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Validation of Ultrasonography for Assessment of Gastric Emptying Time in Healthy Cats by Radionuclide Scintigraphy

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Background: The prevalence of gastric emptying (GE) disorders in cats is unknown due to lack of clinically applicable diagnostic tests.

Objectives: The principal aim of this study was to assess correlation between scintigraphic and ultrasonographic measurements of GE time (GET) in healthy cats. Additionally, variability of ultrasonographic GET, and correlation between scintigraphy and ultrasonographic parameters of gastric motility were evaluated.

Animals: Eight healthy domestic shorthair cats.

Methods: Prospective study. Scintigraphic GET was determined using a solid test meal containing 4 mCi ^{99m}Tc-mebrofenin. Each cat had 3 separate ultrasonographic assessments of GE, performed independent of scintigraphic assessment, after solid test meal consumption. The motility index (MI) of antral contractions was plotted against time and time for each fraction of the area under the MI curve determined. Ultrasonographic GET and MI were correlated to scintigraphic GET.

Results: Scintigraphic GET (mean $\pm$ SD) for 25, 50, and 75% GE was 103 $\pm$ 32 minutes, 196 $\pm$ 45 minutes, and 288 $\pm$ 62 minutes, whereas sonographic GET for 25, 50, and 75% GE was 106 $\pm$ 13 minutes, 203 $\pm$ 19 minutes, and 305 $\pm$ 27 minutes. There was good correlation between scintigraphic and sonographic GET (r = 0.72–0.82) at 45–90% fractional GE and between scintigraphic GET and time of corresponding MI curve fraction (r = 0.78–0.86) at 40–90% fraction of the MI curve. There was moderate intraindividual variability for sonographic GET and MI curve fraction times as well as significant variation among individuals.

Conclusions and clinical importance: Ultrasonography is a valid alternative to scintigraphy for assessment of solid-phase GE and allows assessment of postprandial gastric motility in healthy cats.

Key words: Antral area; Gastrointestinal motility disorder; Motility index; Ultrasound.

The ability to assess gastrointestinal (GI) motility is important for understanding the physiology and pathophysiology of the GI tract, diagnosing motility disorders, and evaluating response to treatment. The prevalence of nonobstructive GI motility disorders in cats is difficult to establish because of the absence of appropriate epidemiologic studies. It is generally thought that they are under recognized in feline practice, in part due to a lack of practical, noninvasive, and accurate diagnostic techniques.[1,2]

Gastric emptying (GE) is a complex process, which is affected and controlled by many physiological, dietary, pharmacological, and disease factors. Nonobstructive disorders affecting the solid phase of GE are of greatest clinical relevance in humans[3] and small animals.[4] Several techniques have been used to evaluate gastric emptying time (GET) in the cat. Methods available to assess GE of solid food in clinical situations include radiography, abdominal ultrasonography, breath tests, and radionuclide scintigraphy.[4] Scintigraphy is considered the gold standard technique;[4–6] however, the clinical utility is limited by the need for specialized equipment and radiation licensing. Consequently, availability is limited to academic institutions and a small number of specialty centers where scintigraphy is used primarily for research rather than clinical purposes. The liquid barium sulfate gastrogram has been widely used to assess GI transit times,[7,8] but the use of liquids is an insensitive method of assessing for GE abnormalities and the use of barium mixed with food is unreliable.[4] The correlation between GE of barium-impregnated polyethylene spheres (BIPS) and scintigraphy to evaluate GI transit times in cats has been disappointing.[9]

Abbreviations:

AUC	area under the curve
BCS	body condition score
BIPS	barium-impregnated polyethylene spheres
BW	body weight
CF	frequency of contractions
CV	coefficient of variation
GE	gastric emptying
GET	gastric emptying time
GI	gastrointestinal
MI	motility index
ROI	region of interest
^{99m}Tc	^{99m}Technetium

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Breath tests, using markers such as octanoic acid or sodium acetate radiolabeled with the stable isotope ^{13}C, have also been validated in cats. A fair correlation was observed between the sodium acetate breath test and ^{99m}Tc scintigraphy.[10] Although this technique may be more practical than scintigraphy, availability remains limited.

Ultrasonographic evaluation of GET relies on the postprandial measurement of the cross-sectional area or estimated volume of the relaxed pyloric antrum over time. As the stomach empties, the size of the antrum decreases and ultimately returns to the fasted state. GET can be derived from a time plot of the obtained values. A close correlation between the rate of both liquid- and solid-phase GE measured by ultrasonography and scintigraphy has been documented in humans.[11] Although ultrasonography has been used to assess GET in cats,[12] it has only been validated in dogs.[13,14] An ultrasonographic technique has the added advantage of allowing evaluation of the amplitude and frequency of antral contractions. These 2 parameters have been shown to be useful in the assessment of gastric motility in dogs.[15–17] In humans, there is physiologic intraindividual variability for GE that needs to be considered when interpreting results.[18–20] Although some data are available on variability of GE in dogs,[21–24] there is a lack of information in cats.[10]

The principal aim of this study was to assess the correlation between scintigraphic and ultrasonographic measurements of GET in healthy cats. Additionally, we evaluated the variability of GET measured ultrasonographically and the correlation between scintigraphic GET and ultrasonographic parameters of gastric motility.

Materials and Methods

Animals

Eight healthy purpose-bred domestic shorthair cats were used in this study. The cats were acclimatized to individual housing, the feeding regimen, and the handling and restraint necessary to obtain ultrasound and gamma camera images for 3 weeks before beginning the study. Only cats deemed healthy after a physical examination, CBC, serum biochemistry profile, serum total thyroxine concentration, and abdominal ultrasound were included in the study. Body condition score (BCS) was recorded for the cats by use of a 9-point system (1 = extremely thin, 5 = optimal, and 9 = obese).[a] Cats were fed ad libitum and group-housed in 2 groups of 4 when not being prepared or evaluated. They were individually housed as needed to allow for fasting and during periods of radioactive isolation. All animal use was approved by the Louisiana State University Institutional Animal Care and Use Committee, and the experiment was performed in an AAALAC-accredited facility.

Study Design

A prospective study utilizing radionuclide scintigraphy is used to validate ultrasonography for the assessment of GET and to correlate scintigraphic GET and ultrasonographic parameters of gastric motility. Each cat had 1 scintigraphy and 3 sonographic evaluations performed on different days with at least 1 sonographic evaluation being performed within 4 days of scintigraphy. All sonographic evaluations for a given cat were completed within 3 weeks.

Test Meal

The test meal for scintigraphy consisted of a combination of a maintenance laboratory diet[b] and 1 teaspoon of a canned cat food,[c] which was mixed with 4 mCi of ^{99m}Tc-mebrofenin diluted in 1 mL of saline (0.9% NaCl). The test meal provided approximately 20% of the daily estimated energy requirement of each cat, as determined on the basis of the following equation: $70 \times BW^{0.75}$, where BW is the body weight (in kilograms) of the cat. The kibble diet was placed in a plastic cup behind a radiation shield, and the ^{99m}Tc-mebrofenin solution was poured over the kibble with constant mixing. Canned cat food was added to the meal 10 minutes later to increase palatability. The test meal for the ultrasound evaluations was the same as the test meal for scintigraphy without the addition of ^{99m}Tc-mebrofenin.

Scintigraphy

Cats were fasted overnight for 18 hours before scintigraphy. Image acquisition began immediately after consumption of all of the test meal or 15 minutes after food was offered if the meal was not completely consumed. The procedure was postponed and rescheduled if a cat did not consume at least 75% of the test meal within 15 minutes. Images were acquired after eating (time zero), then at 5, 15, 30, 45, and 60 minutes for the first hour, and then at 30-minute intervals for a total of 480 minutes. For image acquisition, each cat was restrained in lateral recumbency over a large field-of-view gamma camera equipped with a parallel-hole collimator. A 60-second static image was acquired with the cat in each right and left lateral recumbency. Images were obtained by use of a 128 × 128-pixel matrix. A region of interest (ROI) was manually drawn to include the entire stomach but avoid adjacent bowel for each of the acquired images (Fig 1). Counts within the ROI were then corrected on the basis of the decay for the physical half-life of ^{99m}Tc from the image obtained at time zero. Geometric means of the decay-corrected counts within the left and right ROI (the square root of their product) were calculated. The amount of radiation at every time point was expressed as a percentage of the gastric isotope count at time zero in each subject, and time-versus-

Fig 1. Selected image of the abdomen of a cat from a scintigraphic gastric emptying study 120 minutes after ingestion of the radiolabeled test meal. Radiolabeled ingesta can be seen within the stomach and small bowel. The red line demarcates the region of interest (ROI) which was manually drawn to include the entire stomach.

administered activity curves were generated. GE times for different emptying stages (25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, and 90%) were determined by nonlinear regression analysis with commercially available software.[d]

Ultrasonography

Cats were fasted overnight for 18 hours before the evaluations. Measurement of the antral area was performed immediately after consumption of all of the test meal or 15 minutes after food was offered if the meal was not completely consumed. The procedure was postponed and rescheduled if a cat did not consume at least 75% of the test meal within 15 minutes. All sonographic evaluations were performed by the same sonographer (RH) with a 12 MHz linear array transducer.[e] Cats were examined in dorsal recumbency with the transducer positioned on midline just caudal to the xiphoid with the ultrasound beam directed cranially until the liver was visualized. This positioning technique allowed consistent identification of the gastric antrum just caudal to the liver. The stomach was observed by use of real-time imaging, which allowed the image to be frozen between peristaltic contractions when the antrum was maximally distended (i.e, relaxed antrum). The cross-sectional area of the antrum (Fig 2a) was measured by tracing the serosal side of the antrum with the built-in caliper (Fig 2b). If acoustic shadowing of intraluminal gas obscured the distant wall, the measurement was made by assuming the antrum had a round to oval shape. Measurements of antral area (cm^2) were obtained in triplicate at each time point, and the mean of the 3 measurements was used for statistical analysis. Antral area measurements were performed before ingestion of the test meal (baseline), after eating (time zero), then at 15, 30 and 60 minutes for the first hour, and then at 30-minute intervals for a total of 480 minutes. The baseline antral area was subtracted from each subsequent measurement, and the results were divided by the maximum area acquired during the evaluation. All measurements were expressed as a percentage of the maximum antral area and plotted against time. The total area under the curve (AUC) was calculated for the 480-minute period, and GET for each given emptying stage (25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, and 90%) was determined with commercially available software.[f]

Sonographic Assessment of Antral Motility

The amplitude and frequency of antral contractions were measured before, immediately after (time zero), 15 and 30 minutes after the meal was consumed, and then every 30 minutes for 480 minutes. The amplitude of antral contraction (difference of gastric antrum cross-sectional area in relaxed state [Fig 2b] and contracted state [Fig 2c] divided by cross-sectional area in relaxed state) was determined on 3 separate contractions for each time point. Additionally, the frequency of contractions (CF) was assessed over a 2-minute period. A motility index (MI) was calculated by multiplying mean amplitude by CF for each time point and plotted against time. The total AUC was calculated for the 480-minute period, and time for each given fraction (25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, and 90%) of the MI curve was determined.[f] Polynomial curve fitting was used to determine the values of MI for each fraction of the MI curve.[d]

Statistical Analysis

The normality of data distribution was tested by the D'Agostino and Pearson omnibus normality test, and all data were normally distributed.[g] Unless otherwise stated, values are reported as means and standard deviations. A mixed ANOVA was used to assess the difference in time required for test meal consumption for scintigraphy and ultrasonography and for the 3 ultrasonographic assessments of each cat.[d] To assess intraindividual (day-to-day) variation for each cat, the coefficient of variation (CV) was calculated for the sonographic GET for each emptying stage and time of each fraction of the MI curve.[h] A two-way repeated-measures ANOVA was used to assess the difference of the sonographic GET for each emptying stage and time of each fraction of the MI curve among cats (interindividual variability).[g] The Pearson correlation coefficient was determined for the sonographic and corresponding scintigraphic GET for each emptying stage and for time of each fraction of the MI curve and corresponding scintigraphic GET for each stage of emptying.[g] For all analyses, a value of $P < .05$ was considered significant.

Results

Five cats were neutered males and 3 cats were spayed females with a mean age of 6.9 ± 2.9 years (range 3–10 years) and a mean body weight of 5.7 ± 1.3 kg (range 4.3–8.3 kg). The median BCS was 7 of 9 (range 4/9–9/9). All cats consumed at least 80% of the test meal voluntarily within 15 minutes. The median amount of meal

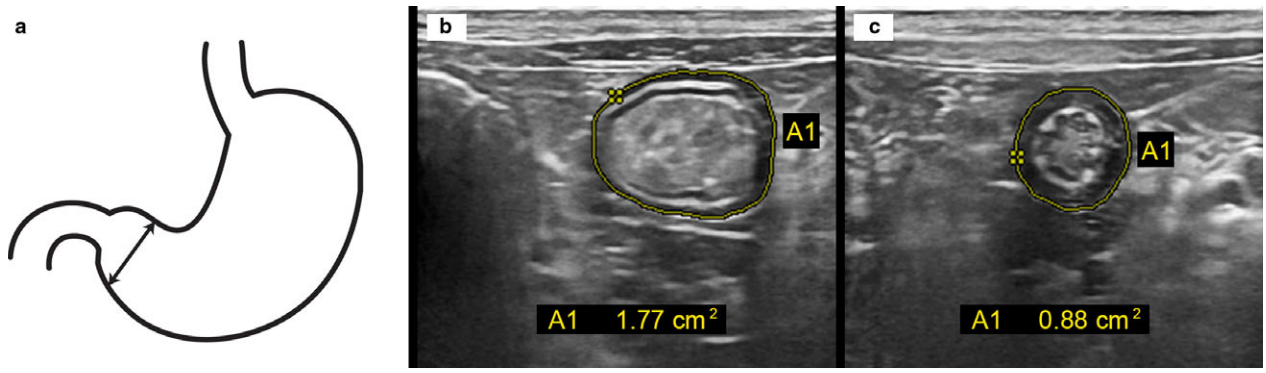

Fig 2. (**a**) The illustration shows the location used to assess the area of the gastric antrum with ultrasonography (double-sided arrow). (**b**) Selected image (cat from Fig 1) of maximal gastric antrum relaxation 120 minutes after meal ingestion. (**c**) Selected image (cat from Fig 1) of maximal gastric antrum contraction 120 minutes after meal ingestion. The yellow line in images B and C demarcates the serosal side of the antrum, which was used to determine the cross-sectional area.

consumed was 98.7% (80–100%) for scintigraphy and 100% (85.3–100%) for ultrasonography. The time required for test meal consumption was not statistically different (P = .31) for scintigraphy (9.3 ± 4.2 minutes [range 3–15 minutes]) and ultrasonography (10.5 ± 3 minutes [range 5–15 minutes]) or for the 3 ultrasonographic assessments of each cat (P = .41).

Scintigraphic GE was approximately linear with a negligible lag phase in nearly all cats (Fig 3). Gastric emptying times for 25, 50, and 75% fractional scintigraphic emptying were 102.5 ± 31.9 minutes, 195.8 ± 45.4 minutes, and 288.3 ± 62.1 minutes, respectively (Fig 4). Group means and standard deviations for scintigraphic gastric emptying times for each stage of GE are shown in Table 1.

The gastric antrum was consistently identified as a round- or oval-shaped structure during the sonographic evaluation in all cats. In preprandial images in which the stomach was empty, the lumen and the rugal folds had a cartwheel-like appearance. Distension caused by the test meal allowed visualization of the lumen as a hyperechoic region. Rarely, gas in the lumen caused distal acoustic shadowing, which obscured the distant wall of the stomach. After meal ingestion, the percentage of the maximum antral area increased reaching a maximum area at 92 ± 36 minutes followed by a continuous reduction in area over time (Fig 3). Gastric emptying times for 25, 50, and 75% fractional sonographic emptying were 106.2 ± 13.0 minutes, 203.1 ± 19.4 minutes, and 305.4 ± 27.0 minutes, respectively (Fig 4). Group means and standard deviations for sonographic gastric emptying times for each stage of GE are shown in Table 1. The CV of time for each given sonographic GE stage is presented in Table 2. A statistically significant difference among individual cats at all sonographic fractional emptying times was detected (P = .003).

The time course of MI of antral contractions demonstrated a double-peak pattern with a maximum value of 5.49 ± 0.62 at 77 ± 42 minutes, a reduction to 2.81 ± 0.49 at 215 ± 23 minutes, and a second peak of 4.11 ± 0.86 at 269 ± 29 minutes (Fig 5). Group means and standard deviations for the MI and time of each MI curve fraction are shown in Table 1. The CV of time for each given fraction of the MI curve is shown in Table 2. A statistically significant difference at all times of each MI curve fraction among individual cats was detected (P = .026).

Pearson correlation between radionuclide scintigraphy and ultrasonography was good beginning at 45% fractional GE (Table 3). Pearson correlation between scintigraphic GET and time of corresponding MI curve fractions was good beginning at 40% (Table 3).

Discussion

Gastric scintigraphy is generally accepted as the gold standard method to assess GE in many species,

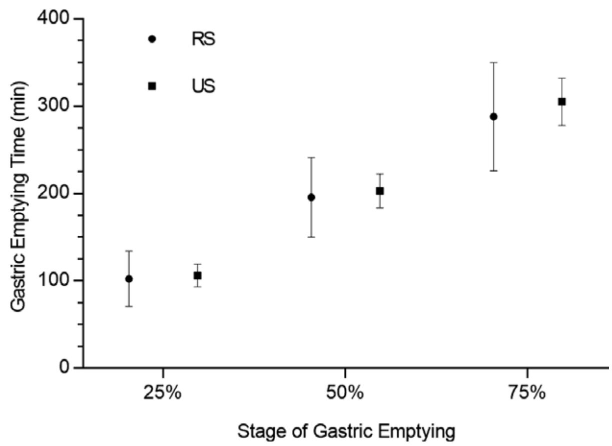

Fig 4. Mean ± SD gastric emptying times for 25, 50, and 75% gastric emptying in 8 healthy cats as assessed by radionuclide scintigraphy (RS) and ultrasonography (US).

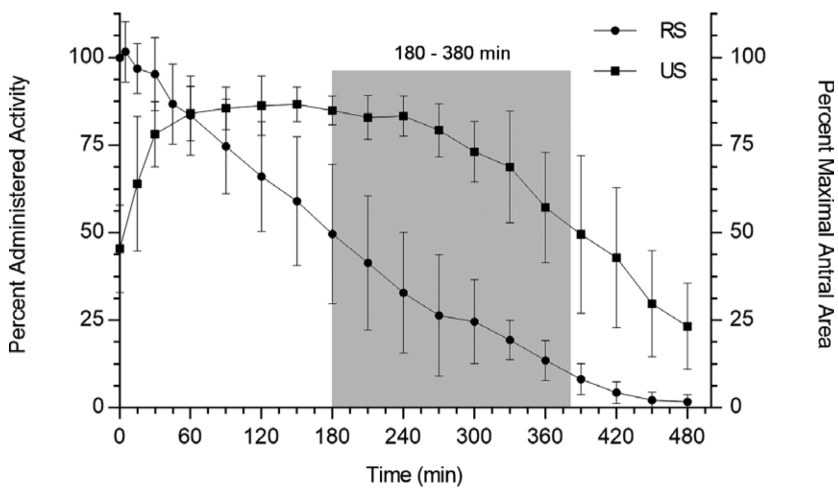

Fig 3. Cumulative scintigraphic residual radioactivity in the gastric area (RS) and cumulative sonographic measurements expressed as a percentage of the maximal antral area (US) plotted against time after meal ingestion. Mean values with standard deviations are shown. Gray area indicates the time frame of a good correlation between US and RS GET at 45–90% fractional GE.

Table 1. Group means and standard deviations for scintigraphic gastric emptying times, sonographic gastric emptying times, MI, and time of each MI curve fraction for each stage of GE.

	GE Stage/MI Curve Fraction													
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%
GET Scintigraphy (min)	102.5 ± 31.9	121.2 ± 34.1	139.8 ± 36.7	158.4 ± 39.4	177.4 ± 42.3	195.8 ± 45.4	214.4 ± 48.6	233.1 ± 51.9	252.2 ± 55.4	270.4 ± 58.8	288.3 ± 62.1	307.7 ± 65.9	326.3 ± 69.5	343.3 ± 71.9
GET Ultrasound (min)	106.2 ± 13.0	125.5 ± 14.6	144.5 ± 15.9	163.8 ± 17.0	183.5 ± 18.0	203.1 ± 19.4	223.0 ± 20.9	243.3 ± 22.0	263.5 ± 23.2	284.0 ± 24.8	305.4 ± 27.0	327.7 ± 28.6	352.3 ± 28.8	379.7 ± 27.7
Motility Index	4.89 ± 0.42	4.63 ± 0.41	4.33 ± 0.42	4.01 ± 0.43	3.71 ± 0.43	3.48 ± 0.42	3.3 ± 0.4	3.27 ± 0.39	3.28 ± 0.4	3.32 ± 0.42	3.29 ± 0.43	3.22 ± 0.43	3.02 ± 0.42	2.61 ± 0.43
Time of MI curve fraction (min)	91.7 ± 9.3	108.2 ± 9.8	125.2 ± 11.2	143.4 ± 13.4	163.3 ± 16.7	184.7 ± 20.9	206.8 ± 24.3	228.6 ± 25.9	249.3 ± 26.7	270.5 ± 27.8	292.1 ± 29.8	314.6 ± 31.8	339.5 ± 33.4	368.6 ± 34.8

GE, gastric emptying; GET, gastric emptying time; MI, motility index.

Table 2. The CV (mean ± SD) of time for each sonographic GE stage and MI curve fraction.

	GE Stage/MI Curve Fraction													
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%
CV Ultrasound (%)	10.3 ± 2.6	8.6 ± 2.9	7.6 ± 2.6	6.9 ± 2.9	6.7 ± 3.2	6.3 ± 3.3	6.2 ± 3.1	6.4 ± 3.0	6.6 ± 3.0	6.6 ± 3.0	6.3 ± 2.9	6.0 ± 2.5	5.8 ± 2.4	5.7 ± 3.0
CV Motility Index (%)	13.1 ± 6.2	12.9 ± 5	12.7 ± 4.7	12.4 ± 4.6	12.2 ± 4.6	11.9 ± 4.7	11.4 ± 5.3	10.9 ± 5.6	10.3 ± 5.3	9.4 ± 4.4	8.7 ± 3.7	7.6 ± 3.0	6.4 ± 2.8	5.6 ± 2.7

CV, coefficient of variation; GE, gastric emptying; MI, motility index.

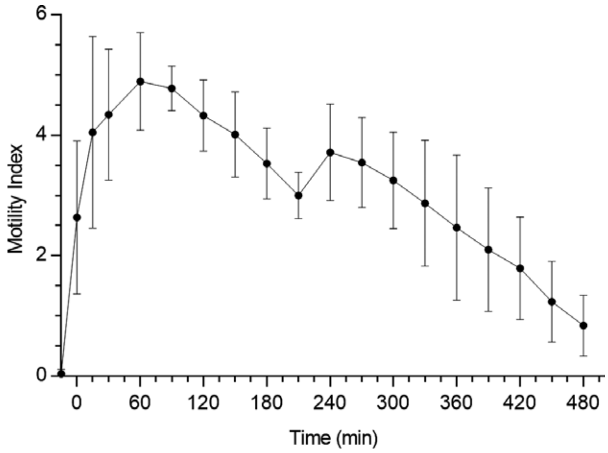

Fig 5. Motility index curve generated by graphing the mean ± SD of the motility index (product of antral contraction amplitude and contraction frequency) in 8 healthy cats over time.

including cats.[4–6] As a result, it has been recommended that all new methods be validated by this technique.[2,4] This study compared the assessment of GET by radionuclide scintigraphy and ultrasonography in cats. The results revealed good correlation in the rate of solid-phase GE measured by both methods. Additionally, the sonographic MI curve of antral contractions over time correlated well with GET assessed by scintigraphy.

In contrast to scintigraphy, ultrasonography is an inexpensive, widely available, radiation-free diagnostic method that can provide information about both structural and functional abnormalities affecting gastric motility.[4,25] The main disadvantage of ultrasonography for assessment of GE is that it requires a skilled operator and is dependent on consistent image acquisition and measurement to minimize variation. Studies in humans that evaluated this concern found acceptable variance among operators.[25,26] Additionally, the presence of gas in the stomach can make the assessment of GE by this method challenging,[13,25] and evaluation could be difficult in some cats that are obese, uncooperative, or those with atypical gastric anatomy.[11,25]

Correlation between both methods was good at the 45–90% fractional GE in this study. Poor correlation at early stages of GE could be a result of the nature of the 2 methods. GE scintigraphy measures the transit of a standardized test meal through the stomach, whereas ultrasonography relies on the postprandial measurement of the cross-sectional area or estimated volume of the relaxed pyloric antrum over time. The point of maximal antral dilatation varied among these cats and as reported in other studies did not occur immediately after eating.[12,27] The delay between food ingestion and maximal antral dilatation is likely associated with the intragastric distribution of the ingested food. The time necessary for the proximal part of the stomach (fundus) to deliver food to the lower part of the stomach (antrum) is not consistent and thus results in variation in methods that use measurement of antral dilatation over time.[3] Other factors that might contribute to this

Table 3. Pearson correlation coefficient for each scintigraphic GET and time of corresponding sonographic GE stage and MI curve fraction.

	GE Stage/MI Curve Fraction													
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%
Pearson correlation (r) between RS and US	0.48 (P = .23)	0.60 (P = .12)	0.67 (P = .071)	0.70 (P = .053)	0.72 (P = .042)	0.76 (P = .027)	0.77 (P = .026)	0.78 (P = .022)	0.79 (P = .02)	0.80 (P = .018)	0.82 (P = .012)	0.80 (P = .016)	0.79 (P = .021)	0.81 (P = .015)
Pearson correlation (r) between RS and MI	0.48 (P = .23)	0.60 (P = .11)	0.69 (P = .058)	0.78 (P = .024)	0.82 (P = .014)	0.86 (P = .007)	0.85 (P = .009)	0.83 (P = .01)	0.82 (P = .013)	0.83 (P = .01)	0.85 (P = .008)	0.84 (P = .01)	0.84 (P = .01)	0.84 (P = .008)

RS, radionuclide scintigraphy; US, ultrasonography; MI, motility index; GE, gastric emptying; GET, gastric emptying time.

delay include rehydration of dry kibbles in the stomach and ability of the gastric body to expand in order to accommodate large amounts of food with little increase in intraluminal pressure.[12,28] In contrast to assessment of changes in antral distension, with the scintigraphic technique, the counts are typically highest immediately after ingestion of the test meal and begin to decrease thereafter. This difference provides another cause for the poor correlation between scintigraphically and sonographically assessed GE until 45% fractional GE.

The mean gastric half-emptying times (50%) in the present study were 196 minutes for scintigraphy and 203 minutes for ultrasonography, which is comparable to other studies performed in healthy cats.[5,10] Lack of standardization of the amount, composition, and caloric content of test meals creates difficulty when attempting to compare the results of this study to previously reported values. Moreover, differences in radionuclide markers, counting techniques, and methods of data analysis may contribute to the wide range of GE times reported and render comparisons difficult to impossible.

Gastric antral motility is regarded as one of the main regulators of GE of solid meals.[3,29] The MI reflects both the frequency and intensity of contractions and thus is an assessment of gastric antral motility. Good correlation between the sonographic MI curve and scintigraphic GET was found in the present study. Similarly, good correlation between the sonographic MI and GE assessed by the ^{13}C-octanoic acid breath test has been reported in dogs.[15] The sonographic assessment of the MI has been used to assess the effects of antiemetic drugs on antral motility and GE as well as the effects of various prokinetics in healthy dogs.[16,17,30] The results of this study support the potential usefulness of the MI to assess the effects of pharmacologic agents on antral motility and GE in cats.

It is important to understand the degree of intraindividual variability and the reproducibility of a technique before clinical application. A previous study found a good reproducibility of GET assessed by the sodium acetate breath test and scintigraphy, and the CV was <10% when cats were assessed on 2 consecutive days.[10] In the present study, similar moderate intraindividual variability was observed for the different sonographic GE times and times of MI curve fractions. It has been shown in healthy people that there is not a significant difference between mean values of sonographic antral volumes on 2 different days at 2-week intervals, but the greatest variation for individual cases occurred in the immediate postprandial period.[31] The same phenomenon was observed in the present study with the greatest variation of both sonographic fractional GE times and times of MI curve fractions occurring immediately after meal ingestion.

The inability to perform scintigraphic and sonographic evaluations simultaneously was a limitation of this study. Simultaneous evaluations were not performed in the current study to minimize the radiation exposure of study personnel. Based on a previous study in cats that found minimal variation in results in the same cat on different days and acceptable variation in scintigraphic emptying times,[10] it is unlikely that the study design had a significant impact on the results obtained in the present study. Additionally, the time between evaluations was minimal with at least 1 sonographic evaluation being performed within 4 days of scintigraphy and all evaluations were completed within a 3-week period.

In conclusion, the results of this study reveal good correlation between the scintigraphic and sonographic assessment of rate of GE of solids as well as good correlation between sonographic MI curve of antral contractions and scintigraphic GET. Thus, ultrasonography is a valid and noninvasive alternative for assessment of solid-phase GE and postprandial gastric motility in healthy cats. There is moderate intraindividual variability with ultrasonography and significant variation among individuals, which must be considered when interpreting test results for a specific cat and when establishing a reference interval. Further studies are required to validate this method in cats with gastrointestinal disease.

Footnotes

[a] Laflamme DP. Development and validation of a body condition score system for cats: a clinical tool. Feline Practice 1997; 25:13-17
[b] LabDiet 5003-Laboratory Feline Diet, LabDiet®, St. Louis, MO
[c] Purina Proplan Focus Chicken & Liver Entrée, Classic, Nestle Purina PetCare Company, St. Louis, MO
[d] JMP Statistical Discovery, SAS, Cary, NC
[e] Hitachi Noblus, Hitachi Aloka Medical America Inc, Wallingford, CT
[f] R version 3.2.2, The R Foundation for Statistical Computing, Vienna, Austria
[g] GraphPad Prism, GraphPad Software Inc., La Jolla, CA
[h] Microsoft Excel, Microsoft Office, Microsoft Corporation, Redmond, WA

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Conflict of Interest Declaration: Authors declare no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

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