Diagnostic utility of abdominal ultrasonography for evaluation of dogs with nontraumatic hemoabdomen: 94 cases (2014–2017)

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OBJECTIVE
To evaluate the utility of abdominal ultrasonography (AUS) to detect grossly evident masses in dogs with nontraumatic hemoabdomen.

ANIMALS
94 client-owned dogs.

PROCEDURES
Electronic medical records from 2014 to 2017 were searched to identify dogs with nontraumatic hemoabdomen that had an AUS performed by a radiologist and subsequently underwent gross evaluation by surgery or necropsy. Ultrasonography, surgery, and histology reports were reviewed, and descriptive statistics were performed. Sensitivity of ultrasonography to detect grossly identifiable masses was calculated.

RESULTS
Differences were identified between AUS and surgical or necropsy findings for 51 of 94 (54%) dogs. Splenic masses were most commonly identified as the cause of hemoabdomen. Sensitivity of AUS was 87.4%, 37.3%, and 31.3% for masses in the spleen, liver, and mesentery, respectively. Five dogs had more lesions identified with AUS than were found on gross evaluation; 0 of 6 dogs with peritoneal diffuse nodular metastasis had lesions detected by AUS.

CONCLUSIONS AND CLINICAL RELEVANCE
In this sample of dogs, the utility of AUS to detect grossly identifiable lesions in dogs with nontraumatic hemoabdomen was limited, with the highest and lowest sensitivity found for splenic masses and diffuse nodular metastasis, respectively. (J Am Vet Med Assoc 2021;258:290–294)

Nontraumatic hemoabdomen is a common finding in dogs presented to emergency departments for evaluation, and it most commonly results from a ruptured intra-abdominal mass originating in the spleen. Surgical exploration for control of hemorrhage is the definitive treatment. Dogs with nontraumatic hemoabdomen are typically geriatric, with a mean age of 10 years. Nontraumatic hemoabdomen is associated with malignant neoplasia in 76% to 80% of cases, and 63% to 70% of malignant splenic neoplasms are hemangiosarcomas. Previous literature indicates that 62.5% to 90% of the lesions in dogs with acute nontraumatic intra-abdominal hemorrhage are splenic in origin, although other organs, including the liver, kidneys, omentum, urinary bladder, and adrenal glands, as well as the peritoneum, have been reported as sources of hemorrhage. For dogs splenectomized for treatment of hemoabdomen secondary to splenic hemangiosarcoma, a retrospective study of 60 cases found a median survival time of 1.6 months, whereas in dogs with benign causes, surgical excision was considered curative. Other tumor types found in dogs with nontraumatic hemoabdomen include mesothelioma, melanoma, lymphoma, malignant splenic carcinoma, poorly differentiated sarcoma, pheochromocytoma, and adrenocortical carcinoma, among others.

There is no single preoperative biochemical or cytologic test that can be used to help clinicians differentiate between hemangiosarcoma and other causes for hemoabdomen in dogs. However, a recent publication identified a risk analysis model that includes physiologic, biochemical, and diagnostic imaging findings to predict the likelihood of hemangiosarcoma in dogs with nontraumatic hemoabdomen. Diagnostic imaging is recommended to provide additional information regarding metastasis and surgical planning prior to proceeding with surgery for dogs with hemoabdomen. Preoperative thoracic radiography may indicate evidence of pulmonary metastasis, which would corroborate the presence of abdominal neoplasia and may also identify concurrent conditions such as megaesophagus, pneumonia, or cardiac enlargement that can increase anesthetic risk and alter anesthetic protocols. Abdominal ultrasonography is often recommended and performed for these patients and may provide information about the location of a bleeding primary mass. However, to the authors’ knowledge, the relationship between AUS results and gross results has not been well characterized. Whereas previous literature provides a precedent for
comparison of AUS and surgical findings,\textsuperscript{12-14} we are aware of no such reports focused on dogs with nontraumatic hemaabdomen. The goal of the retrospective study reported here was to evaluate the utility of AUS for detection of lesions subsequently identified grossly on surgical exploration or necropsy in dogs with nontraumatic hemaabdomen. We hypothesized that AUS would have a low sensitivity for lesion identification in the study sample.

**Materials and Methods**

**Case selection criteria**

All dogs with nontraumatic hemaabdomen that were evaluated by the emergency and critical care service of the Tufts University Cummings School of Veterinary Medicine from January 1, 2014, to October 1, 2017, were eligible for enrollment in the retrospective study. Dogs were only included if they had AUS performed by a board-certified veterinary radiologist or by a veterinary radiology resident with images reviewed by a board-certified radiologist and subsequently underwent gross evaluation by surgical exploration or necropsy. The diagnosis of hemaabdomen was made on the basis of identification of abdominal effusion (with or without visualization of a mass) with AUS and abdominocentesis results revealing nonclotting blood. Dogs for which the treatment of the hemaabdomen was not surgical (ie, causes of hemaabdomen such as trauma, anaphylaxis, or anticoagulant rodenticide toxicity) were excluded from the study.

**Medical records review**

Electronic medical records of dogs evaluated during the study period were searched with the keyword hemaabdomen. Data collected included signalment, diagnostic imaging procedures performed, imaging findings, and surgical or necropsy findings. Abdominal ultrasonographic reports were reviewed for identification of single or multiple lesions affecting the spleen, liver, and mesentery. Masses affecting other abdominal structures were also recorded, as was the presence of peritoneal diffuse nodular metastasis, defined as nodules affecting the diaphragm, body wall, and omentum. Surgery or necropsy reports were reviewed, and the same information on masses was collected for comparison with AUS data. Thoracic radiography reports and histology reports were reviewed when available to evaluate dogs for evidence of metastasis. The final diagnosis and patient outcome (survival to discharge, death, or euthanasia) was recorded if the information was available in the medical record.

**AUS**

Abdominal ultrasonographic examinations were performed by a board-certified veterinary radiologist or performed by a radiology resident and reviewed by a board-certified veterinary radiologist. Dogs were positioned in dorsal recumbency, and the examinations were performed after clipping of hair in the region and standard skin preparation. One of 2 ultrasound machines\textsuperscript{a,b} was used with a microconvex 5- to 8-MHz broadband array transducer and a 5- to 12-MHz linear array transducer.

**Statistical analysis**

Descriptive statistics were performed. Frequencies and percentages were determined for categorical data, and the sensitivity of AUS to detect grossly visible lesions of the spleen, liver, or mesentery or diffuse nodular metastasis (with surgical exploration or necropsy findings used as the gold standard for the presence or absence of lesions) was calculated.\textsuperscript{6} Sensitivity values were examined with frequency tables for each lesion location.

**Results**

Two hundred and forty-three dogs were identified as having nontraumatic hemaabdomen in the study period. Of these 243 dogs, 94 fulfilled inclusion criteria. Patients were primarily excluded because owners decided to euthanize the dog or not to pursue treatment. A small subset of patients had surgery without undergoing AUS. The mean ± SD age of included dogs was 9.9 ± 2.2 years; 57 of 94 (61%) dogs were male (8 sexually intact and 49 castrated) and 37 (39%) were female (1 sexually intact and 36 spayed). A wide variety of breeds were included, with Labrador Retrievers (21/94 [22%]), Golden Retrievers (16 [17%]), and German Shepherd Dogs (10 [11%]) most commonly represented. The remaining 47 dogs were of various breeds or mixed breeds, with 13 categorized as small-breed dogs and 34 categorized as large-breed dogs. Most (74/94 [79%]) dogs survived to hospital discharge. Of 20 nonsurviving dogs, 7 (35%) were euthanized after the discussion of AUS findings with the owner, 4 were euthanized during surgery, 4 were euthanized after surgery, and 5 died while hospitalized, with deaths attributed to postoperative complications.

**Gross evaluation**

Gross evaluation was performed by surgical exploration in 87 of 94 (93%) dogs and by necropsy in the remaining 7 (7%) dogs. In all 94 dogs, mass lesions were confirmed to be the cause of hemaabdomen. Twenty-nine of 94 (31%) dogs had solitary lesions, and 65 (69%) had multiple lesions in ≥1 structure. Splenic masses were most commonly identified (87/94 [93%]), followed by hepatic masses (59 [63%]), mesenteric masses (16 [17%]), and peritoneal diffuse nodular metastasis (6 [6%]; Table 1). Two dogs had masses in other sites (1 retroperitoneal mass and 1 adrenal mass [1% each]).

**AUS**

On AUS, splenic masses were reported for 82 of 94 (87%) dogs, with hepatic masses in 41 (44%) and mesenteric masses in 12 (13%). A retroperitoneal mass was identified in 1 dog. Peritoneal diffuse nodu-
lar metastasis was not identified with this method in any dogs.

**Comparison between methods**

Differences were identified between AUS and gross findings in 51 of 94 (54%) dogs. These differences included masses identified on AUS that were absent on gross examination (false positive results) and masses absent on AUS and that were present on gross examination (false negative results; Table 1). For all dogs in which lesions were identified by both methods but the number of lesions differed between AUS and gross evaluation, a greater number of lesions was found on gross examination. Therefore, these dogs were classified as having false negative results for that lesion type.

Sensitivity of AUS for detection of grossly identifiable splenic lesions was 87.4% (Table 1). Of 11 dogs with splenic lesions for which gross findings differed from AUS findings, 5 had lesions that were not found with AUS but were identified grossly. In these patients, the mass was either located at the head of the spleen or was too large to identify the source organ (although AUS confirmed the presence of a mass). For the remaining 6 dogs, there were more splenic lesions identified grossly than by AUS.

Sensitivity of AUS for detection of grossly identifiable hepatic lesions was 37.3% (Table 1). Of the 39 dogs with hepatic lesions for which findings differed from AUS findings, 20 had lesions not seen with AUS identified grossly, and 17 had more hepatic lesions present than seen with AUS; surgery and necropsy reports suggested that most of these differences were attributable to diffuse surface nodules affecting multiple lobes of the liver. Two dogs had hepatic masses identified by AUS that were not found grossly.

Sensitivity of AUS for detection of grossly evident mesenteric lesions was 31.3%. There were 8 dogs in which mesenteric lesions identified grossly were not seen with AUS, 3 in which more lesions were identified grossly than by AUS, and 4 in which mesenteric lesions identified with AUS were not found grossly.

Owing to the ultrasonographic appearance of these lesions, the reports stated that these lesions could represent either metastasis or blood clots.

Peritoneal diffuse nodular metastasis was not identified by AUS for any of the 6 dogs in which it was identified grossly (0% detection sensitivity). Additional differences included a dog in which both a retroperitoneal mass and a mesenteric mass were identified with AUS, but instead a hepatic mass was found grossly. In another dog, there was a retroperitoneal mass identified grossly that was not visualized on AUS, and in a third dog, no mass was identified with AUS, but an adrenal mass invading the vena cava was found on necropsy.

**Histologic and radiographic findings**

Histology reports were available for 86 of 94 dogs; the remaining 8 dogs were euthanized or died prior to submission of samples. At least 1 malignant lesion was found in 62 of 86 (72%) dogs, and only benign lesions were found in 24 (28%). Multifocal lesions were present in 59 of 86 (69%) dogs (48 and 11 with malignant and benign processes, respectively). The most commonly identified benign lesions were hematoma (10/24 [42%] dogs, including 3 with multifocal lesions) and hepatocellular adenoma (2 [8%], of which 1 had multifocal lesions). Other benign causes were identified in 12 (50%) dogs (7 with multifocal lesions). Thirty-one of 59 (53%) dogs with multifocal lesions on gross examination had evidence of metastasis on histologic examination.

Malignancies included hemangiosarcoma (50/86 [58%]), lymphoma (3 [3%]), and hepatocellular carcinoma (3 [3%]), in addition to splenic carcinosarcoma, extrhepatic hepatobiliary carcinoma, splenic sarcoma, histiocytic sarcoma, pheochromocytoma, and plasma cell neoplasia (1 [1%] each). Not all splenic lesions were hemangiosarcomas; however, a splenic lesion was found in all 50 dogs with hemangiosarcoma, with multifocal lesions in 39 of the 50 (78%) and evidence of metastasis in 25 of the 50 (50%) dogs with this diagnosis at the time of evaluation. All 4 cases

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Table 1—Analysis for sensitivity of AUS to detect lesions subsequently identified on gross examination during surgery (n = 87) or necropsy (7) in 94 dogs with nontraumatic hemoabdomen that were examined at the emergency and critical care service of a veterinary teaching hospital from January 1, 2014, to October 1, 2017.

<table>
<thead>
<tr>
<th>Finding</th>
<th>Gross examination (No. of dogs)</th>
<th>AUS (No. of dogs)</th>
<th>Sensitivity of AUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
<td>TP</td>
</tr>
<tr>
<td>Splenic mass</td>
<td>87</td>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td>Hepatic mass</td>
<td>59</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>Mesenteric mass</td>
<td>16</td>
<td>78</td>
<td>5</td>
</tr>
<tr>
<td>Peritoneal diffuse nodular metastasis</td>
<td>6</td>
<td>88</td>
<td>0</td>
</tr>
</tbody>
</table>

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*When the number of lesions found in a structure differed between AUS and gross findings, fewer lesions were found by AUS in each case, and these were classified as false negatives for sensitivity analysis (n = 6, 17, and 3 for splenic, hepatic, and mesenteric masses, respectively).

FN = False negative (a lesion was present but not found by AUS). FP = False positive (a lesion identified by AUS was not present on gross examination). TN = True negative (lesion not found by either method). TP = True positive (lesion found by both methods).
of diffuse nodular metastasis were in dogs with hemangiosarcoma. Two of 3 dogs with lymphoma, 3 of 3 with hepatocellular carcinoma, and 2 of 2 with other carcinomas had multifocal lesions (with evidence of metastasis in 2, 1, and 1, respectively). The dog with plasma cell neoplasia and the dog with histiocytic sarcoma each had multifocal lesions, with evidence of metastasis on thoracic radiographs in the former, and histologic evidence of metastasis in the latter dog.

Thoracic radiography was performed for 9 of 94 dogs. For the remaining 85 dogs, the procedure was declined by owners, the patient was not considered clinically stable enough for the procedure, or the patient was euthanized without the additional imaging. Pulmonary masses or nodules were identified by a radiologist as evidence of metastasis in 5 of 9 dogs (4 with hemangiosarcoma and 1 with plasma cell neoplasia). None of these 5 patients underwent necropsy.

Discussion

The present study of 94 dogs with nontraumatic hemoabdomen helped to elucidate the utility of AUS for detection of lesions that were grossly identifiable in patients that subsequently underwent surgery or necropsy. Differences between AUS and gross findings were common. The greatest sensitivity (87.4%) of AUS was found for detection of splenic lesions, with substantially lower values for hepatic (37.3%) and mesenteric (31.3%) lesions, and the least sensitivity was found for diffuse nodular metastasis (0%). This information should be considered in discussions with owners regarding the use of AUS to inform decision-making about whether to proceed with surgery.

Our study sample was demographically similar to those in previous studies of dogs with nontraumatic hemoabdomen, with older dogs (mean age, 99 years) and German Shepherd Dogs, Labrador Retrievers, and Golden Retrievers most commonly represented. Our results revealed similar but slightly lower frequencies of malignant lesions (72% vs 76% to 80%), including hemangiosarcoma (57% vs 63% to 70%), compared with the results of previous studies. Overall, the findings of AUS were confirmed by surgical or necropsy findings for 43 of 94 (46%) dogs in the present study, with inconsistent results for the remaining 51 (54%) dogs. Recent literature indicates that AUS has important limitations in large dogs with a deep-chested conformation, and this may have limited the ability to detect liver lesions by AUS in the present study. In the present study, several AUS reports included remarks on patients’ deep-chested conformation hindering complete evaluation of the craniodorsal abdominal region. In addition, the 2-D images provided by ultrasonography make differentiation of multiple lesions in a single organ more difficult. We subjectively noted that poor sensitivity of AUS to detect some lesions may have been associated with their size, as inconsistencies with the gross findings were frequently noted in dogs that had nodules on the surface of the liver or diffuse nodular metastasis. Interpretation of AUS images can be complicated by a large volume of abdominal effusion, reactive peritonitis, and blood clots in dogs with hemoabdomen. For some dogs of the present study, AUS reports indicated that presumed metastatic lesions might also represent blood clots.

Splenic lesions were by far the most common lesions detected in our study, which was consistent with previous reports of dogs with hemoabdomen. All splenic lesions detected on AUS were subsequently identified on gross examination in the study reported here. When splenic lesions were found grossly that were not visualized with AUS (n = 6 dogs), the surgery or necropsy reports suggested this was attributable to location of the mass at the head of the spleen or to a large size that impeded identification of the organ where the mass originated. In a similar number of dogs, differences between AUS results and gross findings resulted from detection of fewer lesions in the spleen with AUS. This would likely have minimal clinical importance, because splenectomy would be performed regardless of the number of lesions present in the organ. Splenic lesions in dogs and cats can usually be identified with AUS in an emergency room setting. Future studies should investigate whether an AUS performed by a radiologist (vs in an emergency room setting) provides additional data that would influence an owner’s decision in regard to pursuing treatment or surgical planning for dogs with nontraumatic hemoabdomen.

The low sensitivity of AUS for detection of grossly evident hepatic lesions in the present study was likely attributable in part to a propensity for multifocal small surface lesions or the presence of multiple lesions that were difficult to differentiate by this method, leading to an underestimation of the lesion number. However, this was not always the case. For the most part, larger lesions were missed due to location of the mass in the region where the head of the spleen, the liver, and the retroperitoneal space are most difficult to differentiate.

Limitations of the study reported here included limitations associated with all retrospective studies and studies with small data sets. In addition, this study excluded dogs that did not have both AUS by a radiologist and surgery or necropsy performed. Histologic and thoracic radiographic results were not available for all dogs in this study, which may have skewed the results. Specificity data could not be reported as, given the retrospective nature of the study, all dogs had causes for hemoabdomen other than ruptured abdominal masses ruled out prior to inclusion.

The goals of AUS include identification of primary lesions and gross metastatic disease. This information can be valuable for surgical planning and for determining prognostic information to provide owners who must decide whether to pursue surgical treatment. Results of the study reported here suggested that AUS findings may be discordant with gross...
findings, particularly in dogs with hepatic masses or diffuse nodular metastasis as a cause for hemoabdomen. Although not analyzed statistically, the fact that slightly more than half of the dogs with multifocal lesions on gross examination (31/59 [53%]) had histologic evidence of metastasis supported that identification of multifocal lesions is not necessarily an indicator of metastatic disease. In the present study, 4 dogs had mesenteric lesions identified by AUS that were not found on gross examination. In 1 of these dogs, the underlying cause of the hemoabdomen was a benign lesion. Mesenteric lesions are the most likely to be confused with blood clots free-floating within the abdomen on AUS evaluation, which may explain the number of false-positive findings for that lesion type in this study. Diffuse nodular metastasis, with small lesions grossly affecting multiple surfaces in the abdomen, has been anecdotally noted to be difficult to detect on AUS. In the present study, AUS had a 0% sensitivity for detection of those lesions, and all 4 of the dogs with this gross finding for which histology reports were available had metastatic hemangiosarcoma. The utility and accuracy of other imaging modalities such as CT for detection of such lesions should be evaluated in future studies.

With the advent of point of care ultrasonography in many emergency rooms, a mass lesion in the spleen can often be identified without a full AUS examination. Complete AUS with a radiologist may represent an investment both financially and in time delay to surgical intervention in potentially unstable patients. Future studies should further evaluate the utility of complete AUS in adding clinically meaningful information, particularly when a mass in the spleen can be identified on AUS in the emergency room.

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Footnotes
a. EPIQ 7G, Philips Healthcare, Andover, Mass.
c. IBM SPSS Statistics for Windows, version 25.0, IBM Corp, Armonk, NY.

References