Liver lobe torsion in six horses

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**Case Description**—Six horses were determined to have torsion of a liver lobe at 4 referral institutions over a 21-year period.

**Clinical Findings**—Clinical findings were nonspecific but often included signs of marked inflammation. Two of the 6 horses were examined because of colic, and 2 were assessed because of peritonitis that failed to respond to treatment. The remaining 2 horses were examined because of nonspecific clinical signs that included inappetence, lethargy, and weight loss. The results of laboratory tests were widely variable, and values for liver enzyme activities were typically within reference limits or only mildly increased. Most affected horses had markedly increased peritoneal nucleated cell counts.

**Treatment and Outcome**—Exploratory laparotomy and resection of the affected liver lobe was performed in 5 horses. Three of those patients survived to discharge.

**Clinical Relevance**—Results suggested that diagnosis of liver lobe torsion in horses may be difficult because clinical signs and results of laboratory testing are nonspecific and variable. Most affected horses had markedly abnormal peritoneal fluid. The prognosis for hepatic lobe torsion can be good, and early surgical correction is expected to improve outcome. (J Am Vet Med Assoc 2012;241:615-620)

A 3-year-old Appaloosa colt (horse 1) used for breeding was examined because of a 2-day history of inappetence, mild signs of depression, and apparent hematuria. The referring veterinarian reported persistent tachypnea (up to 24 breaths/min), and grossly discolored urine, although rectal temperature was normal. A CBC performed by the referring veterinarian revealed a total leukocyte (9,360 cells/µL; reference interval, 5,500 to 12,000 cells/µL) and neutrophil (4,960 cells/µL; reference interval, 3,000 to 7,000 cells/µL) count within reference limits but an increased nonsegmented neutrophil count (1,123 cells/µL; reference interval, <100 cells/µL). Plasma creatinine concentration was increased (1.025). The colt was treated with procaine penicillin (22,000 U/kg [10,000 U/lb], IM, q 12 h), and IV flunixin meglumine (1.1 mg/kg [0.5 mg/lb], IV, q 12 h), and IV fluid therapy for 2 days but was referred for further assessment when its condition failed to improve.

On initial evaluation at the referral institution, the colt appeared comfortable but depressed. Physical examination revealed tachycardia (92 beats/min) and tachypnea (24 breaths/min), but rectal temperature (37.3°C [99.2°F]) was within normal limits. Other relevant findings included injected mucous membranes, cool extremities, decreased borborygmi, and mild dehydration. No abnormalities were detected on palpation of the abdomen per rectum, and no reflux was obtained on passage of a nasogastric tube. Samples were collected for a CBC and serum biochemical analysis at admission (Table 1).

No abnormalities were evident on cystoscopy, and results of urinalysis were within reference limits with the exception of an increased number of erythrocytes (20 to 30 RBCs/hpf; reference interval, 0 to 8 RBCs/hpf) evident on cytologic examination, possibly due to passage of the endoscope. Urine specific gravity was 1.018, and urine chemistries and electrolyte fractional excretions were within reference limits. Ultrasonographic evaluation of the abdomen revealed a moderate volume of swirling, echogenic fluid consistent with free blood. No other abnormalities were identified at that time, and no ultrasonographic abnormalities were appreciated within the thoracic cavity. Peritoneal fluid obtained via abdominocentesis was grossly serosanguineous, and cytologic examination revealed increases in the nucleated cell count (24,500 cells/µL; reference interval, <5,000 cells/µL), erythrocyte count (665,000 RBCs/µL; corresponding to

### Abbreviations

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<tr>
<th>ALP</th>
<th>Alkaline phosphatase</th>
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<td>GGT</td>
<td>γ-Glutamyltransferase</td>
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From the Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois, Urbana, IL 61802 (Tennent-Brown); the Department of Large Animal Medicine, College of Veterinary Medicine, University of Georgia, Athens, GA 30602 (Whelchel); the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, OH 43017 (Mudge); the Department of Large Animal Clinical Sciences, College of Veterinary Medicine, Texas A&M University, College Station, TX 77841 (Hardy); the Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32611 (Freeman); and Chino Valley Equine Hospital, 2945 English Pl, Chino Hills, CA 91709 (Fischer). Dr. Tennent-Brown’s present address is the Equine Centre, Veterinary Clinic and Hospital, Faculty of Veterinary Science, University of Melbourne, Melbourne, VIC 3030, Australia. Address correspondence to Dr. Tennent-Brown (brett.tennent@unimelb.edu.au).
a PCV of 4%), and total protein concentration (3.0 g/dL; reference interval, < 2.5 g/dL). The nucleated cells were predominantly neutrophils, consistent with suppurative inflammation. No microorganisms were observed, and culture of the peritoneal fluid yielded no growth.

Feed was withheld, and broad-spectrum antimicrobials, including potassium penicillin (22,000 U/kg, IV, q 6 h), gentamicin (6.6 mg/kg [3 mg/lb], IV, q 24 h), and metronidazole (15 mg/kg [6.8 mg/lb], PO, q 8 h); flunixin (0.25 mg/kg [0.11 mg/lb], IV, q 8 h); and polyionic fluids (± mL/kg/h [1.8 mL/lb/h], IV) were administered. The colt remained afebrile and appeared comfortable, although its heart rate was consistently increased (72 to 94 beats/min). Although the horse was slightly brighter in attitude on day 2 of hospitalization, its respiratory rate and effort were increased. Plasma creatinine concentration had decreased on repeated serum biochemical analysis; however, both total protein and albumin concentrations had decreased. Ultrasonographic examinations of the abdomen and thorax were repeated; a moderate volume of fluid similar in appearance to that seen in the abdomen previously was apparent within the thorax, and the volume of fluid within the abdomen appeared to have increased. A mass of mixed echogenicity measuring approximately 10 to 15 cm in diameter was apparent in the cranial ventral abdomen. The origin of the mass could not be identified. Abdominocentesis was repeated; results of cytologic examination of the peritoneal fluid were largely unchanged, although the erythrocyte count had increased (2,410,000 RBCs/µL; PCV, 10%). A clotting profile was performed and revealed that prothrombin time was within reference limits (18.1 seconds; reference interval, 10.0 to 20.0 seconds); however, both partial thromboplastin time (> 60 seconds; reference interval, < 39.0 seconds) and concentration of fibrin degradation products (10 to 40 µg/mL; reference interval, < 10 µg/mL) were increased. Venous pH was within reference limits (7.40), although venous lactate concentration was increased (3.6 mmol/L; reference interval, < 1.5 mmol/L).

On the basis of a lack of clinical improvement and concerns of an intra-abdominal septic process, an exploratory laparotomy was performed. Immediately before surgery, approximately 22 L of serosanguineous fluid was drained from the thorax; the PCV and total protein concentration of this fluid were 4% and 2.0 g/dL, respectively. Upon entering the abdomen, a large volume of serosanguineous fluid was evident and a strong odor of necrotic tissue emerged. Both the large and small intestines were diffusely reddened, and the mesentry was hemorrhagic in appearance. On manual exploration, the left liver lobe was found to be very mobile and floating within the peritoneal fluid. A torsion was felt at the base of this lobe; the affected section of liver was friable on palpation with a roughened surface that was gray and tan in color. The torsion was easily corrected; however, to improve access, the abdominal incision was extended to the xiphoid process and the large colon extortedized. This allowed insertion of a thoracoabdominal stapling device and placement of a staple line of 4.8-mm staples at the level of the original torsion. A second line of staples was placed paral-

### Table 1—Selected laboratory results from a 3-year-old Appaloosa colt (horse 1), a 7-year-old Quarter Horse gelding (horse 2), a 12-year-old Quarter Horse gelding (horse 3), a 14-year-old Quarter Horse mare (horse 4), a 12-year-old Thoroughbred mare (horse 5), and a 16-year-old Peruvian Paso Fino gelding (horse 6) determined to have torsion of a liver lobe at 4 referral institutions over a 21-year period.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Reference interval</th>
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</thead>
<tbody>
<tr>
<td>Leukocytes (cells/µL)</td>
<td>7,280</td>
<td>7,300</td>
<td>7,400</td>
<td>11,700*</td>
<td>13,400*</td>
<td>21,500*</td>
<td>8,800</td>
</tr>
<tr>
<td>Segmented neutrophils (%)</td>
<td>56</td>
<td>79</td>
<td>70</td>
<td>87</td>
<td>69</td>
<td>91</td>
<td>79</td>
</tr>
<tr>
<td>Band neutrophils (%)</td>
<td>5*</td>
<td>0</td>
<td>0</td>
<td>2*</td>
<td>19*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lymphocytes (%)</td>
<td>29*</td>
<td>21</td>
<td>28</td>
<td>11</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>40</td>
<td>26</td>
<td>36</td>
<td>34</td>
<td>47</td>
<td>43</td>
<td>32</td>
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<tr>
<td>Fibrinogen (mg/dL)</td>
<td>500*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>988*</td>
<td>220</td>
<td>600*</td>
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<tr>
<td>Total protein (g/dL)</td>
<td>4.3*</td>
<td>3.0*</td>
<td>5.1*</td>
<td>5.9</td>
<td>6.5</td>
<td>7.3</td>
<td>7.9</td>
</tr>
<tr>
<td>Albumin (g/dL)</td>
<td>2.3*</td>
<td>1.7*</td>
<td>2.4</td>
<td>3.0</td>
<td>2.2*</td>
<td>4.0*</td>
<td>—</td>
</tr>
<tr>
<td>AST (U/L)</td>
<td>352*</td>
<td>287*</td>
<td>283</td>
<td>228</td>
<td>500*</td>
<td>273</td>
<td>1,272*</td>
</tr>
<tr>
<td>CK (U/L)</td>
<td>772*</td>
<td>156</td>
<td>598*</td>
<td>685*</td>
<td>122</td>
<td>61</td>
<td>325*</td>
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<tr>
<td>ALP (U/L)</td>
<td>248*</td>
<td>287*</td>
<td>127</td>
<td>136</td>
<td>209*</td>
<td>931*</td>
<td>198</td>
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<tr>
<td>GGT (U/L)</td>
<td>14</td>
<td>14</td>
<td>20</td>
<td>15</td>
<td>18</td>
<td>144*</td>
<td>32*</td>
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<tr>
<td>SDH (U/L)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Total bilirubin (mg/dL)</td>
<td>6.4*</td>
<td>7.3*</td>
<td>2.3</td>
<td>2.1*</td>
<td>6.7*</td>
<td>3.1*</td>
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<td>Creatinine (mg/dL)</td>
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<td>1.7</td>
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<td>1.8</td>
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<td>Glucose (mg/dL)</td>
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<td>113</td>
<td>166*</td>
<td>112</td>
<td>168*</td>
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<tr>
<td>Lactate (mmol/L)</td>
<td>3.6*</td>
<td>0.6</td>
<td>—</td>
<td>—</td>
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Because testing was performed at several laboratories, only approximate reference intervals are presented.

*Results fell outside the testing laboratories’ reference intervals.

— = Data not available. AST = Aspartate aminotransferase. CK = Creatine kinase. SDH = Sorbitol dehydrogenase.

For horse 2, a CBC was performed by the referring veterinarian on the morning of initial examination and plasma biochemistry analysis was performed at the referring institution. For horse 5, a CBC and plasma biochemistry analysis were performed by the referring veterinarian 2 days prior to initial examination. For horse 6, a CBC and plasma biochemistry analysis were performed by the referring veterinarian 1 day prior to initial examination.
2 L of heparinized (20 U/L) plasma was administered and subsequently closed routinely. During surgery, lavaged copiously with sterile saline (0.9% NaCl) solution from the transected hepatic stump. The abdomen was examined closely; no other abnormalities were evident, and there was no evidence of hemorrhage from the transected hepatic stump. The abdomen was lavaged copiously with sterile saline (0.9% NaCl) solution and subsequently closed routinely. During surgery, lavaged copiously with sterile saline (0.9% NaCl) solution from the transected hepatic stump. The abdomen was examined closely; no other abnormalities were evident, and there was no evidence of hemorrhage from the transected hepatic stump.

After surgery uneventfully. Perioperative treatment included broad-spectrum antimicrobials (potassium penicillin [22,000 U/kg, IV, q 6 h]; gentamicin [0.6 mg/kg, IV, q 24 h]; and metronidazole [15 mg/kg, PO, q 8 h]), flu- nixin (1.1 mg/kg, IV, q 12 h), and polyionic fluids (4 mL/kg/h, IV).

After recovery from surgery, the gelding developed intra-abdominal hemorrhage that was diagnosed on the basis of clinical signs, a decrease in PCV, and ultrasonographic findings. The hemorrhage was assumed to originate from the site of liver lobe resection, necessitating whole blood transfusion (6 L). Acute renal failure was diagnosed on day 3 of hospitalization on the basis of an increased plasma creatinine concentration (4.5 mg/ dL) and isothenuria; consequently, the dose of flunixin meglumine was decreased (0.5 mg/kg [0.23 mg/lb], IV, q 12 h) and the gentamicin was replaced with enro- floxacin (7.5 mg/kg [3.4 mg/lb], IV, q 12 h). On day 7 of hospitalization, the gelding developed a fever of unknown origin that responded to a change in antimicrobial treatment to chloramphenicol (50 mg/kg [23 mg/lb], PO, q 8 h). Subsequently, the gelding's condition steadily improved and it was discharged on day 16 of hospitalization. Twelve months after discharge, the gelding was returned to the hospital for a dental procedure; the owners reported that it was competing successfully and had had no further episodes of colic.

A 7-year-old Quarter Horse gelding (horse 2) was used for rein in was evaluated because of mild but progressive colic of approximately 18 hours' duration. Eight liters of reflux were obtained on passage of a nasogastric tube by the referring veterinarian on the morning of admission. A CBC performed by the referring veterinarian revealed mild anemia (Table 1). On initial evaluation at the referral institution, the gelding was mildly sedated (0.3 mg of xylazine/kg [0.13 mg/lb], IV) and appeared comfortable, with both heart (42 beats/min) and respiratory (16 breaths/min) rates within normal limits and a low-normal rectal temperature (36.5°C [97.7°F]). Findings on palpation per rectum and on ultrasonographic examination of the abdomen were considered within normal limits. Serum biochemical analysis was performed (Table 1). Fluid obtained via abdominocentesis during the initial examination was grossly serosanguineous, and the gelding developed signs of abdominal discomfort once placed in a stall. Subsequently, an exploratory laparotomy was performed approximately 3 hours after arrival at the referral institution, during which torsion of the left medial liver lobe was diagnosed. The initial laparotomy incision was 30 cm in length beginning 20 cm caudal to the xiphoid process but was extended 1.5 cm cranially once torsion of the liver was diagnosed. The torsion of the affected liver lobe was corrected, and a stapling device6 was applied twice at the most proximal aspect of the affected lobe. Mayo scissors were then used to resect the affected lobe distal to the double row of staples. The remainder of the abdominal contents was within normal limits, and no hemorrhage was appreciated at the site of the resection. The gelding recovered from surgery uneventfully. Perioperative treatment included broad-spectrum antimicrobials (potassium penicillin [22,000 U/kg, IV, q 6 h]; gentamicin [0.6 mg/kg, IV, q 24 h]; and metronidazole [15 mg/kg, PO, q 8 h]), flunixin (1.1 mg/kg, IV, q 12 h), and polyionic fluids (4 mL/kg/h, IV).

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In veterinary medicine, liver lobe torsion has most commonly been described in dogs but, even in this species, it is considered rare. Liver lobe torsions have also been described in laboratory animals (rats, rabbits, and mice), cats, an otter, pigs, and 2 horses. A handful of reports exist describing liver lobe torsions in humans, most of which involve accessory liver lobes (Reidell’s lobe), which are a common and otherwise benign abnormality of the liver. The liver in horses is maintained in position by multiple ligamentous attachments, and it is considered rare.

Discussion

In veterinary medicine, liver lobe torsion has most commonly been described in dogs but, even in this species, it is considered rare. Liver lobe torsions have also been described in laboratory animals (rats, rabbits, and mice), cats, an otter, pigs, and 2 horses. A handful of reports exist describing liver lobe torsions in humans, most of which involve accessory liver lobes (Reidell’s lobe), which are a common and otherwise benign abnormality of the liver. The liver in horses is maintained in position by multiple ligamentous attachments, and it is considered rare.
tachments to the diaphragm and body wall and by the pressure exerted by other abdominal organs. The equine liver is anchored by 6 ligaments; in humans, congenital absence, disruption, or stretching of these attachments is required to allow torsion of a lobe to occur. However, only the dorsal margins of the equine left and right liver lobes are secured to the diaphragm and changes in gastrointestinal fill might allow rotation of the less restricted ventral margins. An abnormality of the securing ligaments might have allowed lobe torsion in some of the patients of the present report, although this was not apparent at surgery or necropsy. In domestic animals, hepatic lobe torsion has occasionally been associated with gastric dilatation-volvulus, hepatic abscesses, neoplastic masses, and trauma; however, in most cases, the underlying cause is not apparent. In 1 horse of the present report, bile duct carcinoma was identified at necropsy that might have predisposed to torsion. In dogs, large breeds appear to be more commonly affected and, in early reports, torsion most often involved the left lateral lobe. The predilection for torsion of the left lateral lobe is less apparent in later reports and other lobes can be affected. The left medial liver lobe was affected in 3 of the 6 patients described in the present report and in 1 previous report of hepatic lobe torsion in a horse; the entire left liver lobe was affected in one of the horses of the present report and likely was involved in the initial report of liver lobe torsion in a horse.

Animals with liver lobe torsions can have severe clinical abnormalities, including weakness, collapse, and signs of shock. In some cases, affected animals are found dead, probably as a result of septic or hypovolemic shock subsequent to hepatic necrosis. Commonly reported historical complaints in affected dogs include lethargy or signs of depression, anorexia, polyuria or polydipsia, and sporadic vomiting. The duration of disease is often chronic (days), with animals evaluated after acute worsening of nonspecific signs. Physical examination findings commonly reported for affected dogs are nonspecific but include weakness or recumbency, pyrexia, tachycardia, tachypnea, signs of hypovolemia, and abdominal distention. Signs of pain on palpation of the cranial abdomen are not uncommon but can be absent. Clinical signs in other species are similar. In the first published description of a horse with a liver lobe torsion, a 14-year-old Arab gelding was initially examined because of signs of mild abdominal pain, signs of depression, and anorexia. In a second report, a 4-year-old Belgian mare was examined because of anorexia and fever of unknown origin. Two of the patients described in the present report were examined because of signs of abdominal discomfort; clinical signs in the others were less specific but included signs consistent with a severe inflammatory process.

Hematologic and plasma biochemistry abnormalities in animals with liver lobe torsion are widely variable and nonspecific. Changes in the leukogram are generally consistent with severe inflammation, although the peripheral WBC count can be increased, decreased, or within reference limits. In a report describing liver lobe torsion in 13 dogs, mature neutrophilia and leukocytosis were the most common hematologic abnormalities. An increase in the number of band neutrophils is not an infrequent finding. In most cases in dogs, there is an increase in hepatocellular enzyme activity (ie, alanine transferase, aspartate aminotransferase, and sorbitol dehydrogenase) indicative of hepatocellular necrosis and enzyme leakage. Increases in enzyme activities more consistent with cholestatic disease (ie, ALP and GGT) have also been described. In the first report of a horse with liver lobe torsion, there was an increase in sorbitol dehydrogenase activities but ALP, GGT, and aspartate aminotransferase activities were within reference limits. In that case, enzyme activities rapidly returned to within reference limits after resection of the affected liver lobe. In the patients of the present report and the previously reported case in a Belgian mare, liver enzyme activities were either within reference limits or only mildly increased; the notable exception was the mare diagnosed with bile duct carcinoma, which had marked increases in GGT and ALP activities. Total bilirubin concentration was increased in many cases, although interpretation is confounded by anorexia in horses. In affected dogs, as in horse 1 of this report, there can often be clinical and clinicopathologic evidence of coagulopathy.

Peritoneal fluid in animals with liver lobe torsion is often grossly serosanguineous with an increased protein concentration. Diapedesis of erythrocytes subsequent to venous obstruction, passive congestion, and increased hydrostatic pressure within the liver is likely, at least in part, responsible for the hemorrhagic abdominal effusion. Abnormalities of hemostasis secondary to a severe inflammatory response might also contribute to hemoabdomen in some animals. Coagulopathy is the likely explanation for effusions of similar character in both the abdominal and thoracic cavities in horse 1 of this report. In reported cases, peritoneal leukocyte counts usually exceed that which would be expected from hemorrhage alone consistent with peritoneal inflammatory response. Moderately to markedly increased peritoneal nucleated cells counts were recorded in all horses of this report for which results from abdomino-centesis samples were reported.

In the initial report describing liver lobe torsion in a horse, intracellular and extracellular bacteria were observed in peritoneal fluid samples, and similar findings have been reported in affected dogs. In clinically normal dogs, bacteria can be present in the liver due to migration through the portal vein from the intestine and this might also occur in clinically normal horses. Clostridial organisms are present in normal bovine livers and might also be present in normal equine livers. It has been suggested that tissue hypoxia and necrosis subsequent to lobe torsion results in proliferation and overgrowth of resident clostridial organisms in affected dogs. The presence of these and other bacterial organisms and their toxins are thought to contribute to the clinical picture of marked inflammation reported in some canine cases and might have played a role in the equine cases described in the present report.

Abdominal imaging has provided supportive evidence for a diagnosis of liver lobe torsion in small animal and human medicine. Techniques used include radiography, ultrasonography, CT, and MRI. Radio-
graphs of dogs with liver lobe torsion often reveal a mass within the cranial abdomen and can indicate the presence of necrosis, gas-forming organisms, and periportal effusion. Ultrasonographic findings consistent with liver lobe torsion include evidence of decreased blood flow or vessel congestion, a hypoechoic or heterogenous appearance to the hepatic parenchyma, and peritoneal effusion. Ultrasonography revealed a mass of mixed echogenicity in the cranial abdomen in 2 of the horses of the present report, but results of abdominal ultrasonography of the other patients of this report and the 2 previous reports were either not reported or considered within normal limits. Intraoperative imaging of the torse lobe was considered valuable in one of the horses of this report as previously suggested. Ultrasonographic diagnosis of hepatic lobe torsion in horses is limited by the small available imaging windows and the difficulty in identifying individual lobes. In particular, much of the ventral aspect of the left liver lobe is usually obscured by the gastrointestinal tract. Standing flank laparoscopy was not useful in the 1 horse in which it was used. However, laparoscopy performed with the horse in dorsal recumbency was useful in both reaching a diagnosis and planning the subsequent surgical approach.

In the 5 horses of this report that were taken to surgery, stapled resection of the affected liver lobe was performed with a stapling device. A stapled resection technique was also described in a previous report of liver lobe torsion in dogs. Intraoperative hemorrhage is a potentially life-threatening complication of liver resection; the stapled technique has the advantage of providing hemostasis of the lobar vessels and parenchyma without requiring tissue dissection and vessel identification. A bipolar vessel sealing device and harmonic scalpel have been used in human patients for hepatic resection, and these techniques might also have applicability in horses. This case series illustrates the difficulties in diagnosing liver lobe torsion in horses. Clinical signs are often suggestive of an inflammatory disease but are nonspecific and can be either acute or chronic. Results from laboratory tests are also nonspecific, and liver enzyme activities are only occasionally increased. The peritoneal fluid in each of the horses of the present report was abnormal, and most patients had markedly increased peritoneal nucleated cell counts. Two horses underwent laparotomy that allowed definitive diagnosis because of persistent clinical signs of abdominal pain. Surgical exploration of the abdomen of 3 horses was performed when their condition failed to respond to medical management. A recent report has suggested that horses with peritonitis and persistent signs of pain are more likely to require surgery; however, overt signs of colic were not present in all the patients described in the present report. Liver lobe torsion might also be considered in horses with peritonitis that fails to respond to apparently appropriate medical treatment. On the basis of this case series, the prognosis for hepatic lobe torsion can be good. Early surgical correction is expected to improve outcome; however, this is hindered by the difficulty in reaching a definitive diagnosis.

References