In cattle with RDA, the dilated abomasum is displaced to the right and undergoes torsion of ≤ 180°. In cattle with AV, the torsion is > 180°. Both disorders are common in cattle. Clinical findings and metabolic changes associated with these disorders are described in standard textbooks; the ultrasonographic findings have also been described. In cows with RDA and AV, the omasum, liver, and intestine also become displaced because of their proximity or attachment to the abomasum. This has been confirmed during laparotomy but, with the exception of the omasum, not via ultrasonography, although the normal ultrasonographic appearance of these neighboring organs has been described. Blessing described the ultrasonographic appearance of the omasum in healthy cows and those with RDA and AV. The aim of the study reported here was to describe the ultrasonographic appearance of the liver, small and large intestines, and omasum in cows with RDA and AV and to determine whether RDA and AV can be differentiated on the basis of ultrasonographic findings. Differentiation of RDA and AV is important because cattle with AV require immediate surgical correction of the volvulus to prevent irreversible organ damage. In contrast, cattle with RDA may be treated conservatively. Because no reliable method of differentiating the 2 disorders exists, cattle suspected of having either RDA or AV must be operated on promptly.

### Materials and Methods

**Animals**—The study involved the following cows: 10 healthy cows (control cows), 17 client-owned cows with RDA, and 9 client-owned cows with AV. Cows with RDA or AV were referred to our clinic for further workup. None of the cows were pregnant. All cows underwent a thorough clinical examination as described by Radosits et al prior to ultrasonography. Client consent was obtained for all procedures, and the study protocol was approved by the Animal Care Committee of the Canton of Zurich, Switzerland.

Ten clinically healthy cows, 4 to 13 years old (mean, 5.9 years old), were used as control cows. Control cows

### Abbreviations

| AV | Abomasal volvulus |
| RDA | Right displacement of the abomasum |

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From the Department of Farm Animals, Vetsuisse Faculty, University of Zurich, Winterthurerstrasse 260, CH-8057 Zurich, Switzerland.
Address correspondence to Dr. Braun.
included 7 Swiss Braunviehs, 2 Simmentals, and 1 Holstein-Friesian cow. The 17 cows with RDA ranged from 2.5 to 9.0 years old (mean, 4.3 years old). Cows with RDA included 8 Simmentals and 9 Holstein-Friesian cows. The 9 cows with AV included 6 Simmentals and 3 Holstein-Friesian cows and ranged from 2.0 to 10.0 years old (mean, 4.4 years old).

Procedures—The 8th to 12th intercostal spaces on the right and the cranial and caudal regions of the right flank were examined beginning dorsally and progressing ventrally with a 5.0-MHz linear transducer held parallel to the ribs.* The abomasum, omasum, liver, and small and large intestines were first evaluated subjectively. To establish the size and position of the organs, the dorsal and ventral margins were determined at each imaging position. These landmarks were assessed in a manner similar to those described for the liver,⁹ lungs,¹⁵ spleen,¹³ omasum,¹⁴ small intestine,¹⁰ and large intestine¹¹; the distances between the midline of the dorsalum of the cow and the dorsal and ventral margins of the organ were measured. The size of the liver and omasum and the extent of the small and large intestines were determined by subtracting the distance from the midline of the dorsalum to the dorsal margin from the corresponding distance for the ventral margin.

In all cows, the distance from the dorsal midline to the ventral midline was measured caudal to the last intercostal space between 15.0 and 26.1 cm (mean, 20.8 cm) and between 2.5 and 10.5 cm (mean, 6.8 cm) for the liver and the ventral margin, respectively.
rib on the right side, as a measure of half the abdominal circumference. In control cows, this distance (mean ± SD) measured 118 ± 11.5 cm (range, 104 to 138 cm), in cows with RDA it measured 119 ± 7.1 cm (range, 108 to 136 cm), and in cows with AV it measured 120 ± 10.8 cm (range, 106 to 135 cm). This distance did not differ significantly among the 3 groups.

**Diagnosis and treatment**—In cows with RDA and cows with AV, the diagnosis was confirmed in all but 1 cow via right flank laparotomy; in 1 cow that was slaughtered at the request of the owner, the diagnosis was confirmed at postmortem examination. After proximal paravertebral anesthesia, an incision, approximately 25 cm long, was made parallel and 5 cm caudal to the last rib, starting approximately 10 cm ventral to the transverse processes of the lumbar vertebrae. After releasing the gas and repositioning the abomasum, an omentotomy was performed.2

**Statistical analysis**—Statistical analysis was performed by use of a statistics software program.4 The mean, SD, and frequency distribution were determined for all variables. Differences among groups were analyzed by use of a factorial ANOVA with a Bonferroni post hoc test and χ2 analysis of association. When observed frequencies were < 5, the Fisher exact test was used. Results are expressed as mean values in centimeters for all measurements. Values of P < 0.05 were considered significant.

**Results**

**Ultrasonographic findings of the liver**—In control cows, the liver could be imaged in the 8th intercostal space in 8 cows, the 9th to 12th intercostal spaces in 10 cows, and the cranial region of the flank in 2 cows (Table 1). In cows with RDA, the liver was imaged significantly less frequently (6 to 8 cows) in the 8th to 12th intercostal spaces than in control cows. The same was true for cows with AV, in which the liver was imaged in the 8th to 12th intercostal spaces in only 2 to 6 cows. In 6 of 17 cows with RDA and in 3 of 9 cows with AV, the liver could not be imaged in any of the positions because of displacement by the abomasum. The liver was not imaged in the cranial aspect of the flank of any cows with RDA or AV.

In control cows, the dorsal margin of the liver was on average 16.8 to 56.4 cm from the midline of the back, depending on location (Figure 1). No significant difference was found in the location of the dorsal margin of the liver between cows with RDA and control cows. In cows with AV in which the liver could be imaged (6 cows), the dorsal margin of the liver was located significantly more dorsally in the 10th and 11th intercostal spaces (16.0 to 24.3 cm from the dorsal midline) than in control cows.

In control cows, the ventral margin of the liver was on average 39.5 to 69.0 cm from the midline of the back, depending on location (Figure 1). In cows with RDA or AV in which the liver could be imaged, the ventral margin was located significantly more dorsally in the 11th and 12th (cows with RDA, 25.3 to 30.8 cm from the dorsal midline) or 10th, 11th, and 12th (cows with AV, 22.8 to 33.7 cm from the dorsal midline) intercostal spaces than in control cows.

The typical size of the liver per imaging position was 12.6 to 29.6 cm in control cows. In comparison, in cows with RDA or AV, the liver was significantly smaller in the 11th and 12th (cows with RDA, 10.2 to 10.5 cm) or 10th, 11th, and 12th (cows with AV, 7.8 to 9.3 cm) intercostal spaces (Figure 1).

**Ultrasonographic findings of the small intestine**—In control cows, the small intestine could be imaged in the 11th and 12th intercostal spaces and the flank in all 10 control cows, in the 10th intercostal space in 9 control cows, in the 9th intercostal space in 7 control cows, and in the 8th intercostal space in 1 control cow (Table 2).
In cows with RDA or AV, the small intestine could be imaged in at least 1 position. However, in comparison with control cows, the small intestine could be imaged significantly less frequently in the 9th to 12th intercostal spaces in cows with RDA and in the 9th to 11th intercostal spaces in cows with AV. The small intestine could not be imaged in the 8th, 9th, or 10th intercostal space in any cows with AV.

The dorsal margin of the visible small intestine ranged from 54.4 to 77.1 cm from the dorsal midline in all groups. The only significant difference was at the 12th intercostal space, where the dorsal margin was significantly farther from the dorsal midline in cows with AV (77.1 cm) than in control cows (Figure 2). The ventral margin of the small intestine was significantly closer to the dorsal midline in the 11th and 12th intercostal spaces in cows with RDA (89.9 cm), compared with control cows (108.8 to 110.8 cm). The extent of the small intestine was significantly smaller in the 11th and 12th intercostal spaces in cows with RDA (25.8 to 32.6 cm) and in the 12th intercostal space.
and cranial region of the flank in cows with AV (25.1 to 36.1 cm), compared with control cows (45.5 to 47.7 cm).

Ultrasonographic findings of the large intestine—The large intestine could be imaged in the cranial and caudal region of the flank in all control cows, in the 12th intercostal space in 9 control cows, and in the 11th intercostal space in 5 control cows (Table 3). In cows with RDA or AV, the large intestine was imaged significantly less frequently in the 11th and 12th intercostal spaces and the cranial region of the flank, compared with control cows. Thus, in the cranial region of the flank, the large intestine was imaged in only 5 of 17 cows with RDA and in only 2 of 9 cows with AV. The dorsal margin of the large intestine did not differ among groups (Figure 3). It had a mean range of 24.5 to 69.0 cm from the dorsal midline. In the cranial region of the flank, the ventral margin of the large intestine was significantly closer to the dorsal midline in diseased cattle (49.8 to 50.0 cm) compared with control cattle (97.0 to 102.0 cm) (Table 4).

### Table 4—Distance (in centimeters) of dorsal and ventral margin of the omasum from the dorsal midline and size of the omasum (in centimeters) in 10 healthy control cows, 17 cows with RDA, and 9 cows with AV.

<table>
<thead>
<tr>
<th>Location</th>
<th>ICS 8</th>
<th>ICS 9</th>
<th>ICS 10</th>
<th>ICS 11</th>
<th>ICS 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD (range)</td>
<td>No.</td>
<td>Mean ± SD (range)</td>
<td>No.</td>
<td>Mean ± SD (range)</td>
</tr>
<tr>
<td>Dorsal margin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>60.2 ± 9.3 (45–76)</td>
<td>10</td>
<td>56.6 ± 6.7 (48–67)</td>
<td>10</td>
<td>54.6 ± 8.1 (40–63)</td>
</tr>
<tr>
<td>RDA</td>
<td>69.7 ± 13.9 (42–83)</td>
<td>71</td>
<td>70.3 ± 13.7 (36–89)</td>
<td>11*</td>
<td>71.2 ± 11.9 (50–81)</td>
</tr>
<tr>
<td>AV</td>
<td>62.0 ± 10.2 (53–76)</td>
<td>41</td>
<td>62.0 ± 8.4 (50–71)</td>
<td>5*</td>
<td>61.7 ± 13.6 (36–60)</td>
</tr>
<tr>
<td>Ventral margin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>97.0 ± 11.8 (72–120)</td>
<td>10</td>
<td>95.2 ± 10.6 (77–109)</td>
<td>10</td>
<td>81.1 ± 8.8 (65–93)</td>
</tr>
<tr>
<td>RDA</td>
<td>95.3 ± 16.5 (64–115)</td>
<td>7</td>
<td>97.8 ± 15.0 (63–118)</td>
<td>11*</td>
<td>102.0 ± 14.0 (75–116)</td>
</tr>
<tr>
<td>AV</td>
<td>92.3 ± 7.4 (64–102)</td>
<td>4</td>
<td>91.8 ± 7.8 (82–103)</td>
<td>5</td>
<td>89.0 ± 13.5 (75–102)</td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>36.8 ± 8.7 (24–49)</td>
<td>10</td>
<td>38.6 ± 7.7 (29–51)</td>
<td>10</td>
<td>26.6 ± 8.7 (13–41)</td>
</tr>
<tr>
<td>RDA</td>
<td>25.6 ± 8.5* (14–39)</td>
<td>7</td>
<td>26.9 ± 9.01 (10–46)</td>
<td>11</td>
<td>30.8 ± 8.1 (25–43)</td>
</tr>
<tr>
<td>AV</td>
<td>30.3 ± 12.3 (16–46)</td>
<td>4</td>
<td>29.8 ± 14.0 (19–53)</td>
<td>5</td>
<td>37.3 ± 26.1 (15–66)</td>
</tr>
</tbody>
</table>

ONV = Omasum not visible at this location. No. = Number of cows with a visible omasum in the location examined. See Table 1 for remainder of key.
cm) than in control cows (66.0 cm) because of dorsal displacement of the large intestine by the abomasum. The extent of the large intestine was significantly smaller in the flank of diseased cattle (20.8 to 25.5 cm), compared with control cows (41.1 cm).

**Ultrasonographic findings of the omasum**—The ultrasonographic appearance of the omasum of healthy and diseased cows was similar to that described in previous studies. The omasal laminae were not visible in control cows (Table 4). In 4 cows with RDA and 2 cows with AV, laminae were imaged as echogenic parallel lines within the omasum (Figure 4). The omasum was always imaged in the 8th and 9th intercostal spaces of all control cows and in the 10th intercostal space in 7 control cows. In comparison, in cows with RDA, the omasum was imaged significantly less frequently in the 8th (7 cows with RDA) and 9th (11 cows with RDA) intercostal spaces. This also applied to cows with AV, in which the omasum was imaged in the 8th and 9th intercostal spaces in only 4 and 5 cows with AV, respectively. In 6 diseased cows, the omasum was also imaged in the 11th or 12th intercostal space, where it was never imaged in the control cows. The dorsal margin of the omasum was 54.6 to 60.2 cm from the dorsal midline in control cows (Figure 5). In cows with RDA, the dorsal margin was 70.9 cm from the dorsal midline in the 9th intercostal space and 71.2 cm from the dorsal midline in the 10th intercostal space; thus, the dorsal margin was significantly farther from the dorsal midline, compared with control cows. The ventral margin of the omasum was 81.1 to 97.0 cm from the dorsal midline in control cows. In cows with RDA, the ventral margin was 102.0 cm from the dorsal midline in the 10th intercostal space, which was significantly farther than in control cows. The size of the omasum per imaging position was 26.6 to 38.6 cm in control cows. In cows with RDA or AV, the omasum was significantly smaller with values of 25.6 and 26.9 cm, respectively, in the 8th or 9th intercostal spaces.

**Discussion**

Two main factors were found to influence imaging of the liver and small and large intestines in diseased cows in our study. One was that the displaced abomasum was located between these organs and the abdominal wall, thus rendering them inaccessible to ultrasonographic examination. Another was that these organs were actively displaced medially during the process of the abomasal displacement, with the same effect on ultrasonographic imaging. However, the ultrasonographic appearance of the liver and small and large intestines did not differ from that of control cows, and these findings were in agreement with earlier findings. In cows with RDA or AV, the liver was imaged significantly less frequently in all of the intercostal spaces.

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**Figure 4**—Ultrasonogram of the omasum in a cow with RDA. The omasal laminae are visible as echogenic parallel lines. 1 = Abdominal wall. 2 = Omasal wall. 3 = Omasal laminae. Ds = Dorsal. Vt = Ventral.

**Figure 5**—Distance of dorsal margin (A) and ventral margin (B) of the omasum from the midline of the back and extent of the omasum (C) in 10 healthy control cows, 17 cows with RDA, and 9 cows with AV.
spaces examined, compared with control cows; the liver could not be imaged in 6 cows with RDA and in 3 cows with AV. Instead, the displaced or torsed abomasum was imaged, as previously described.2,4 In cows with AV, the dorsal margin of the liver was significantly closer to the midline of the back in the 10th and 11th intercostal spaces than in control cows because it had been displaced by the abomasum. The significant decrease in the apparent size of the liver in some of the intercostal spaces of diseased cows was attributable to displacement of the ventral part of this organ from the abdominal wall by the abomasum, which rendered it inaccessible to ultrasonographic examination.

The small intestine was imaged significantly less frequently in diseased cows than in control cows because of the displaced abomasum, which, in some affected cows, completely obscured the small intestine. The apparent extent of the small intestine imaged in the 11th and 12th intercostal spaces in cows with RDA and in the 12th intercostal space and cranial region of the flank in cows with AV was significantly smaller than in control cows because the displaced abomasum obscured the small intestine in these locations.6,4 Illes of the small intestine can usually be ruled out in cattle with indigestion when no or only a few loops of small intestine are imaged via ultrasonography. In illes, the small intestine becomes dilated with large numbers of visible loops, depending on the location of the illes.17 However, it is not possible to diagnose RDA or AV in cows on the basis of a low number of visible intestinal loops, because similar findings for other disorders, such as a severely dilated rumen occupying a large part of the right abdomen.

The large intestine was imaged in the 11th and 12th intercostal spaces in only 1 diseased cow. In this affected cow, the abomasum was displaced so far dorsally that the large intestine could be imaged ventral to it. In the cranial region of the flank, the large intestine was imaged in all control cows but only occasionally in 7 of 26 diseased cows because the dilated abomasum had displaced the large intestine from view.

Because of its direct attachment to the abomasum, the location of the omasum is affected more than other abdominal organs when the abomasum becomes displaced or undergoes a volvulus.7,18 The change in position of the omasum in cows with RDA and AV has been described.2,7,9 In cows with AV, the omasum is pulled caudally and rotates counterclockwise medially (in 90% of affected cattle)2 so that the wider lateral side of the omasum is situated more dorsally than normal and the narrower ventral side can be imaged ultrasonographically in the intercostal spaces.16 Additionally, the omasum becomes partially obscured from view by the displaced abomasum, especially after a volvulus. In cows with RDA, fluid content of the omasum is increased, which results in an increase in the size of the organ.19 The omasum was imaged significantly less frequently in diseased cows in the 8th and 9th intercostal spaces than in control cows, which was thought to be because of caudal and medial displacement of the organ. The ultrasonographic appearance of the omasum varied greatly. In 21 diseased cows, the omasal laminae could not be imaged, which is a typical finding in healthy cows.16 In 6 diseased cows, the laminae appeared as echogenic parallel lines within the omasum. This can be explained by reflux of abomasal contents into the omasum, resulting in better imaging of the laminae because of their separation from each other. Similar to earlier findings,18 we found that the omasum was smaller and located farther caudally, with the dorsal margin farther away from the dorsal midline in diseased cows, compared with healthy cows. It was not possible ultrasonographically to distinguish whether the omasum was rotated or not.

Results of our study indicate that cows with RDA and AV, compared with healthy cows, have numerous changes in positioning and, therefore, extent of ultrasonographic imaging of the liver, omasum, and small and large intestines. However, these findings are not useful in differentiating between cows with RDA and AV.

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