Effects of prophylactic incisional gastropexy on markers of gastric motility in dogs as determined by use of a novel wireless motility device

Krista M. Gazzola DVM
Laura L. Nelson DVM, MS
Michele C. Fritz BS
Michelle R. Clancy BS, MPA
Joe G. Hauptman DVM, MS

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From the Department of Small Animal Clinical Sciences, College of Veterinary Medicine (Gazzola, Nelson, Clancy, Hauptman), and Department of Epidemiology and Biostatistics, College of Human Medicine (Fritz), Michigan State University, East Lansing, MI 48824.

Address correspondence to Dr. Nelson (michae19@cvm.msu.edu).

OBJECTIVE
To evaluate effects of laparoscopic-assisted incisional gastropexy (LAIG) on gastric motility in dogs by use of a wireless motility device (WMD).

ANIMALS
10 healthy client-owned large or giant-breed dogs.

PROCEDURES
10 dogs owned by clients interested in prophylactic LAIG were enrolled. To determine effects of LAIG on gastrointestinal motility in dogs during the nonfed state, each dog was evaluated by use of a noninvasive WMD before and > 4 weeks after LAIG. All dogs underwent LAIG, with or without concurrent elective gonadectomy. Data obtained before and after LAIG were analyzed by use of proprietary software to determine the gastric emptying time, small bowel transit time, large bowel transit time, whole bowel transit time, and motility index.

RESULTS
No changes in variables were detected between measurements obtained before and after prophylactic LAIG.

CONCLUSIONS AND CLINICAL RELEVANCE
In this study, prophylactic LAIG did not have an effect on gastrointestinal motility. The WMD was tolerated well by all dogs and appeared to be a safe and effective method for evaluating gastrointestinal motility in this population of dogs. (*Am J Vet Res* 2017;78:100–106)

Gastric dilatation–volvulus is an acute and often life-threatening condition affecting primarily large and giant-breed dogs. It is characterized by an accumulation of gas in the stomach accompanied by gastric malpositioning, which results in increased intragastric pressure and cardiogenic shock that can often lead to death. Many predisposing factors have been associated with GDV in dogs. These factors include increasing age, underweight body condition, history of GDV in a first-degree relative, rapid eating, once-daily feeding, fearful or anxious temperament, and increased thoracic depth-to-width ratio.[1,2] Of additional importance, but less frequently mentioned, delayed gastric emptying has also been associated with GDV.[3–5]

The reported lifetime risk for specific dogs predisposed to the development of GDV is estimated to be between 4% and 37%.[6] Prophylactic gastropexy (fixation of the pyloric antrum region of the stomach to the right body wall) reportedly can significantly reduce the mortality rate for GDV, compared with that for dogs that have not undergone gastropexy.[1] In dogs that develop GDV, failure to perform a gastropexy following gastric derotation has been associated with a risk of disease recurrence as high as 80%.[7] Several gastropexy techniques have been described, including belt-loop gastropexy, CG, incorporating gastropexy, gastrocolopexy, IG, laparoscopic gastropexy, and laparoscope- or endoscope-assisted procedures.[8]

Evaluation of long-term outcomes in dogs that underwent gastropexy procedures has revealed low rates of GDV (0% for belt-loop gastropexy and IG, 4.3% for CG, and 15% for gastrocolopexy).[2,9–12] However, gastric dilatation without volvulus occurred in dogs that underwent prophylactic IG or IG as part of GDV treatment, with rates of 11.1% and 8.8%, respectively.[1] The occurrence of gastric dilatation in dogs undergoing IG prophylactically or therapeutically raises concerns about an underlying gastric motility disorder as a potential cause of GDV or negative effects on gastric motility attributable to IG. To be able to determine the safety of this potentially life-saving technique and to improve understanding about pathophysiologic ef-

ABBREVIATIONS

CG	Circumcostal gastropexy
GDV	Gastric dilatation–volvulus
GET	Gastric emptying time
IG	Incisional gastropexy
IMC	Interdigestive migrating contraction
LAIG	Laparoscopic-assisted incisional gastropexy
LBTT	Large bowel transit time
SBTT	Small bowel transit time
WBTT	Whole bowel transit time
WMD	Wireless motility device

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fects of GDV, it is important to determine the effects that IG may have on gastric motility.

The gastric motility pattern in humans and dogs in a nonfed state is dominated by the presence of IMCs (also called migrating motor complexes).[13] Gastric IMCs function to clear nondigestible solids and are characterized by a cycle composed of 3 or 4 distinct phases, with each cycle occurring every 90 to 120 minutes. Phase I is a quiescent period with minimal contractions, phase II contains low-amplitude mixing contractions, and phase III consists of high-amplitude, regular propulsive contractions. Phase IV has been described by some groups of investigators and represents a short transition period back to the quiescence of phase I.[13,14] These phases are under hormonal control (motilin and ghrelin), with modulation by the autonomic nervous system.[13,14] Gastric phase III contractions are initiated by motilin spikes and can be inhibited by stress in dogs.[13] Stressful stimuli can reduce vagal activity and increase sympathetic tone in both humans and dogs, which decreases maintenance of IMCs.[13]

An association has been identified between GDV and abnormal gastric motility in dogs, including the observation that dogs with experimentally induced GDV have motility patterns that differ from motility patterns of dogs with naturally occurring gastric dilatation.[3,15] In 1 study,[15] investigators evaluated gastric myoelectric and motor activity by use of surgically placed electrodes and strain-gauge force transducers in dogs that underwent CG as part of GDV treatment and control dogs that underwent CG. Evaluation of recordings obtained from dogs after CG as part of GDV treatment revealed increased slow-wave propagation velocity and atypical IMC nonfed-state phase III activity fronts, compared with results for clinically normal dogs and control dogs that underwent CG. The investigators concluded that abnormalities in gastric motor activity in dogs with naturally occurring GDV are associated with GDV and not associated with the gastropexy procedure. A similar study[5] conducted by the same laboratory group involved the use of nondigestible radiopaque markers to evaluate GET in clinically normal dogs that underwent or did not undergo CG and dogs with GDV that underwent CG. Gastric emptying was significantly prolonged in the dogs with GDV that underwent CG. Investigators of another study[16] described decreased clearance of liquid barium from the stomach in large dogs that survived acute attacks of gastric torsion. Results of these studies suggest that gastropexy procedures performed to prevent GDV recurrence are probably not the cause of postoperative changes in gastric motility in dogs with GDV, but they do not address whether abnormalities in gastric motility preceded or precipitated GDV. Investigators of these studies evaluated the effect of CG, rather than the effects of IG. Also, the diagnostic methods used in these studies were invasive or did not represent the current standard for evaluation of gastric emptying.

Radioscintigraphy is considered to be the criterion-referenced standard for evaluation of gastric emptying in dogs. Disadvantages of the technique include limited availability because of the requirement for nuclear medicine facilities and use of radiation.[14] One noninvasive method for evaluating gastrointestinal motility in dogs is the use of a WMD that has been validated for the noninvasive evaluation of gastrointestinal motility in large dogs.[17,18] Specifically, repeatability of measurements obtained by use of a WMD or scintigraphy was found to be equivalent.[18] The WMD used in that study[18] was a 26 × 13-mm capsule that contained sensors for the measurement of pressure, temperature, and pH; it was administered orally to each dog. The device transmitted data wirelessly to a small receiver worn by the dog. After data were transferred to a computer, proprietary interpretation software allowed the quantitative interpretation of motility data. This device has been used in the evaluation and diagnosis of gastroparesis, functional dyspepsia, and chronic constipation in humans.[19,20] Unlike other means of evaluating gastric motility or GET, the WMD is noninvasive, provides quantitative data, and does not involve radioisotopes, hospitalization, or physical restraint.[18]

The objective of the study reported here was to use a WMD to noninvasively determine effects of prophylactic LAIG on gastric motility in healthy large and giant-breed dogs in a nonfed state. We hypothesized that there would be no effect of LAIG on gastric motility variables.

Materials and Methods

Animals

Large and giant-breed dogs of clients who were interested in prophylactic gastropexy were recruited through American Kennel Club–affiliated breed groups and community contacts within the Veterinary Medical Center at the Michigan State University College of Veterinary Medicine. Informed consent for participation of dogs was obtained from all clients. The study was approved by an institutional animal care and use committee.

All dogs enrolled in the study underwent evaluation of gastrointestinal motility by use of a WMD[a] before and > 4 weeks after prophylactic LAIG. This was the WMD used in an aforementioned study.[18] Dogs were excluded from the study if they were receiving medications that were likely to affect gastric motility or gastric pH or if they had a history of gastrointestinal tract disease or surgery of the gastrointestinal tract. Medications that resulted in exclusion included H_2-receptor antagonists, proton pump inhibitors, gastroprokinetic agents, antihistamines, opioids, anticholinergics, tricyclic antidepressants, calcium channel blockers, progesterone compounds, corticosteroids, synthetic hormones or other hormone treatments, antacids, and β-adrenergic receptor agonists or antagonists. The only exception for medications was immediate postoperative pain control, whereby

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dogs were allowed to receive transient postoperative treatment with NSAIDs and opioids because these interventions were not expected to influence gastrointestinal motility after metabolic clearance. Because of the size of the WMD, dogs that weighed < 20 kg also were excluded. For each dog, information obtained included signalment (breed, age, sex, and neuter status), current medications, body weight, and medical and surgical history.

WMD administration

The same protocols were used for administration of the WMD before and after prophylactic LAIG. Food was withheld (water was allowed) for a minimum of 8 hours prior to assessment. Dogs were fed a meal, which was not a standardized meal or amount (ie, each dog was fed the meal typically provided to that specific dog); food was then withheld overnight, and a WMD was administered the next morning. To limit the effect of stress on gastric motility and GET, the presurgical assessment was performed in each dog's home environment. The WMD was calibrated, and data collection by the receiver was confirmed. The receiver was secured to a harness worn by the dog, and the WMD was administered by manually placing the capsule in the pharyngeal region of the dog's mouth. Dogs were fed no sooner than 6 hours after WMD administration; thus, the nonfed period was a minimum of 14 hours to increase the likelihood that the IMC would be the dominant gastric motility pattern. The IMC is responsible for clearance of nondigestible solids (eg, the WMD); thus, it was anticipated that gastric clearance would be relatively rapid. By 6 hours after the WMD was administered, it was expected that the WMD would have exited the stomach. Owners were asked to curtail strenuous activity of their dogs until the WMD was passed in the feces. After the WMD was passed in the feces, the receiver was removed from the dog, and the information was evaluated.

Motility evaluation

Two motility evaluations were performed for each dog (one before prophylactic LAIG and the other after prophylactic LAIG). Data obtained by use of the WMD were analyzed with proprietary software[b] and investigator interpretation. Variables analyzed included the GET, temperature, mean gastric pH, mean small intestinal pH, pressure profiles (mean pressure amplitude in the small bowel), frequency of gastric contractions, motility index, SBTT, LBTT, and WBTT.

Transit times

Transit times for GET, SBTT, LBTT, and WBTT were determined with the proprietary software and confirmed by the investigators using methods described in other studies.[17,18] A loss of signal was evident when the WMD was no longer in the gastrointestinal tract. Tracings were obtained, and the GET, SBTT, LBTT, and WBTT were calculated. The GET was considered the interval between ingestion and the change in pH from an acidic to an alkaline environment or as an increase in pH of > 3 units; the GET also was determined by manual analysis of the motility pattern (specifically the onset of small bowel contractions). The SBTT was determined as the interval between gastric emptying and a decrease in pH of > 1 unit associated with passage of the WMD through the ileocolic valve or as a change in the pressure pattern from continuously high pressure (IMC phase III) to isolated segmented contractions commonly considered as colonic motor complexes. The WBTT was determined as the interval from the initial change in both temperature and pH transmitted from the WMD to the time of an abrupt decrease in temperature or loss of data. The LBTT was calculated as WBTT – SBTT.

Pressure measurements

The WMD directly measured intraluminal pressures within the gastrointestinal tract; both the amplitude and frequency of contractions were recorded. These measurements were transformed by the proprietary software, which yielded both area under the curve and the motility index. The motility index, as it relates to the gastrointestinal tract, quantifies frequency of contraction and concurrent amplitude. The motility index was calculated as follows[20]: natural logarithm ([sum of amplitudes X number of contractions] + 1). All pressure measurements for the fundus and antrum were calculated by the proprietary software; however, the measurements referred to the period of the highest contractions prior to passage of the WMD into the duodenum.

Prophylactic LAIG

After the presurgical evaluation of gastric motility was completed, each dog was anesthetized by use of a protocol approved by the veterinary hospital anesthesiologists. The LAIG was performed by placement of 2 abdominal ports. The first port was placed on the ventral midline and was used for insufflation, visualization of the abdomen, and identification of the pyloric antrum. The second port was placed to the right of midline at a point lateral to the right margin of the rectus abdominis muscle and 2 to 3 cm caudal to the last rib. This port was used to grasp and withdraw the pyloric antrum with laparoscopic Babcock forceps. The pyloric antrum was exteriorized at the second port by extending the incision by 3 cm cranially or caudally. The exteriorized pyloric antrum was maintained with stay sutures. A 3- to 4-cm incision was made parallel to the gastric axis in the seromuscular layer of the pyloric antrum and extended to the level of the submucosa. The cranial border of the seromuscular incision was sutured to the transversus abdominis muscle in the cranial aspect of the incision at the second port; suturing was repeated at the caudal aspect of this incision. The oblique muscles were closed over the gastropexy site, which was followed by closure of the subcutaneous tissues and skin. When requested by the owner, elective gonad-

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ectomy was performed during the same anesthetic episode.

Statistical analysis

The WMD data obtained before and after prophylactic LAIG were compared by means of a paired 2-tailed *t* test. Comparisons included results for regional transit times (GET, SBTT, and LBTT) as well as transit time for the entire gastrointestinal tract (WBTT), gastric pressure, and frequency of contractions. Results were reported as mean ± SD. Values were considered significant at $P < 0.05$.

Results

Animals

Of the 10 dogs in the study, 8 were Great Danes, and 2 were Great Dane–Weimaraner crossbred dogs. There were 5 sexually intact males, 1 neutered male, and 4 sexually intact females; however, 4 dogs (1 male and 3 females) underwent concurrent gonadectomy. Thus, after the LAIG, there were 6 neutered males, 1 sexually intact female, and 3 spayed females. Median age of dogs at the time of gastropexy was 3 years (range, 2.5 to 6.5 years). Mean body weight was 55.26 kg. One dog was affected occasionally with allergies, 1 dog had a history of shoulder joint osteochondrosis, and 1 dog had a history of a patent ductus arteriosus (which had resolved). All dogs currently received monthly heartworm preventative. One dog received glucosamine and fish oil, and 1 dog received cephalexin because of skin allergies. No other abnormalities were detected. One dog (a Great Dane) had a relative that was affected by GDV. During the study, both of the Great Dane–Weimaraner crossbred dogs occasionally vomited in the morning or if fed late at night.

Transit times

The second WMD was administered a median of 37 days (range, 30 to 63 days) after the prophylactic LAIG. There were no significant differences between preoperative and postoperative values for any of the regional transit times (GET, SBTT, and LBTT) or the WBTT **(Table 1)**. In addition, there was no evidence that the WMD was still in the stomach at the time the postadministration meal was fed (ie, 6 hours after WMD administration).

Pressure measurements

Preoperative and postoperative measurements did not differ significantly for any of the gastric pressure measurements in the fundus or antrum **(Table 2)**. There was no significant difference found be-

Table 1—Transit time (minutes) for the gastrointestinal tract determined by use of a WMD administered before and > 4 weeks after prophylactic LAIG in 10 large or giant-breed dogs.

	Before LAIG		After LAIG		
Variable	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	***P* value***
GET	122.3 ± 55.99	52–235	115.3 ± 66.05	11–24	0.70
SBTT	115.3 ± 48.30	91–259	155.3 ± 37.82	109–213	0.56
LBTT	815.2 ± 503.65	244–1,678	1,100.0 ± 660.03	362–2,553	0.16
WBTT	1,093.0 ± 503.04	474–1,949	1,368.5 ± 631.86	666–2,776	0.19

*Values were considered significant at $P < 0.05$.

Table 2—Gastric pressure (mm Hg) for portions of the stomach determined by use of a WMD administered before and > 4 weeks after prophylactic LAIG in 10 large or giant-breed dogs.

	Before LAIG		After LAIG		
Variable	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	***P* value***
Fundus	3.78 ± 1.69	1.5–6.2	4.73 ± 1.28	3.0–6.8	0.13
Antrum	3.31 ± 1.56	1.4–6.3	4.44 ± 1.54	3.0–7.1	0.07

See Table 1 for key.

Table 3—Frequency of gastric contractions (contractions/min) for portions of the stomach determined by use of a WMD administered before and > 4 weeks after prophylactic LAIG in 10 large or giant-breed dogs.

	Before LAIG		After LAIG		
Variable	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	***P* value***
Fundus	2.53 ± 3.41	0.2–11.8	2.10 ± 0.82	0.9–3.5	0.63
Antrum	2.43 ± 3.99	0.2–13.5	2.33 ± 1.24	1.1–5.2	0.12

See Table 1 for key.

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tween preoperative or postoperative measurements for any of the gastric contraction frequencies **(Table 3)**. Mean ± SD motility index for the antrum was 92.8 ± 80.4 before prophylactic LAIG, which differed (but not significantly [$P = 0.08$]) from the mean value after prophylactic LAIG (158.07 ± 68.6).

Discussion

Prophylactic gastropexy is a commonly recommended procedure in large and giant-breed dogs that are at risk for the development of GDV. Incisional gastropexy, which is frequently performed with laparoscopic assistance, can be an effective method for use in the prevention of GDV.[1] However, up to 11% of treated dogs may still develop gastric dilatation.[1] Because similar rates of gastric dilatation have been described for dogs after GDV and therapeutic gastropexy, it has been speculated that these dogs may be affected by an underlying motility disorder or that the surgical procedure has a negative effect on gastric motility. Another possible consequence is that gastropexy could change gastric emptying and absorption mechanisms because of potential iatrogenic duodenogastric reflux attributable to positioning and point of attachment of the associated gastropexy.[21] Investigators evaluated gastric emptying by use of radiographic assessment of barium clearance before and after LAIG and found that the decrease in gastric area was unaffected by gastropexy.[21] In that study,[21] residual contrast medium was observed in the stomach of dogs 10 hours after eating both before and after gastropexy. Results of the present study indicated that LAIG did not have an effect on gastrointestinal motility of dogs in the nonfed state on the basis of variables recorded by use of the WMD and clearance of the WMD (a nondigestible solid) from the stomach.

The IMC is the aspect of gastrointestinal motility found to be atypical in dogs with GDV; therefore, we believed that analysis of the effect of LAIG during the nonfed state would be most useful to validate the safety of LAIG and to allow for future differentiation of the effects of GDV from those of an accompanying gastropexy procedure. Had we chosen to analyze this effect in the fed state, GET would have been affected by diet composition and would have represented the more complex trituration and filtering functions of the pylorus that result in passage of food.[22,23] During the nonfed state, the mechanism that solely governs gastric emptying is the IMCs responsible for the clearance of nondigestible solids from the stomach. Function of the IMC is under the control of motilin, which is only released during the nonfed state.[24] Because the WMD represents a nondigestible solid of substantial size, it will not pass until the stomach is free of food and phase III IMCs commence, regardless of whether the test is initiated during the fed or nonfed state. With this in mind, we thought that the addition of food would only make it more difficult to interpret the results. Had there been sufficient resources, it would have been interesting to administer an additional WMD during the fed state both before and after prophylactic LAIG to determine whether there was a significant intraindividual effect on transit times when a dog is fed at the time of WMD administration.

The decision not to standardize the diet may be considered a limitation of the study reported here. All dogs were fed different diets. Indeed, provision of a standardized meal is critical to the interpretation of results when a WMD is administered with food. However, we did not consider this to be a critical issue in the present study for several reasons. The maintenance of each dog's specific diet minimized stress, which can affect motility patterns. Because diet is not known to affect motility patterns during the nonfed state (ie, the IMC), the benefit of dietary standardization on interpretation of results was considered to be minimal. Finally, statistical analysis and study design allowed for the use of each dog as its own control animal, which further minimized the effect of dietary differences on the conclusions for this study.

The use of WMDs to evaluate gastrointestinal motility of dogs is a relatively novel technique. The decision to use this particular technology was based on previous studies[17,18] in which investigators validated its use in dogs. Equivalent diagnostic value, ease of administration, and the ability to assess dogs in their home environments were all practical and attractive qualities of the WMD, compared with use of other methods (eg, scintigraphy). For a prospective controlled clinical trial conducted to evaluate serial repeatability of the use of a WMD and scintigraphy, investigators concluded that the repeatability of measurements obtained by use of the WMD was equivalent to that obtained by use of scintigraphy, with some intraindividual variation evident for each measurement type.[18] When considering possible limitations of the present study, and in consideration of the findings in the aforementioned study,[18] it may have been of benefit to administer additional WMDs both before prophylactic LAIG and at later times after LAIG to examine intraindividual repeatability preoperatively and the long-term effects of LAIG. Additionally, use of a control population of low-risk dogs for comparison would have been of benefit when comparing gastrointestinal transit times.

Compared with published[18] values for GET (range, 405 to 897 minutes) determined by use of a WMD in dogs fed a standard diet, results of the present study indicated faster transit times for the nonfed state. This finding corresponds with results for a study[25] in which investigators used a pH capsule in conscious dogs during a nonfed state. The SBTT for the present study was similar to that described for dogs evaluated by use of a WMD administered with a standard meal (range, 96 to 224 minutes).[19] The LBTT in the present study had the most variability (427 to 2,573 minutes), which is consistent with the variability for large bowel emptying described in other studies.[17,18] Variability in diet and hydration status are factors that contribute

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to constipation in both dogs and cats, and these factors possibly could have had an effect on LBTT.[26] In addition, the number of times that a dog was allowed outside and given the opportunity to defecate, and the interval between those times, was not standardized in the study reported here. Because defecation is generally under conscious control, variability of a dog's environment, amount of stress, and defecation habits should be considered as major contributing factors. When performing studies to evaluate colonic motility, it would be beneficial to attempt to standardize the time periods in which dogs are allowed the opportunity to defecate. In humans, similar intraindividual and interindividual colonic transit times are observed even when a standardized high-fiber diet is provided.[27] Additionally, it has been suggested[27] that there is a high degree of variability among individuals with regard to the transit times of each portion of the colon. Based on this research, evaluation of WBTT and LBTT should be interpreted carefully because there is large variability among individuals. Repeated motility evaluations would be necessary to characterize an individual's typical WBTT when considering a colonic motility disorder.

The decision to provide a brief period of postoperative analgesia (NSAID or opioid) was made in accordance with the standards of our institution. Most dogs received an opioid for pain control after surgery; however, this was only during a brief time period (2 to 5 days). This brief period of analgesia administration was not expected to influence gastrointestinal motility because the second WMD was administered at least 4 weeks later. Additionally, analysis of the results indicated that WMD tracings (before and after prophylactic LAIG) were almost identical.

The most important limitation of the present study was the small number of dogs in the study population. Although each dog served as its own control animal, it would have been beneficial to enroll additional dogs and to potentially include a control group of dogs undergoing nongastric surgery. Additionally, had there been sufficient resources, comparison of dogs in both a fed and nonfed state would have allowed for interindividual and intraindividual comparison of gastrointestinal motility in both states. Future studies may be aimed at evaluating dogs in the fed state after prophylactic gastropexy.

For the study reported here, we concluded that LAIG was a prophylactic procedure that did not have a negative effect on gastric motility of dogs in the nonfed state. The WMD was a safe and effective tool that enabled us to evaluate gastrointestinal motility in dogs.

Acknowledgments

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Footnotes

a. SmartPill, Given Imaging, Duluth, Ga.
b. MotiliGI, Given Imaging, Duluth, Ga.

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