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Clinical and videofluoroscopic outcomes of laparoscopic treatment for sliding hiatal hernia and associated gastroesophageal reflux in brachycephalic dogs

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Abstract

Objective: To describe a laparoscopic technique for treatment of sliding hiatal hernia (SHH) and associated gastroesophageal reflux (GER) in brachycephalic dogs and document clinical and videofluoroscopic outcomes postoperatively.

Study design: Prospective clinical trial.

Animals: Eighteen client-owned dogs.

Methods: A three-port laparoscopic approach was used. Intracorporeal suturing was used for hiatal plication and esophagopexy, and left-sided laparoscopic or laparoscopic-assisted gastropexy was performed. A standardized canine dysphagia assessment tool (CDAT) questionnaire was completed by owners pre- and postoperatively. Videofluoroscopic swallow studies (VFSS) were used to evaluate esophageal function, and impedance planimetry was used to assess lower esophageal sphincter geometry preoperatively and in a subset of dogs postoperatively.

Results: Median age was 27.5 (range 5–84) months. Conversion to open surgery was necessary in 1 (5.5%) of 18 dogs. Regurgitation after eating, and associated with activity/exercise, improved significantly when comparing pre- and postoperative CDAT assessments. Hiatal hernia and GER severity scores improved significantly between pre- and postoperative VFSS assessments, whereas SHH and GER frequency scores did not. One dog developed pneumothorax intraoperatively, underwent cardiopulmonary arrest, and died. Minor complications included splenic ($n = 6$) and hepatic lacerations ($n = 3$) that did not require specific therapy.

Conclusion: A laparoscopic approach to treatment of SHH and GER led to improvements in clinical and VFSS indices in the majority of brachycephalic dogs. However, a subset of dogs still demonstrated some clinical signs postoperatively.

Clinical relevance: In experienced hands, laparoscopic treatment of SHH and GER offers a minimally invasive alternative to open surgery.

1 | INTRODUCTION

Sliding hiatal hernia (SHH) and associated gastroesophageal reflux (GER) are a relatively common problem in brachycephalic dog breeds causing regurgitation of food and water, discomfort, esophagitis, esophageal stricture formation, and aspiration pneumonia.[1-4] A putative pathogenesis linking upper airway obstructive conditions to increased negative intrathoracic and intraesophageal pressures and subsequent GER has been shown in experimental animal studies.[5,6] The common concurrence of brachycephalic pathology with secondary gastrointestinal intestinal sequela is well established in clinical canine patients.[7-9] Recently, prospectively collected outcomes from a cohort of mostly brachycephalic dogs that underwent open surgical management with a combination of hiatal plication (phrenoplasty), esophagopexy, and left-sided fundic gastropexy for management of SHH and/or GER were reported.[10] Outcomes reported included the results of client questionnaires and videofluoroscopic swallow studies (VFSS) evaluated pre- and postoperatively. The study reported clinical improvement in a majority of patients with regurgitation, although not all dogs were significantly improved.[10] Similarly, scores assessed for SHH severity improved significantly postoperatively, although the SHH frequency score was not significantly different on postoperative VFSS studies.[10]

Minimally invasive management of SHH and GER in people has become the standard of care when medical management is not successful in alleviating clinical signs, and many advantages of laparoscopic over open surgery have been documented.[11] Advantages include shorter hospitalization and convalescent time for patients, fewer short- and long-term complications postoperatively, and better long-term reflux control.[11] In recent years, minimally invasive surgical approaches in veterinary patients have become more popular, although no laparoscopic surgical intervention for SHH repair and associated GER has been described to date.

The aims of this study were to describe a technique for the laparoscopic management of SHH and GER in a cohort of client-owned dogs and to report postoperative outcomes using a standardized client questionnaire and VFSS. The primary hypothesis was that clinical signs and evidence of SHH and GER on VFSS would be reduced after SHH repair.

2 | MATERIALS AND METHODS

2.1 | Case selection

All dogs that were presented with clinical signs and had a VFSS consistent with SHH with or without concurrent GER and whose owners consented to a laparoscopic approach for surgical management were enrolled in the study. Dogs were excluded if they were not brachycephalic, if medical management alone was elected for treatment of clinical signs, or if the dog underwent an open surgical approach for SHH repair. The study protocol was approved by the institutional animal care and use committee (IACUC).

2.2 | Medical history and clinical outcome assessment

Medical records for each dog were evaluated for clinical history, physical examination findings, and previous medical therapies. The results of diagnostic imaging studies were evaluated for evidence of SHH and GER, as well as the presence or absence of aspiration pneumonia or other thoracic pathology. Owners were asked to complete a standardized questionnaire: the canine dysphagia assessment tool (CDAT), identical to one previously reported (Appendix S1).[10]

Owners were asked to return to the hospital with their dog for reevaluation approximately 3–6 months postoperatively. Dogs were reevaluated via VFSS whenever feasible, and owners were asked to complete the CDAT questionnaire a second time. Pre- and postoperative data from the CDAT questionnaire were compared statistically to evaluate for changes in the owner-reported severity of clinical signs postoperatively.

2.3 | Positive-contrast videofluoroscopic swallow studies

All dogs underwent a preoperative VFSS using the same protocol described in a previous publication.[10] Each VFSS was evaluated by a board-certified radiologist (RP) who was blinded to the signalment, case number, and order of study (pre- vs. postoperative). A standardized scoring system that has been previously published[10] was used to assign separate scores for the following criteria: frequency and severity of esophageal dysmotility, frequency and severity of GER, and frequency and severity of SHH (Appendix S2). The criteria used for defining herniation of the hiatus are also defined in Appendix S2. Scores for each parameter were evaluated statistically to evaluate for differences between pre- and postoperative studies.

2.4 | Impedance planimetry studies

Impedance planimetry was used to evaluate the geometry of the lower esophageal sphincter (LES) in the first

12 dogs operated in the study in a similar fashion to a technique previously published.[10] For the remaining six dogs, for technical reasons, the unit was no longer available for use in the study. The EndoFLIP device (Medtronic Inc, Salem, MA) uses a balloon-tipped catheter placed across the LES and calculates the following parameters using the principles of impedance planimetry[12]: LES minimum diameter (MD), cross-sectional area (CSA), and LES length and intrabag pressure (IBP). Inflation of the balloon to 30- and subsequently 40-ml volumes was performed at each measurement time point as recommended by previous studies using the EndoFLIP in dogs.[13] Each measurement was calculated prior to the initiation of surgery but after the induction of general anesthesia, and a second set of measurements was taken after completion of the surgical techniques but prior to the dog recovering from anesthesia.

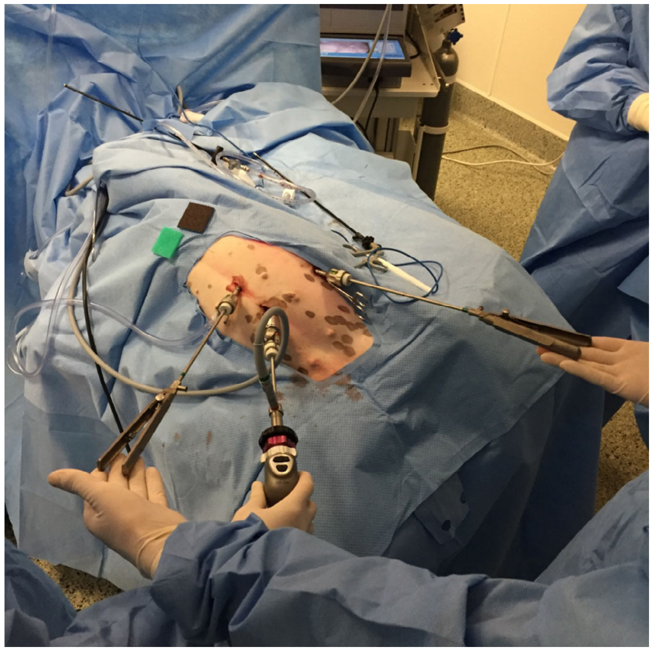

FIGURE 1 Port placement for laparoscopic hiatal hernia repair is shown. The telescope portal was placed subumbilically, with instruments placed 3–5 cm more cranially on the ventral midline and in the caudal right lower quadrant

2.5 | Anesthesia and surgical technique

Dogs were anesthetized using a nonstandardized protocol at the discretion of the attending anesthesiologist. All dogs were placed in dorsal recumbency close to the end of the operating table so the surgeon could stand behind the hindlegs. A wide surgical clip of the ventral abdomen extending proximally toward the dorsal midline was performed on the left side. A three-port laparoscopic approach was performed using a subumbilical telescope port, and a pneumoperitoneum of 8–12 mmHg was induced using a mechanical insufflator. Instrument ports were placed on the ventral midline 5–8 cm cranial to the umbilicus and in the left caudal quadrant of the abdomen (Figure 1). After initial port placement, dogs were rotated into oblique right or complete right lateral recumbency. The triangular ligament of the left lateral liver lobe was incised with a j-hook monopolar electrosurgical probe (Medtronic Inc, Salem, MA), and a blunt laparoscopic probe was used to encourage the left lobes of the liver to fall to the right side to expose the hiatus (Figure 2). Hiatal plication (phrenoplasty) was performed by placement of interrupted 2–0 to 3–0 polypropylene sutures starting ventrally and moving dorsally. Suture bites engaged the crural muscle on both sides of the hiatus (Figure 3). Sutures were placed and tied using laparoscopic needle holders (Karl Storz Inc, Goleta, CA). Subjective assessment of the dimensions of the hiatus was performed intermittently by palpation with the blunt probe and by grasping of the cardia with an atraumatic laparoscopic grasper (Microline Inc., Beverly, MA) and simulating passage of the cardia through the hiatus. After completion of the hiatal plication, an esophagopexy was performed by

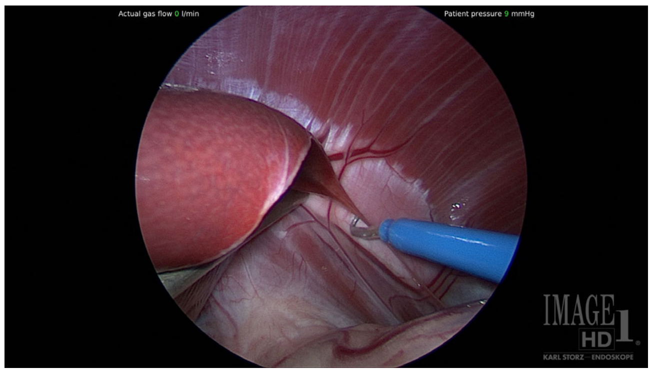

FIGURE 2 The triangular ligament of the left liver lobes are initially incised using a j-hook monopolar electrosurgical probe before the left lateral lobes are retracted medially to reveal the hiatus

placement of a simple continuous line of 2–0 to 3–0 barbed polyglyconate sutures (6- or 9-inch VLOC 180, Medtronic Inc., Salem, MA), extending from the hiatus and incorporating bites of the left crural musculature to the distal esophagus and cardia. The first bite of the esophagopexy generally engaged both left and right crural muscles. Thereafter, bites were anchored only in the left crus and the distal esophagus and cardia. Finally, a left-sided gastropexy was completed in either a laparoscopic-assisted (for cases performed early in the case series) or intracorporeally sutured laparoscopic

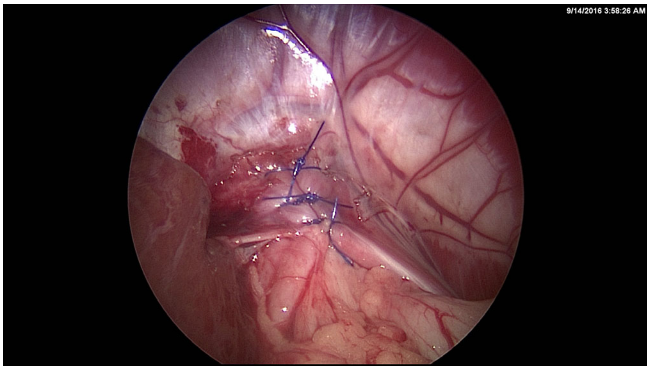

FIGURE 3 For the hiatal plication, suture bites are taken in the right and left crural muscles ventral to the hiatus to decrease the size of the esophageal hiatus

gastropexy (performed in later cases). When a laparoscopic-assisted gastropexy was performed, it was completed using a technique similar to that previously described by Rawlings,[14] although it was performed on the left rather than the right side. When performed using a total laparoscopic technique, it was performed similarly to a previously described intracorporeally sutured technique[15] but again on the left side and not the right. With either technique, fundic location for the gastropexy was selected to allow subjectively mild tension to discourage gastric displacement into the thorax through the hiatus. For intracorporeally sutured gastropexy, the fundus and the transversus were opposed by a single line of 2-0 to 3-0 barbed polyglyconate sutures (6- or 9-inch VLOC 180, Medtronic Inc., Salem, MA) in a simple continuous pattern. After completion of all procedures, the laparoscopic ports were removed after the pneumoperitoneum had been purged. Surgical time, anesthesia time, and complications were documented for each dog enrolled.

2.6 | Follow up

All dogs were carefully monitored in an intensive care unit environment for the initial postoperative period. Analgesic medications were administered at the discretion of the attending clinician. Medications prescribed included the following: hydromorphone hydrochloride (0.05–0.1 mg/kg, IV, every 4 h for 24 h) or buprenorphine hydrochloride (0.01 mg/kg, IV, every 6 h for 24 h) or fentanyl citrate (2–10 mcg/kg/h, IV, as needed). Some dogs were discharged with oral analgesic medications including tramodol hydrochloride (2–4 mg/kg, per os, every 8 h for 3–5 days) or gabapentin 10 mg/kg, PO, for 3–5 days). Dogs were also discharged with a 2–3-week course of cisapride (1 mg/kg once every 8–12 h by mouth) and omeprazole (1 mg/kg every 12 h by mouth), and owners were asked to wean their dogs off these medications prior to their recheck reexamination. General advice regarding dietary therapy was provided in the discharge instructions. It was recommended that dogs be fed a highly digestible dry diet divided in at least two meals per day. As compliance with these medical and dietary recommendations was not evaluated, it is not possible to verify whether owners followed these recommendations. Follow-up data were obtained from the medical record or by phone interview with owners. In dogs that had suffered episodes of aspiration pneumonia preoperatively, owners were specifically asked whether any further episodes had been diagnosed postoperatively.

2.7 | Statistical analysis

A sample size of 18 dogs was estimated to have 80% power to identify a CDAT item score change of 0.7 as statistically significant, assuming a baseline value of 1.2 $\pm$ 1.0, correlation of 0.5 between paired observations and $\alpha = .05$. This estimate was based on data derived from a previously published study.[10] Wilcoxon signed-rank tests were used to compare pre- and postoperative CDAT and VFSS scores. All tests were two-sided, and $p < .05$ was considered statistically significant.

3 | RESULTS

3.1 | Animals

Eighteen brachycephalic dogs met the inclusion criteria for enrollment in the study. Breeds represented included French bulldogs (n = 13), English bulldogs (4), and one Boston terrier. Eight dogs were male intact, five were male castrated, three were female spayed, and two were intact females. Median age was 27.5 (range 5–84) months. Median weight of dogs was 10.4 kg (range 7.3–25.2 kg). Median body condition score was 5/9 (range 2/9 to 6/9).

History, clinical signs, and physical examination: The most common historical and clinical findings were regurgitation (n = 18), respiratory stridor and/or stertor (5), weight loss (4), hacking/gagging (1), polydipsia/polyuria (1), paroxysmal events after regurgitation (1), collapse (1), reverse sneezing (1), cough (1), and dyspnea (1). Age at which clinical symptoms started was a median of 4 months (range 2–34 months). The duration of regurgitation prior to presentation was a median of 12 months (range 0.75–72 months). Regurgitation was described by owners as gradual in onset in 12 dogs and sudden in onset in 5 dogs. Eleven owners described regurgitation as being progressive, whereas five described it as static. Two owners noted regurgitation 1–3 times per week, four owners reported regurgitation 4–6 times per week, three owners reported regurgitation exceeding 7 times per week, and eight owners reported regurgitation with every meal. Information on the frequency of regurgitation per week was not provided by one owner. The material appeared undigested ($n = 16$ dogs), mucoid ($n = 9$ dogs), and bile-stained but digested ($n = 5$ dogs), with some dogs exhibiting more than one type of material regurgitated.

Seven dogs had a history of at least one episode of aspiration pneumonia or had evidence of aspiration pneumonia on thoracic radiographs at the time of presentation. The median number of preoperative episodes of aspiration pneumonia that occurred in these seven dogs was 2.75 (range 1–10).

On physical examination, abnormalities detected included respiratory stertor or stridor ($n = 11$) and poor body condition (3).

3.2 | Preoperative treatment

Medical management had been prescribed to treat the clinical signs in 16 dogs and included treatment with omeprazole ($n = 11$), cisapride (7), and sucralfate (4) or combinations thereof. Specific dosing regimens were variable and not always reported. Two dogs did not receive any medical management in the immediate preoperative period. Preoperative dietary management of the dogs was variable and not recorded in sufficient detail to be reported. Seven dogs had undergone brachycephalic obstructive airway syndrome (BOAS) surgery (of unspecified type) at a median of 6 months (range 1–60 months) prior to evaluation at our clinic.

3.3 | Diagnostic imaging

Preoperative thoracic radiographs were available for review for all dogs. In three dogs, a mild to diffuse bronchointerstitial pattern was evident. Four dogs had evidence of alveolar infiltration consistent with aspiration pneumonia. In four dogs, SHH was suspected from thoracic radiographs alone. Five dogs underwent a complete abdominal ultrasound examination. In two of those five dogs, a portion of the gastric fundus could be seen displacing into the thorax consistent with SHH.

3.4 | Anesthesia

The following drugs were used for premedication: methadone (15/18 dogs, dose range 0.2–1.0 mg/kg), atropine (7/18 dogs, dose range 0.016–0.02 mg/kg), acepromazine (3 of 18 dogs, dose range 0.02–0.03 mg/kg), hydromorphone (2/18 dogs, dose 0.05 mg/kg), dexmedetomidine (1/22 dogs, dose 5mcg/kg), and butorphanol (1/22 dogs, dose 0.2 mg/kg). The following drugs were used for anesthesia induction: propofol (14/18 dogs, dose range 1.0–4.1 mg/kg), midazolam (17/18 dogs, dose range 0.16–3.0 mg/kg), alfaxolone (3/18 dogs, dose range 0.73–1.5 mg/kg), and ketamine (1/22 dogs, dose 2.5 mg/kg). In all dogs, anesthesia was maintained by inhalation of isoflurane in oxygen administered to effect.

3.5 | Surgery

A three-port technique was used in all 18 dogs. The first three dogs operated underwent a laparoscopic-assisted gastropexy, whereas the remainder of the dogs underwent an intracorporeally sutured gastropexy. Three dogs had four interrupted polypropylene sutures placed for hiatal plication, with the remainder having three sutures placed.

Additional surgical procedures performed under the same anesthetic episode included BOAS surgery ($n = 8$), laparoscopic ovariectomy (2), and castration (2). Dogs that underwent BOAS surgery had the following procedures performed: laryngeal sacculectomy ($n = 7$), staphylectomy (6), and alarplasty using either a skin punch or wedge technique (6). Median total anesthesia time for all procedures performed was 225 min (range 160–315 min). Median total surgical time for the laparoscopic hiatal hernia repair procedure (in cases where surgical time was reported separately from other procedures performed) was 120 min (range 90–160 min).

3.6 | Conversion and complications

Of 18 dogs in the series, 1 (5.5%) was converted from a laparoscopic to an open approach. The dog, a French bulldog, underwent conversion after detection of a pneumothorax during the hiatal plication. The dog rapidly developed cardiopulmonary arrest, and despite rapid conversion to celiotomy with open cardiac massage through a diaphragmatic incision and cardiopulmonary resuscitative efforts including defibrillation, the dog died. This was the 13th dog to be operated in the series, and after this event, postoperative lateral radiographs were taken in four of five dogs to assess for pneumothorax. Small-volume subclinical pneumothorax was documented in one dog and was allowed to resolve without intervention.

Other intraoperative complications encountered included splenic hemorrhage ($n = 6$) that generally occurred due to needle trauma during the gastropexy procedure and liver laceration ($n = 3$) that occurred during manipulation of the liver or from needle trauma during hiatal plication. None of the splenic or liver lacerations required specific treatment or conversion.

One dog experienced an obvious recurrence of more severe regurgitation and was reevaluated 19 months postoperatively. At this time, recurrence of the hiatal hernia was evident on a VFSS. A celiotomy was performed, which revealed breakdown of the gastropexy. The left-sided gastropexy was repeated by incision of the transversus abdominis muscle and seromuscular layer of the stomach, which were opposed using two rows of simple continuous 3–0 polypropylene suture layers. The hiatal plication and esophagopexy appeared intact and thus were not revised.

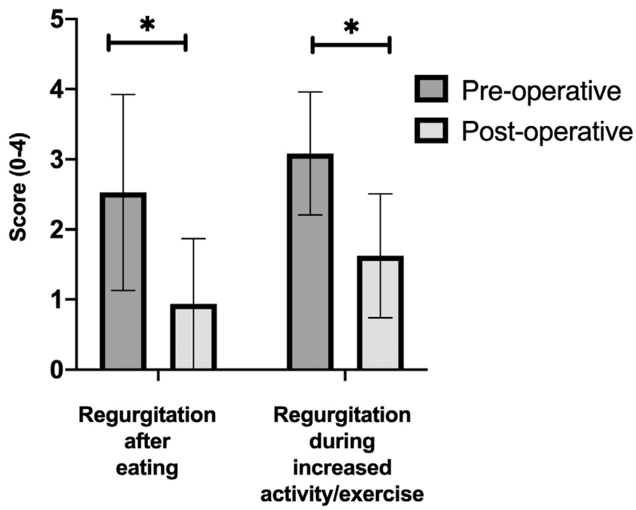

FIGURE 4 Graphical representation of the results of owner-assessed Clinical Dysphagia Assessment tool (CDAT) questionnaires from 16 dogs in which both pre- and postoperative questionnaire results were available

3.7 | Outcome measures

Standardized clinical scoring and VFSS were performed a median of 102 days postoperatively (range 44–318 days).

3.8 | Standardized clinical scoring

The results of the CDAT questionnaires completed both pre- and postoperatively were available for 16 dogs and are summarized in Figure 4 and Table 1. Statistically significant improvements occurred for the following clinical questions: problem caused dog to lose weight ($p = .005$), problem occurs with dry kibble ($p = .031$), regurgitation after eating ($p = .009$), and regurgitation during increased activity/excitement ($p = .004$). There were no significant

TABLE 1 Summary of the results from 16 dogs diagnosed with sliding hiatal hernias and/or gastroesophageal reflux with both pre- and postoperative Clinical Dysphagia Assessment Tools (CDAT) questionnaire and responses available for review

CDAT question	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Grade decreased (%)	Grade increased (%)	p Value
Has the swallowing problem caused your dog to lose weight?	1.44 ± 1.26	0.25 ± 0.58	10/16 (63%)	1/16 (6%)	.005
Does your dog have a problem swallowing water?[a]	1.13 ± 1.68	0.67 ± 1.23	4/15 (27%)	1/15 (7%)	.15
Does your dog have a problem swallowing food?	1.00 ± 1.32	0.56 ± 0.81	7/16 (44%)	3/16 (19%)	.19
Does the swallowing problem occur with canned food?[b]	1.00 ± 1.52	0.43 ± 0.76	4/14 (29%)	1/14 (7%)	.15
Does the swallowing problem occur with dry kibble?[a]	1.73 ± 1.53	0.73 ± 0.88	9/15 (60%)	3/15 (20%)	.031
Does the swallowing appear painful?	0.63 ± 1.09	0.13 ± 0.50	4/16 (25%)	1/16 (6%)	.15
Has your dog's bark changed in pitch or sound?	0.38 ± 1.09	0.13 ± 0.50	1/16 (6.3%)	0/16 (0%)	.32
Does your dog regurgitate after eating?	2.34 ± 1.38	0.94 ± 0.93	11/16 (69%)	2/16 (12%)	.009
Does your dog regurgitate during increased activity/excitement?	3.03 ± 0.90	1.63 ± 0.89	11/16 (69%)	2/16 (12%)	.004
Does your dog smack its lips?	0.75 ± 1.06	1.06 ± 1.34	2/16 (12%)	4/16 (25%)	.38

Note: Each question was graded by owners in ascending severity of grade from 0 to 4 (no problem to severe problem). Not all owners answered every question.
[a]Missing data for one dog.
[b]Missing data for two dogs.

differences in the remaining clinical signs evaluated between pre- and postoperative timepoints, and none of the questions yielded statistically significant deterioration. For dogs where regurgitation after eating was present preoperatively and postoperative evaluation was available ($n = 14$; owners of two dogs that completed the CDAT questionnaire indicated scores of 0 for this question), 11 owners reported at minimum a 1-grade improvement, the grade remained the same in two dogs, and one owner reported a worse grade. For dogs where regurgitation during increased activity/excitement was present preoperatively and post-operative evaluation was available ($n = 16$), 11 owners reported at minimum a 1-grade improvement, the grade remained the same in three dogs, and owners of two dogs reported a worse grade.

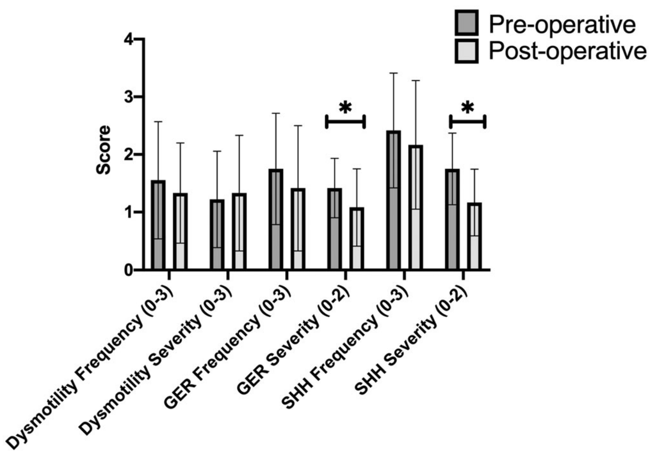

FIGURE 5 Graphical representation of the assigned scores from videofluoroscopic swallow studies from 12 dogs in which both pre- and postoperative studies were available for evaluation

3.9 | Videofluoroscopic swallow studies

Both pre- and postoperative VFSS were available for evaluation from 12 dogs for which results are summarized in Figure 5 and Table 2. Esophageal dysmotility frequency and severity scores were not statistically different between pre- and postoperative timepoints ($p = .08$ and $p = .68$, respectively). Gastroesophageal reflux frequency scores were not significantly different between pre- and postoperative timepoints ($p = .08$), but GER severity scores were lower postoperatively ($p = .045$). The frequency of SHH was not statistically different between pre- and postoperative timepoints ($p = .53$); however, the severity of SHH was significantly improved postoperatively ($p = .033$). SHH severity improved in seven dogs, remained the same in four dogs, and worsened in one dog.

3.10 | Impedance planimetry

Results of impedance planimetry (IP) variables are summarized in Table 3. At a balloon fill of 30 ml, CSA was significantly smaller postoperatively versus preoperatively. At balloon fills of both 30 and 40 ml, LES length was significantly longer postoperatively. No other variables were different between pre- and postoperative timepoints.

3.11 | Follow up

Of 18 dogs, 17 survived to discharge from the hospital. Thirteen dogs were available for follow up at a median time of 23 months postoperatively (range 1–61 months). Ten dogs were alive at the time of follow up, and three had died. All three dogs died of unrelated disease.

TABLE 2 Summary of data from videofluoroscopic swallow studies in dogs with sliding hiatal hernia and/or gastroesophageal reflux using the scoring scheme described in Appendix S2

Variable	Available studies (*n*)	Preoperative (mean ± SD)	Postoperative (mean ± SD)	p-value
Dysmotility frequency score	8	1.75 ± 0.89	1.38 ± 0.92	0.08
Dysmotility severity score	8	1.38 ± 0.74	1.38 ± 1.06	0.68
GER frequency score	12	1.75 ± 0.97	1.42 ± 1.08	0.08
GER severity score	12	1.42 ± 0.51	1.08 ± 0.67	0.046
SHH frequency score	12	2.41 ± 1.00	2.08 ± 1.08	0.53
SHH severity score	12	1.75 ± 0.62	1.17 ± 0.58	0.033

Note: Pre- and postoperative studies were available for review from 16 dogs, although an assessment of all parameters could not be made from every study.
Abbreviations: GER, Gastroesophageal reflux; SHH, sliding hiatal hernia; SD, standard deviation.

TABLE 3 Summary of the mean (± standard deviation) endoscopic functional luminal imaging probe (EndoFLIP) variables from dogs with sliding hiatal hernia and/or gastroesophageal reflux measured prior to the first incision being made and after completion of the gastropexy but prior to recovery from anesthesia

	Preincision		Postgastropexy	
Balloon volume parameter	**30 ml**	**40 ml**	**30 ml**	**40 ml**
Cross-sectional area (mm^2)	62.7 ± 32	128.5 ± 59.8	31.4 ± 9.1[a]	87.4 ± 25.3
Minimum diameter (mm)	8.3 ± 2.3	13.5 ± 5.0	6.2 ± 0.9	10.5 ± 1.5
Intrabag pressure (mmHg)	7.5 ± 5.2	10.1 ± 5	7.3 ± 4.8	11.9 ± 5.6
Lower esophageal sphincter length (mm)	33.3 ± 3.9	25 ± 5.6	36.8 ± 5.1[a]	30.5 ± 5.7[b]

[a]Significantly different ($p < .05$) from preincision value at 30-ml balloon fill.
[b]Significantly different ($p < .05$) from preincision value at 40-ml balloon fill.

Of the seven dogs in which aspiration pneumonia was diagnosed at least once preoperatively, four dogs did not suffer any known episodes of aspiration pneumonia postoperatively in a median follow-up time of 20 months (range 10–50 months). One dog that had suffered at least 10 episodes of aspiration preoperatively experienced 2–3 postoperative episodes in the 7-month follow-up time available. The remaining two dogs with preoperative aspiration pneumonia were lost to follow up.

4 | DISCUSSION

This study documents a technique for the laparoscopic treatment of SHH and associated GER in a cohort of client-owned dogs. The decision to treat these dogs using this surgical approach was made in conjunction with the owners after careful consideration of their dog's history and clinical signs. The authors do not advocate this treatment above any other treatment, either medical or surgical, for the management of SHH and associated GER. The aim of the study was principally to report the clinical outcomes for this particular surgical approach. It should also be noted that the laparoscopic surgical approach is challenging and was performed at two veterinary centers with extensive experience in minimally invasive surgery and intracorporeal suturing.

Optimization of portal positions is key to the development of novel laparoscopic procedures. The authors triangulated ports around a subumbilical camera portal with the telescope aimed at the left craniodorsal abdomen. These port positions worked well but only when the dog was significantly rotated onto the right side as, without this maneuver, it was very difficult to get the left lateral and medial lobes of the liver to move toward the right side and allow visualization of the hiatus.

Once the hiatus could be adequately evaluated, hiatal plication was performed with nonabsorbable suture material to try and minimize the chances of repair failure. The degree to which hiatal plication was performed was subjective just as it is when an open surgical approach is used. The authors used blunt probe palpation of the hiatal margins and forced passage of the fundus of the stomach as rough guides to gauge resistance to axial movement in and out of the thorax. It is acknowledged that these are subjective maneuvers and open to variable interpretation by different surgeons. However, these authors believe that the laparoscopic approach offers no significant disadvantages to an open approach for subjective assessment of hiatal geometry. Furthermore, optimal hiatal geometry has yet to be defined for the various dog breeds predisposed to SHH and GER.

Esophagopexy was performed using a simple continuous pattern of absorbable barbed sutures in an effort to maximize efficiency and facilitate endosuturing. Future studies should attempt to clarify the optimal suture patterns and materials used to complete the hiatal plication and esophagopexy. In particular, it would be interesting to evaluate a single continuous line of barbed sutures for completion of the hiatal plication with extension into the esophagopexy. The authors of this study hypothesized that nonabsorbable sutures in the hiatal plication might be beneficial to improve durability of the repair, but differences in these variables should be evaluated. Use of a single line of continuous suture for hiatal plication and esophagopexy may aid in reducing surgical time for the procedure.

A laparoscopic-assisted gastropexy was performed in the first three dogs in the study. Surgical time for completion of the hiatal plication and esophagopexy was initially quite long, and laparoscopic-assisted gastropexy was an attempt to speed up surgical time. However, as experience with the technique increased, an intracorporeal approach for the gastropexy became feasible and was performed in subsequent cases. When performing intracorporeally sutured gastropexy, it is important not to place the instrument port in the left caudal abdominal quadrant too cranially as intracorporeal suturing is greatly hampered by positioning of the instrument port too close to the gastropexy site, particularly in small breeds.

The median surgical time for the hiatal hernia procedure was 120 min (range 90–160 min), which compares favorably to that reported for the open surgical procedure (median 90 min, range 85–135 min).[9] Laparoscopic repair of SHH using this technique is likely to take approximately 30 min longer than when performed through an open celiotomy, although we hypothesize that this difference is likely to decrease commensurate with increased surgeon experience.

The clinical outcomes of laparoscopic repair of SHH appear to approximate those reported for open surgical treatment of this condition.[10] The results of the CDAT questionnaire revealed significant improvements in both regurgitation associated with eating and regurgitation associated with increased activity or excitement, which are the principal clinical complaints of owners presenting dogs with SHH and GER. Improvements in owner-assigned scores for regurgitation after eating in those dogs that were presented with this clinical sign occurred in 80% and 78% of dogs after open[10] and laparoscopic repair, respectively. Improvements in owner-assigned scores for regurgitation associated with increased activity or excitement occurred in 88% and 69% of dogs after open[10] and laparoscopic repair, respectively. Similar to the outcome in dogs following open surgery, however, not every dog improved significantly after laparoscopic repair, which is important information to convey to owners contemplating the procedure for their dog. Similarly, the analysis of VFSS revealed comparable overall results for laparoscopic repair as was previously reported for open repair; SHH and GER severity scores were statistically improved following laparoscopic repair, whereas open surgical repair[9] was associated with a significant improvement in SHH severity and GER frequency score but not GER severity scores. SHH severity scores were improved postoperatively in 58% of dogs operated on both by open[9] and laparoscopic surgery. In the future, an objective assessment of newer generation surgical approaches, such as fundoplication techniques, should be performed to assess whether improvements in outcomes can be realized for this patient population.

Some dogs with SHH and GER also present with aspiration pneumonia, which might necessitate repeated antimicrobial treatments and supportive care, and even hospitalization. Of the five dogs in this study with evidence of preoperative aspiration pneumonia and postoperative follow up ranging from 7 to 50 months, only one of the dogs developed subsequent episodes and that was a French bulldog that had experienced an estimated 10 episodes of pneumonia preoperatively. A previous study of dogs undergoing open surgical repair of hiatal hernia noted that, of four dogs diagnosed with SHH/GER and aspiration pneumonia, three did not develop further episodes, whereas one dog suffered a fatal episode of pneumonia 27 months postoperatively.[10] Although reflecting a small sample, these data provide hope for the subgroup of dogs with GER and/or SHH at high risk of the development of aspiration pneumonia. In the majority of these cases, surgical management appears to reduce the future incidence of aspiration pneumonia but does not eliminate the possibility of further episodes occurring. Data from larger cohorts of cases are needed to confirm these findings.

Interestingly, while the cross-sectional area of the LES was not significantly different in dogs where an open approach to surgery was used,[10] it was different postsurgically when a laparoscopic approach was used. It is difficult to say with certainty whether this represents a greater tightening of the area of the LES using the laparoscopic approach as many other factors can affect LES tone under anesthesia, and this finding was only significantly different when a balloon fill of 30 ml was used and was not found to be significant when the balloon was filled to 40 ml. However, it is possible that hiatal plication in this laparoscopic cohort led to a more extreme attenuation of the LES compared to when open hiatal plication was performed. Further randomized studies are needed to explore this hypothesis.

It is imperative to critically evaluate the surgical morbidity associated with any novel laparoscopic intervention. The most common complication in this case cohort was hemorrhage from iatrogenic trauma to the liver or spleen. While sometimes frustrating, as bleeding can obscure visualization, none of these events necessitated conversion or treatment with blood products. The most serious complication encountered in this study was the solitary case of fatal pneumothorax during the hiatal plication that occurred in a French bulldog. Unfortunately, this led to cardiac arrest within minutes of diaphragmatic billowing being noted, and the dog died. The surgical dissection in this dog was not performed differently from other cases. In people, this complication most commonly occurs when insufflated CO_2 gains access to the pleural space through a defect in the parietal pleura.[16,17] Pneumothorax has been reported to occur in as many as 22% of cases, particularly in people with massive hiatal hernias.[16,17] The defect is usually visualized, and attempts at closure along with thoracic drainage are usually successful, allowing completion of the procedure without conversion or adverse effects on outcome in most cases.[16] In the dog in our study, no obvious pleural defect was noted, although cardiac arrest occurred so quickly that little time was available for examination of the hiatus prior to conversion. Obtaining immediate postoperative radiographs in subsequent cases, we identified minor pneumothorax in one patient. Although clinically insignificant for that patient, the finding does highlight the risk of pneumothorax with this procedure. Surgeons should be constantly aware of the possibility of insufflated CO_2 leaking into the pleural space. To mitigate this risk, it is recommended that surgeons limit aggressive dissection of the perihiatal area and operate at relatively low insufflation pressures.

There are several important limitations to this study. First, dogs treated were not a homogeneous cohort with different brachycephalic breeds of different ages represented. Pre- and postoperative medical and dietary regimens were not uniform within the cohort. Documentation of disease severity was not performed using plethysmography or recently validated BOAS indices for grading of the severity of respiratory compromise in brachycephalic dogs.[18] Similarly, identification of GER relied on a relatively crude method of detection (VFSS and clinical signs) in comparison to the "gold-standard" approach of ambulatory esophageal pH testing commonly used in human medicine. As a consequence, it is possible that the severity of GER in dogs pre- and postoperatively was underestimated in this study. While ambulatory pH monitoring has been described in dogs, expense and practical issues in implementation limit its usage. The modality was not available for this study.[19,20] Finally, the performance of BOAS surgery was not standard throughout the cohort. Of brachycephalic dogs treated, some did not undergo BOAS surgery at all, some had undergone BOAS procedures prior to the laparoscopic procedure, and others had undergone the BOAS surgery at the time of the SHH surgery. The performance of concurrent BOAS surgery in eight dogs and the inherent variability in the procedure itself most likely influenced some of the clinical outcome measures in a way that is challenging to quantify. However, this cohort represents a cross section of the dogs that are presented in a client-owned population, and standardization of these factors is impossible in the absence of a breeding colony of dogs with this combination of pathologies.

In conclusion, a laparoscopic approach to managing GER and/or SHH proved feasible and delivered outcomes similar to those previously reported for dogs treated with an open celiotomy approach.[10] With either surgical approach, owners of prospective patients should be counseled that the procedure may not be curative as some patients will continue to exhibit varying degrees of GER. Future prospective studies with robust assessment of clinical outcomes should be performed to evaluate next-generation surgical procedures to improve on the clinical outcomes reported in this and previously published studies.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

AUTHOR CONTRIBUTIONS

Philipp D. Mayhew: conceived surgical technique, study design, performed surgical procedures, acquisition of data, and manuscript preparation. Ingrid M. Balsa: study design, performed surgical procedures, manuscript preparation. Stanley L. Marks: study design, manuscript preparation. Rachel Pollard: study design, masked evaluation of videofluoroscopic studies, manuscript preparation. J. Brad Case: performed surgical procedures, manuscript preparation. William T.N. Culp: study design, manuscript preparation. Michelle A Giuffrida: study design, performed statistical analysis, manuscript preparation.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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