Effects of management, feeding, and treatment on clinical and biochemical variables in cattle with displaced abomasum

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Objective—To determine effects of management, feeding, and treatment on clinical and biochemical variables in cows with displaced abomasum (DA).

Animals—374 cows that received 470 treatments for DA.

Procedure—Blood and milk samples were obtained from 139 affected cows for analysis; for all cows, clinical data, management, feeding, and treatments were evaluated.

Results—Multiparous cows were more predisposed to DA than primiparous cows were, and Swedish Friesians were more predisposed than Swedish Red and Whites were. Eighty percent of cows had left-sided DA, and 20% had right-sided DA. In > 50% of affected cows, clinical signs appeared just before calving to 2 weeks after calving. Incidence of twin calves and periparturient diseases was significantly higher in affected cows than in the overall Swedish cow population. Content of neutral detergent fiber in the silage was low in herds with DA. Feeding a total mixed ration was a risk factor for DA. Treatment by surgical methods gave a significantly higher recovery rate than nonsurgical methods.

Conclusions and Clinical Relevance—Displaced abomasum is a periparturient nutritional disease. Feeding roughage with low neutral detergent content is a more important causative factor than the amount of concentrates fed at the time of calving. The basic principle for prevention of DA is to maintain good ruminal filling before and at calving. The amount of high-quality roughage fed before and at calving should be kept to a minimum. By changing routines for periparturient feeding, it should be possible to reduce the incidence of DA. (*Am J Vet Res* 2002;63:137–142)

As milk production has intensified, the incidence of **displaced abomasum (DA)** has increased in many countries, including the United States and Germany.[1,2] In Sweden between 1993 and 1999 the incidence of DA increased from 0.3 to 0.7%, and during the same period mean annual milk production increased from 7,740 to 8,300 kg of **energy-corrected milk (ECM**; 0.25 × kg of milk + 12.2 × kg of fat + 7.7 × kg of protein)/cow. Further increases in milk production can be expected, which could further increase the incidence of DA unless effective methods for preventing the disease can be developed.

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Any further increase in the incidence of the disease will make the necessity for effective treatment methods even more urgent. Under Swedish conditions, this conclusion is strengthened by the fact that since 1998 emergency slaughter is no longer available in most areas of the country; as a result, if a cow with DA cannot be treated in an effective way, it must be euthanatized.

It is generally agreed that an increase in the production of gas in the abomasum and a reduction in its tonicity are prerequisites for the disease, but the factors that give rise to these conditions are uncertain. As a result, many methods are used to treat DA, but little is known about their short- or long-term effects or their relative effectiveness.

Many earlier studies have been performed on hospitalized animals, with the unavoidable effects of transport stress and other factors. The purpose of the study reported here was to determine effects of management, feeding, and treatment on clinical and biochemical variables in cows with DA. In this investigation, all cows were studied in their normal environment.

Materials and Methods

Cows—Between December 1997 and June 1998, 374 cows with suspected DA were studied; 470 treatments were administered to these cows. Cows were allocated into 2 groups: group A consisted of 139 cows in 109 herds within an area close to the Swedish University of Agricultural Sciences in Skara, and group B consisted of 235 cows in 199 herds in more distant parts of Sweden that were served by 26 veterinary stations.

Data collection and sampling—Each case was diagnosed by the local veterinarian who completed a questionnaire giving information about the cow's history and the choice of treatment. From cows in group A, the veterinarians were asked to collect samples of blood and milk. In all instances, they also advised the owner to feed the cow only roughages for 4 days after treatment and then to gradually increase the amount of concentrates for 10 days until the cow's feed intake had returned to normal.

Samples of blood and milk were stored temporarily in a refrigerator on the farm and transported within 48 hours to the laboratory where the blood samples were centrifuged; samples of serum, plasma, and milk were stored at –20 C until analyzed. During the visit to collect the samples at the group-A farms, 1 of the authors also made a thorough clinical examination of the cow and obtained further information about the feeding and management routines and the design and dimensions of the cow stalls. Group-B farms were not visited in this way, and blood and milk samples were not obtained.

Because the investigation relied on information derived from several people, the data were in some instances incomplete; as a result, the number of observations varied among different variables.

Data about posttreatment milk production and fertility of the cows were derived from the Swedish official milk recording system, and data about the incidence of disease among the Swedish cow population were derived from the Swedish Dairy Association.[3]

Biochemical analyses—Analyses were made only on samples that had been deep-frozen within 48 hours after the sample was obtained. Serum total protein concentration was analyzed colorimetrically by use of a biuret reaction,[a] and serum albumin concentration was determined after adding bromcresol green.[b] Serum globulin concentration was calculated as the difference between total protein and albumin concentrations. Activity of **aspartate aminotransferase (AST)** and the concentrations of total bilirubin and calcium in serum were measured with a clinical dry chemistry analyzer.[c] Milk samples were analyzed for acetone and urea by use of a flow-injection technique.[4,5]

Plasma glucose concentration in samples from tubes containing Na-fluoride was measured, using glucose dehydrogenase.[a] Glucose concentration was not determined in samples from cows that had been treated with corticosteroids < 4 days before diagnosis or in samples that were severely hemolyzed.

Methods of treatment—It was not possible to standardize the method of treatment among the veterinarians involved in the study; therefore, the authors did not influence the choice of treatment made by the local veterinarian, which was also considered the best way to reflect the situation in clinical practice. Most of the veterinarians preferred 1 method to be used in most cows with **left-sided displacement of the abomasum (LDA)** and another in cows with **right-sided displacement of the abomasum (RDA)**, independently of the clinical status of the cow. Many of the nonmedical treatments were combined with medical treatments, most commonly, administration of corticosteroids. The effects of such supplementary treatments were not evaluated statistically. If a particular treatment was unsuccessful, another treatment was usually administered; as a result, there were more treatments than cows.

For LDA, the toggle-pin method[6] was used in 116 cows, left-sided laparotomy with omentopexy[7] was used in 60 cows, right-sided laparotomy with omentopexy[8,9] was used in 3 cows, rolling the cow[10] was used in 127 cows, induced exercise (transportation on a wagon on rough ground for at least 30 minutes) was used in 26 cows, a combination of rolling and induced exercise was used in 9 cows, only medical treatment (most commonly with corticosteroids, calcium infusions, or both) was used in 19 cows, no treatment was used in 11 cows, and 7 cows were culled without treatment.

For RDA, a toggle-pin operation was performed in 1 cow, right-sided laparotomy with omentopexy[11] was used in 30 cows, trocarization was used in 2 cows, rolling was used in 17 cows, induced exercise was used in 15 cows, a combination of rolling and induced exercise was used in 2 cows, only medical treatment was used in 9 cows, no treatment was used in 2 cows, and 13 cows were culled.

Right-sided displacement with torsion was verified in 10 cows. Six of these were culled immediately, and 4 were treated by use of right-sided omentopexy. In 10 other cows, a torsion was suspected by the local veterinarian, although verification of the diagnosis was not made.

Methods for evaluating the effect of treatment—Approximately 1 month after the diagnosis, information about the cow's status was obtained by use of a telephone call to the farmer. A cow was considered to have recovered if its milk production, assessed on the basis of the monthly test during the first month after treatment, had returned either to the value recorded before the cow became ill or to the value predicted for that cow's stage of lactation. If no milk production figures were available, the farmer's opinion was accepted as evidence of the cow's state of health. To improve the validity of the final conclusion, each farmer was interviewed again approximately a year after the cow had been treated.

Statistical analyses—A statistical program[d] was used in combination with *t*-tests, ANOVA, and χ^2 analyses.[12] Because the study cows had a different distribution of ages and breeds than the overall population of Swedish cows did, direct standardization of rates[13] was used to obtain comparable frequencies for the numbers of twin births, stillborn calves, percentage of bull calves, and incidences of clinical milk fever, retained placenta, and clinical ketosis. A value of $P < 0.05$ was considered significant for all comparisons.

Results

Clinical data—A higher proportion of multiparous cows than primiparous cows developed DA. However, among the multiparous cows, there was little variation in the incidence of the disease with parity. There was also a clear breed difference, with a higher proportion of Swedish Friesians developing the disease than Swedish Red and Whites (**Table 1**).

Overall, 80.2% of the DA were left-sided, and 19.8% were right-sided. There was no significant difference between cows with LDA and RDA in the time when the clinical signs first appeared in relation to calving (**Table 2**). In > 50% of the cows, clinical signs first appeared in the period from just before calving to 2 weeks after calving. Only approximately 15% of the cows had the first signs more than a month after calving. No significant difference was detected between cows with LDA and RDA with respect to the period between becoming ill and the day of diagnosis.

In cows with DA, incidence of twin births was 10.3% (8.8% after standardization), compared with 2.4% in the overall population, which was a highly significant ($P < 0.001$) difference. Incidence of stillborn

Table 1—Percentage distribution of lactation No. (n = 374 cows) and breed of cows (372) with displaced abomasum (DA), compared with that of the overall Swedish cow population

	Lactation No.				Breed		
Cows	**1**	**2**	**3**	**> 3**	**SRW**	**SF**	**Others**
DA	14*	26	28	32	37*	60*	3
Overall	36	26	18	20	50	44	6

SRW = Swedish Red and White cows. SF = Swedish Friesian cows.
*Significantly ($P < 0.001$) different from the value for the overall population.

Table 2—Percentage distribution of cows with left-displaced abomasum (LDA; n = 266) or right-displaced abomasum (RDA; 60) for the No. of days from calving when the first clinical signs of DA appeared

Days from calving	LDA	RDA
–28 to –11	0.7	0
–10 to –2	5.2	6.1
–1 to +1	17.0	22.4
+2 to +7	22.6	16.3
+8 to +14	19.0	22.4
+15 to +30	20.7	18.4
+31 to +60	7.8	10.2
> +60	7.0	4.1

calves (including instances in which 1 of the twin calves was stillborn) was 5.3% (4.8% after standardization), compared with 5.1% in the overall population; the difference was not significant. Percentage of bull calves was 52.3% (54.7% after standardization), compared with 51.5% in the overall population, which was not a significant difference.

Two-thirds of the cows that developed DA within a month after calving had at least 1 other disease either before or at the time at which DA was diagnosed. In the cows with DA, incidence of retained placenta was 6 times higher than in the overall population (18.5 vs 3.2%, respectively), incidence of milk fever was more than twice as high (8.5 vs 4.0%, respectively), and incidence of clinical ketosis was 10 times as high (21.4 vs 2.1%, respectively). Approximately 50% of the cows with DA and hyperketonemia (> 0.4 mmol of acetone/L[14]) had clinical signs of ketosis.

Incidence of metritis, based on a subjective evaluation of the severity of the discharge from the uterus, was 21.0% and probably higher than in the overall population. Incidence of mastitis (12.5%) was difficult to interpret, because it was based on the local veterinarian's assessment of the clinical importance of local reactions in the udder. Among all cows with DA, 74% had other diseases, and 26% did not have any other diseases.

Types of herds—Mean ± SD size of herds with cows with DA was 51.3 ± 41.6 cows, compared with the mean of 35.7 cows in herds in the overall population, and their mean annual milk production was 8,490 ± 1,145 kg of ECM, which was similar to the mean of 8,300 kg in the overall population. The distribution of stall systems used to house the affected cows was as follows: tied in long stalls, 39.1%; tied in short stalls, 44.3%; loose-housing systems, 14.7%; and other systems, 1.9%.

Feeding—In 287 of the 308 herds with affected cows, cows were fed in the traditional Swedish manner in which roughages and concentrates are fed separately. In the other 21 (6.8%) herds, roughages and concentrates were mixed in a mixer wagon and fed as a **total mixed ration (TMR)**.

In group A, silage was the main roughage fed to 105 of the herds, and only 4 herds were fed hay as the only roughage. The quantity of silage fed at calving ranged from 2 kg of **dry matter (DM)** to free access, and the mean was estimated to be 7.5 kg of DM. In 38 herds, the **neutral detergent fiber (NDF)** content of the silage was available at the farm. Its content (mean ± SD, 477 ± 50 g/kg of DM) was significantly lower than the mean of 573 ± 149 g/kg measured in 883 conventional Swedish herds.[15]

Biochemical data—Of cows with LDA, 51.3% had hyperketonemia (> 0.4 mmol/L) and approximately 20% had an acetone concentration > 2.0 mmol/L. Cows with RDA had significantly ($P < 0.01$) higher serum glucose concentrations (mean, 3.39 ± 1.50 mmol/; n = 21) than the cows with LDA did (2.50 ± 1.35 mmol/L; 82).

Serum concentration of calcium was < 2.0 mmol/L in 5.8% of the cows with DA. Concentration of total bilirubin was above the laboratory's reference limit (< 12 µmol/L) in 65.3% of cows with DA, although mean value (10.2 ± 17.8 µmol/L; range, 6 to 69 µmol/L) for 124 cows was within reference range. Activity of AST was above the laboratory's reference limit (< 0.05 U/L) in 48.8% of cows with DA (median 0.05, interquartile range 0.03 to 0.08 U/L). There was a weak positive correlation ($R = 0.07$; $P < 0.01$) between bilirubin and AST. Concentration of total serum protein was above reference range (59 to 89 g/L) in 14.9% of 121 cows with DA and below reference range in 1.7% of the cows; mean value (81.2 ± 10.7 g/L; range, 55 to 126 g/L) was within reference range. Concentration of globulin was above reference range (27 to 51 g/L) in 22.4% of 116 cows; none of the cows with DA had globulin concentration below the reference range, and mean value (46.1 ± 8.1 g/L) was within reference range. Concentration of urea in the milk of 117 cows with DA was less than the laboratory's reference limit (3 to 5 mmol/L) in 25.6% of cows and above the reference limit in 18.9% of cows. Mean value for all the cows was 4.2 ± 2.1 mmol/L.

Treatments—In the cows with LDA, surgical methods (toggle-pin and laparotomy with omentopexy) gave a significantly higher recovery rate than rolling or induced exercise did (**Table 3**). More than 50% of the cows that were not treated or were treated only medically recovered. In cows with RDA, recovery rate after induced exercise was as high as after surgical treatment. Results were based on the farmer's evaluation of the clinical status of the cow and its milk production after treatment, including cows that were reported as healthy but were slaughtered later in the lactation for reasons other than DA.

Culling and fertility—During the lactation year, 240 of the 374 (64.2%) cows were removed from herds, and approximately 50% of these removals (n = 119) were estimated to have been attributable to DA. Among cows that were removed, 31 (12.9%) were removed because they did not become pregnant, 26 (10.8%) because of mastitis or high somatic cell count, 29 (12.1%) because of low production, 19 (7.9%)

Table 3—Treatment methods and percentage recovery rates for 470 treatments in 374 cows with LDA or RDA

	LDA		RDA	
Treatment	**n**	**Recovered**	**n**	**Recovered**
Toggle-pin	116	70.7*	1	(1)
Left-sided omentopexy	60	73.8*	0	0
Right-sided omentopexy	3	(2)	30	63.3
Trocarized	0	0	2	(1)
Rolling	127	34.9	17	35.3
Induced exercise	26	34.6	15	66.7
Rolling and induced exercise	9	(3)	3	(2)
Only medical	19	57.9	9	(7)
No treatment	11	54.5	2	(2)
Culled	7	NA	13	NA

Values in parentheses are No. of cows that recovered verses percentage recovery.

*Significantly ($P < 0.001$) different from the values for rolling and induced exercise. NA = Not applicable.

because of planned culling, and 16 (6.7%) for other reasons. Of the 134 affected cows that remained in the herds, 119 (89%) calved again. The interval from calving to last insemination was available for 95 of these cows, and mean interval was 129 days, compared with 116 days in the overall population of cows in Sweden. The interval from calving to last insemination was 13 days longer in cows with DA, compared with the overall population.

Discussion

The difference observed in breed disposition for DA has been reported.[16] It has been suggested that size and shape of the abdominal cavity may influence the risk of DA.[17] It has also been reported that cows with DA were typically heavier than cows without DA.[18] It is possible that the higher incidence of DA among Swedish Friesians was attributable to the fact that they were taller and heavier than the Swedish Red and White cows.

The low incidence of DA among the primiparous cows contrasts with 1 report[19] and agrees with another.[20] However, in 1 study,[19] the first-calf heifers were exposed to much more radical changes in feeding, management, and environment in the period before calving than occurs in Sweden, where most heifers are stalled together with older cows for a considerable period before they calve. Anything that disturbs the behavior or feed intake of cows before they calve may increase the risk of DA.

Among multiparous cows, the incidence of DA was similar among cows of different ages. The risk of DA has earlier been reported to increase with age.[16,21] However, on the contrary, Cameron et al[22] found that the risk of DA decreased with increasing parity.

Proportions of cows with LDA and RDA have been reported to be between 70 and 90% and 10 to 30%, respectively.[18,23-25] In our investigation, the proportion of cows with RDA was within these limits. However, it is possible that some of the diagnoses of RDA were incorrect, because pinging sounds are often heard on the right side in other gastrointestinal tract diseases such as acute traumatic peritonitis, cecal dilatation, pneumoperitoneum, and gas colic.[26,27]

Of the 10 cows with RDA, which were suspected by the local veterinarian to be combined with a torsion (without verification of the diagnosis), 5 recovered without surgical treatment, which indicates misdiagnosis. The 5 other cows did not recover. The incidence of RDA with torsion was, thus, at least 14% (10/72) but may have been as high as 21% (15/72), if the 5 cows that did not recover truly had torsion as well as RDA.

There was no difference between cows with LDA and RDA in the time at which the clinical signs began. More than half the cows became ill between a few days before calving and 2 weeks after calving. It is well established that DA occurs most commonly during the first few weeks of lactation,[16,28,29] and the disease can be considered a periparturient disease. Only approximately 15% of the cows developed clinical signs later than a month after calving.

In agreement with several earlier studies,[16,20,30] our results indicate that DA is closely related to other periparturient diseases that are associated with a reduced appetite, leading to a reduction in rumen filling as a common predisposing factor.[16,31] The presence of twin calves would be expected to reduce rumen filling and reduce the appetite of a cow close to parturition, as a result of the reduction in space available for the rumen within the abdomen. Other factors may also be expected to predispose a cow to DA. For example, hypocalcemia associated with milk fever may reduce the tonus of the abomasum, as would the potential toxic products derived from a retained placenta, metritis, or mastitis. The reduced appetite associated with DA would predispose a cow to secondary ketosis. Nearly all the herds were kept in tie-stalls, with approximately equal numbers of long and short stalls, as is the general practice in Swedish herds.[e]

In agreement with results of a study[19] in the United States, it was found that TMR was a risk factor for DA. It was not possible to evaluate the quality of each TMR fed, but the most likely causes of the effect were probably either inadequate mixing in the feeder wagon, chopping the roughages too finely, too little fiber in the complete feed, or a combination of these factors.

The suggestion that a low fiber diet is a risk factor for DA is supported by the fact that the NDF content of the silage fed to the herds was significantly lower than in a typical Swedish herd.[15] Earlier studies[32,33] support this finding. A roughage low in fiber would be expected to be highly digestible and pass quickly through the rumen, so that components of the diet that should be metabolized in the rumen would be digested in the abomasum.[34] These factors are thought to predispose cows to DA by increasing the production of gas in the abomasum and by reducing the abomasal tonus.[9,16,35]

During the weeks before calving and the days after calving, voluntary feed intake of cows is often reduced to < 12 to 13 kg of DM.[36-38] As a result, the space occupied by the rumen in the abdomen is also reduced. Any further reduction in appetite (eg, because of the presence of twin calves) will reduce the size of the rumen. After calving, the absence of the forward and upward pressure of the pregnant uterus on such a small rumen provides the ideal conditions for a displacement of the abomasum to the left.

The amount of concentrate fed at calving (from 1.5 to 13 kg) was estimated by the farmers and may, therefore, have included substantial errors. Mean quantity of concentrates fed was estimated to 5.5 kg/d, of which 3.3 kg were wheat, oats, or barley. The large differences among herds in concentrate feeding patterns suggest that the total amount of concentrates fed at calving is much less important for the development of DA than the amount of highly digestible roughages fed. This conclusion agrees with the results of earlier investigations in the United States[19] and Canada.[39] However, large changes in feeding and the feeding of large quantities of concentrates (mainly corn) shortly after calving predispose cows to DA.[28,29]

It seems reasonable that the high concentrations of serum glucose were attributable to stress. Guard[24] proposed that hyperglycemia in cows with DA could be the result of transport, sudden environmental changes, or other stress factors.

It is generally considered that hypocalcemia may reduce the tonus of the abomasum and result in an increase in the accumulation of gas.[40] However, the lowest serum calcium concentration measured in the cows with DA in our study was 1.3 mmol/L, and mean concentration (2.29 mmol/L) was within reference range. Hypocalcemia is common in high-producing cows close to calving, partly as a result of reduced feed intake, and hypocalcemia at the time of diagnosis is, therefore, unlikely to be a characteristic of DA.[41] However, the severe hypocalcemia typical of milk fever may be much more common among cows with DA than among clinically normal cows. This suggests that severe hypocalcemia at calving may be a predisposing factor for the disease, in agreement with earlier results.[40,42]

High concentrations of total bilirubin and high activities of AST as well as the positive correlation between them indicated that approximately 50% of the cows with DA may have had a disturbance of liver function, although some of the high AST values may have been attributable to muscle injuries. It is also possible that some of the high AST values may have been attributable to increased pressure on the liver. The bilirubin and AST values observed in this study were similar to those observed by Frerking and Wolfers,[43] who stated that it was not possible to draw any conclusions regarding prognosis for DA from measurements of total bilirubin concentration and activity of AST.[43] There is no ideal variable for evaluating liver function in cattle, but our results indicate that the putatively disturbed liver function in DA was of little clinical importance.

Concentrations of serum total protein and globulin were above reference ranges in approximately 20% of the cows with DA, indicating that chronic inflammatory reactions may be relatively common in cows with the disease, although it is unlikely that they have any causal relationship. Nearly 60% of the cows had had > 3 lactations, and high globulin concentrations are more common in older cows.[f] Moreover, mastitis, dehydration, or severe endometritis in a cow with DA may have increased the globulin concentration.

Concentration of urea in the milk samples varied widely, possibly as a result of selective eating behavior. The cows with low values (< 3 mmol/L) may have eaten mainly roughages, and the cows with high values (> 5 mmol/L) may have eaten mainly concentrates.

Most investigations of the effectiveness of treatments for DA have evaluated 1 method or compared different methods on the basis of single treatments. It is generally considered that rolling cows with DA is less effective than surgical methods, because recovery rates of 25 to 40% have been reported for rolling,[6,44,45] whereas the corresponding figures for left or right laparotomy with omentopexy and toggle-pin operations are 73 to 100%.[1,7,8,46]

In cows with LDA, surgery by the toggle-pin method or left-sided laparotomy with omentopexy was equally effective in our study. Both methods gave results nearly as good as those reported in the literature. A right-sided laparotomy with omentopexy was used in only 3 cows.

The toggle-pin method was unsuccessful in 11 cows, because no contact could be achieved with the abomasum after the trocar had been inserted into the abdominal cavity. These cows were, therefore, included in the rolling category. The difficulties in completing the toggle-pin method satisfactorily reduce the effectiveness of this method to some degree, compared with the laparatomy method.

The high recovery rates associated with no treatment and only medical treatment were surprising; however, sample size was rather small. Moreover, we suppose that these cows had unclear signs of DA, and the veterinarian probably preferred to wait and monitor the cow's progress before administering a more radical method of treatment. If so, the recovery rates for no treatment and only medical treatment were overestimated.

There were relatively few cows with RDA, and evaluation of the methods of treatment was, therefore, more uncertain. However, induced exercise appeared to be as successful as right-sided laparotomy with omentopexy. Rolling was apparently as effective for the cows with RDA as for those with LDA. As mentioned, it is likely that the number of cows with RDA was overestimated, and the effectiveness of the treatments of this condition may, therefore, have been lower than estimated. As mentioned, right-sided pinging sounds are commonly heard in other gastrointestinal tract diseases and often disappear spontaneously.

Of the 374 cows in our study, 240 (64.2%) were culled during the lactation year. Ten percent of these cows were culled because of low production, but it is possible that the low production was in some instances a result of DA. As a consequence, the proportion of cows recorded as culled because of DA may have been underestimated. However, the proportion of cows recorded as culled for reasons other than DA (121/374; [32.4%]) was similar to that recorded in the overall population of Swedish cows (37.4%), suggesting that our data were relevant.

[a]Roche Unimate, Basel, Switzerland.
[b]Boehringer Mannheim, Mannheim, Germany.
[c]VetTest version 5.0, Kruuse Svenska AB, Stockholm, Sweden.
[d]JMP Software, SAS Institute Inc, Cary, NC.
[e]Hultgren J, Swedish University of Agricultural Sciences, Skara, Sweden: Personal communication, January 2000.
[f]Liberg P. *Blood protein screening in healthy and diseased cattle*. PhD thesis, Swedish University of Agricultural Sciences, Department of Animal Environment and Health Skara, 1982.

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