thawed and their osmolality was determined in duplicate with a calibrated osomometer (Osmomat 030; Gonotec), the measurement being based on the depression of the freezing point; all the samples were analysed on the same day.

Statistical analysis

The cows' daily milk production, DM intake, ratio of roughage to concentrates, the position of the abomasum (cranial, caudal and ventral midline), and the pH and osmolality of the rumen fluid were entered into a spreadsheet program (MS Excel 97; Microsoft). For the cows that developed a displaced abomasum, only data collected before it developed were used in the analysis.

The cows that developed clinical signs of a displaced abomasum were divided into two categories: floaters and cows with a displaced abomasum. The floaters were defined as cows that had a clinically displaced abomasum for one or two consecutive days, but no recurrence; the cows with a displaced abomasum were defined as cows that had a clinically displaced abomasum for more than two consecutive days. This resulted in three categories of cows: two floaters, three cows with a displaced abomasum and three healthy cows with no displacement. These categories are a reflection of the situation in dairy practice, which, in this study, enabled the difference between healthy cows and cows with a displaced abomasum to be shown.

The variables were analysed by the linear mixed effects method, which takes the dependency of the data into account and is suitable for the statistical analysis of repeated measurements (S-PLUS 2000; MathSoft). The method uses maximum likelihood techniques for estimating the fit of the model. The identity of the cow was used as random effect. (Auto)correlation structures were tested and selected on the basis of a likelihood ratio test. An autocorrelation structure of the first order was used for all the variables except the osmolality and the pH of the rumen contents, for which no autocorrelation structure was used. The normality of the residuals and the random effects in the final model were checked visually with Q-Q plots and both followed a more or less straight line, showing that the data were normally distributed. The significance of the differences between the variables measured in the three categories of cows was analysed. A backward stepwise selection procedure was made; linear, quadratic or cubic effects of the day postpartum with a P value above 0·10 were deleted from the model. The following formula for the fixed effects was used: $Y \sim$ day postpartum + (day postpartum)^2 + (day postpartum)^3 + category of cow, where Y is the variable of interest.

RESULTS

None of the cows developed clinical mastitis or endometritis. Seven hours after it calved, one cow had problems with rising, but this was not associated with hypocalcaemia. Five of the eight cows developed a displaced abomasum; two of them were categorised as floaters and the other three as cows with a displaced abomasum. The first displaced abomasum occurred four days after the cow calved, two occurred six days after calving, one after eight days and one after 21 days; the first three cases were cows with a displaced abomasum, but the other two were floaters. In the first three cows the displacement had a recurrent character, that is, it was clinically present in the morning, disappeared in the afternoon, and was

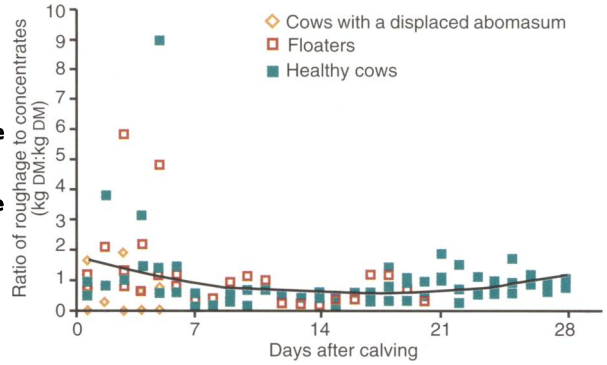

FIG 1: Ratio of roughage to concentrates (kg dry matter [DM]:kg DM) in the feed ingested by the three groups of cows after they calved. The line represents the regression line (linear and quadratic) for the healthy cows

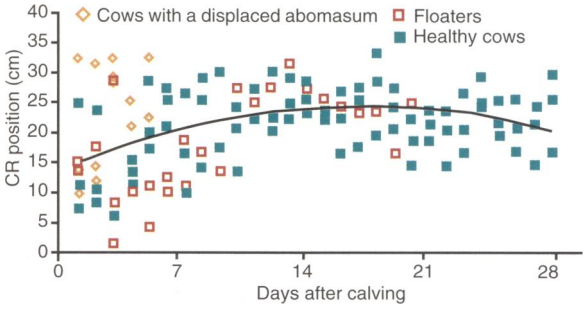

FIG 2: Cranial (CR) position (cm) of the abomasum in the three group of cows at intervals after they calved. The CR position is the distance from the ventral midline to the abomasal margin in the CR part of the abomasum. The line represents the regression line (linear and quadratic) for the healthy cows

present again the next day. No veterinary treatment was given and at the end of the experiment all the cows were healthy.

Table 2 gives the overall average data for the healthy cows, the floaters and the cows with a displaced abomasum. Data for the last two groups have been corrected for the length of the period of measurements, because they were recorded only in the period before the displaced abomasum developed. There were no significant differences between the healthy cows and the floaters, but there were several differences between the cows with a displaced abomasum and the healthy cows. First, the ratio of roughage to concentrates was on average 0·87 lower in the affected cows, indicating that they ate more concentrates (Fig 1). Secondly, before the displacement developed, the abomasum was in a higher position on the left side; in the cranial region the abomasal margin was 7·9 cm higher than in the healthy cows; in the caudal region it was 4·3 cm higher and the length of the abomasum in the ventral midlines was 6·0 cm longer (Figs 2 to 4). The changes with time in the cranial and caudal positions differ from those reported by Van Winden and others (2002), possibly in association with the specific feeding regimen in this study. Finally, the osmolality of the rumen contents was on average 19·2 mosmol/kg higher in the cows that developed a displaced abomasum than in the three healthy cows (Fig 5).

DISCUSSION

The results show that it is possible to induce a displaced abomasum in dairy cows, in agreement with the findings of Coppock and others (1972). They found that cows fed large amounts of concentrates had a reduced feed intake at the end of the dry period, and were also more likely to develop a displaced abomasum than cows fed less concentrate. In this experiment the cows were fed a restricted amount of energy-dense grass silage during the dry period, imitating the diet fed to the cows that developed a displaced abomasum in the experiment of Coppock and others (1972). After calving the cows were fed concentrates and maize silage according to a specified regimen and five of the eight developed a clinically displaced abomasum, confirmed by ultrasonography. The feeding regimen was based on epidemiological observations (Shaver 1997, Østergaard and Gröhn 2000) and hypotheses (Martens 2000, Van Winden and others 2002) as to the possible mechanisms underlying the development of a displaced abomasum.

There were no significant differences between the cows that remained healthy and the floater cows. The floaters had a clinically displaced abomasum, but apparently experienced no adverse effects, possibly because it was short-lived. However, there were only two floaters so that the interpretation of the data and extrapolation of dairy practice is uncertain.

There were no significant differences between the total feed intakes of the three groups of cows. In contrast, Østergaard and Gröhn (2000) observed that cows that developed a displaced abomasum had a reduced feed intake. The difference may be due to the small number of cows in this study. Similarly, there were no differences between the milk yields of the three groups, whereas Lacasse and others (1993) reported a decrease in milk production before cows developed a displaced abomasum. However, the ratio of roughage to concentrates in the diet of the three cows that developed a displaced abomasum was significantly lower than in the diet of the three healthy cows, in agreement with the findings of Dirksen (1962), Coppock and others (1972) and Shaver (1997). The consumption of relatively large amounts of concentrates results in an increased production of volatile fatty acids in the rumen, and an increase in the osmolality of the rumen contents, as was observed, supporting the hypothesis of Martens (2000), who suggested that the increased osmo-

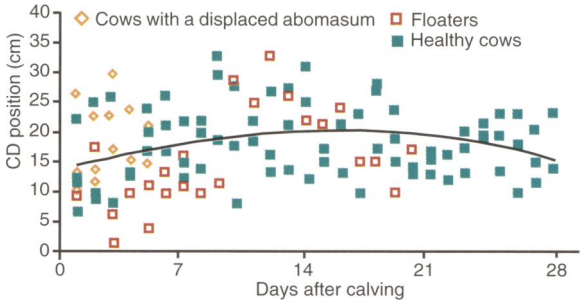

FIG 3: Caudal (CD) position (cm) of the abomasum in the three groups of cows at intervals after they calved. The CD position is the distance from the ventral midline to the abomasal margin in the CD part of the abomasum. The line represents the regression line (linear and quadratic) for the healthy cows

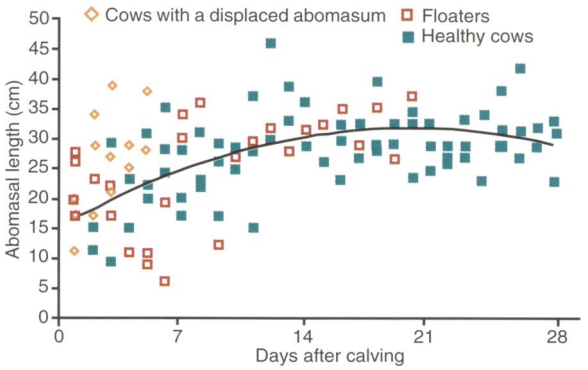

FIG 4: Length of the abomasum in the ventral midline of the three groups of cows at intervals after they calved. The line represents the regression line (linear and quadratic) for the healthy cows

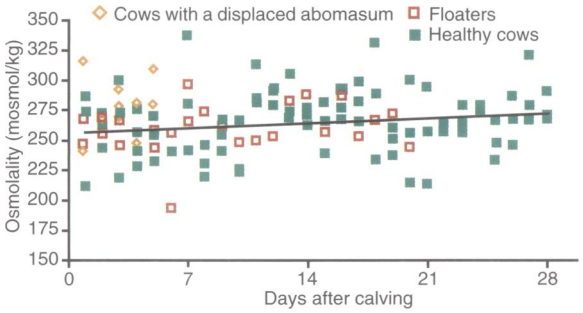

FIG 5: Osmolality of the rumen contents of the three groups of cows at intervals after they calved. The line represents the linear regression line for the healthy cows

lality results in an extension of the abomasal wall; too large an extension may result in paralysis and the development of a displaced abomasum (Geishauser and others 1998). The observation that the abomasum was in a higher position on the left side of the rumen before the displacement occurred is in accordance with the hypothesis of Van Winden and others (2002). However, it is uncertain whether this change in position is due to an extension of the abomasum.

The lower ratio of roughage to concentrates in the diet of the affected cows, the higher osmolality of their rumen contents and the higher position of their abomasum, are probably interrelated, and it is uncertain which of these variables can be considered as a primary causal factor in the development of displaced abomasum. The testing of larger numbers of animals in clinical settings and under field conditions, and the use of an induction model can be complementary approaches to solving this problem.

References

BRAUN, U., WILD, K. & GUSCETTI, F. (1997) Ultrasonographic examination of the abomasum of 50 cows. *Veterinary Record* **140,** 93-98

CENTRAAL VEEVOEDER BUREAU (1998) Voedernormen landbouwhuisdieren en voederwaarde veevoeders, verkorte tabel. Lelystad, CVB-Reeks. Number 24. (In Dutch)

CONSTABLE, P. D., MILLER, G. Y., HOFFSIS, G. F., HULL, B. L. & RINGS, D. M. (1992) Risk factors for abomasal volvulus and left abomasal displacement in cattle. *American Journal of Veterinary Research* **53,** 1184-1192

COPPOCK, C. E. (1974) Displaced abomasum in dairy cattle: etiological factors. *Journal of Dairy Science* **57,** 926-933

COPPOCK, C. E., NOLLER, C. H., WOLFE, S. A., CALLAHAN, C. J. & BAKER, J. S. (1972) Effect of forage-concentrate ratio in complete feeds fed ad libitum on feed intake prepartum and the occurrence of abomasal displacement in dairy cows. *Journal of Dairy Science* **55,** 783-789

DAWSON, L. J., AALSETH, E. P., RICE, L. E. & ADAMS, G. D. (1992) Influence of fiber form in a complete mixed ration on incidence of left displacement abomasum in postpartum dairy cows. *Journal of the American Veterinary Medical Association* **200,** 1989-1992

DIRKSEN, G. (1962) Die Erweiterung, Verlagerung und Drehung des Lebmages beim Rind. Berlin, Hamburg, Paul Parey

GEISHAUSER, T., REICHE, D. & SCHEMANN, M. (1998) In vitro motility disorders associated with displaced abomasum in dairy cows. *Neurogastroenterology and Motility* **10,** 395-401

GOFF, J. P. & HORST, R. L. (1997) Physiological changes at parturition and their relationship to metabolic disorders. *Journal of Dairy Science* **80,** 1260-1268

HEUER, C., SCHUKKEN, Y. H. & DOBBELAAR, P. (1999) Postpartum body condition score and results from the first test day milk as predictors of disease, fertility, yield and culling on commercial dairy herds. *Journal of Dairy Science* **82,** 295-304

JACOBSEN, K. L. (1995) Displaced abomasa and thin cows in a component-fed dairy herd. *Compendium. Food Animal* S21-S27

KANE, P. (1983) Displaced abomasums on a dairy farm in Hong Kong. *Veterinary Record* **113,** 96

LACASSE, P., BLOCK, E., GUILBAULT, L. A. & PETITCLERC, D. (1993) Effect of plane of nutrition of dairy heifers before and during gestation on milk production, reproduction, and health. *Journal of Dairy Science* **76,** 3420-3427

MARTENS, H. (2000) Relations between feeding, physiology of the forestomachs and pathogenesis of abomasal displacement. In Ätiologie, Pathogenese, Diagnostik, Prognose, Therapie und Prophylaxe der Dislocatio abomasi. Proceedings of an International Workshop. Leipzig, Germany, October 14, 1998. Ed M. Fürll. Leipzig, Leipziger Universitätsverlag

MASSEY, C. D., WANG, C., DONOVAN, G. A. & BEEDE, D. K. (1993) Hypocalcemia at parturition as a risk factor for left displacement of the abomasum in dairy cows. *Journal of the American Veterinary Medical Association* **203,** 852-853

ØSTERGAARD, S. & GRÖHN, Y. T. (2000) Concentrate feeding, dry-matter intake, and metabolic disorders in Danish dairy cows. *Livestock Production Science* **65,** 107-118

SHAVER, R. D. (1997) Nutritional risk factors in the etiology of left displaced abomasum in dairy cows: a review. *Journal of Dairy Science* **80,** 2449-2453

STENGÄRDE, L. U. & PEHRSON, B. G. (2002) Effects of management, feeding, and treatment on clinical and biochemical variables in cattle with displaced abomasum. *American Journal of Veterinary Research* **63,** 137-142

VAN WINDEN, S. C. L., BRATTINGA, C. R., MÜLLER, K. E., NOORDHUIZEN, J. P. T. M. & BEYNEN, A. C. (2002) Position of the abomasum in dairy cows during the first six weeks after calving. *Veterinary Record* **151,** 446-449

WINTER, T. & HOFMANN, W. (1996) Die Sonographie als Hilfsmittel bei der Diagnose von Labmagenverlagerungen. *Tierärztlicher Praxis* **24,** 243-247

ABSTRACT

Cribbing and entrapment of the small intestine in the epiploic foramen in 68 horses

RESULTS from two equine veterinary clinics (Leahurst, University of Liverpool, UK, and Champaign-Urbana, Illinois, USA) suggest that there may be a relationship between cribbing, including crib-biting and wind-sucking, and epiploic foramen entrapment (EFE) in a study involving a preoperative questionnaire (Liverpool) or follow-up telephone calls (Illinois). In Liverpool, the odds ratio was 8·2 that, among horses with colic, those with EFE were about eight times more likely to have a history of cribbing than those horses undergoing surgery for colic of other causes (24 of 49 compared with 72 of 687). Comparative figures from Illinois were 13 of 19 compared with two of 34, when EFE was contrasted with other strangulating small intestinal lesions. The authors cannot postulate a cause-and-effect relationship, as cribbing could be associated with EFE through management practices rather than altered intra-abdominal pressure during the act of cribbing forcing the small intestine towards the epiploic foramen.

ARCHER, D., FREEMAN, D. E., DOYLE, A. J., PROUDMAN, C. J. & EDWARDS, G. B. (2004) Association between cribbing and entrapment of the small intestine in the epiploic foramen in horses: 68 cases (1991-2002). *Journal of the American Veterinary Medical Association* **224,** 562-564