Ultrasonographic evaluation of preprandial and postprandial gallbladder volume in healthy cats

Alessia Diana, DVM, PhD; Carlo Guglielmini, DVM, PhD; Swan Specchi, DVM, PhD; Morena Di Tommaso, DVM, PhD; Marco Pietra, DVM; Marco Baron Toaldo, DVM, PhD; Mario Cipone, DVM

Objective—To noninvasively assess the influence of ingestion of a standard meal on gallbladder volume (GBV) in healthy cats.

Animals—10 healthy adult domestic shorthair cats (4 neutered females, 5 neutered males, and 1 sexually intact male).

Procedures—Nonsedated cats were positioned in dorsal and left lateral recumbency to obtain ultrasonographic measurements of the gallbladder via the subcostal and right intercostal acoustic windows, respectively. Gallbladder volume was calculated from linear measurements by use of an ellipsoid formula (volume [mL] = length [mm] X height [mm] X width [mm] X 0.52). Measurements were recorded after food was withheld for 12 hours (0 minutes) and at 5, 15, 30, 45, 60, and 120 minutes after cats were fed 50 g of a standard commercial diet (protein, 44.3%; fat, 30.3%; and carbohydrate, 15.6% [dry matter percentage]).

Results—Agreement between gallbladder linear measurements or GBV obtained from the subcostal and right intercostal windows was good. Feeding resulted in linear decreases in gallbladder linear measurements and GBV. Via the subcostal and intercostal windows, mean ± SD GBV was 2.47 ± 1.16 mL and 2.36 ± 0.96 mL, respectively, at 0 minutes and 0.88 ± 0.13 mL and 0.94 ± 0.25 mL, respectively, at 120 minutes. Gallbladder width most closely reflected postprandial modification of GBV.

Conclusions and Clinical Relevance—Results indicated that ultrasonographic assessment (via the subcostal or right intercostal acoustic window) of postprandial changes in GBV can be used to evaluate gallbladder contractility in cats. These data may help identify cats with abnormal gallbladder emptying. (Am J Vet Res 2012;73:1583–1588)
the gallbladder and biliary tract in clinically normal cats and cats with pathological conditions have been described.6,8,9,21 In healthy cats from which food was withheld, GBV has been quantified during abdominal ultrasonography via a subcostal acoustic window.8 Gallbladder volume can be estimated by use of an ellipsoid formula after measurements of maximal gallbladder linear dimensions (ie, length, height, and width) have been obtained.8,21–24

For dogs, the pattern of gallbladder contraction induced by ingestion of meal or cerulein has been assessed by use of real-time ultrasonography.23 Furthermore, a practical ultrasonographic protocol for real-time assessment of gallbladder contractility in dogs has recently been established.6 To the authors’ knowledge, noninvasive evaluation of the kinetics of normal gallbladder emptying after ingestion of a meal in cats has not been reported. The purpose of the study reported here was to assess the effect of ingestion of a standard meal on GBV in healthy cats by use of abdominal ultrasonography; the results obtained via 2 ultrasonographic windows were compared. In addition, the intent was to determine which ultrasonographic linear measurement of the gallbladder (length, height, or width) most reliably reflected changes of the overall volume of the organ.

Materials and Methods

Animals—Ten healthy client-owned domestic shorthair cats were used in this study. Cats were considered healthy on the basis of results of clinical history (no history of hepatobiliary, pancreatic, or gastrointestinal disease), physical examination, a CBC, routine serum biochemical analyses, urinalysis, and fecal examination for intestinal parasites. Prior to study commencement, informed consent of owners was obtained, and the Ethical Committee of the University of Bologna approved the protocol of the study.

Procedures—Food was withheld from each cat overnight (a period of at least 12 hours) before ultrasonographic evaluation (without sedation) was performed. Preprandial ultrasonographic measurements of the gallbladder were obtained (0 minutes) before each cat received food. The test meal consisted of a canned cat food† that had a total humidity of 76.0% and was composed (dry matter percentage) of 44.3% protein, 30.3% fat, 15.6% carbohydrate, and 1.2% crude fiber. A test meal size of 50 g was chosen to minimize the ultrasonographic artifacts due to gas and food particles. All cats were acclimatized to the test environment. In particular, before performance of the ultrasonographic examination, each cat was housed only with the owner in the ultrasound room for half an hour. The food was then offered to each cat by its owner during a time-restricted meal feeding (ie, 10 minutes). Ultrasonographic evaluation of the GBV was repeated at 5, 15, 30, 45, 60, and 120 minutes after feeding.

Ultrasonographic measurements—For each of the 10 cats, the ultrasonographic evaluation of the gallbladder was conducted by the same experienced sonographer (MC), using a real-time ultrasound machine equipped with a broadband curved array transducer (5 to 8 MHz).‡ Hair over the abdomen was clipped and the skin surface was cleaned with 70% isopropyl alcohol; coupling gel was applied to the prepared area. Each cat was awake and restrained manually by the owner during the examination.

For each cat, ultrasonographic measurements of the gallbladder were obtained via a subcostal and a right intercostal acoustic window (with cat positioned in dorsal and left lateral recumbency, respectively). Longitudinal and transverse views of the gallbladder were obtained in each acoustic window. The images were recorded in the Digital Imaging and Communications in Medicine (ie, DICOM) format and transferred to a personal computer for offline evaluation. An open-source commercial software program was used for measurement of gallbladder linear dimensions.26 The GBV was determined from measurements obtained in each acoustic window by use of the ellipsoid equation (volume = length x height x width x 0.52).8,21–24 The percentage reduction in GBV as a result of feeding was calculated by use of the following formula8:

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\text{Percentage change in GBV} = \left(\frac{\text{GBV at 0 minutes} - \text{GBV at specific time point}}{\text{GBV at 0 minutes}}\right) \times 100
\]

Statistical analysis—Data analysis was performed with a statistical software package.4 After a normal distribution of data was confirmed, a 1-way repeated-measures ANOVA was used to analyze data, followed by a Tukey honestly significant difference test for multiple comparisons. Variables indicative of gallbladder emptying (ie, GBV and gallbladder length, height, and width) were normalized against the basal volume and linear measurements (determined at 0 minutes) of the organ (basal volume and linear measurements designated as 100%). Linear regression and Bland-Altman analyses were performed to compare ultrasonographic measurements obtained through the subcostal acoustic window with those obtained through the right intercostal acoustic window. Data are reported as mean ± SD or SEM. For all statistical analyses, a value of \( P < 0.05 \) was considered significant.

Results

The experiment was completed for all 10 cats included in the study, of which 4 were neutered females, 5 were neutered males, and 1 was a sexually intact male. The ages of the cats ranged from 1 to 8 years (mean ± SD age, 3.8 ± 2.9 years); the cats’ weights ranged from 3.8 to 9 kg (mean body weight, 5.8 ± 2.2 kg). For the group of study cats, mean linear gallbladder measurements obtained by use of the subcostal or intercostal acoustic windows were determined (Table 1). From measurements obtained via the subcostal and intercostal acoustic windows, mean ± SD GBV at 0 minutes (ie, after food was withheld for 12 hours) was 2.47 ± 1.16 mL (median, 2.41 mL) and 2.37 ± 0.96 mL (median, 2.37 mL), respectively; mean GBV at 120 minutes after ingestion of a standard meal was 0.88 ± 0.13 mL (median, 0.87 mL) and 0.94 ± 0.23 mL (median, 0.90 mL), respectively. The mean ± SEM decrease in GBV relative to the basal value was 35.5 ± 1.7% and 39.9 ± 3.4%.
as estimated via the subcostal and intercostal acoustic windows, respectively.

Ingestion of the test meal resulted in prompt gallbladder contraction, and the pattern of gallbladder emptying was quite similar among the study cats. Linear dimensions of the gallbladder and GBV following meal-induced gallbladder emptying were measured at intervals via the subcostal (Figure 1) and intercostal (Figure 2) acoustic windows. Compared with the preprandial GBV, a significant (\(P = 0.05\) and \(P = 0.01\) for the subcostal and intercostal acoustic window, respectively) decrease in GBV was detected at 30 minutes after ingestion of the meal. Approximately half of the gallbladder emptying was evident at 60 minutes after ingestion of the meal; at that time point, mean ± SEM decrease in GBV relative to the basal value was 49.3 ± 3.2% and 45.7 ± 3.5% as estimated via the subcostal and intercostal acoustic windows, respectively.

During meal-induced gallbladder emptying, gallbladder length, height, and width each decreased in a linear fashion. At the 120-minute postprandial time point, the mean ± SEM decrease in the gallbladder width relative to the basal value was 65.0 ± 4.3% and

### Table 1—Mean ± SD GBV, length, height, and width derived from ultrasonographic measurements obtained via the subcostal (SC) or right intercostal (IC) acoustic windows in 10 healthy cats after food was withheld for 12 hours (0 minutes) and at 5, 15, 30, 45, 60, and 120 minutes after ingestion of a standard meal (50 g of commercial diet).

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Acoustic window</th>
<th>Volume (mL)</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SC</td>
<td>2.47 ± 1.16</td>
<td>28.8 ± 4.3</td>
<td>10.7 ± 3.4</td>
<td>14.4 ± 2.7</td>
</tr>
<tr>
<td>5</td>
<td>SC</td>
<td>2.05 ± 0.84</td>
<td>27.5 ± 4.0</td>
<td>10.2 ± 2.6</td>
<td>13.4 ± 3.4</td>
</tr>
<tr>
<td>15</td>
<td>SC</td>
<td>1.99 ± 0.76</td>
<td>26.9 ± 6.1</td>
<td>10.4 ± 1.8</td>
<td>13.2 ± 3.1</td>
</tr>
<tr>
<td>30</td>
<td>SC</td>
<td>1.69 ± 0.58</td>
<td>24.3 ± 3.5</td>
<td>10.4 ± 1.7</td>
<td>12.6 ± 2.7</td>
</tr>
<tr>
<td>45</td>
<td>SC</td>
<td>1.44 ± 0.50</td>
<td>23.0 ± 3.5</td>
<td>10.3 ± 1.6</td>
<td>12.3 ± 2.4</td>
</tr>
<tr>
<td>60</td>
<td>SC</td>
<td>1.22 ± 0.25</td>
<td>22.3 ± 3.1</td>
<td>9.6 ± 1.2</td>
<td>10.4 ± 1.6</td>
</tr>
<tr>
<td>120</td>
<td>SC</td>
<td>0.88 ± 0.13</td>
<td>22.1 ± 2.5</td>
<td>8.2 ± 1.3</td>
<td>9.3 ± 2.0</td>
</tr>
</tbody>
</table>

Figure 1—Assessment of meal-induced gallbladder emptying by use of ultrasonographic measurements of the GBV (A), length (B), height (C), and width (D) obtained via the subcostal acoustic window in 10 healthy cats. Measurements were recorded after food was withheld for 12 hours (0 minutes) and at 5, 15, 30, 45, 60, and 120 minutes after cats were fed a standard meal (50 g of commercial diet), and were expressed as a percentage of the basal (0-minute) value. Gallbladder volume was calculated from linear measurements by use of an ellipsoid formula (volume [mL] = length [mm] \times height [mm] \times width [mm] \times 0.52). Data are reported as mean ± SEM. *At this time point, value is significantly (\(P < 0.05\)) different from the basal (0-minute) value. †At this time point, value is significantly (\(P < 0.05\)) different from the 5-minute value. ‡At this time point, value is significantly (\(P < 0.05\)) different from the 15-minute value.
68.9 ± 4.6% as estimated via the subcostal and intercostal acoustic windows, respectively. This change in gallbladder width was comparatively greater than both the decrease in gallbladder length relative to the basal value (76.6 ± 2.7% and 84.4 ± 4.0% as estimated via the subcostal and intercostal acoustic windows, respectively) and the decrease in gallbladder height to the basal value (76.6 ± 3.9% and 72.9 ± 5.1% as estimated via the subcostal and intercostal acoustic windows, respectively) at the same time point.

The linear regression analysis revealed a coefficient of determination of 0.96 (P < 0.001) for GBV, 0.95 (P < 0.001) for gallbladder length, 0.78 (P = 0.009) for gallbladder height, and 0.97 (P < 0.001) for gallbladder width. The Bland-Altman analysis revealed mean ± SD differences of 0.07 ± 0.11 mL (LA [ie, mean ± 1.96 SD], +0.29 and −0.15 mL) for GBV, 0.12 ± 0.84 mm (LA, +1.77 and −1.53 mm) for gallbladder length, 0.35 ± 0.46 mm (LA, +1.25 and −0.56 mm) for gallbladder height, and 0.04 ± 0.37 mm (LA, +0.70 and −0.69 mm) for gallbladder width.

Discussion

In the study reported here, a practical ultrasonographic protocol for real-time assessment of changes in GBV following ingestion of a meal after a period of food withholding in healthy cats was established. Various methods can be used for determination of GBV and gallbladder motility in a clinical setting, including IV cholangiocystography, hepatobiliary scintigraphy, and abdominal ultrasonography.3,27–31 Hepatobiliary scintigraphy provides information on gallbladder emptying and cystic duct patency but does not allow evaluation of gallbladder morphology and requires use of radioactive pharmaceuticals and expensive equipment.3,27–29 Abdominal ultrasonography provides information about the morphology of the gallbladder, including the features of the wall (ie, thickness and layering) and of the content (ie, anechoic bile, sludge, calculi, and solitary or multiple masses), and the technique is noninvasive, accurate, and widely available.3,4,30,31 For physiologic and clinical studies of gallbladder motility, accurate measurements of GBV are required, and the
method of measurement should not be time-consuming.21 In the present study in cats, sequential ultrasonographic examinations of the gallbladder before and after a standard meal were feasible, as previously reported for dogs.22,23 Furthermore, good-quality ultrasonographic images of the gallbladder were obtained by use of 2 acoustic windows (ie, the subcostal and intercostal acoustic windows), allowing linear measurements of the 3 orthogonal axes of the organ.

Following food withholding, a 50-g test meal was provided to the cats in the present study; ingestion of that amount of food resulted in a consistent pattern of gallbladder emptying among all cats. Moreover, no substantial meal-induced ultrasonographic artifacts were generated in the gastrointestinal tract, which would have possibly prevented accurate measurement of the gallbladder linear dimensions. Good agreement was found between the ultrasonographic linear measurements of the gallbladder obtained via each of the 2 acoustic windows as well as between the values of GBV calculated from the measurements obtained via each of the 2 acoustic windows.

Several mathematical equations have been proposed for estimating GBV on the basis of linear ultrasonographic measurements for dogs.22,23 Compared with other more complicated methods, the ellipsoid equation can adequately estimate relative volume changes.22,23 This formula has been recently used for the ultrasonographic assessment of changes in GBV in healthy dogs after ingestion of a meal24 and for quantification of GBV in healthy cats from which food had been withheld.25 In the present study, normal distribution of data was consistently obtained at each time point. Among the study cats, median GBV at 0 minutes (ie, after food withholding of ≥12 hours’ duration) was 2.41 and 2.37 mL as estimated via the subcostal and intercostal acoustic windows, respectively; both values were similar to that recently determined via a subcostal approach for 30 healthy cats (2.42 mL).21 In contrast, basal values of GBV following food withholding in dogs are more variable; therefore, GBV in dogs is preferentially expressed as milliliters per unit of body weight (kg).9,22,32 A pattern of decreasing GBV and linear measurements over time after ingestion of the meal was generally apparent in all cats of the present study, although an increase in mean gallbladder height and, consequently, GBV was detected at 45 minutes after feeding via intercostal acoustic window. Among the cats in the present study, height was the most variable linear measurement of the gallbladder, as reported for dogs,23 and also the variable with the lowest agreement between measurements obtained via the 2 acoustic windows. Changes in GBV were more pronounced, compared with those of the gallbladder linear measurements, in the present study. During postprandial gallbladder emptying, the reduction (relative to preprandial findings) in the gallbladder width was greater than the relative reduction in its length and height, as previously demonstrated in dogs.24 The commercial meal used in the present study contained highly digestible ingredients and proteins; a different gallbladder-emptying pattern might be observed following ingestion of a meal with a different formulation.

Accurate evaluation of GBV depends on the shape of the organ in the examined animal. In cats, the gallbladder is occasionally bilobed, and this anatomic shape can create some technical difficulties in the evaluation of GBV.22,23 The temperament of the examined animal is another limiting factor for obtaining accurate consecutive measurements of the gallbladder. Typically, cats are more easily stressed during abdominal ultrasonographic examination, compared with dogs, and assessment of the gallbladder is more difficult when the patient moves. The 7-step protocol used in the present study was well tolerated by the cats, and repeated measurements of the gallbladder were obtained. However, performing fewer ultrasonographic examinations or gallbladder measurements might be advisable when dealing with stressed and noncooperative cats. Results of the present study suggested that more simplified ultrasonographic protocols for evaluating gallbladder motility in cats would be to obtain measurements of the 3 major axes of the organ after food withholding and at 60 and 120 minutes after subsequent ingestion of a meal or to obtain serial measurements of only gallbladder width after food withholding and at 5, 15, 30, 45, 60, and 120 minutes after subsequent ingestion of a meal.

The evaluation of the effects of the stress on changes in GBV is the main limitation of the present study. To minimize stress, all cats were acclimatized to the test environment and restrained manually by the owners during the entire ultrasonographic examination. Nevertheless, data obtained from healthy cats in the present study have provided functional information about the biliary system that could be used to evaluate cats with hepatobiliary, pancreatic, and gastrointestinal disorders associated with altered gallbladder emptying.

References