Surgery to alleviate upper airway obstruction is considered the standard of care for dogs with brachycephalic obstructive airway syndrome (BOAS). Nevertheless, despite an improved understanding of the underlying pathophysiology of BOAS and despite surgical intervention, some dogs have abnormalities that cannot be corrected. Various surgical techniques have been used to address BOAS, and various materials have been used for resecting excessive tissue, including Metzenbaum scissors, electrosurgery, vessel-sealing devices, CO₂ and diode lasers, and harmonic scalpels. The many anomalies that comprise BOAS suggest its complexity. Although staphylectomy and alaplasty are recommended for the treatment of airway obstruction, some dogs do not improve following these procedures. The appropriate amount of the soft palate and the wing of the nostril that must be excised remains unknown. Furthermore, the best way to manage other anomalies such as aberrant turbinates, inflamed tonsils, everted laryngeal saccules, macroglossia, laryngeal collapse, and redundant pharyngeal mucosa that may affect recovery also remains unknown.

In 1982, Harvey described the first palatoplasty procedure that alleviated laryngeal obstruction by shortening the soft palate. In 2008, Findji and Dupré described folded-flap palatoplasty, which in addition to addressing the length of the soft palate also addressed problems related to its thickness (hypoplasia). Brdecka et al. in 2008 and Dunié-Mérigot et al. in 2010 proposed more extensive staphylectomies, but pharyngeal obstruction caused by redundant pharyngeal mucosa was still not addressed. Recently, multilevel surgeries that involve alaplasty and palatoplasty associated with ≥ 1 of the following

### OBJECTIVE

To describe the H-pharyngoplasty procedure, report the outcomes of dogs with brachycephalic obstructive airway syndrome (BOAS) treated with ala-vestibuloplasty and H-pharyngoplasty with a CO₂ laser, and identify prognostic factors.

### ANIMALS

423 dogs.

### PROCEDURES

Medical records of dogs admitted for BOAS from 2011 to 2017 were reviewed. Dogs were included if they were treated with ala-vestibuloplasty and H-pharyngoplasty with a CO₂ laser. Signalment, physical examination findings, grades at admission of clinical signs associated with respiratory and digestive systems, diagnostic test results, postoperative treatments, and short-term follow-up results were extracted from medical records. Long-term follow-up of > 12 months was evaluated via questionnaire. Generalized ordered logistic regression was used for bivariable and multivariable analyses.

### RESULTS

Overall mortality rate was 2.6%. Median duration of follow-up was 36 months (12 to 91 months), and 341 (80.6%) dog owners completed the questionnaire. Major complications included respiratory distress (2.1%), heatstroke (0.5%), and bronchopneumonia (0.5%). No dogs required revision surgery. Improvement in signs associated with the respiratory and digestive systems was reported in 72% and 34% of the dogs, respectively, and owners’ satisfaction was high (97.1%). Risk of death increased by 29.8% (95% CI, 11.8% to 50.7%) for every 1-year increase in age.

### CONCLUSION AND CLINICAL RELEVANCE

H-pharyngoplasty was possible in all dogs with BOAS, including those previously treated with conventional surgery and was associated with low morbidity and improved respiratory and digestive signs. H-pharyngoplasty combined with ala-vestibuloplasty may be an alternative treatment for even the most severely affected dogs.
procedures—laser-assisted turbinectomy, vestibuloplasty, removal of laryngeal sacculles, partial tonsillectomy (ie, removal of the everted portion of the tonsil), and partial cuneiformectomy (laryngoplasty [trimming of deformed or collapsed cuneiform processes])—have been proposed to improve nasal and pharyngeal clearance. These procedures are associated with improved outcomes, compared with traditional surgeries such as alaplasty and cut-and-sew staphylectomy.1,18 Laser-assisted turbinectomy and vestibuloplasty, in combination with a multilvel surgery or after an unsatisfactory response to conventional surgery, have yielded good outcomes for the relief of nasal obstruction.1,18,19

With the aim of attenuating the redundant pharyngeal mucosa and optimizing relief from pharyngeal obstruction, a new surgical technique, H-pharyngoplasty (which included tonsillectomy plus pharyngoplasty) with ala-vestibuloplasty, had been designed as part of a standardized multilevel approach (SMA). Therefore, the goals of the study reported here were to describe this surgical technique for dogs with BOAS, report patient outcome following this procedure as part of an SMA, and identify prognostic factors. An additional goal was to determine whether H-pharyngoplasty could be used in dogs that had previously undergone other surgeries for BOAS. The hypothesis was that H-pharyngoplasty with ala-vestibuloplasty as part of an SMA would improve signs attributable to BOAS, minimize postoperative morbidity, and result in good long-term outcomes.

Materials and Methods

Medical records of all dogs diagnosed with BOAS from June 2011 to July 2017 were reviewed. Signalment, history, presenting complaints, thoracic radiographic findings, procedural information as part of the SMA, and follow-up information were recorded. Study inclusion required that all dogs were treated by the same board-certified surgeon (CMP). Dogs that underwent surgery performed by another surgeon or that did not undergo an SMA or had missing data in their medical records were excluded from the study.

Clinical signs associated with the respiratory and digestive systems were graded during the preoperative visit according to a grading scale that categorized snoring, exercise intolerance, syncope, retching, vomiting, and ptalism by their frequency as follows: never, < 1X/mo, 1X/wk, 1X/d, > 1/d, or constantly (Supplementary Appendix S1). Every dog owner was provided an explanation about and asked to indicate the frequency of each clinical sign and then to assign a grade. Overall preoperative grade for each dog for each body system was determined on the basis of the highest grade assigned to one of the clinical signs associated with that body system.

The SMA consisted of a 3-step protocol. For the first step, each dog had a complete physical examination before hospitalization, and before surgery, CBC, serum biochemical analysis, and thoracic radiography were performed, with the latter to assess for tracheal hypoplasia and pulmonary lesions. Each dog was premedicated on arrival to the hospital with IM administration of 0.05 mg of acepromazine/kg (0.02 mg/lb), 0.2 mg of dexamethasone/kg (0.09 mg/lb), 0.01 mg of glycopyrrolate/kg (0.005 mg/lb), 0.5 mg of ranitidine/kg (0.23 mg/lb), and 0.5 mg of metoclopramide/kg (0.23 mg/lb). After preoxygenation (with anesthetic mask over the nose and mouth), anesthesia was induced with 4 to 8 mg of propofol/kg (1.81 to 3.63 mg/lb) and each dog was orotracheally intubated. Anesthesia was maintained with isoflurane in 100% oxygen.

The second step consisted of esophagogastro-duodenoscopy, pharyngolaryngoscopy, and surgery. Esophagogastro-duodenoscopy plus tissue biopsy acquisition was performed by a board-certified internal medicine specialist (KLB) for dogs with preoperative grade 3 clinical signs associated with the digestive system or preoperative grade 2 clinical signs that progressively worsened. Pharyngolaryngoscopy was performed by a board-certified surgeon (CMP) for all dogs. Each dog was briefly extubated for pharyngoesophageal examination. Length and thickness of the soft palate were subjectively evaluated through laryngoscopy and direct palpation. Tonsils were visually inspected for signs of inflammation and eversion, and laryngeal sacculles were assessed for eversion and the presence of granulomas on their surface. Laryngeal collapse was graded as previously described.20 Each dog was placed in sternal recumbency with its mouth wide open and its tongue taped rostrally to expose the oropharynx. Wet gauze was placed behind the soft palate to prevent collateral damage from the laser beam. The surgeon and accompanying staff wore safety glasses when the laser was in use, and a smoke evacuator was used to prevent inhalation of the laser plume.

Tonsillectomy and staphylectomy, part of the H-palatoplasty procedure, were performed with a 6- to 12-W noncontact superpulsed, scanned-mode small-size CO₂ laser (Space Vet, Deka, Manchester, NH). A deep circumferential incision was made in the tonsillar fossa to completely remove both tonsils. The caudal tip of the soft palate was grasped with forceps and pulled ventrally, which put tension on it and facilitated the cut. The incision line on the soft palate formed an arch between the ventrolateral-most aspect of each tonsillar crypt (Figure 1; Supplementary Video S1). The top of the arch was at the level of the soft palate along a virtual line that joined the most rostral aspect of each tonsillar fossa. The entire length of the oral mucosa of the soft palate was incised up to the nasopharyngeal mucosa. When the incision on the soft palate reached the lateral aspect of the tonsillar crypts, the incision was extended caudally on the pharyngeal mucosa on both sides to free the soft palate from its lateral attachments in the pharyngeal region. The final incision roughly had an inverted U shape.
Closure was achieved with 3 simple continuous suture patterns with absorbable suture material 4-0 (Caprosyn [Polyglytone 6211], Medtronics, Dublin, Ireland) in an H shape (H-pharyngoplasty). The vertical lines of the H were created by apposition of the free borders of the tonsillar crypts for the most rostral half of the suture and by apposition of the free borders of the oropharyngeal mucosa for the most caudal half of the suture. The pharyngeal mucosa was pulled cranially before being sutured in the continuity of the tonsillar crypt. These sutures smoothed the redundant pharyngeal mucosa. The horizontal line of the H consisted of apposition of the nasopharyngeal mucosa with the oropharyngeal mucosa of the free border of the remaining soft palate.

Vertical wedge ala-vestibuloplasty was performed as previously described. The nares were sprayed with xylocaine immediately before beginning the procedure. Three to 4 simple interrupted sutures with absorbable monofilament suture (Caprosyn [Polyglytone 6211], Medtronics, Dublin, Ireland) were used to close the incisions. Everted laryngeal saccules were not removed unless a granuloma was observed on their surface.

At the end of surgery on the basis of the surgeon's clinical impression, a nasotracheal tube was placed for postoperative oxygen supplementation, especially when the surgeon expected a complicated recovery because of laryngeal collapse, laryngeal edema, obesity, or other pharyngeal or laryngeal abnormalities observed during pharyngolaryngoscopy.

The third step was postoperative recovery in the intensive care unit. After surgery, each dog remained intubated as long as possible. Each dog was closely monitored during hospitalization, especially during the first 24 hours after surgery, and water and food were incrementally reintroduced over a 12-hour period after surgery. Each dog was discharged from the hospital 24 hours after surgery unless complications occurred. The duration of hospitalization and the presence of any postoperative complications were recorded. Respiratory distress, temporary tracheostomy, signs of heatstroke, and signs and radiographic findings consistent with aspiration pneumonia were considered major complications, and vomiting, regurgitation, and nasal discharge were considered minor complications.

Treatment with 0.7 to 1.0 mg of omeprazole/kg (0.32 to 0.45 mg/lb), PO, every 12 hours; 0.5 mg of prednisolone/kg, PO, every 12 hours; and 0.3 to 0.5 mg of metoclopramide/kg (0.14 to 0.23 mg/lb), PO, every 8 hours, was recommended for 6 days. If inflammatory gastrointestinal (GI) disease was diagnosed on the basis of histologic examination of GI tissue samples obtained via endoscopy, affected dogs received 1 mg of prednisolone/kg (rather than 0.5 mg/kg), PO, every 12 hours, and then at decreasing dosages every 2 weeks, such that prednisolone was administered for a total of 6 to 8 weeks; received 15 mg of metronidazole/kg (6.8 mg/lb), PO, every 12 hours, for 2 weeks; and were fed a hydrolyzed protein diet.
Follow-up examination at the hospital was performed 2 weeks after surgery or earlier if complications occurred. Correspondences with dog owners and their dog’s primary care veterinarian through email and summaries of telephone conversations were also recorded when an in-hospital follow-up examination was not possible. Postoperative grades for clinical signs associated with the respiratory and digestive systems were obtained through a questionnaire administered by one of the authors (JPRC) with an online survey tool (Survey Monkey, SVMK Inc, San Mateo, CA; Supplementary Appendix S2) at least 12 months after surgery. Owners graded the clinical signs in relation to those assigned preoperatively, either as unchanged, worse, or improved. In an attempt to obtain accurate postoperative grades and avoid recall bias, owners were asked to evaluate their dog at the time they were completing the questionnaire, not how their dog was 12 months after surgery. Additionally, dog owners were asked whether they were satisfied with the surgery and whether they would recommend it to a dog owner whose dog was similarly affected.

Statistical analyses

Categorical data (eg, sex and breed) were reported as frequencies and percentages. Continuous data (eg, age at presentation and duration of hospitalization) were reported as median, minimum, and maximum values because of deviation from the Gaussian distribution (ie, data not normally distributed).

To explore possible prognostic factors, the grades that were based on the dog owner’s answers to the questionnaire during the preoperative visit and the grades that were based on the dog owner’s answers to the questionnaire > 12 months after surgery were used. Questionnaires from dog owners whose dogs had died at the time of final follow-up were not included in the analyses to avoid recall bias. A clinical improvement score for the 3 clinical signs associated with the respiratory system (snoring, exercise intolerance, and syncope) that were included in the questionnaire was determined by subtracting the preoperative grade from the postoperative grade (obtained at the time of the final follow-up examination). If the calculation yielded a negative value, a grade of -1 was recorded. If the calculation yielded a positive value, a grade of 1 was recorded. If the calculation yielded a value of 0, a grade of 0 was recorded. A clinical improvement grade was assigned analogously for the 3 clinical signs associated with the digestive system (vomiting, regurgitation, and ptyalism) that were included in the questionnaire. Generalized ordered logistic regression was used for bivariable and multivariable analyses of factors that were significantly associated with improved scores for signs associated with the respiratory and digestive systems. Because improvement scores of -1 and 0 indicated that treatment was ineffective, worsening or unchanged outcome versus improved outcome was only considered. Hence, postoperative improvement was indicated by a score of 1. The evaluated factors were age, sex, body weight within a breed, breed, preoperative clinical signs associated with the respiratory and digestive systems, and grade of laryngeal collapse. French Bulldog was selected as the referent breed because it was the most common brachycephalic breed presented to the authors’ hospital. Other brachycephalic breeds were specified in the statistical analysis on the basis of previous studies and the authors’ experience that postsurgical outcome varies for various breeds. Results were presented as ORs and 95% CI, with the OR a reflection in the change in odds of postoperative improvement of signs associated with the respiratory or digestive systems observed with each incremental change in the evaluated prognostic variable. If the OR was > 1 or < 1, an improvement or worsening, respectively, in signs associated with the respiratory or digestive systems was expected postoperatively with each incremental change of the prognostic variable. All variables with a value of P < 0.1 in the bivariable analyses were selected for inclusion in the multivariable analysis.21 Only those variables that remained significant in the multivariable analysis were considered as independent prognostic factors. Furthermore, the associations between possible prognostic factors and survival rate were evaluated by use of a log-rank test for categorical variables or a Cox proportional hazards regression model for continuous variables. All dogs that died regardless of the time between surgery and death (ie, perioperative death and death before and after the first reexamination) were included in the analysis. Results were presented as change in the risk of death observed with each incremental change in the evaluated prognostic variables. Only bivariable analysis was performed for survival rate because the number of deaths was small to perform a multivariable analysis. Statistical analyses were performed with commercially available software (STATA, version 14.0; StataCorp LP, College Station, TX). Values of P < 0.05 were considered significant.

Results

Of 532 dogs that underwent surgery for BOAS during the study period, 423 met the inclusion criteria. Breeds represented by at least 2 dogs included French Bulldog (n = 216 [51.1%]), Pug (87 [20.6%]); English Bulldog (80 [18.9%]), Boston Terrier (15 [3.1%]), Cavalier King Charles Spaniel (11 [2.6%]), Pekingese (4 [0.9%]), Shih Tzu (3 [0.7%]), and Boxer (3 [0.7%]). In total, 315 (74.5%) dogs were male and 108 (25.5%) were female. Median body weight was 12 kg (range, 2.2 to 56.0 kg), and median age at the time of surgery was 29 months (range, 4 to 145 months). Thirty-two (7.6%) dogs had already undergone surgery for BOAS elsewhere, and their owners brought their dogs to the hospital independent of or referred by their primary care veterinarian because...
of a poor response to the previous surgical intervention or reoccurrence of clinical signs. No clinical grades were available for these dogs before and after the first surgical intervention. Six dogs had alaplasty alone that was performed 3 to 12 months earlier with no or only mild improvement and subsequent reoccurrence of clinical signs soon after surgery. Seven dogs had a palatoplasty alone that was performed 9 to 24 months earlier, and only 1 of these 7 dogs improved during the year following surgery before reoccurrence of clinical signs. One dog had had palatoplasty performed 24 months before alaplasty and had been performed with subsequent mild improvement in clinical signs. This dog was admitted to the hospital 12 months after alaplasty with grade 3 clinical signs associated with the digestive and respiratory systems, extensive oral ulcers, and grade 2 laryngeal collapse. The other 18 dogs had both palatoplasty and alaplasty performed 5 to 48 months earlier; 11 of these dogs specifically had folded flap palatoplasty.

Esophagogastroduodenoscopic and pharyngolaryngoscopic anomalies were summarized (Table 1). All dogs had grade 2 to grade 3 clinical signs associated with the respiratory system. H-pharyngoplasty was successfully performed in all dogs, including those that had previously undergone surgery elsewhere, and no dog required revision surgery during the long-term follow-up period. One Cavalier King Charles Spaniel with grade 2 respiratory clinical signs only had an elongated soft palate with unremarkable tonsils. The other 3 dogs that had unremarkable tonsils had grade 2 to grade 3 respiratory signs. Eight dogs underwent unilateral laryngeal sacculectomy.

Table 1—Anomalies observed preoperatively during pharyngolaryngoscopy (n = 423) and esophagogastroduodenoscopy (94) in dogs that had brachycephalic obstructive airway syndrome.

<table>
<thead>
<tr>
<th>Anomaly</th>
<th>No. (%) of dogs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everted laryngeal saccules</td>
<td>397 (93.9)</td>
</tr>
<tr>
<td>Tonsillar eversion</td>
<td>419 (99.1)</td>
</tr>
<tr>
<td>Elongated and hyperplastic soft palate†</td>
<td>422 (99.8)</td>
</tr>
<tr>
<td>Grade of laryngeal collapse</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>125 (29.6)</td>
</tr>
<tr>
<td>2</td>
<td>202 (47.8)</td>
</tr>
<tr>
<td>3</td>
<td>70 (16.5)</td>
</tr>
<tr>
<td>None</td>
<td>26 (6.1)</td>
</tr>
<tr>
<td>Esophagogastrroduodenal lesion</td>
<td>94 (22.2)</td>
</tr>
<tr>
<td>Lymphoplasmacytic esophagitis</td>
<td>24 (5.7)</td>
</tr>
<tr>
<td>Lymphoplasmacytic gastritis</td>
<td>38 (8.9)</td>
</tr>
<tr>
<td>Severe chronic lymphoplasmacytic gastritis</td>
<td>47 (11.1)</td>
</tr>
<tr>
<td>Lymphoplasmacytic duodenitis</td>
<td>40 (9.5)</td>
</tr>
<tr>
<td>Severe chronic lymphoplasmacytic duodenitis</td>
<td>25 (5.9)</td>
</tr>
<tr>
<td>Helicobacter bacteria (stomach)</td>
<td>22 (5.2)</td>
</tr>
<tr>
<td>Hiatal hernia</td>
<td>5 (1.2)</td>
</tr>
</tbody>
</table>

The denominator for all percentage calculations is 423. †Eight (1.9%) dogs also had granulomas on the surface of their laryngeal saccules. †The 1 dog excluded from this group had only an elongated soft palate.

Short- and long-term outcomes

Complications were observed in 51 (12.1%) dogs. Major complications included respiratory distress (n = 9 [2.1%]), aspiration pneumonia (2 [0.5%]), signs of heatstroke (2 [0.5%]), and the need for a temporary tracheostomy (1 [0.2%]). One dog was euthanized because of severe aspiration pneumonia. Two other dogs had 1 episode each of aspiration pneumonia. Of these, one dog had an episode 2 days after surgery, recovered quickly with oxygen supplementation through a nasotracheal tube and medical support, and was discharged from the hospital 2 days later. The second dog died because of aspiration pneumonia 6 months after surgery. Minor complications included vomiting (26 [6.1%]), regurgitation (16 [3.8%]), and nasal discharge (8 [1.9%]). Of the dogs with postoperative vomiting and regurgitation, 9 (2.1%) required rehospitalization so medications could be administered IV rather than PO. These 9 dogs underwent esophagogastroduodenoscopy before or after surgery to investigate the cause of the clinical signs associated with the digestive system and were discharged from the hospital when vomiting and regurgitation had stopped for at least 24 hours. Considering the entire cohort of 423 dogs, median duration of hospitalization was 1 day (range, 12 hours to 9 days), with most dogs (365 [86.3%]) discharged 1 day after surgery.

A total of 341 (80.6%) dog owners completed the questionnaire at the time of the final follow-up examination (median, 36 months; range, 12 to 91 months). No dog required revision surgery during the long-term follow-up period. Most dog owners (331 [97.1%]) were satisfied with the outcome of the surgery, and most (336 [98.5%]) would recommend the surgery to the owners of similarly affected dogs. After surgery, 72.6% (244/336 dogs) showed improvement in GI signs (after vs before surgery: grade 1 or 2 vs grade 3, or grade 1 vs grade 2) and 34.1% (115/337 dogs) showed improvement in GI signs (after vs before surgery: grade 1 or 2 vs grade 3, or grade 1 vs grade 2; Table 2).

Oxygen was supplemented through nasotracheal tubes for 48 dogs before recovery from anesthesia. Three of these dogs died postoperatively before hospital discharge because of severe respiratory distress, with 2 that had acute cardiopulmonary collapse before a tracheostomy could be performed and unsuccessful resuscitation. A phase of overexcitement followed by a heatstroke-like episode and cardiorespiratory collapse were suspected. Both were French Bulldogs with preoperative grade 3 respiratory signs and grade 2 digestive signs. The third dog was an obese Pug with preoperative grade 3 respiratory signs and grade 2 laryngeal collapse. Despite oxygen supplementation through the nasotracheal tube, this dog experienced severe respiratory distress 24 hours after surgery, and a tracheostomy was performed. This dog died 48 hours after surgery because of intractable respiratory compromise. The other
Table 2—Grades for clinical signs associated with the respiratory and gastrointestinal (GI) systems.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Respiratory signs</th>
<th>GI signs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%) with snoring</td>
<td>No. (%) with exercise intolerance</td>
</tr>
<tr>
<td>Preoperative grade*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>51 (15.2)</td>
<td>101 (30.1)</td>
</tr>
<tr>
<td>1</td>
<td>162 (48.2)</td>
<td>61 (18.2)</td>
</tr>
<tr>
<td>2</td>
<td>114 (33.9)</td>
<td>128 (38.1)</td>
</tr>
<tr>
<td>3</td>
<td>51 (15.2)</td>
<td>101 (30.1)</td>
</tr>
<tr>
<td>Difference†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>162 (48.2)</td>
<td>61 (18.2)</td>
</tr>
<tr>
<td>1</td>
<td>114 (33.9)</td>
<td>128 (38.1)</td>
</tr>
<tr>
<td>0</td>
<td>51 (15.2)</td>
<td>101 (30.1)</td>
</tr>
<tr>
<td>–1</td>
<td>9 (2.7)</td>
<td>35 (10.4)</td>
</tr>
<tr>
<td>–2</td>
<td>0 (0)</td>
<td>11 (3.3)</td>
</tr>
<tr>
<td>Adjusted difference grades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>276 (82.1)</td>
<td>189 (56.3)</td>
</tr>
<tr>
<td>–1 or 0</td>
<td>60 (17.9)</td>
<td>147 (43.7)</td>
</tr>
</tbody>
</table>

aData represent 423 dogs. †Data represent 336 dogs for respiratory signs and 337 dogs for gastrointestinal signs. ‡Difference between pre- and postoperative respiratory signs determined for 336 dogs and between pre- and postoperative gastrointestinal signs for 337 dogs.

45 dogs were discharged from the hospital after 1 to 4 days of oxygen supplementation.

No dogs died intraoperatively. Death occurred before hospital discharge in 5 of 423 (1.2%) dogs; besides the 5 dogs that received supplemental oxygen through a nasotracheal tube, a fourth dog died following an episode of respiratory distress, and 1 died for unknown reasons. An additional 6 (1.4%) dogs died postoperatively between the time of hospital discharge and the first follow-up examination because of respiratory distress (n = 2), an unknown cause (2), aspiration pneumonia (1), or vasculitis at the base of the tongue (1). The overall mortality rate was 2.6% (11/423). In the long-term follow-up period, 22 dogs died, with only 3 that died for reasons related to BOAS.

Prognostic factors

Results from the bivariable and multivariable analyses are summarized (Supplementary Tables S1 and S2). From the multivariable analyses, snoring was less likely to improve in Pugs after surgery than in French Bulldogs (adjusted OR, 0.32; 95% CI, 0.14 to 0.72; P = 0.006). Dogs that had higher preoperative snoring grades were more likely to improve in snoring postoperatively (adjusted OR, 10.15; 95% CI, 5.06 to 20.37; P < 0.001). Exercise intolerance was less likely to improve after surgery in Pugs (adjusted OR, 0.37; 95% CI, 0.19 to 0.71; P = 0.003) and English Bulldogs (adjusted OR, 0.06; 95% CI, 0.01 to 0.29; P = 0.001) than in French Bulldogs, but as body weight increased for English Bulldogs, exercise intolerance was more likely to improve after surgery (adjusted OR, 1.18; 95% CI, 1.06 to 1.31; P = 0.003). Dogs that had higher preoperative exercise intolerance grades were more likely to show improvement in exercise tolerance postoperatively (adjusted OR, 8.63; 95% CI, 4.52 to 16.47; P < 0.001). Furthermore, the higher the preoperative snoring grade, syncope was more likely to improve postoperatively (adjusted OR, 1.99; 95% CI, 1.08 to 3.67; P = 0.03).

Results from the bivariable analyses for postoperative survival were summarized (Supplementary Table S3). Perioperative death and death before and after the first reexamination were considered together. Only age was significantly (P < 0.001) associated with an increased risk of death, such that the risk of death increased by 29.8% (95% CI, 11.8% to 50.7%) as a dog’s age increased by 1 year. Sex, body weight, breed, preoperative respiratory and digestive system signs, and presence and grade of laryngeal collapse did not significantly impact the risk of death.

Discussion

The SMA was found to be applicable to all dog breeds, regardless of their grades, for management of their clinical signs associated with the respiratory
and digestive systems, and the SMA resulted in improvement in respiratory signs in most dogs. Although 65.5% (220/336 dogs) still had postoperative respiratory grades of 2 or 3, most dogs (72.6% [244/336]) had improved respiratory signs. Complication rates were low (12.1%, including 2.6% mortality rate), and owner satisfaction was high (97.1%). The design of the surgical technique, H-pharyngoplasty, which included bilateral tonsillectomy and extensive staphylectomy, allowed the soft palate to be shortened and may have optimized relief from oro- and nasopharyngeal obstruction. The incision boundaries provided a large pharyngeal clearance area, and the plasty allowed the redundant pharyngeal mucosa to be flattened (ie, following H-pharyngoplasty, a defect is created in the pharyngeal mucosa, and suture puts the mucosa under slight tension such that the redundant mucosal fold flattens).

Preoperative findings, postoperative improvement, and complication rates in the present study were similar to those previously reported.1,3,5,7,18,22,23 Tonsillectomy has been shown to be a safe procedure with low complication rates.1,7,23 Previous studies5,15,17,24,25 also reveal that redundant pharyngeal mucosa contributes to airway obstruction. In a recent study,1 conventional multilevel surgery has an 8-fold higher risk of a poor prognosis versus modified multilevel surgery. The modified multilevel surgery involves vestibuloplasty, partial cuneiformectomy, and folded flap palatoplasty. The benefit of partial cuneiformectomy was questioned by the authors of that study,1 and they could not determine whether the procedure was effective in dogs affected by BOAS. Conversely, vestibuloplasty and folded flap palatoplasty provide better relief from airway obstruction than alaplasty alone and standard staphylectomy.1,2 Therefore, less aggressive surgeries, such as conventional multilevel surgery, may lead to persistent airway obstruction or airflow turbulence in the pharyngeal and laryngeal regions, resulting in poorer outcomes or postoperative relapse of clinical signs. The SMA is also a multilevel surgery that involved extensive staphylectomy and bilateral tonsillectomy plus an original pharyngoplasty and vertical wedge alaplasty with vestibuloplasty. Subjectively, SMA may optimize relief from nasopharyngeal and oropharyngeal obstruction by thinning and shortening of the soft palate and by resection of the tonsils and the action on the redundant pharyngeal mucosa by the associated plasty, respectively. This configuration may have explained the favorable results in the dogs in the present study but further studies, especially those that include diagnostic imaging, are warranted.

Everted laryngeal saccules were not systematically excised from the dogs in the present study. Only 8 laryngeal saccules (1 saccule/dog; 8 dogs) were removed because they had granulomas on their surface.26 This strategy is controversial, and supporting evidence is lacking. A 2012 study27 reveals that everted laryngeal saccules did not resolve after cut-and-sew staphylectomy and vertical wedge rhinoplasty, but the results of that study are questionable because rhinoplasty and cut-and-sew staphylectomy alone may not have been sufficient for some dogs with BOAS, as discussed previously, and persistent airway obstruction may lead to persistent laryngeal edema and everted laryngeal saccules. Moreover, the everted laryngeal saccules were edematous in all 10 dogs (moderate, n = 4; severe, 3) and mildly fibrotic in only 4 dogs (mild, 3; moderate, 1). Thus, everted laryngeal saccules may not be irreversible and better relief from airflow resistance and medical support may improve or eliminate this condition. Another recent study26 shows that morbidity and duration of hospitalization increased for dogs following laryngeal sacculectomy (vs those that did not undergo laryngeal sacculectomy). Yet, not all dogs in that study also had staphylectomies and therefore increased morbidity and duration of hospitalization may not be specifically attributable to the sacculectomies. Furthermore, the benefits of laryngeal sacculectomy alone are unknown; therefore, on the basis of the available data and authors’ experiences, everted laryngeal saccules were not systematically removed.

Dogs with mild anomalies (eg, soft palate either only elongated or only thickened, or normal tonsils) had moderate to severe preoperative clinical signs. Conversely, some dogs with severe anomalies had mild preoperative clinical signs. These dogs may have had favorable results with conventional treatment but considering the severity of their clinical signs or anomalies, respectively, they underwent an SMA and enrolled in the present study. However, dogs with mild anomalies and mild clinical signs may still benefit from less extensive surgery. Visual inspection and imaging of the lesions may be altered by anesthesia depth, head positioning, and the degree of mouth opening and may have impacted grading of the lesions.

Laryngeal collapse had no impact on respiratory grade. This finding was consistent with the finding of a previous study5 in which global improvement was noted following palatoplasty and alaplasty in dogs that suffered from laryngeal collapse. H-pharyngoplasty seemed to improve the condition of dogs with severe laryngeal collapse.

Each dog that was diagnosed with an inflammatory GI disease on the basis of histologic examination of GI tissue samples received prednisolone, metronidazole, omeprazole, and a hydrolyzed diet in an attempt to resolve and prevent recurrence of vomiting, regurgitation, and gastroesophageal reflux. The acidic gastric content may have caused inflammation in the laryngeal and pharyngeal regions, which may have contributed to airway obstruction. Some dogs with severe GI signs, including extensive oral ulcers, had important laryngeal and pharyngeal edema and severe respiratory signs. Managing GI disease with appropriate medical treatment may improve both GI and respiratory signs and may prevent postoperative
obtain objective results.\textsuperscript{30} This is demonstrated in the present study by the discrepancy between owner satisfaction (97.1\%) and dogs with global improvement in their respiratory signs (72.6\%). Yet, because each owner assessed their dog both pre- and postoperatively with explanations for each clinical sign, the results obtained were directly comparable and relatively reliable. Comparative studies coupled with whole-body plethysmography or other diagnostic tests are warranted to better understand BOAS and the optimal treatment.\textsuperscript{31,32} To avoid recall bias, questionnaires completed by the owners whose dogs had died at the time of the final follow-up examination were not considered. This may have created an overestimation of the percentage of postoperative improvement, but this bias should be limited considering that only 5 dogs died before hospital discharge and only 3 dogs died from their BOAS after hospital discharge. The retrospective nature of the study was another limitation. Postoperative follow-up was not standardized as it would have been in a prospective study. Lesions were only assessed through pharyngolaryngoscopy and thoracic radiography; CT was not performed. Dogs with no to mild improvement after SMA may have benefited from additional diagnostic imaging or surgery.

In conclusion, SMA that included the new technique H-pharyngoplasty was appropriate for most dogs with BOAS, even those that had undergone previous surgeries, regardless of breed, age, or severity of their respiratory and GI signs. The SMA was associated with an improvement in respiratory and GI signs and low morbidity and mortality rates. Prognostic factors were identified, and the provision of appropriate supportive care may help to decrease the complication rates.

\textbf{Acknowledgments} 

No external funding was used for this study. The authors declare that there were no conflicts of interest. 

Presented in part as an abstract at the 27th Annual Meeting of the European College of Veterinary Surgeons, Athens, July 2018. The authors thank Loic Desquilbet, Head of the Biologic and Pharmacuetic Sciences Department of the National Veterinary School of Alfort, for his assistance with the statistical analysis.

\textbf{References} 


Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org