

Implementation of a standard perioperative protocol reduces postoperative respiratory distress events in dogs undergoing surgical correction of brachycephalic obstructive airway syndrome

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Objective

To determine whether a standardized perioperative protocol for patients undergoing brachycephalic obstructive airway syndrome (BOAS) surgery reduces the incidence of regurgitation, aspiration pneumonia, and respiratory distress in the postoperative period.

Methods

The records of client-owned dogs referred to the Texas A&M University Small Animal Teaching Hospital for surgical correction of BOAS over 4 years (February 2019 to June 2023) were retrospectively reviewed. A perioperative protocol for patients undergoing surgical correction of BOAS was implemented in June 2021, which included preoperative cisapride and antacid administration, minimizing opioid use, and a slow recovery with nebulization of hypertonic saline. Patient factors, perioperative treatments administered, and complications identified in hospital were recorded and compared between pre- and postprotocol groups.

Results

The pre- and postprotocol groups included 42 and 47 dogs, respectively. A significant reduction in postoperative respiratory distress events was identified after protocol implementation (postprotocol, $n = 6$ [12.77%]; preprotocol, 15 [35.71%]). Postoperative regurgitation (preprotocol, $n = 15$ [35.71%]; postprotocol, 23 [48.94%]) and aspiration pneumonia events (preprotocol, 4 [9.52%]; postprotocol, 3 [6.38%]) did not differ significantly between groups. More dogs enrolled after protocol implementation experienced historical regurgitation prior to BOAS surgery (postprotocol, $n = 31$ [65.96%]; preprotocol, 18 [42.86%]).

Conclusions

Standardized protocol implementation reduced postoperative respiratory distress events, but not postoperative regurgitation nor aspiration pneumonia events, in patients undergoing BOAS surgery at our institution. Prospective studies are required to further assess these findings.

Clinical Relevance

Veterinarians performing surgery in BOAS patients should consider implementation of a protocol to proactively minimize complications in the postoperative period.

Keywords: postoperative, complications, canine, surgery, soft tissue

Brachycephalic obstructive airway syndrome (BOAS) is a condition characterized by stenotic nares, elongated soft palate, everted laryngeal ventricles, abnormal nasopharyngeal turbinate morphology, and hypoplastic trachea.^{1,2} Due to altered anatomic

conformation, it has been hypothesized that BOAS patients have increased negative intrathoracic pressure required to overcome airway resistance secondary to upper airway obstruction.^{3,4} This may contribute to hiatal hernia formation, disruption of the lower esophageal sphincter, and gastroesophageal reflux.^{5,6} Surgical intervention is indicated for select components of BOAS to improve respiratory status and clinical gastrointestinal symptoms.⁷⁻¹⁰ However, dogs with BOAS have increased risk of complication in the perioperative period when compared to nonbrachycephalic breeds.⁹

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Of particular concern in the brachycephalic dog is the potential for regurgitation events, defined at our institution as the passive flow of ingesta oral to the level of the pharynx. This is considered a common sequela to esophagitis secondary to gastroesophageal reflux.¹¹ Perioperative regurgitation may predispose BOAS patients to aspiration pneumonia, dyspnea, and/or sudden death.^{9,12} Disruption to esophageal sphincter pressure and risk for regurgitation events are compounded by perianesthetic drug administration. Injectable premedications including certain pure μ opioids have been identified as a cause of decreased lower esophageal sphincter tone, increased gastroesophageal reflux, and induction of vomiting in dogs.¹³⁻¹⁶ Similarly, under general anesthesia, the loss of control of the lower esophageal sphincter, swallowing, and cough reflexes may further increase the risk of regurgitation and aspiration events.^{14,17}

Additional complications may occur in the postoperative period, such as respiratory distress secondary to airway swelling induced by common BOAS surgical procedures.^{9,18,19} Upper airway occlusion by pharyngeal edema impedes passive airflow and increases the risk for dyspnea following extubation.¹⁹ Additionally, anesthetic drugs such as μ opioids may lead to respiratory depression and offset compensatory mechanisms, which may exacerbate respiratory distress. This increased respiratory effort may lead to an acute increase in negative intrathoracic pressure, predisposing the patient to further regurgitation events, potential aspiration pneumonia, and death.^{10,19}

To address the increased perianesthetic risk associated with BOAS patients, clinical researchers from the Cummings School of Veterinary Medicine at Tufts University implemented a standardized perioperative management protocol, leading to a significant decrease in postoperative regurgitation events.¹ A standardized perioperative protocol modeling similar management strategies employed by Costa et al¹ was established and implemented for brachycephalic patients undergoing surgical correction of BOAS in June 2021 at our institution. The objective of this retrospective study was to determine whether implementation of the standardized protocol for BOAS patients reduced the incidence of regurgitation, aspiration pneumonia, and respiratory distress in the postoperative period at our institution. Based on previously published data,¹ we hypothesized that a standardized protocol would reduce the incidence of regurgitation, aspiration pneumonia, and respiratory distress in the postoperative period for brachycephalic dogs undergoing upper airway surgery for correction of BOAS when compared to those that underwent surgical correction for BOAS prior to protocol implementation.

Methods

Protocol development

The BOAS protocol implemented at our institution in June 2021 for perioperative management of brachycephalic dogs undergoing upper airway surgery was developed through a collaboration of diplomates from the American and European College of Veterinary Anesthesia and Analgesia, American

College of Veterinary Surgeons, and American College of Veterinary Emergency Critical Care. This protocol described specific medications to be administered or omitted from the perianesthetic and anesthetic management strategy in addition to monitoring and nursing care recommendations and was summarized in a single-page document distributed to all services in the hospital (**Supplementary Material S1**).

Brachycephalic risk (BRisk) score was recorded prior to undergoing general anesthesia to quantify patient risk for postoperative complications.²⁰ Implementation of medical management was recommended at the time of hospitalization prior to airway surgery. Hospitalization occurred either the day prior to surgery or the morning of surgery and was owner and patient dependent. In anxious dogs, preoperative sedatives such as butorphanol (0.2 to 0.4 mg/kg, IM or IV, q 4 to 6 h), trazodone (5 to 10 mg/kg, PO, q 8 to 12 h), acepromazine (0.01 to 0.03 mg/kg, IV or IM, q 4 to 6 h), gabapentin (10 to 20 mg/kg, PO, q 8 to 12 h), or dexmedetomidine (0.5 to 1 μ g/kg/h, constant rate infusion [CRI]) were prescribed to decrease excitation and respiratory distress. If the dog had not previously been on an antacid, famotidine (1 mg/kg, PO or IV, q 12 h) was initiated at the time of hospital admission, given its rapid onset of action; if the patient had a history of regurgitation and was already receiving omeprazole or famotidine, this was continued.^{14,21-23} Preoperative cisapride (0.3 to 0.5 mg/kg, IV or PO, q 8 to 12 h) was initiated in all dogs to improve lower esophageal sphincter tone and for prokinetic effects.²⁴⁻²⁶ Maropitant (2 mg/kg, PO, or 1 mg/kg, IV) was administered the night before surgery or at time of premedication, respectively, for antiemetic effects, and intraoperative metoclopramide with a loading dose of 1 mg/kg, IV, followed by 1 mg/kg/h, CRI, was utilized for improvements in lower esophageal sphincter tone and antiemetic effects.²⁷⁻²⁹ Alternative analgesics such as lidocaine, ketamine, dexmedetomidine, and regional nerve blocks were recommended to maintain an opioid-free protocol. If opioids were required, butorphanol, buprenorphine, methadone, or fentanyl were recommended in the listed order with anesthesiologist-dependent decisions made based upon degree of anticipated intra- and postoperative hyperesthesia. Butorphanol was the first-line opioid of choice due to its mild analgesic benefit and sedative effects to minimize excitation.³⁰ These opioids were prioritized in favor of hydromorphone due to the risk for emesis induction and aspiration pneumonia.³¹ To address airway inflammation and swelling, dexamethasone sodium phosphate (0.15 mg/kg, IV) was administered at the start of the surgical procedure if contraindications did not exist. A mannitol-soaked lap sponge was placed in the oropharynx for its osmotic effects following soft palate revision and prior to extubation.³² Oropharyngeal nebulization with 7.2% hypertonic saline was performed for 15 minutes in recovery prior to extubation to decrease the incidence of respiratory obstruction.³³

Following BOAS surgery, a slow and controlled recovery in either the soft tissue surgery treatment area

or ICU was performed under close monitoring. Extubation was delayed until the dog was fully alert, with staff prepared for emergent reintubation. Sedatives such as acepromazine and dexmedetomidine were used during recovery at the discretion of the attending anesthesiologist. Oxygen administration including nasotracheal supplementation, high-flow nasal cannula support, temporary tracheostomy placement, and mechanical ventilator support were advised for patients in respiratory distress when indicated.^{34,35} Prokinetic administration was continued following surgery including a metoclopramide CRI versus cisapride at the discretion of the attending clinician to reduce the risk of postoperative regurgitation.

Inclusion criteria

Electronic medical records of brachycephalic dogs undergoing surgical correction of BOAS at our institution from February 1, 2019, to June 1, 2023, were identified. Dogs were excluded if they required intubation prior to surgery for stabilization or emergency surgery due to airway occlusion or when the medical records were incomplete.

Procedures

Brachycephalic risk score was calculated, and laryngeal collapse stage was identified according to previously defined criteria.^{20,36} Attending anesthesiologists implemented the American Society of Anesthesiologists Physical Status classification and determined the anesthetic protocol.³⁷ Surgical procedures and technique were clinician dependent, with decisions made based upon preference, preoperative imaging, and upper airway examination. The specific procedure(s) performed were recorded.

Postoperative complications were classified as minor, major, or catastrophic based on previously reported guidelines for complication reporting.³⁸ Catastrophic complications were defined as events resulting in death or humane euthanasia. Major complications were defined as events that required surgical revision or intensive medical management including reintubation, temporary tracheostomy placement, or mechanical ventilator support. Minor complications were defined as regurgitation, aspiration pneumonia, or respiratory distress events that resolved with less-invasive medical management strategies. For this classification method, dogs with multiple complications of varying severity were categorized into the highest complication group for statistical analysis.

Intraoperative regurgitation events were recorded and defined as regurgitation occurring prior to extubation. Postoperative regurgitation, aspiration pneumonia, and respiratory distress events were recorded and independently classified by severity for statistical analysis. For dogs that experienced postoperative regurgitation events, severity was defined as evidence of esophagitis and classified on a 1-to-5 scale following the Veterinary Cooperative Oncology Group—Common Terminology Criteria for Adverse Events guidelines (**Supplementary Table S1**).³⁹ The Accordion Severity Classification of Postoperative Complications: Contracted Classification scale of 1

to 4 was utilized to individually classify postoperative respiratory distress and aspiration pneumonia events (**Supplementary Table S2**).⁴⁰

Statistical analysis

Data were recorded in Excel, version 16.74 (Microsoft Corp). Variables recorded were age; breed; sex; neuter status; weight; body condition score; history of prior airway surgery; history of regurgitation; history of aspiration pneumonia; history of respiratory distress; preoperative imaging and findings; BRisk score; fasting time prior to surgery; upper airway examination findings including laryngeal collapse stage; perioperative medical management including dosing, frequency, and route of administration for cisapride, famotidine, omeprazole, pantoprazole, trazodone, acepromazine, gabapentin, dexmedetomidine, maropitant, metoclopramide CRI, propofol, lidocaine, ketamine, local blocks, butorphanol, buprenorphine, methadone, fentanyl, dexamethasone sodium phosphate, and acepromazine; surgical procedure(s) performed; mannitol-soaked lap sponge placement in the oropharynx prior to extubation for soft palate revision; total surgery time; total anesthesia time; intraoperative regurgitation including number of events; recovery location; postoperative nebulization with 7.2% hypertonic saline versus epinephrine plus 0.9% NaCl; postoperative regurgitation including number of events and severity; postoperative aspiration pneumonia including severity; postoperative respiratory distress including severity; requirement for reintubation, nasotracheal oxygen administration, high-flow nasal cannula supplementation, temporary tracheostomy placement, or ventilation; survival to discharge; and suspected cause of death, if applicable. Data were analyzed with Prism, version 9.0.0 (GraphPad Software Inc). A Fisher exact test was used to compare incidence of historical regurgitation, historical airway surgery, historical aspiration pneumonia, historical respiratory distress, minor complications, major complications, catastrophic complications, intraoperative regurgitation, postoperative regurgitation, postoperative aspiration pneumonia, and postoperative respiratory distress between the pre- and postprotocol groups. Significance was set as $P < .05$. Descriptive data were reported as median (range).

Results

Case selection

Between February 1, 2019, and June 1, 2023, 100 dogs were identified as having undergone elective BOAS surgery. Eleven patients were excluded; 4 had incomplete medical records, 3 required intubation prior to surgery for stabilization, and 4 underwent emergent BOAS surgery due to upper airway occlusion on presentation. Of the 89 dogs that met the selection criteria, 42 dogs underwent surgery prior to protocol implementation and 47 dogs underwent surgery following protocol implementation.

Animals

Patient characteristics are summarized in **Table 1**. The sample population included 6 brachycephalic dog

Table 1—Signalment and pertinent characteristics identified in 89 dogs prior to undergoing upper airway surgery before and after implementation of a standardized perioperative protocol for brachycephalic obstructive airway syndrome (BOAS). The protocol included preoperative treatment with antacids, prokinetics, and antiemetics, minimization of opioid use in the perioperative period, intraoperative steroid administration, mannitol gauze applied to the oropharynx after intraoral procedures, and hypertonic saline nebulization (Supplementary Material S1).

Characteristic	Preprotocol (n = 42)	Postprotocol (n = 47)
Age (y)	1 (0.5–12)	3 (0.5–8)
Breed		
Boston Terrier	2 (4.76)	2 (4.26)
Brussels Griffon	0 (0)	1 (2.13)
French Bulldog	22 (52.38)	29 (61.7)
English Bulldog	15 (35.71)	8 (17.02)
Pug	1 (2.38)	7 (14.89)
Shih Tzu	2 (4.76)	0 (0)
Sex		
Intact male	12 (28.57)	11 (23.4)
Castrated male	10 (23.8)	15 (31.91)
Intact female	9 (21.43)	6 (12.77)
Spayed female	11 (26.19)	15 (31.91)
Weight (kg)	11.6 (3.6–32.5)	11.2 (3.6–24)
BCS (1–9)	5 (3–9)	5 (4–9)
BRisk score	3.5 (0.5–5)	3 (0.5–6.5)
ASA physical status	2 (2–4)	2 (2–4)
Laryngeal collapse stage		
I	3 (7.14)	14 (29.79)
II	5 (11.90)	9 (19.15)
III	4 (9.52)	13 (27.66)
No evidence of laryngeal collapse	2 (4.76)	9 (19.15)
Not reported	28 (66.67)	2 (4.26)
Hiatal hernia diagnosis	4 (9.52)	9 (19.14)
Hypoplastic trachea diagnosis	2 (4.76)	1 (2.13)
Preoperative aspiration pneumonia diagnosis	2 (4.76)	1 (2.13)

Data are presented as number (%) or median (range).

ASA = American Society of Anesthesiologists. BCS = Body condition score (1 to 9). BRisk = Brachycephalic risk.

breeds, with French Bulldogs being most prevalent in both preprotocol (n = 22 [52.38%]) and postprotocol groups (29 [61.70%]). Sex distribution included castrated males (n = 25 [28.09%]), intact males (23 [25.84%]), spayed females (26 [29.21%]), and intact females (15 [16.85%]). Age was similar in preprotocol (median, 1 year; range, 0.5 to 12 years) and postprotocol groups (median, 3 years; range, 0.5 to 8 years). Weight was similar in preprotocol (median, 11.6 kg; range, 3.6 to 32.5 kg) and postprotocol groups (median, 11.2 kg; range, 3.6 to 24 kg). Brachycephalic risk score was similar between preprotocol (median, 3.5; range, 0.5 to 5) and postprotocol groups (median, 3; range, 0.5 to 6.5).

Pertinent historical diagnoses are summarized in **Table 2**. The proportion of dogs in the postprotocol group (n = 11 [23.4%]) with a history of undergoing upper airway surgery prior to presentation was significantly higher ($P = .0437$) than in the preprotocol group (3 [7.14%]). Historical airway procedures performed in

the postprotocol group included soft palate resection (n = 8), nares resection (8), and laryngeal ventriculectomy (6). Historical airway procedures performed in the preprotocol group included soft palate resection (n = 2), nares resection (2), and laryngeal ventriculectomy (1). Similarly, a significant ($P = .0345$) proportion of dogs in the postprotocol group (n = 31 [65.96%]) experienced historical regurgitation compared to the preprotocol group (18 [42.86%]). Significant differences were not identified in the proportion of dogs with historical aspiration pneumonia (preprotocol, n = 8 [19.05%]; postprotocol, 7 [14.89%]; $P = .777$) or respiratory distress events (preprotocol, n = 3 [7.14%]; postprotocol, 10 [21.28%]; $P = .0753$).

Fasting time was similar between pre- (median, 11 hours; range, 7 to 19 hours) and postprotocol groups (median, 11 hours; range, 8 to 20 hours). Anesthesia time was similar between pre- (median, 103 minutes; range, 25 to 245 minutes) and postprotocol groups (median, 90 minutes; range, 40 to

Table 2—Historical airway findings for 89 dogs undergoing upper airway surgery before and after implementation of a standardized perioperative protocol for BOAS as described in Table 1.

	Preprotocol (n = 42)	Postprotocol (n = 47)	P value
History of prior airway surgery	3 (7.1)	11 (23.4)	.0437
History of regurgitation	18 (42.9)	31 (66.0)	.0345
History of aspiration pneumonia	8 (19.1)	7 (14.9)	.777
History of respiratory distress	3 (7.1)	10 (21.3)	.0753

Data are presented as number (%). Categorical data were compared between groups with Fisher exact tests. Values of $P < .05$ were considered significant.

180 minutes). Similarly, surgery time was similar between pre- (median, 65 minutes; range, 15 to 155 minutes) and postprotocol groups (median, 60 minutes; range, 20 to 125 minutes). Procedures performed in the preprotocol group included laryngeal ventriculectomy (n = 34 [80.95%]), soft palate resection (38 [90.48%]), nares resection (37 [88.1%]), and palatine tonsillectomy (2 [4.76%]). Procedures performed in the postprotocol group included laryngeal ventriculectomy (n = 33 [70.21%]), soft palate resection (41 [87.23%]), nares resection (45 [95.74%]), and palatine tonsillectomy (3 [6.38%]). The proportion of dogs that underwent an additional procedure under general anesthesia at time of airway surgery was higher in the preprotocol group (n = 17 [40.48%]) than the postprotocol group (11 [23.4%]). Procedures performed in addition to BOAS surgery in the preprotocol group included castration (n = 4 [9.52%]), superficial mass removal (3 [7.14%]), laparoscopic ovariectomy (2 [4.76%]), ophthalmic procedures (2 [4.76%]), transesophageal echocardiogram (1 [2.38%]), CT scan (1 [2.38%]), MRI (spine; 1 [2.38%]), digit amputation (1 [2.38%]), cleft palate repair with inguinal cryptorchid castration (1 [2.38%]), and colonoscopy with intestinal biopsies (1 [2.38%]). Additional nonairway procedures performed under general anesthesia at time of BOAS surgery in the postprotocol group included castration (n = 4

[8.51%]), CT scan (4 [8.51%]), superficial mass removal (1 [2.13%]), thoracic radiographs (1 [2.13%]), and urethropexy (1 [2.13%]).

Perianesthetic protocol

Common medications received by dogs before and after protocol implementation are summarized in **Table 3**, with an emphasis on medical management strategies outlined in the BOAS perianesthetic protocol. Fewer dogs received cisapride as a preoperative treatment in the preprotocol group (n = 19 [45.24%]) compared to the postprotocol group (48 [100%]). Similarly, fewer preprotocol dogs received preoperative famotidine (n = 8 [19.05%]) compared to after protocol implementation (21 [44.68%]).

A reduction in intraoperative pure- μ -opioid administration (fentanyl and methadone) was identified in dogs that underwent BOAS surgery after protocol implementation (n = 11 [23.4%]) compared to the preprotocol group (27 [64.29%]). Use of alternative analgesics including ketamine (preprotocol, n = 12 [28.57%]; postprotocol, 25 [53.19%]), lidocaine (preprotocol, n = 12 [28.57%]; postprotocol, 39 [82.98%]), and dexmedetomidine (preprotocol, n = 21 [50%]; postprotocol, 41 [87.23%]) increased following protocol implementation. Bilateral infraorbital and maxillary nerve blocks were administered more frequently following protocol implementation (preprotocol,

Table 3—Evaluating the use of medications recommended for 89 dogs undergoing upper airway surgery before and after implementation of a perioperative protocol for BOAS as described in Table 1.

Perioperative administration	Medication	Preprotocol (n = 42)	Postprotocol (n = 47)
Preoperative	Cisapride	19 (45.2)	47 (100.0)
	Famotidine	8 (19.1)	21 (44.7)
	Omeprazole	7 (16.7)	10 (21.3)
	Pantoprazole	5 (11.9)	8 (17.0)
	Trazodone	27 (64.3)	32 (68.1)
	Acepromazine	9 (21.4)	8 (17.0)
	Gabapentin	6 (14.3)	5 (10.6)
	Dexmedetomidine CRI	1 (2.4)	2 (4.3)
	Maropitant	42 (100.0)	45 (95.7)
	Intraoperative	Bilateral maxillary block	3 (7.1)
Bilateral infraorbital block		10 (23.8)	26 (55.3)
Metoclopramide CRI		27 (64.3)	40 (85.1)
Lidocaine		12 (28.6)	39 (83.0)
Ketamine		12 (28.6)	25 (53.2)
Dexmedetomidine		21 (50.0)	41 (87.2)
Butorphanol		9 (21.4)	8 (17.0)
Buprenorphine		5 (11.9)	3 (6.4)
Methadone		22 (52.4)	10 (21.3)
Fentanyl		19 (45.2)	2 (4.3)
Dexamethasone sodium phosphate		35 (83.3)	45 (95.7)
7.2% hypertonic saline nebulization		18 (42.9)	45 (95.7)
Epinephrine plus 0.9% NaCl nebulization		12 (28.6)	1 (2.1)
Mannitol-soaked lap sponge in oropharynx	7 (16.7)	40 (85.4)	
Postoperative	Cisapride	24 (57.1)	42 (89.4)
	Metoclopramide CRI	30 (71.4)	35 (74.5)
	Dexmedetomidine	17 (40.5)	15 (31.9)
	Acepromazine	15 (35.7)	14 (29.8)
	Buprenorphine	11 (26.2)	4 (8.5)
	Butorphanol	21 (50.0)	24 (51.1)
	Methadone	7 (14.3)	0
	Fentanyl	4 (9.5)	0

Data are presented as number (%). Incidences in which pre- and postprotocol management use was more than doubled are bolded. CRI = Constant rate infusion.

n = 13 [30.95%]; postprotocol, 36 [76.6%]). Similarly, the proportion of dogs that received mannitol-soaked gauze placement in the oropharynx following soft palate surgery increased following protocol implementation (preprotocol, n = 7 [16.67%]; postprotocol, 36 [76.6%]). Oropharyngeal nebulization during recovery was similar between groups (preprotocol, n = 30 [71.43%]; postprotocol, 46 [97.87%]). However, 7.2% hypertonic saline was more commonly used after protocol implementation (n = 45 [95.74%]) compared to before protocol implementation (18 [42.86%]). Alternatively, use of epinephrine plus 0.9% NaCl occurred more frequently before protocol implementation (n = 12 [28.57%]) compared to after protocol implementation (1 [2.13%]).

A proportion of preprotocol dogs were treated with methadone or fentanyl (n = 10 [23.81%]) in the postoperative period, while no dogs received pure μ opioids during recovery after protocol implementation. Prokinetic (metoclopramide or cisapride) administration was consistent between pre- and postprotocol groups in the postoperative period (preprotocol, n = 41 [97.62%]; postprotocol, 47 [100%]). Nasotracheal oxygen supplementation was administered more commonly in dogs following protocol implementation (n = 18 [38.3%]) compared to preprotocol patients (10 [23.81%]). Requirement for high-flow oxygen administration was similar between groups (preprotocol, n = 4 [9.52%]; postprotocol, 3 [6.38%]). Similarly, clinical indication for temporary tracheostomy placement was comparable between groups (preprotocol, n = 2 [4.76%]; postprotocol, 1 [2.13%]). Ventilator support was not required in

any dog after protocol implementation but was necessary in 2 preprotocol dogs (n = 2 [4.76%]).

Postoperative complications

The proportion of dogs that experienced postoperative complications, complication classification, and incidence of postoperative regurgitation, aspiration, and respiratory distress events including severity grading before and after protocol implementation are summarized in **Table 4**. A significant reduction in the proportion of dogs that experienced postoperative respiratory distress events was identified following protocol implementation (preprotocol, n = 15 [35.71%]; postprotocol, 6 [12.77%]; $P = .0133$). The proportion of dogs affected by intraoperative regurgitation did not vary significantly between groups (preprotocol, n = 2 [4.76%]; postprotocol, 7 [14.89%]; $P = .1634$). Similarly, reduction was not observed in the proportion of dogs that experienced postoperative regurgitation (preprotocol, n = 15 [35.71%]; postprotocol, 23 [48.94%]; $P = .2834$) or aspiration pneumonia events (preprotocol, n = 4 [9.52%]; postprotocol, 3 [6.38%]; $P = .7028$). Mortality was similar between groups, with 4 total deaths (preprotocol, n = 1 [2.38%]; postprotocol, 3 [6.38%]; $P = .6188$).

Discussion

Implementation of a standard perioperative protocol for dogs undergoing upper airway surgery for correction of BOAS resulted in a significant reduction in the proportion of dogs experiencing postoperative respiratory distress events at our institution. However, significant reduction in the proportion of dogs

Table 4—Postoperative complications identified in hospital prior to discharge in 89 dogs undergoing upper airway surgery before and after implementation of a perioperative protocol for BOAS as described in Table 1.

	Preprotocol (n = 42)	Postprotocol (n = 47)	P value
Any complication experienced	23 (54.8)	26 (55.3)	> .9999
Complication classification			
Minor complication	19 (45.2)	21 (44.7)	> .9999
Major complication	3 (7.1)	2 (4.3)	.6636
Catastrophic complication	1 (2.4)	3 (6.4)	.6188
Regurgitation	15 (35.71)	23 (48.94)	.2834
Regurgitation severity			
I	9 (21.4)	18 (38.3)	
II	5 (11.9)	5 (10.6)	
III	1 (2.4)	0 (0)	
IV	0 (0)	0 (0)	
Aspiration pneumonia	4 (9.5)	3 (6.4)	.7028
Aspiration pneumonia severity			
I	0 (0)	0 (0)	
II	3 (7.1)	1 (2.1)	
III	1 (2.4)	1 (2.1)	
IV	0 (0)	1 (2.1)	
Respiratory distress	15 (35.7)	6 (12.8)	.0133
Respiratory distress severity			
I	8 (19.1)	0 (0)	
II	3 (7.1)	1 (2.1)	
III	3 (7.1)	4 (8.5)	
IV	1 (2.4)	1 (2.1)	

Data are presented as number (%). Categorical data were compared between groups with Fisher exact tests. Values of $P < .05$ were considered significant.

Severity of regurgitation events was classified following the Veterinary Cooperative Oncology Group—Common Terminology Criteria for Adverse Events grading for esophagitis. Severity for aspiration pneumonia and respiratory distress events was classified following the Accordion Severity Classification of Postoperative Complications: Contracted Classification.

affected by postoperative regurgitation and aspiration pneumonia was not identified. Therefore, the hypothesis that perioperative protocol implementation reduces the incidence of postoperative regurgitation, aspiration pneumonia, and respiratory distress events in dogs undergoing upper airway surgery for correction of BOAS must be partially rejected. This is in contrast to a previous report¹ in which a significant reduction in postoperative regurgitation was identified.

Mechanical airway occlusion secondary to previously described components of BOAS is commonly exacerbated in the postoperative period due to oropharyngeal swelling.¹⁹ Mannitol-soaked lap sponge placement in the oropharynx following soft palate revision was frequently employed in the postprotocol group and likely acted as a contributing factor to decreased incidence of postoperative respiratory distress. While mannitol is widely regarded for its use as an osmotic diuretic to modify intracranial pressures, its use in airway swelling is rarely described in the literature. A single case report⁴¹ identified mannitol as a contributor to decrease airway edema following a facial snake bite incident in a human child.

Postoperative oropharyngeal nebulization was more commonly employed following protocol implementation and may have contributed to decreased respiratory distress events. This relationship has been previously evaluated in a prospective clinical study,³³ in which 0.05 mg/kg epinephrine diluted in 0.9% saline nebulization resulted in a statistically significant decrease in airway obstruction when administered preoperatively and decreased airway obstruction in the majority of dogs postoperatively when comparing whole body barometric plethysmography. The lack of comparison groups within the aforementioned study³³ highlights the need for future randomized controlled trials evaluating the impact of nebulization on respiratory distress events in BOAS dogs.

While not a direct component of the present BOAS perianesthetic protocol, more dogs in the postprotocol group received postoperative nasotracheal oxygen supplementation at the discretion of the attending clinician. A previous report³⁵ has identified decreased respiratory distress events when prophylactic oxygen supplementation is provided including high-flow oxygen administration. This may have contributed to the decrease in respiratory distress events observed in the present study and warrants further investigation.

Local anesthetics including bilateral maxillary and infraorbital blocks were used more commonly following protocol implementation. This coincided with a marked reduction in the use of intraoperative pure μ opioids in the postprotocol group. Fentanyl has been previously found to induce dose-dependent hypoventilation and apnea contributing to respiratory distress in dogs.⁴² In contrast, the use of bilateral intraoral maxillary nerve blocks in brachycephalic dogs has been found to decrease the required dose of intraoperative fentanyl.⁴³ This same study⁴³ did not find a significant decrease in respiratory distress events with the use of maxillary blocks, highlighting the need for a multimodal approach to management of the brachycephalic patient.

Of note, a similar proportion of oropharyngeal surgical manipulation was performed between pre- and postprotocol groups. However, the impact of specific surgical procedures and surgeon experience on respiratory status and clinical outcome was not evaluated in the present study. A previous report⁴⁴ indicates that modified multilevel surgical procedures may produce better patient outcomes than traditional multilevel surgery, warranting further study of the impact of select surgical technique and surgeon expertise in the BOAS perioperative protocol.⁴⁴

Patient factors were considered in this analysis, as significant differences existed between pre- and postprotocol groups. Of note, a significant proportion of dogs enrolled following protocol implementation had a history of prior airway surgery. The relationship between historical airway surgery and subsequent anesthetic risk is debated in the literature. Doyle et al¹⁸ identified a significant decrease in the odds of postanesthetic complication in subsequent anesthetic events in dogs that had previously received BOAS surgery. In contrast, researchers developing and validating the BRisk score found previous upper airway surgery to be associated with negative outcome in the postoperative period.²⁰ The discrepancy in findings noted in the aforementioned studies may be due to patient population. Doyle et al¹⁸ evaluated odds of perianesthetic risk in BOAS dogs undergoing subsequent anesthetic events for a host of procedures including preventative medicine, advanced imaging, upper airway surgery, orthopedic surgery, minimally invasive procedures, intra-abdominal surgery, and neurosurgery. In contrast, Tarricone et al²⁰ was specifically evaluating dogs undergoing surgery for BOAS when validating the BRisk score. Like Tarricone et al,²⁰ the patients with a history of prior airway surgery in the present study were undergoing a revisional procedure due to persistent signs of BOAS following initial surgery. These findings suggest a relationship between revisional BOAS surgery and postoperative complications that should be further evaluated. No significant difference in intraoperative or postoperative regurgitation was identified between groups despite the implemented medical management strategy including prokinetic usage and a pure- μ -opioid-free protocol. It is thought that this may be related to a significant proportion of postprotocol dogs with a reported history of regurgitation, consistent with previous studies.^{1,12} Of note, Fenner et al¹² identified a 2.5-fold risk of postoperative regurgitation in dogs with a previous history of regurgitation. While the present study was suggestive of an increased risk in postoperative regurgitation in patients with historical regurgitation, it was not within the initial scope of this study to statistically evaluate this relationship. To the best of our knowledge, a prospective study evaluating the relationship between historical regurgitation and risk for postoperative regurgitation has not been evaluated in brachycephalic dog breeds and further study is warranted.

The use of intra- and postoperative opioid administration did not strongly impact regurgitation or aspiration pneumonia events between pre- and postprotocol groups. This may be related to the types of opioids commonly used at our institution. Of note, hydromorphone has been implicated in the development of aspiration pneumonia when given at time of induction.³¹ However, hydromorphone was not administered in any patients

enrolled in the present study. Additionally, aspiration pneumonia occurred in < 10% of dogs both before and after protocol implementation in the present study, which is lower than the incidence of 35% before protocol implementation in the Costa et al¹ study. The low incidence in our population may have contributed to the lack of difference after protocol implementation in our population. While butorphanol was recommended for perioperative sedation, given its antitussive effects it must be used with caution in patients with aspiration pneumonia.⁴⁵

While all dogs in the postprotocol group received oral or IV cisapride at time of hospitalization, its use was not correlated with a reduction in postoperative regurgitation or aspiration pneumonia. It is hypothesized this may be related to the short duration of administration prior to patients experiencing excitation in hospital and undergoing general anesthesia for upper airway surgery. To our knowledge, a study evaluating the impact on regurgitation in brachycephalic dogs receiving prolonged (1-week) cisapride administration prior to hospitalization and general anesthesia has not been evaluated and further study is warranted.

The single death prior to protocol implementation occurred secondary to upper airway occlusion with severe aspiration pneumonia. Of the 3 reported deaths identified following protocol implementation, 1 dog died following identification of aspiration pneumonia with concurrent upper airway occlusion, 1 died following severe aspiration pneumonia secondary to multiple regurgitation events, and 1 died following 0.5-mg/kg-alfaxalone-IV administration for sedation in the postoperative period. Of note, the dog that died secondary to alfaxalone administration had a known history of pulmonic stenosis. The few reported deaths make it difficult to extrapolate whether the implementation of the perioperative protocol had a significant impact on patient mortality.

While consistent perioperative medical management was identified in a select number of medications including preoperative cisapride administration, intraoperative dexamethasone sodium phosphate injection, and postoperative nebulization, considerable variability persisted in the use of other medications included in the implemented perioperative protocol. This may be due to attending-clinician preference and protocol standardization across multiple specialty services within the hospital.

Limitations of the current study included its retrospective nature and dependence on accuracy and completeness of available documentation in the medical records. During the time period of this study, our institution underwent a transition from paper patient treatment sheets to electronic patient treatment forms (Instinct Veterinary Software; Instinct Science LLC). This change may have resulted in variability in reporting or inconsistency in notation of complications evaluated in this study. The enrollment of dogs in this study with historical regurgitation may have influenced interpretation of patient outcomes following the establishment of the BOAS protocol. As historical regurgitation is reported in a large proportion of patients presenting for BOAS surgery at our institution, this was not an exclusion criterion for this study. Additional research analyzing the impact of protocol implementation in dogs

with and without historical regurgitation is warranted. Additionally, the small sample size may have impacted the significance of this study when evaluating the larger patient population it applied to.

In conclusion, we developed a protocol to be used in the perioperative period for all dogs undergoing upper airway surgery for correction of BOAS. This protocol significantly reduced the proportion of dogs affected by respiratory distress at our institution. We believe this protocol will be of assistance to other institutions in determining their perioperative management strategies for brachycephalic dogs.

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Supplementary Materials

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