Evaluation of diagnostic and prognostic usefulness of abdominal ultrasonography in dogs with clinical signs of acute pancreatitis

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OBJECTIVE
To report abdominal ultrasonography (AUS) findings in dogs with clinical signs of acute pancreatitis (AP) during the first 2 days of hospitalization and to compare AUS findings with severity of disease and mortality rate.

ANIMALS
37 client-owned dogs with clinical signs of AP.

PROCEDURES
Dogs suspected of having AP with complete medical records, AUS examinations performed throughout the first 2 days of hospitalization, and available frozen surplus serum samples for quantitative measurement of canine pancreatic lipase (cPL) concentrations at hospital admission met the criteria for study inclusion. Dogs were grouped as AUS+ or AUS– on the basis of positive or negative findings for AP on AUS, respectively. Abdominal ultrasonography findings of AP were stratified (as mild, moderate, or severe) by use of an AUS severity index, and a canine acute pancreatitis severity score was calculated.

RESULTS
24 of 37 (64.8%) dogs had AUS findings of AP at hospital admission, whereas 10 had positive findings for AP on AUS within 2 days of hospitalization. Three (8%) dogs were AUS– but had serum cPL concentrations > 400 µg/L (ie, values considered diagnostic for AP). On the AUS severity index, 5 of 34 (14.7%) AUS+ dogs had mild findings, 18 (52.9%) AUS+ dogs had moderate findings, and 11 (32.4%) AUS+ dogs had severe findings. Severe findings were associated with a higher risk of death than mild and moderate findings. A significant association was found between canine acute pancreatitis severity scores and mortality rates.

CONCLUSIONS AND CLINICAL RELEVANCE
For dogs with clinical signs of AP, repeated AUS examinations during hospitalization should be performed, severe findings on the AUS severity index may indicate an increased risk of death, and serum cPL concentrations may increase earlier than findings on AUS of AP.

Materials and Methods
Case selection and medical record review
Hospitalized client-owned dogs with clinical signs of AP that had been enrolled in a larger prospective study conducted at our veterinary teaching hospital.
between March 2017 and April 2019 were evaluated for inclusion in the present study. The study protocol was reviewed and approved by the Committee of the Ethics of Animal Experiments of the University of Pisa (permit No. 16749/2017), and informed consent was obtained from owners of privately owned dogs.

For each dog, a CBC, serum biochemical analysis, and coagulation profile were performed at hospital admission. Acute pancreatitis was suspected in dogs on the basis of the following: 2 clinical signs that included abdominal pain, diarrhea, vomiting, and anorexia or inappetence; hematologic variables indicative of acute inflammation; and abnormal result on a rapid point-of-care semiquantitative cPL immunoassay. When available, surplus serum samples from dogs obtained at hospital admission were frozen and stored at –80 °C for a maximum of 1 year until further analysis. Stored serum samples from each dog were frozen-packaged and delivered on dry ice to a commercial laboratory for quantitative evaluation of cPL. This test reference interval for serum cPL concentration in healthy dogs was 0 to 200 µg/L. A serum cPL concentration of ≥ 400 µg/L was considered diagnostic for AP, whereas a serum cPL concentration of 201 to 399 µg/L was considered to be indeterminate (ie, possibly consistent with AP) and required further clinical data to confirm a diagnosis of AP.

Medical records of dogs with clinical signs of AP at hospital admission were retrospectively reviewed by 1 author (EG) to identify affected dogs with complete medical records. Abdominal ultrasonographic reports and ultrasonographic images of dogs at hospital admission and during hospitalization were also reviewed. Dogs without the necessary criteria for study inclusion (ie, complete medical records, AUS reports and images, and available stored serum samples) were excluded from the study. Dogs for which visualization of the entire pancreas on AUS was not achieved on the basis of the AUS report were also excluded from the study. In addition, dogs with persistently negative findings on AUS for AP and with a serum cPL concentration ≤ 200 µg/L were classified as not having AP and were therefore excluded from the study. Dogs with clinical signs compatible with AP and a serum cPL concentration between 201 to 399 µg/L but with persistently negative findings on AUS for AP were excluded from statistical analysis.

**AUS examination**

Abdominal ultrasonography was performed at hospital admission and every 24 hours for up to 2 days. Dogs were placed into 2 groups on the basis of AUS findings as follows: the AUS+ group included dogs that had AUS findings of AP within 2 days of hospitalization, and the AUS– group included dogs that had AUS findings that were negative for AP from the time of hospital admission through the last AUS examination on day 2 of hospitalization. For AUS, dogs were positioned in lateral recumbency, the hair on the abdominal region was shaved, and ultrasound gel was used to facilitate the ultrasound probe contact. The entire abdomen was scanned for signs of other potential abdominal diseases as well as the suspected AP. Abdominal ultrasonographic findings were considered consistent with AP (AUS+ group dogs) if there was a hypoechoic-heterogeneous enlarged pancreas surrounded by hyperechoic mesentery with or without abdominal effusion. The echogenicity of the pancreas was evaluated in relation to surrounding landmarks, such as the surrounding mesentery, kidneys, spleen, and liver. The echogenicity of the peripancreatic mesentery was compared with other parts of the mesentery. In addition, AUS report and image reviews were performed to stratify findings of AP by use of an AUS severity index as follows (Figure 1): mild, presence of a hypoechoic-heterogeneous enlarged pancreas alone; moderate, pancreatic alterations and peripancreatic hyperechogenicity and peripancreatic free fluid; and severe, pancreatic alterations and diffuse abdominal hyperechogenicity with free fluid.

**CAPS score**

The CAPS score for each dog was retrospectively calculated according to the following formula developed by Fabrès et al: CAPS score = 8 X (1 if SIRS, 0 otherwise)+c+c+c+c+X (1 if coagulation disorders, 0 otherwise)+c+c+c+X (1 if increased creatinine, 0 otherwise). Systemic inflammatory response syndrome was defined by the presence of ≥ 2 of the following criteria: heart rate > 120 beats/min, respiratory rate > 20 breaths/min, rectal temperature < 38.1 °C or > 39.2 °C, and WBC count < 6,000 cells/µL or > 16,000 cells/µL. Coagulation disorders were defined by the presence of ≥ 1 of the following criteria: thrombocytopenia (platelet count < 63,000 platelets/µL) and prothrombin time or activated partial thromboplastin time or both prolonged by > 25% of the upper end of the reference interval. Increased serum creatinine was defined as a creatinine concentration > 1.6 mg/dL and ionized hypocalemia as ionized calcium concentration < 4.4 mg/dL.

Dogs were then placed into 2 groups on the basis of the CAPS score (CAPS score < 11 and ≥ 11). Lastly, the mortality rate was assessed on the basis of survivors (ie, dogs that were discharged from the hospital) and nonsurvivors (dogs that died during hospitalization).

**Statistical analysis**

All continuous variables (age and cPL concentration) were tested with the Kolmogorov-Smirnov test. Normally distributed variables are reported as mean ± SD values, and nonnormally distributed variables are reported as median and range values. To investigate associations between AUS findings of AP (AUS+ group dogs vs AUS– group dogs), mortality rate, and CAPS score groups, the Fisher exact test was used. Odds ratios were also calculated. In addition, the AUS
severity indices were compared with the mortality rate and the severity of the disease (CAPS score groups) by use of the $\chi^2$ test. Lastly, serum cPL concentrations were compared between AUS severity index stratifications (ie, mild, moderate, or severe) by use of a Kruskal-Wallis test with pairwise comparisons. Data were analyzed with commercial statistical software.\textsuperscript{e,f} Values of $P < 0.05$ were considered significant.

**Results**

Sixty-three client-owned dogs with clinical signs of AP were assessed for study eligibility. Of the 63 dogs, 5 were excluded because of lack of serial AUS examinations and 11 were excluded because of lack of available stored serum samples. Forty-seven dogs remained for consideration for study inclusion; 6 of 47 dogs were excluded because they were categorized as not having AP (ie, persistently negative findings on AUS for AP and a serum cPL concentration $\leq 200$ µg/L). Of the 41 dogs that remained, 4 more were excluded because the serum cPL concentration was indeterminate (ie, possibly consistent with AP; 201 to 399 µg/L) with a persistently negative AUS finding for AP. The final cohort for the present study included 37 dogs.

Of 37 dogs, 10 (27%) were small-to medium-sized mixed-breed dogs (body weight range, 7 to 14.1 kg). The most represented purebreds were Poodle, Beagle, Jack Russell Terrier, Labrador Retriever, Lagotto Romagnolo, German Shepherd Dog, English Setter, and Springer Spaniel (2 dogs each). The remaining 11 dogs were other purebreds (1 dog each). The mean age was 10.52 ± 3.5 years. Of 37 dogs, 11 (29.7%) died during hospitalization, 2 of which were euthanized because of other causes besides AP and were removed from the statistical analysis of mortality rate.

Canine acute pancreatitis severity scores were as follows: 4 of 37 (11%) dogs had a CAPS score of 0; 22 (59.5%) dogs had a CAPS score of 8; 5 (13.5%) dogs had a CAPS score of 11; and 6 (16%) dogs had a CAPS score of 12.

Twenty-four of 37 (64.8%) dogs had AUS findings of AP at hospital admission, whereas another 10 dogs had positive findings for AP on AUS within

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**Figure 1**—AUS images of the pancreas in dogs to illustrate the AUS severity index for AP used in the present study. A—Mild AUS score; notice the slightly enlarged hypoechoic pancreas (asterisk). B—Moderate AUS score; notice the pancreas (arrowhead), which is mildly enlarged, hypoechoic, with the presence of intrapancreatic anechoic stripes and peripancreatic hyperechoic mesenteric fat. Duodenum (section mark). C—Severe AUS score; notice the pancreas (arrow), that is significantly increased in size, hypoechoic, with of intrapancreatic anechoic stripes, peripancreatic hyperechoic mesenteric (pound sign) fat and peripancreatic anechoic effusion (cross).
2 days of hospitalization. Three of 37 (8%) dogs continued to have negative findings on AUS for AP for 2 days after hospital admission, despite serum cPL concentrations > 400 µg/L at hospital admission. No association between mortality rate and AUS findings of AP was found (P = 0.54).

Median serum cPL concentration was 648 µg/L and ranged from 69 µg/L to > 2,000 µg/L (which was the maximum concentration of detection). Three dogs remained in the AUS– group despite having serum cPL concentrations > 400 µg/L (ie, 690, 699, and 882 µg/L). Of the 10 dogs that had positive findings for AP on AUS within 2 days of hospitalization (but not at hospital admission), 9 had serum cPL concentrations > 400 µg/L at hospital admission. Dogs in the AUS+ group had a median serum cPL concentration of 631 µg/L (range, 69 to 2,000 µg/L), whereas AUS– group dogs had a median serum cPL concentration of 699 µg/L (range, 690 to 882 µg/L). No significant (P = 0.38) difference in serum cPL concentrations were found between AUS+ group dogs and AUS– group dogs.

Of 37 dogs, 34 (91.9%) had positive findings for AP on AUS (at hospital admission or within 2 days of hospitalization) and constituted the AUS+ group. All AUS+ group dogs had a hypoechoic-heterogeneous enlarged pancreas on AUS examination. Of 34 AUS+ group dogs, 28 (82.4%) had a peripancreatic hyper-echogenicity of the mesentry and 20 (58.8%) and 11 (32.4%) had peripancreatic free fluid and diffuse abdominal hyper-echogenicity with free fluid, respectively. Findings of AP were stratified for the 34 AUS+ dogs by use of the AUS severity index as follows: 5 (14.7%) had mild findings, 18 (52.9%) had moderate findings, and 11 (32.4%) had severe findings.

A significant (P = 0.017) association was found between stratification findings on the AUS severity index and mortality rate (Table 1). In particular, severe findings were associated with a higher risk of death than mild and moderate findings. No significant (P = 0.87) association was found between stratification findings on the AUS severity index and serum cPL concentrations. A significant (P = 0.003) association was found between CAPS scores and mortality rates. No significant associations were found between CAPS scores and AUS findings of AP (P = 0.30) or between CAPS scores and stratification findings on the AUS severity index (P = 0.26).

### Table 1—Comparisons between AUS severity index stratifications (ie, mild, moderate, severe) with CAPS score, mortality rate, and serum cPL concentrations in 34 dogs with positive findings for AP on AUS (at hospital admission or within 2 days of hospitalization).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mild (n = 5)</th>
<th>Moderate (n = 18)</th>
<th>Severe (n = 11)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPS score</td>
<td>8 (0–12)</td>
<td>8 (0–12)</td>
<td>11 (8–12)</td>
<td>0.30</td>
</tr>
<tr>
<td>Mortality rate</td>
<td></td>
<td></td>
<td></td>
<td>0.017</td>
</tr>
<tr>
<td>Survivors</td>
<td>5</td>
<td>14</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Nonsurvivors</td>
<td>0</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Serum cPL (µg/L)</td>
<td>252 (76–1,182)</td>
<td>664 (69–2,000)</td>
<td>545 (135–1,878)</td>
<td>0.87</td>
</tr>
</tbody>
</table>

*Values of P < 0.05 are considered significant.

### Discussion

Although recent studies have investigated CT for arriving at a diagnosis of AP in dogs,2,3 information on the diagnostic usefulness of AUS in the detection of AP in dogs is limited.5,6 The usefulness of AUS for detecting AP in dogs has been anecdotally thought to be relatively high, although this has not been investigated in specifically designed studies.3 Hess et al8 found that an AUS finding of normal images of the pancreas is not sufficient to rule out AP in dogs. However, it is thought that the usefulness of AUS in the diagnosis of AP in dogs may be related to the experience and training of the radiologist and the quality of the ultrasonographic equipment used.1

In the present study, 10 AUS+ group dogs were positive for AP within 2 days of hospitalization (but not at hospital admission), and 9 of these dogs had serum cPL concentrations that were consistent with AP at hospital admission (ie, > 400 µg/L). Serum concentrations of cPL may not have any relation to the magnitude of either pancreatic impairment or AUS findings because serum cPL concentration only reflects pancreatic acinar cell injury.12 In addition, as shown by Dossin et al,7 the half-life of cPL is approximately 90 minutes; thus, pancreatic AUS changes may not be evident later.

As reported in human and veterinary literature,13,14 the initial and second phases of AP are characterized by an intrapancreatic digestive enzyme activation and intrapancreatic inflammation immediately afterward. In addition, it has been demonstrated that only the third phase of AP is associated with either mortality rates or CAPS scores. However, after AUS findings of AP were stratified into mild, moderate, and severe findings on the basis of the AUS severity index, a significant association was found between AUS severity index findings and mortality rate. Inclusion of the AUS severity index in the evaluation of dogs with AP may increase the prognostic value of AUS. At this time, a direct comparison with findings in human literature cannot be made because the severity of AP in human patients is determined by use of...
a CT severity index. However, AUS is more often used as the first imaging modality, especially in emergency settings, to exclude gallstones or other causes of an acute abdomen. In the present study, the AUS severity index finding of severe was more frequently found in dogs that died, compared with dogs that survived. This finding could be related to the pathophysiology of the late phases of AP, in which the inflammation is transformed from local (intrapancreatic) to systemic. It is thus possible that dogs with moderate to severe AUS severity index findings may have had more severe inflammation or more severe disease than dogs with mild AUS severity index findings, even if it was not associated with the magnitude of the increase in serum cPL concentrations.

The CAPS score is a novel clinical scoring system for the short-term prediction of mortality rate in dogs with AP that was developed and validated by Fabrès et al. These authors found 4 independent risk factors (ie, presence of SIRS, coagulation disorders, high serum creatinine concentration, and low serum ionized calcium concentration [hypocalcemia]) for death that were weighted and integrated into the CAPS score. In the present study, although CAPS score was found to be associated with mortality rate, CAPS score was not associated with the AUS severity index findings or AUS findings of AP. This may be because the variables included in the CAPS score are indicative of systemic impairment, whereas local pancreatic inflammation was most prevalent in AUS+ group dogs of the present study. In addition, no association was found between AUS severity index findings and the CAPS score.

Steiner et al in 2002 showed that cPL is exclusively expressed in pancreatic acinar cells and thus can be considered as a specific marker for pancreatic acinar cell injury. In addition, no evidence has been found of cross-immunoreactivity with other lipases or related proteins expressed by other tissues. The rapid point-of-care semiquantitative cPL immunoassay and quantitative evaluation of cPL in the present study have a sensitivity of 91% to 94% and 71% and a specificity of 71% to 78% and 100%, respectively.

In the present study, no associations were found between either the AUS severity index findings or AUS findings of AP and serum cPL concentrations. The serum cPL concentration may not have the same high sensitivity for detection of AUS findings of AP as found by Steiner et al in 2008 for histologically confirmed AP. It appears that dogs may have a normal-appearing pancreas on AUS examination with a high serum cPL concentration or AUS findings of AP with a low serum cPL concentration. In the present study, AUS+ group dogs (n = 3) and 9 of 10 AUS+ group dogs that had positive AUS findings for AP within 2 days of hospitalization (but not at presentation) had serum cPL concentrations consistent with AP (> 400 μg/L) at hospital admission. These results indicated that serum cPL concentrations may increase earlier than AUS findings of AP, suggesting that dogs with suspected AP with high serum cPL concentrations should be monitored with repeated AUS examinations.

Limitations of the present study included the lack of any information in our cases regarding pancreatic cytology; thus, we were not able to exclude other pancreatic diseases (eg, pancreatic neoplasia), which may have led to some false-positive AUS findings for AP. Moreover, 2 days was used as the cutoff time for the final AUS recheck examination; however, it is possible that some of the AUS- group dogs may have become AUS+ after 2 days of hospitalization. In the present study, 4 dogs were excluded that had both negative findings on AUS for AP and serum cPL concentrations that were indeterminate (201 to 399 μg/L, possibly consistent with AP). However, the clinical presentation was compatible with AP in the 4 dogs and no other abdominal diseases were identified on AUS. For these dogs, a pancreatic injury with only mild increases in serum cPL concentrations cannot be excluded.

As hypothesized, in dogs with AP, findings on AUS of AP can occur later during hospitalization, thus highlighting the importance of repeated AUS examinations in the days following hospital admission. In addition, AUS findings of AP were not associated with either serum cPL concentrations or CAPS scores. However, the presence of a severe finding on the AUS severity index was associated with an increase in mortality rate. Further studies in a larger population of dogs are warranted to confirm these findings. In addition, in some dogs, the serum cPL concentration may be a more sensitive diagnostic tool in dogs with clinical signs of AP, compared with AUS, as serum cPL concentrations seemed to increase earlier than findings on AUS of AP.

Acknowledgments

No third-party funding or support was received in association with the present study or the writing or publication of the manuscript. The authors declare that there were no conflicts of interest.

Presented as a poster presentation at the 2019 European College of Veterinary Internal Medicine Congress, Milan, September 2019.

Footnotes

b. SNAP cPL test, Idexx Laboratories Inc, Milan, Italy.
c. Spec cPL assay, Idexx Laboratories Inc, Westbrook, Me.
d. SPSS Statistics, version 25, IBM Corp, New York, NY.
e. Prism 7, version 7.0a, GraphPad Software, San Diego, Calif.

References