Ultrasonographic assessment of change in abomasal position during the last three months of gestation and first three months of lactation in Holstein-Friesian cows

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Objective—To determine changes in abomasal position and dimensions during the last 3 months of gestation and first 3 months of lactation via transabdominal ultrasonography and determine whether surgical correction of left-displaced abomasum (LDA) by right flank omentopexy alters abomasal position within the abdomen in Holstein-Friesian cows.

Design—Observational study.

Animals—20 heifers and 20 cows with no history of an LDA and 7 cows that had been treated for LDA via right flank omentopexy during an earlier lactation.

Procedure—Ultrasonographic measurements were obtained 8 times during the last 3 months of gestation and first 3 months of lactation. Abomasal length, width, and volume were calculated from these measurements.

Results—The abomasum was always wider than it was long and located predominantly to the right of the midline. The presence of a right flank omentopexy had no effect on the measured parameters. Abomasal length decreased and width increased during the last 3 months of gestation, resulting in a more transverse orientation of the abomasum within the abdomen. These changes appeared to be in response to cranial expansion of the gravid uterus. The abomasum returned to a more caudal and right sagittal position within 14 days after parturition.

Conclusions and Clinical Relevance—Abomasal dimensions, position, and volume change markedly during the last 3 months of gestation and first 3 months of lactation. Results permit detection of abnormal abomasal position in ill cows and indicate that the preferred location for abomasopexy is 20 cm caudal to the xiphoid process and 5 to 10 cm to the right of the ventral midline. (*J Am Vet Med Assoc* 2005;227:1469–1475)

Abomasal displacement is an economically important disease in dairy cattle.[1] Factors such as parturition, concurrent diseases, season, breed, sex, age, diet, housing, management, and weather may influence the incidence of abomasal displacement.[2-11] Abomasal hypomotility is considered to be an important factor in the etiopathogenesis of abomasal displacement[8,12]; however, mechanical factors, such as abomasal position and volume, and the volume of the rumen and uterus may also be important.[13-16]

Cross-sectional studies using dissection of frozen cattle, examination of slaughtered cattle, or transruminal palpation indicate that the position of the abomasum within the abdomen changes during gestation and the early period after parturition.[17-20] Ultrasonography provides an alternative, noninvasive method to describe the anatomic dimensions and associations of organs within the abdomen in cattle. The first cross-sectional study that used ultrasonography to characterize the abomasal position in cattle appears to have been performed by Kurosawa et al[21] in 1991. A preliminary ultrasonographic study[22] of abomasal position in 41 Swiss Braunvieh, 8 Simmental, and 2 Holstein cows of unknown pregnancy status was published in 1994. In that study, the abomasum was best visualized from the right ventral midline. A large cross-sectional ultrasonographic study of abomasal position in 50 nonpregnant Swiss Braunvieh and Simmental cows was published by Braun et al[23] in 1997. The authors described the appearance, dimensions, and location of the abomasum in association with other anatomic structures within the abdomen but were not able to investigate the effect of a gravid uterus on abomasal dimensions and position.[22,23]

A longitudinal study[16] on changes in abomasal position was performed in 6 cows for the first 6 weeks after calving; however, because this study measured only the left margin of the abomasum, the results did not provide a complete description of the change in abomasal position in the periparturient period. A large longitudinal study examining the change in abomasal position during the last 3 months of gestation and first 3 months of lactation, which are the critical times for abomasal displacement, does not appear to have been undertaken. Because expansion of the gravid uterus in cows during the last 3 months of gestation decreases ruminal volume and alters the anatomic association of the viscera,[17] we hypothesized that the dimensions and position of the abomasum within the abdominal cavity change during the last 3 months of gestation and first 3 months of lactation.

Left-displaced abomasum (**LDA**) is commonly corrected by returning the abomasum to the ventral region of the abdominal cavity and fixing the abomasum in this location by omentopexy or abomasopexy.[24-28] There appears to be little objective information available as to the ideal location on the ventral abdominal wall for

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abomasopexy and whether surgical fixation of abomasal position by omentopexy alters the position of the abomasum within the abdominal cavity. We therefore hypothesized that surgical correction of LDA during an earlier lactation by right flank omentopexy[25] alters the position of the abomasum in the abdomen, in that the abomasum lies more to the right of the abdominal midline than in cattle without an omentopexy. Accordingly, the purposes of the study reported here were to use transabdominal ultrasonography to determine the change in abomasal dimensions and position during the last 3 months of gestation and first 3 months of lactation and determine whether surgical correction of LDA by right flank omentopexy alters the position of the abomasum within the abdomen in Holstein-Friesian cows.

Materials and Methods

Cattle and experimental design—Holstein-Friesian heifers and cows were examined at the University of Illinois dairy farm. This farm milks approximately 215 Holstein-Friesian and Jersey cows and has a rolling 12-month average milk production of 21,300 lb (9,670 kg) at 4.1% fat, 3.2% protein, and a rolling bulk milk somatic cell count of 355,000 cells/mL. Cows were housed in concrete lots with access to straw-bedded 3-sided sheds during the transition to the nonlactating period. Approximately 2 weeks before the anticipated calving date, cows were moved to individual straw-bedded box stalls. After calving, cows were moved to tie stalls with mattresses or to sand-bedded free stall barns. The same corn silage–based total mixed ration was fed to nonlactating and lactating cows, and lactating cows were milked twice daily in a parallel parlor. Cattle on the dairy are used in nutrition trials; therefore, the dairy has a high incidence of LDA (> 10%/y).

A convenience sample of 3 groups of Holstein-Friesian cattle was obtained on the basis of anticipated calving date, lactation number, and whether surgical correction of LDA by right flank omentopexy had been performed during an earlier lactation. Groups included pregnant heifers (n = 21), pregnant cows that had completed at least 1 lactation and in which an LDA had not been diagnosed previously (23), and pregnant cows in which an LDA had been surgically corrected by right flank omentopexy[25] during an earlier lactation (7). The study was performed during a 9-month continuous period (March to November), with cattle being admitted to the study at the beginning of the last 3 months of gestation and continuing for 3 months after the onset of lactation. Measurements were obtained at least once each month and twice each month in the period of 30 days before and after parturition. This schedule generated 8 measurements of abomasal position during a 6-month period for each animal.

Ultrasonographic measurements and calculations—Ultrasonographic examination of the abdomen was performed with an ultrasound unit[a] and a 3.5-MHz linear transducer by 1 investigator (TW). A previously described technique[23,29,30] was used to identify the following dimensions: the distance between the caudal aspect of the xiphoid process and the cranial abomasal margin, the distance between the caudal aspect of the xiphoid process and the caudal abomasal margin, the maximal left and right lateral extensions at the midpoint of the cranial half of the abomasum, and the maximal left and right lateral extensions at the midpoint of the caudal half of the abomasum (**Figure 1**). All ultrasonographic measurements were based on the location of the most cranially, caudally, or laterally visible portion of the abomasum and not the location immediately adjacent to the ventral abdominal wall. The maximal visible dorsal-ventral dimension (depth) of the abomasum was also measured. Whether the pylorus could be ultrasonographically identified and the distance from the ventral abdominal wall to the center of the pylorus were also recorded.

Abomasal length was calculated as the difference between the caudal and cranial margins. Mean abomasal width at the first and third quartiles of length was defined as the sum of the mean abomasal extension to the left and the mean abomasal extension to the right (width = [{maximal left abomasal extension of cranial and caudal halves}/2] + [{maximal right abomasal extension of the cranial and caudal halves}/2]). The true abomasal width was calculated by use of the calculated value for mean abomasal width at the first and third quartiles and the standard form of the equation of an ellipse, whereby true width = (mean abomasal width at the first and third quartiles of length) $\times \sqrt{(4/3)}$. Abomasal volume was therefore calculated from the measured length and depth measurements and calcu-

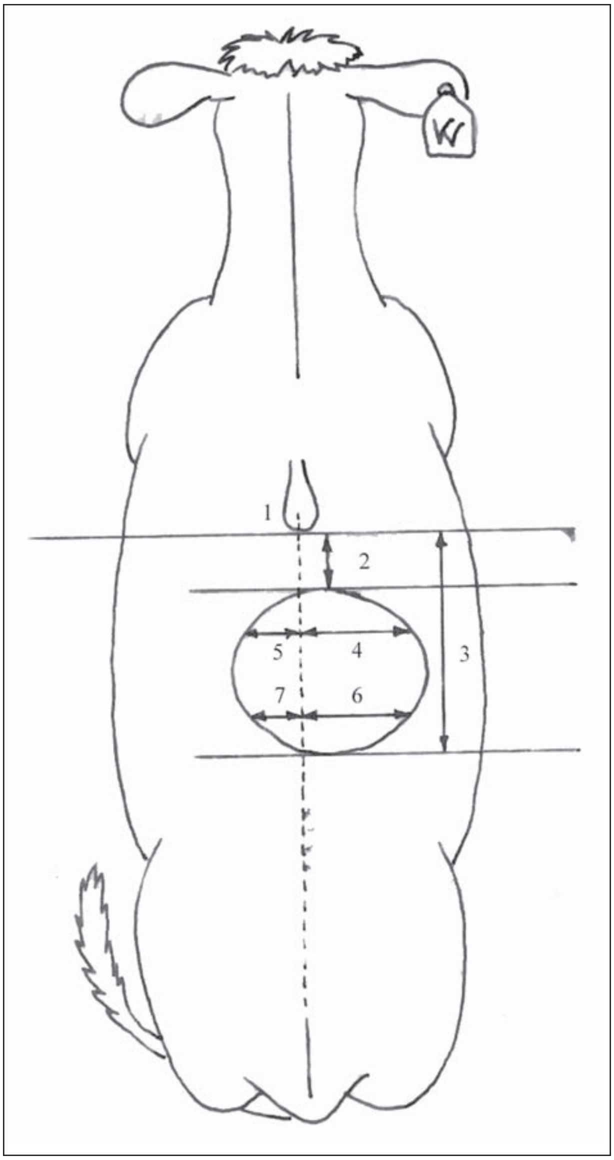

Figure 1—Illustration of transabdominal ultrasonographic measurements of abomasal margins on the ventral abdominal wall (dorsal view) in Holstein-Friesian heifers and cows. The numbers indicate the following anatomic landmarks and measurements: 1, xiphoid process; 2, cranial abomasal margin; 3, caudal abomasal margin; 4, right lateral extension in cranial region; 5, left lateral extension in cranial region; 6, right lateral extension in caudal region; 7, left lateral extension in caudal region.

Table 1—Change in abomasal dimensions during the last 3 months of gestation and first 3 months of lactation in Holstein-Friesian cows during their first lactation (n = 20) and cows completing at least 1 lactation (20) without a left-displaced abomasum (LDA) and in cows (7) in which an LDA had been surgically corrected by right flank omentopexy during an earlier lactation.

		Days before parturition				Days after parturition			
Measurement	**Group**	**61 to 90**	**31 to 60**	**16 to 30**	**1 to 15**	**1 to 15**	**16 to 30**	**31 to 60**	**61 to 90**
Distance from xiphoid process to cranial abomasal margin (cm)	Heifer	9.2 ± 1.5	7.7 ± 1.9	6.9 ± 1.5	6.5 ± 1.7	9.4 ± 2.0*	9.8 ± 1.0	10.6 ± 2.0	10.5 ± 1.4
	Cow	9.6 ± 2.3	9.1 ± 1.4	8.3 ± 1.4	7.3 ± 1.8	10.5 ± 1.6*	10.6 ± 1.7	10.8 ± 1.8	11.2 ± 2.6
	LDA	10.4 ± 1.3	9.6 ± 1.9	8.7 ± 1.3	7.8 ± 2.3	9.0 ± 1.6	10.4 ± 2.7	11.6 ± 2.4	11.5 ± 1.3
Distance from xiphoid process to caudal abomasal margin (cm)	Heifer	26.4 ± 2.6	24.2 ± 2.6*	22.0 ± 1.6*	19.9 ± 2.8	28.6 ± 3.6*	29.1 ± 4.2	29.9 ± 3.9	28.4 ± 4.9
	Cow	29.4 ± 4.0	25.6 ± 2.7*	22.9 ± 2.1*	21.1 ± 2.8	29.4 ± 3.2*	32.1 ± 3.9	30.4 ± 2.9	31.8 ± 3.8
	LDA	30.1 ± 4.4	28.6 ± 4.3	26.4 ± 4.5	22.5 ± 4.4	27.6 ± 3.7*	30.7 ± 3.3	31.3 ± 6.5	33.1 ± 4.8
Right lateral extension in cranial region (cm)	Heifer	15.9 ± 2.3	16.6 ± 2.1	16.8 ± 2.3	17.8 ± 2.8	16.5 ± 2.2	16.1 ± 2.3	15.2 ± 2.6	14.8 ± 2.9
	Cow	16.0 ± 2.8	15.6 ± 3.1	16.9 ± 3.1	16.0 ± 2.5	17.2 ± 2.7	16.8 ± 2.0	18.3 ± 1.9	16.0 ± 2.3
	LDA	20.2 ± 5.7	17.2 ± 6.0	16.7 ± 4.3	16.4 ± 2.5	16.0 ± 2.9	17.5 ± 4.3	16.9 ± 3.9	20.7 ± 7.8
Right lateral extension in caudal region (cm)	Heifer	18.0 ± 3.2	18.0 ± 2.0	17.6 ± 1.8	18.2 ± 2.3	17.2 ± 2.1	16.4 ± 2.1	17.4 ± 1.9	17.2 ± 2.5
	Cow	18.3 ± 2.7	17.3 ± 4.0	17.3 ± 3.4	16.8 ± 1.9	17.7 ± 2.9	16.9 ± 2.2	18.9 ± 1.4	19.1 ± 3.5
	LDA	20.6 ± 5.6	17.2 ± 6.1	18.3 ± 6.4	17.4 ± 3.9	15.9 ± 3.2	18.4 ± 4.1	18.2 ± 3.9	17.9 ± 2.0
Left lateral extension in cranial region (cm)	Heifer	6.4 ± 3.4	7.5 ± 2.6	9.1 ± 1.6*	10.9 ± 2.6	6.5 ± 3.2*	8.1 ± 3.3	7.1 ± 2.5	6.6 ± 1.8
	Cow	7.0 ± 3.6	7.4 ± 3.4	8.4 ± 2.6	9.6 ± 2.4	6.0 ± 3.0*	5.6 ± 2.7	4.9 ± 2.2	5.7 ± 2.8
	LDA	3.3 ± 5.7	7.2 ± 4.4	8.3 ± 1.2	9.9 ± 3.7	6.5 ± 3.9	6.1 ± 4.1	7.4 ± 6.5	4.3 ± 3.1
Left lateral extension in caudal region (cm)	Heifer	4.9 ± 2.7	7.5 ± 2.5*	8.8 ±1.7	10.5 ± 2.5	6.2 ± 3.5*	6.9 ± 3.6	6.6 ± 2.1	6.6 ± 1.6
	Cow	6.6 ± 3.6	6.5 ± 3.6	9.0 ± 3.0	9.8 ± 2.8	5.5 ± 3.4*	5.4 ± 2.5	4.8 ± 2.1	4.9 ± 2.7
	LDA	2.5 ± 6.4	5.8 ± 4.8	6.4 ± 3.3	8.5 ± 4.9	5.8 ± 3.6	5.5 ± 3.7	7.2 ± 6.4	5.3 ± 4.1
Abomasal volume (mL)	Heifer	1,766 ± 390	2,011 ± 580	1,909 ± 474	1,795 ± 437	2,030 ± 525	1,995 ± 455	2,046 ± 452	2,033 ± 890
	Cow	2,117 ± 574	1,748 ± 572	1,734 ± 403	1,567 ± 293	1,938 ± 393	2,238 ± 684	2,144 ± 631	2,300 ± 653
	LDA	2,509 ± 395	1,878 ± 557	1,843 ± 417	1,707 ± 400	1,933 ± 334	2,333 ± 312	2,114 ± 766	2,609 ± 544

Values are given as mean ± SD.
*Significantly ($P < 0.05$) different from the preceding time measurement.

lated value for true width by use of the formula for the volume of an ellipsoid (volume = length × true width × depth × π/6), where the constant π is an irrational number (approx 3.142). Modeling the abomasum as an ellipsoid has been validated in milk-fed calves[30] but not in adult cattle. The interassay coefficient of variation for the ultrasonographic measurement of abomasal dimensions has been estimated to be 13.4% and 19.7% for the maximal left abomasal extension in the cranial and caudal halves, respectively.[16]

Body weight estimation—The body weight of cows at 3 months of lactation was estimated by measuring the thoracic circumference (heart girth) by use of a flexible tape. This method provides an accurate estimate of body weight in Holstein-Friesian cows[31] and an excellent estimate of body weight in Holstein-Friesian heifers.[32]

Statistical analyses—Data are given as mean ± SD, and a value of $P < 0.05$ was considered significant. A repeated-measures ANOVA (with repeated measures on time) was used to compare the change in abomasal dimensions, position within the ventral abdomen, and calculated abomasal volume with time for the 3 groups. When results of an F test were significant, appropriate Bonferroni adjusted comparisons were made. A statistical software program[b] was used for analysis.

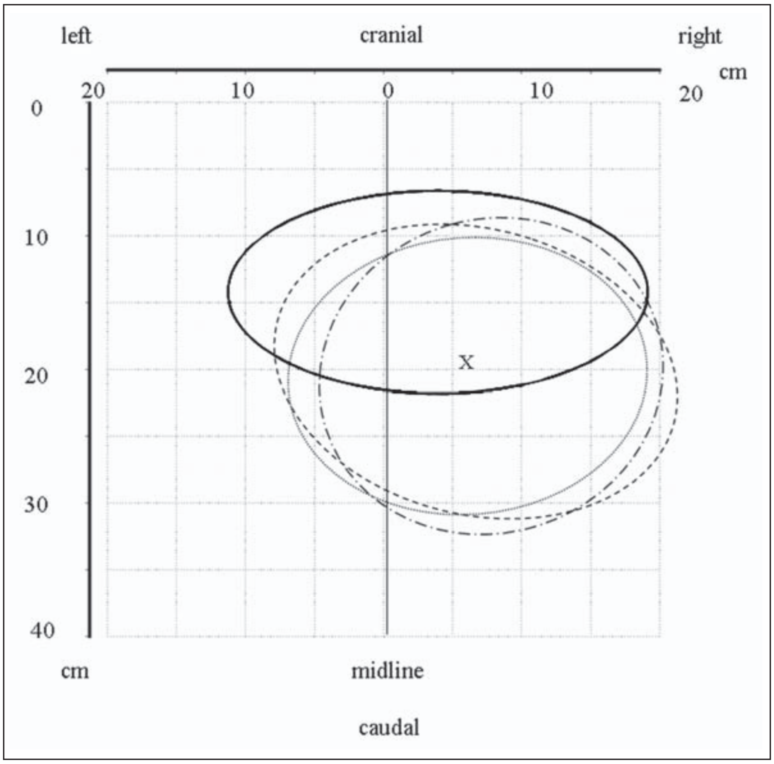

Figure 2—Dorsal view of abomasal position and shape (modeled as an ellipse in the horizontal plane) of Holstein-Friesian cows at the beginning of the last 3 months of gestation (dashed line), immediately before parturition (black line), immediately after parturition (gray line), and during the third month of lactation (dashed and dotted line). The abomasum moves cranially and to the left in late gestation. X = Center of the abomasal body projection in non-pregnant cows.

Results

One heifer and 3 cows developed an LDA 5, 12, 13, and 15 days after calving, respectively, and all data from these 4 animals were excluded from repeated-measures

ANOVA. However, data for each of these 4 animals were compared with the 95% confidence interval (mean ± 1.96 × SD) for the appropriate groups at each time measurement. Two cows (without LDA) were culled from the herd at 9 and 32 days after calving because of severe mastitis, but all available data from these 2 cows were included in the statistical analyses. Complete data were therefore obtained for at least 8 measurements in 20 heifers, 18 of 20 cows, and 7 cows that had an LDA surgically corrected during an earlier lactation.

We were able to identify the abomasum during each measurement session in all cattle; however, the pylorus was visible in only 7% (26/360) of the ultrasonographic examinations. The abomasum was generally located with three quarters of the organ to the right of the midline and one quarter to the left of the midline during the last 3 months of gestation and first 3 months of lactation (**Table 1**).

Marked changes in the position and dimensions of the abomasum occurred during the last 3 months of gestation and first 3 months of lactation (Table 1; **Figure 2**). The distance from the xiphoid process to the cranial and caudal abomasal margins decreased during the last 3 months of gestation as a result of the gravid uterus pushing the abomasum cranially. However, the caudal margin of the abomasum moved cranially to a greater extent than the cranial margin. This resulted in a decreased abomasal length toward the end of gestation (**Figure 3**), with the gravid uterus abutting the caudal aspect of the abomasum (**Figure 4**). The abomasum moved caudally within 14 days after parturition, and its length increased.

The right cranial and caudal margins of the abomasum did not change in location during the last 3 months of gestation and first 3 months of lactation. In contrast, the left cranial and caudal margins of the abomasum moved markedly to the left with advancing pregnancy, resulting in an increased abomasal width toward the end of gestation (**Figure 5**). The left abomasal margin moved toward the right within 14 days after parturition. In non-pregnant cows, the center of the projection of the abomasal body on the ventral abdominal wall was found 15 to 20 cm caudal to the xiphoid process and 5 to 8 cm right of the ventral midline (Figure 2).

Abomasal depth did not change during the study (**Figure 6**). Calculated abomasal volume decreased gradually during the last 3 months of gestation and increased after parturition (Table 1). Three months after parturition, the abomasal volume was equivalent to 0.37 ± 0.15% of body weight in heifers, 0.37 ± 0.07% of body weight in cows, and 0.36 ± 0.08% of body weight in cows that had an LDA surgically corrected during an earlier lactation.

There were no differences in abomasal position and dimensions between clinically normal cows and cows that had surgical correction of LDA during an earlier lactation. The omentopexy appeared intact in all 7 cows, as determined by palpation per rectum and ultrasonographic examination of the omentopexy site in the right flank.

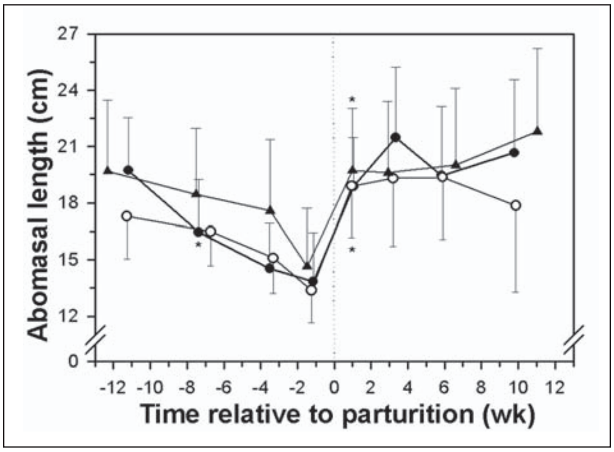

Figure 3—Change in abomasal length (mean ± SD) during the last 3 months of gestation and first 3 months of lactation in Holstein-Friesian cows during their first lactation (open circles; n = 20) and cows completing at least 1 lactation (closed circles; 20) without a left-displaced abomasum (LDA) and in cows (triangle; 7) in which an LDA had been surgically corrected by right flank omentopexy during an earlier lactation. *Significantly different from the preceding time measurement.

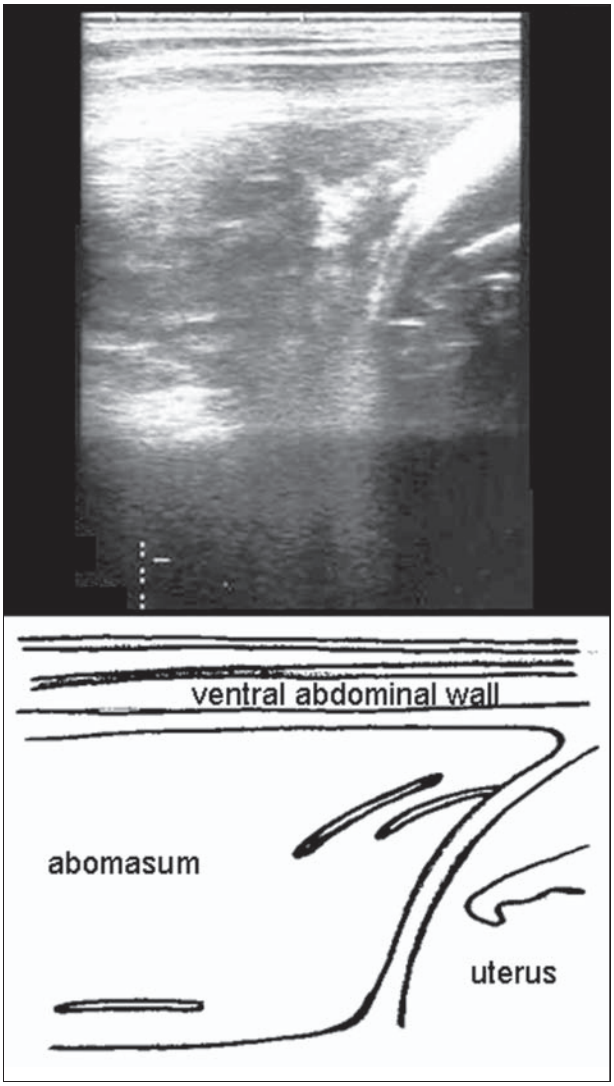

Figure 4—Transabdominal ultrasonographic image (3.5-MHz linear probe placed on the ventral abdominal midline) and illustration of the abdomen of a Holstein-Friesian cow. Notice the cranial border of the gravid uterus abutting the caudal abomasal margin.

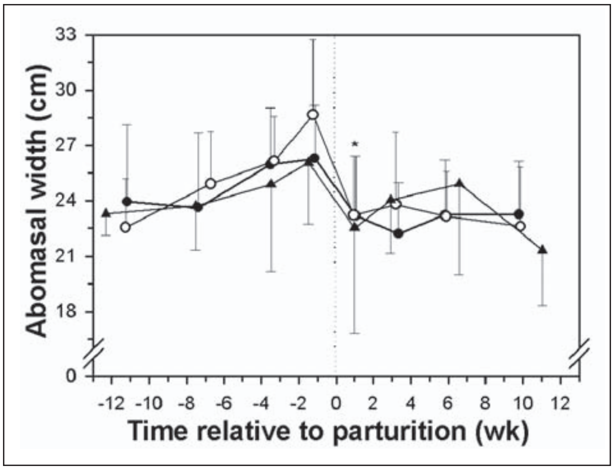

Figure 5—Change in abomasal width (mean ± SD) during the last 3 months of gestation and first 3 months of lactation in Holstein-Friesian cows during their first lactation (n = 20) and cows completing at least 1 lactation (20) without an LDA and in cows (7) in which an LDA had been surgically corrected by right flank omentopexy during an earlier lactation. *See* Figure 3 for remainder of key.

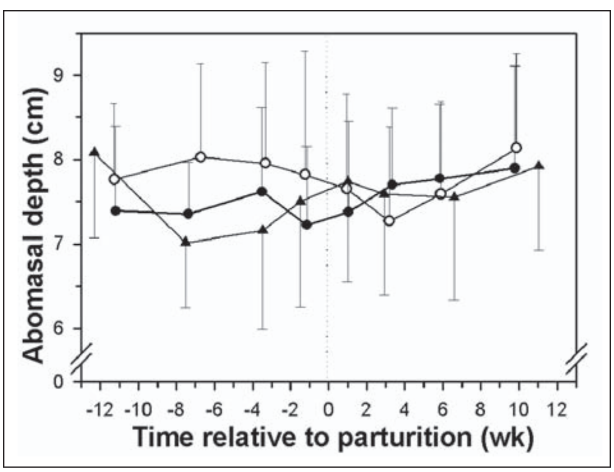

Figure 6—Change in abomasal depth (mean ± SD) during the last 3 months of gestation and first 3 months of lactation in Holstein-Friesian cows during their first lactation (n = 20) and cows completing at least 1 lactation (20) without an LDA and in cows (7) in which an LDA had been surgically corrected by right flank omentopexy during an earlier lactation. *See* Figure 3 for remainder of key.

Abomasal dimensions and position within the abdomen of 3 cows and 1 heifer that developed LDA during the study were within the 95% confidence intervals of data for cows and heifers at all time measurements before LDA was diagnosed.

Discussion

Results of the study reported here indicate that marked changes in abomasal dimensions and position occur during the last 3 months of gestation and first 3 months of lactation. The abomasal length decreased and the width increased during the last 3 months of gestation, resulting in a more transverse orientation of the abomasum within the abdomen, compared with nongravid cattle or cattle in early gestation. These changes appeared to be a direct response to cranial expansion of the gravid uterus. Within 14 days after parturition, the abomasum returned to a caudal and right sagittal position, similar to that at the beginning of the last 3 months of gestation. Contrary to most pictorial representations of the shape of the abomasum within a cow's abdomen, results of our study indicated that the abomasum in adult cows is always wider than it is longer.

In the study reported here, the abomasal position determined ultrasonographically was consistent, in general, with that described in other studies as determined by anatomic preparation,[17] abdominal palpation,[20] abomasocentesis,[33] examination of slaughtered cattle,[18] lateral radiographic views obtained after PO administration of barium sulfate in cattle with induced esophageal groove closure,[34] and ultrasonography.[22,23,35] Results of our study indicated that the abomasum is located predominantly to the right of the midline, with a small portion being located to the left of the midline, which is in agreement with findings of other studies.[22,23,33,35] However, other investigators[19] studying female dairy cattle embalmed in a standing position concluded that the abomasum was more frequently located predominantly to the left of the midline.

Our initial hypothesis that the surgical correction of LDA by right flank omentopexy during an earlier lactation altered the position of the abomasum within the abdomen was not supported by our results. This result may reflect the time span of at least 1 lactation between omentopexy and measurement of abomasal position, in that the greater omentum associated with the omentopexy tends to stretch with time, thereby potentially permitting changes in abomasal position similar to cows without omentopexy while preventing LDA. Results of other studies[17,19] indicate that the abomasal position within the abdomen is dependent on the uterine and ruminal volume, and the changes in abomasal position we observed during the last 3 months of gestation and first 3 months of lactation support the concept that uterine and ruminal volume influence abomasal position. However, the observational nature of our study prevented us from determining the relative importance of changes in uterine and ruminal volume on abomasal position.

Results of our study support the results of Braun et al,[23] which indicate that ultrasonography is a useful clinical tool for measurement of abomasal dimensions and identification of the position of the abomasum within the abdomen. However, the pylorus was difficult to identify, as previously reported,[23] and can probably only be readily identified when the pylorus is situated in the same plane as the ultrasound transducer.

Ultrasonographic measurements of abomasal location differed slightly from those obtained via abdominal palpation[20] or ultrasonography.[23] A large distance of 10 to 18 cm between the xiphoid process and the cranial border of the abomasum was estimated during abdominal palpation in Jersey, Ayrshire, and Holstein-Friesian cows,[20] compared with our range in mean values of 7 to 12 cm. The mean abomasal length obtained by abdominal palpation[20] (27 cm) was similar to results of our study (28 cm). Braun et al[23] performed an ultrasonographic study in nonpregnant Simmental and Swiss Braunvieh cows; therefore, cows in the third month of lactation in the study reported here would provide a suitable group for comparing measurements of abomasal dimensions. Potentially important differences were detected in the mean distance from the xiphoid process to the caudal abomasal margin (Simmental and Swiss Braunvieh, 34.4 cm; Holstein-Friesian, 27.9 cm) and the mean distance from the midline to the right caudal margin (Simmental and Swiss Braunvieh, 32.2 cm; Holstein-Friesian, 18.8 cm). These differences resulted in a longer mean abomasal length (27 cm) and width (38 cm) in Simmental and Swiss Braunvieh cows, compared with Holstein-Friesian cows (length, 21 cm; width, 24 cm). We attribute these breed differences in abomasal dimensions to breed differences in the ventral abdominal contour, with Simmental and Swiss Braunvieh cows appearing to have a flatter ventral abdomen. Whether breed differences in abdominal contour account for all or part of the observed breed differences in the incidence of LDA[1,8] is not known.

The method used to calculate abomasal volume has been validated in calves[30] but not in cows. The assumption that the abomasal volume in cows can be modeled as an ellipsoid is supported by the elliptic shape of the abomasum in the horizontal plane and lateral radiographic images of the abomasum containing barium sulfate after induction of esophageal groove closure in adult cattle.[34] However, the volume calculation underestimated the actual abomasal volume because the volume of the pyloric antrum was not included in the measurements, and this volume appears to be of some consequence in adult cattle,[34] compared with the situation in suckling calves.[30] Although exact volume measurements of the abomasal body and pyloric antrum are not available, it appears that the volume of the pyloric antrum is approximately one fifth of the volume of the abomasal body.[17] Modeling the abomasum as an ellipsoid from the ultrasonographic measurements of Simmental and Swiss Braunvieh cows[23] (mean body weight, 529 kg [1,164 lb]) resulted in a calculated mean abomasal volume of 4,197 mL (equivalent to 0.77% of body weight). For comparison, in the study reported here, the calculated mean abomasal volume of Holstein-Friesian cows at 3 months of lactation was 2,372 mL and the mean body weight was 619 kg (1,362 lb; equivalent to 0.38% of body weight). Abomasal volumes for 2-year-old male Holstein-Friesian cattle (2 bulls and 1 steer; mean body weight, 474 kg [1,043 lb]) were 1.7 to 2.3 L, which represents 0.35% to 0.48% of the individual body weights.[36] The abomasal volumes in 2 male cattle (mean body weight, 300 kg [660 lb]) varied between 1.1 and 2.0 L at several measurements, which was equivalent to 0.37% to 0.51% of body weight.[37] The abomasal volume in 10 Holstein-Friesian cows in the first 35 days of lactation ranged from 2.7 to 3.4 L at slaughter, which was equivalent to 0.46% to 0.61% of body weight.[38] Our calculated abomasal volumes therefore appear to be in agreement with those reported in the literature for Holstein-Friesian cattle, particularly in view of the fact that the volume of the pyloric antrum was not included in our calculations.

In our study, measurements of the left abomasal margin are not consistent with the findings of Van Winden et al,[16] who reported that the mean left margin of the abomasum at 6 weeks of lactation ranged from 18 to 31 cm from the midline, with the abomasum being situated between the rumen and the ventral abdominal wall. Results of Van Winden et al[16] contrast with those obtained in the study reported here and in other studies.[20,23] We found that the mean left margin of the abomasum was 5 to 10 cm from the midline during the second month of lactation, and we always observed the cranial portion of the rumen to be in direct contact with the ventral abdominal wall on the left side. Our results were in agreement with those of Braun et al,[23] who reported that the mean value for the left margin of the abomasum of nonpregnant Simmental and Swiss Braunvieh cattle was < 15 cm. Additionally, the left abomasal margin in 7 nonpregnant dairy cows when measured by transruminal palpation ranged from 5 to 18 cm.[20]

Our finding that the position of the abomasum within the abdomen was typical for 4 cattle in the 2-week period before diagnosis of LDA is interesting. Although the numbers are small, our results do not support a widely held belief that the abomasum is located more to the left than normal for some time before the clinical diagnosis of LDA. However, our results indicated that the abomasum is typically located more to the left than normal immediately before calving; this leftward shift during late gestation may increase the risk of LDA development, with displacement developing during a period of hours to days rather than days to weeks.

We believe that our findings have clinical value. First, our results suggested that an abomasopexy performed in the right paramedian area provides an anatomically appropriate site for fixation. Our results also indicated that a right flank omentopexy does not alter the normal position of the abomasum on the ventral abdominal wall, at least when measured at least 1 year later. Second, ultrasonographic measurement of abomasal position after calving indicated that the center of the abomasum is typically located approximately 20 cm caudal to the xiphoid process and 5 to 10 cm lateral to the midline on the right. This means that the ideal anatomic position for abomasocentesis and blind suture fixation of the abomasum is 12 finger widths caudal to the xiphoid process and 3 to 6 finger widths to the right of the midline. This is similar to recommended sites for fixation of the abomasum during right paramedian abomasopexy[39] (5 to 20 cm caudal to the xiphoid process and 5 cm to the right of the midline), left flank approach with right ventral abomasopexy or omentopexy[24] (15 and 10 cm cranial to the umbilicus, respectively, and 5 to 10 cm to the right of the ventral midline), and laparoscopic abomasopexy[28] (10 cm cranial to the umbilicus and 1 hand width to the right of the ventral midline). This ideal position differs from that recommended by Stöber,[33] who suggests performing abomasocentesis on the ventral midline. The ideal position is similar to that obtained in nonpregnant Simmental and Swiss Braunvieh cattle by Braun et al.[35]

Additional findings of clinical interest in this study were that the reference ranges for the cranial, caudal, and lateral abomasal margins during the last 3 months of gestation and first 3 months of lactation provide a useful comparison to determine whether the abomasum is malpositioned in cattle suspected of having an LDA but that do not have a detectable ping during simultaneous percussion and auscultation. Our results therefore compliment results of a study[40] describing the ultrasonographic examination of the left flank in cows that were suspected of having an LDA. Our results also support the widely held belief that the gravid uterus pushes the abomasum into a more transverse and leftward position on the ventral abdominal wall, compared with nongravid cattle or cattle in early gestation.

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a. Ultramark 4, 3.5-MHz linear probe, Advanced Technology Laboratories, Tempe, Ariz.
b. SAS, version 8.2, SAS Institute Inc, Cary, NC.

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