Received: 25 March 2024 | Revised: 22 May 2024 | Accepted: 8 June 2024

DOI: 10.1111/vsu.14131

WILEY

INVITED REVIEW

Surgical management of brachycephalic obstructive airway syndrome: An update on options and outcomes

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Abstract

Dogs with a brachycephalic conformation often experience a collection of abnormalities related to their craniofacial conformation, which can lead to a variety of clinical signs such as stertor, exercise intolerance, respiratory distress, and gastrointestinal signs such as regurgitation, among others. This collection of abnormalities is termed brachycephalic obstructive airway syndrome (BOAS). With the rise in popularity of several brachycephalic breeds, veterinarians and veterinary surgery specialists are seeing these dogs with increasing frequency for surgical and medical treatment of these clinical signs, leading to an increased interest in developing surgical techniques for dogs with BOAS and evaluating objective methods of determining outcome after surgery. Advances in anesthetic management including standardized protocols and use of local nerve blocks to decrease opiate use may decrease postoperative complications. A variety of new or modified surgical techniques to manage hyperplastic soft palate and stenotic nares, among other BOAS components, have been developed and studied in recent years. Newer studies have also focused on risk factors for development of major complications in the postoperative period and on objective measurements that may help determine which patients will receive the most benefit from BOAS surgery. In this review, the newest studies focused on updates in anesthetic management, surgical techniques, and postoperative care will be discussed. Additionally, updated information on complication rates and outcomes for dogs undergoing surgical management of BOAS will be included.

1 | INTRODUCTION

Dogs with a brachycephalic conformation have risen in popularity over recent years, with French bulldogs becoming the most popular dog breed in the United States in 2022 according to the American Kennel Club.[1] This rise in popularity has also resulted in an increased focus on the medical concerns in these breeds and has resulted in reproductive bans of English bulldogs (though this ban was not upheld by Norway's court of appeals) and Cavalier King Charles Spaniels in Norway, the end of registration of 12 brachycephalic breeds by the Dutch Kennel Club, and recently, legislation introduced in New Hampshire, USA, to ban the breeding and sale of brachycephalic dogs, in addition to changes to breeding guidelines and proposed breeding bans in other

countries.[2,3] Additionally, the increased popularity of these breeds has resulted in a renewed interest in research surrounding the medical and surgical conditions seen in brachycephalic dogs.

Brachycephalic obstructive airway syndrome (BOAS) refers to a collection of primary abnormalities related to craniofacial conformation in brachycephalic dogs. These abnormalities include hyperplastic soft palate with mucosal hyperplasia,[4] stenotic nares, hypoplastic trachea, aberrant nasal turbinates, and macroglossia. While some of these components can be addressed surgically with currently described techniques, hypoplastic trachea and macroglossia are currently not able to be surgically addressed. Relative macroglossia refers to a tongue that is too large for the mouth, which leads to dorsal displacement of the soft palate and further narrowing of the nasopharynx. Macroglossia is a component that has not been traditionally recognized as part of BOAS; however, newer literature has focused on the presence of this component and its potential contribution to airway resistance in dogs with BOAS. A study by Jones et al. comparing tongue dimensions between brachycephalic and mesaticephalic dogs found that brachycephalic dogs had a greater tongue volume relative to bodyweight, skull length, and skull length/width ratio than mesaticephalic dogs. Additionally, this study found that the ratio of air to soft tissue was decreased by 60% and the tongue was 10x more dense in brachycephalic dogs.[5] Song et al. found that brachycephalic dogs have significantly higher total tongue muscle and total tongue fat when normalized to bodyweight than mesaticephalic dogs, with more fat deposits in the caudal tongue in both groups.[6] Interestingly, in a study that compared tongue volume in English bulldogs, French bulldogs, and Pugs by Siedenburg et al., Pugs were found to have significantly smaller tongue volumes than the other two breeds, calling into question whether macroglossia is an occurrence in Pugs.[7] This information may allow for consideration of surgical treatment options for decreasing the impact of macroglossia in affected dogs in the future.

The airway resistance present in dogs with BOAS can lead to different sequelae that can lead to further clinical signs. These sequelae include everted tonsils, pulmonary changes, gastrointestinal signs, and laryngeal collapse; however, it is important to note that certain research indicates that some of the conditions leading to gastrointestinal signs may be primary in nature and not a sequelae in brachycephalic dogs.[8,9] Additionally, Conte et al. found that brachycephalic dogs have a significantly larger esophageal hiatus when compared to non-brachycephalic dogs which likely increases incidence of gastroesophageal reflux, regurgitation, and presence of sliding hiatal hernias in these dogs.[10] Surgical correction of various components of BOAS can result in improved quality of life and outcomes for affected dogs; however, some dogs will also benefit from continued medical and environmental management for components that are not treatable with surgical intervention. Sadly, despite appropriate medical and surgical treatment for dogs with BOAS, brachycephalic dogs have a significantly shorter life expectancy compared to non-brachycephalic dogs with a higher proportion of deaths attributed to upper respiratory tract disorders.[11] This review will focus on the updates on surgical treatment of conditions commonly encountered in brachycephalic dogs.

2 | ANESTHETIC CONSIDERATIONS FOR BOAS SURGERY

There are many anesthetic considerations and concerns when it comes to brachycephalic dogs, with much of the risk occurring at the time of extubation. These dogs are prone to developing upper airway swelling and obstruction along with postoperative regurgitation and vomiting, which can lead to aspiration pneumonia. In a study by Gruenheid et al., brachycephalic dogs were 1.57x more likely to have an intra-anesthetic complication and 4.33x more likely to have a post-anesthetic complication when compared to non-brachycephalic dogs. A longer duration of anesthesia increased perianesthetic complication risk overall in dogs in this study, whereas increasing bodyweight and having procedures performed by the orthopedics or radiology services decreased those risks.[12] Considerations such as reducing use of full mu opiates and having standardized anesthesia and postoperative protocols have been proposed as methods which may decrease risk of postoperative complications.

One method that has been investigated for controlling intra- and postoperative pain without the use of systemic opiates is the use of a bilateral maxillary nerve block. One study by De Gennaro et al. evaluated intra- and postoperative opioid administration and intraoperative complications in dogs undergoing surgery for BOAS that received a bilateral maxillary nerve block preoperatively with lidocaine or levobupivacaine versus those that did not receive a maxillary block. This study found that significantly more dogs in the group that did not receive the maxillary block required intraoperative fentanyl and intraoperative propofol or alfaxalone than dogs that received the maxillary block. There were no differences in need for postoperative analgesia between the two groups, though pain scores were not evaluated, and there were similar intra- and postoperative complication rates between the groups.[13] An additional study by

Williams et al. evaluated the benefit of adding epinephrine to the maxillary nerve block in these dogs. In this prospective, randomized study, all dogs received a bilateral maxillary nerve block with half receiving a block of lidocaine alone and the other half receiving a combination of lidocaine and 0.00198% epinephrine. Blood loss during a cut-and-sew staphylectomy was evaluated in all dogs, with total blood loss being significantly lower for dogs receiving the lidocaine and epinephrine combination maxillary block. No adverse events were noted in dogs receiving either block.[14] These studies indicate that the addition of a local maxillary block in patients undergoing BOAS surgery may result in decreased need for intraoperative opiates and decreased hemorrhage, both of which may lead to improved outcomes in some patients.

Standardized perianesthetic protocols have also been given consideration as a method to decrease postoperative complications in dogs undergoing surgery for BOAS. Preoxygenation after premedication administration and prior to induction has been evaluated as one standardized method to decrease desaturation in brachycephalic dogs while endotracheal intubation is performed. McNally et al. showed that preoxygenation for 3 min prior to anesthetic induction resulted in a significantly longer time to desaturation when compared to dogs that were breathing room air prior to induction.[15] Preoxygenation should be employed in all brachycephalic dogs undergoing surgery as part of a standardized protocol to increase time for upper airway evaluation and endotracheal intubation while minimizing risk of desaturation. When evaluating other standardized protocols, one such protocol included preoperative administration of metoclopramide and famotidine or a proton pump inhibitor, with medication choice, dose, and administration timing dependent on presence of preoperative regurgitation and vomiting as reported by the owners. Additionally, alternatives to opioid administration for postoperative pain management were encouraged, and administration of dexamethasone sodium phosphate was recommended, though not required. All dogs were recovered in an intensive care unit. After implementation of this protocol at one institution, a study was undertaken by Costa et al. evaluating postoperative regurgitation and respiratory complications comparing brachycephalic dogs undergoing corrective surgery for BOAS before and after protocol implementation. This study found that rates of postoperative regurgitation were significantly decreased in dogs having surgery after implementation of the protocol; however, no differences were present between groups regarding development of postoperative pneumonia or respiratory distress.[16] The results indicate that there may be some benefit of having an established protocol for perioperative management of dogs undergoing corrective surgery for BOAS. Additional studies evaluating different protocols and the outcomes of those protocols are warranted.

3 | SURGICAL OPTIONS FOR COMPONENTS OF BRACHYCEPHALIC OBSTRUCTIVE AIRWAY SYNDROME

3.1 | Hyperplastic soft palate

Hyperplastic soft palate is one of the main components of BOAS resulting in laryngeal obstruction and many of the clinical signs associated with BOAS in dogs. Additionally, in dogs with soft palates that are overly thick, oropharyngeal and nasopharyngeal obstruction can also occur, potentially worsening those clinical signs and upper airway obstruction in affected dogs. There are several options for reducing soft palate length in dogs with BOAS, with various studies comparing the options to one another. Beyond the more traditional cut-and-sew or sharp staphylectomy, carbon dioxide laser,[17,18] monopolar electrocautery,[18] bipolar vessel sealing devices,[17,19] air plasma devices,[20] harmonic scalpel,[21,22] diode laser,[18,20,21] and a plasma-mediated bipolar radiofrequency device[23] have all been suggested as devices that can be used to complete this surgical procedure. Throughout the studies, all of the devices were found to be effective and generally safe, with minimal differences noted overall between device used. One study by Jones et al. of over 600 dogs evaluated mortality rates after surgery between dogs undergoing staphylectomy with a traditional cut-and-sew technique, carbon dioxide laser, or a bipolar vessel sealing device. This study found that the mortality rate prior to discharge from the hospital was 4% and that dogs undergoing staphylectomy with a bipolar vessel sealing device had a significantly higher rate of perioperative mortality than dogs undergoing the procedure with the other two techniques. A higher grade of laryngeal collapse was also independently associated with perioperative mortality.[24] In two other studies evaluating the bipolar vessel sealing device for staphylectomy, there were no perioperative deaths out of 22 dogs in a study by Cook et al.,[19] and there were four perioperative deaths out of 34 dogs in a study by Kirsch et al.[17] While the difference in perioperative mortality rate was not significant between groups in the Kirsch et al. study, it is higher than what would be expected based on mortality rates in other studies evaluating dogs undergoing BOAS surgery. As these were all retrospective studies, prospective, randomized studies may be beneficial in determining if there is truly a higher perioperative mortality rate in dogs undergoing staphylectomy with bipolar vessel sealing devices compared to other methods of staphylectomy.

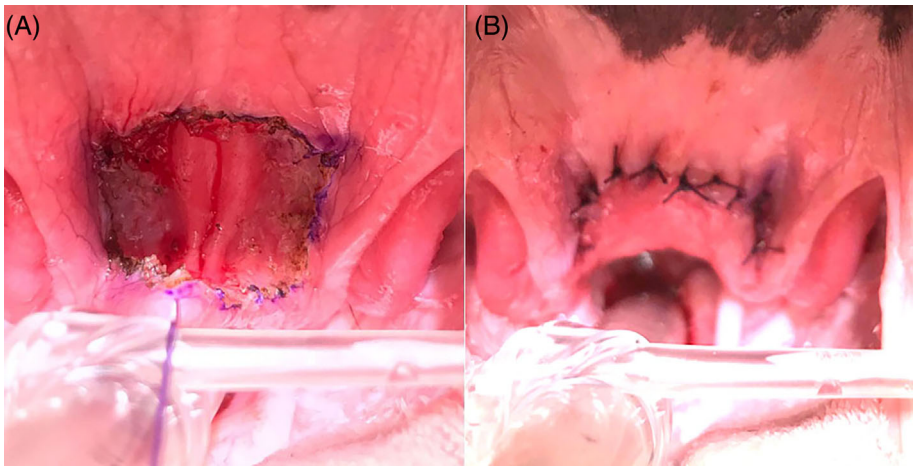

FIGURE 1 Images from a folded flap palatoplasty (FFP) procedure. In the first image (A), the soft palate is shown after removal of the ventral mucosa along with the palatinus muscle and part of the levator vili palatini. In the second image (B), the caudal cut edge of the ventral mucosa of the soft palate has been opposed to the cranial cut edge using simple interrupted sutures. This procedure both shortens and thins the soft palate in dogs undergoing brachycephalic obstructive airway syndrome surgery.

New techniques for staphylectomy have focused on ways to thin the palate while also shortening the palate or decreasing other redundant tissue within the pharynx while shortening the palate. The folded flap palatoplasty (FFP) procedure aims to address both the length and thickness of the soft palate in dogs with BOAS. The FFP procedure was first described by Dupré in 2005 and further described in 2008.[25] In this procedure, the ventral mucosa of the palate along with the palatinus muscle and part of the levator vili palatini are removed within a predetermined area of the soft palate, which decreases both the length and thickness of the soft palate (Figure 1). In the first study to evaluate outcomes from the FFP procedure in 55 dogs, no intraoperative complications were noted; however, 11% of dogs required a temporary tracheostomy postoperatively and two dogs died in the perioperative period. In the dogs where follow-up was obtained, 39/40 (97.5%) had improvement of their respiratory clinical signs after surgery, with the majority showing improvement within 15 days of surgery.[25] A study by Haimel and Dupré evaluated Pugs and French bulldogs that received FFP and wedge rhinoplasty. In this study, 9% of patients required a temporary tracheostomy, and 2/72 dogs died in the perioperative period. One dog's cause of death was respiratory arrest secondary to aspiration pneumonia. The second dog developed soft palate necrosis 43 h after surgery and was euthanized due to pneumonia and respiratory distress. The cause of the soft palate necrosis was not evident, though the authors noted that thinning the soft palate too much or leaving the folded flap too long could result in vascular compromise. Overall improvement of clinical signs was noted in 88.5% of dogs after surgery.[26] A recent study by Khoo et al. evaluated wound healing complications in dogs undergoing FFP. In this study, 25 dogs underwent FFP and had a re-evaluation of their soft palate at least 28 days after surgery. Wound dehiscence was present in 36% of dogs at a median of 36 days, with two patterns of wound dehiscence noted. In some dogs, there was incisional dehiscence accompanied with caudal retraction of the soft palate, and in others, a full thickness palate defect was present. Interestingly, in half of the cases with major wound dehiscence, no clinical signs were noted, indicating that more dogs with FFP could have wound healing complications that are not documented unless re-evaluation of the palate is performed after allowing time for surgical healing.[27] Miller et al. retrospectively compared outcomes in 124 dogs undergoing FFP or standard staphylectomy. In this study, dogs undergoing FFP had longer surgery and anesthesia durations than dogs undergoing staphylectomy. No differences were seen in anesthetic complications, length of hospitalization, or postoperative regurgitation between the two groups. Major complications were rare overall in this study.[28] Additionally, a prospective study by Grimes et al. comparing cut-and-sew staphylectomy and FFP in 16 English Bulldogs used preoperative and 30-day postoperative CT scans to compare palate length and width, along with oropharyngeal and nasopharyngeal air volumes. In this study, dogs undergoing FFP had longer soft palates postoperatively than dogs undergoing staphylectomy. No differences were present in postoperative soft palate width, oropharyngeal air volume, or nasopharyngeal air volume between the two procedures. It was noted that due to the prospective nature of the study and the need for dogs to have a preoperative sedated CT scan that dogs that were more clinically affected were not able to be included and that the palates for many dogs within the study were not considered overly thick, with only 2/16 dogs have a palate width greater than 10 mm. This could have limited the benefit of the FFP procedure in this population. Interestingly, two dogs in this study also experienced dehiscence of the FFP surgical site requiring removal from the study, with one having a full thickness defect as

described in the study mentioned previously.[29] One important aspect to consider in all of the studies discussed here is that case selection was not limited to dogs with overly thick palates, which likely benefit more from this procedure as compared to dogs with thinner palates which may have an increased risk of palatal defects and complications after this procedure.

Another procedure that has been proposed to thin the soft palate in dogs with BOAS is the split staphylectomy. In this procedure, the soft palate is split down midline using a carbon dioxide laser to the desired length, then at the thickest point of the palate, the redundant palate tissue between the mucosal layers is removed using the laser, allowing for both shortening and thinning of the palate. Holloway et al. evaluated 75 dogs undergoing this procedure and found that major complications occurred in 2.7% of patients with an overall complication rate of 8.3%. None of the complications were related to the staphylectomy, and none were life-threatening. Of owners that completed the follow up questionnaire, 88% noted that the surgery had improved their dog's quality of life.[30] This study unfortunately did not compare this procedure to any other staphylectomy procedures, so it is not possible to make comparisons between this and the folded flap palatoplasty which has a similar goal.

The H-pharyngoplasty procedure has the goal of reducing pharyngeal obstruction through reduction of redundant pharyngeal mucosa, along with a staphylectomy and bilateral tonsillectomy. In a study by Carabalona et al. evaluating this procedure in 423 dogs with BOAS, no dogs required revision surgery per an owner survey, with very high owner satisfaction of 97%. Overall mortality rate was 2.6% within 2 weeks of surgery with most causes of death related to respiratory distress or upper airway obstruction.[31] This study also did not compare the procedure to any other procedures; therefore, future prospective randomized studies comparing this procedure to other procedures may be beneficial in determining if there is a benefit of this procedure over other staphylectomy procedures.

3.2 | Stenotic nares

Stenotic nares result in increased airway resistance due to smaller than normal external nasal openings. Stenotic nares affect over 75% of dogs presenting for BOAS surgery, with nasal airway resistance from a combination of stenotic nares and nasal cavity obstruction contributing to 80% of the airway resistance experienced by dogs with BOAS, highlighting the importance of correction in these dogs.[32] Various techniques have been described to correct this issue including the vertical wedge resection, horizontal wedge resection, the Trader's technique, the dorsal offset rhinoplasty, and the ala vestibuloplasty, among others.

The Trader's technique was first described in 1949 and involves partial amputation of the tissue craniioventral to the dorsolateral nasal cartilage. A study by Huck et al. evaluating this technique in Shih Tzus that were a mean of 16.8 weeks of age found improvement in nasal discharge and noise, breathing difficulty, and exercise intolerance after surgery. Owners unanimously reported that the outcome was aesthetic and favorable.[33] The dorsal offset rhinoplasty was first described in 2020 by Dickerson et al. This procedure is suggested to move the alar cartilage both caudally and dorsally, which theoretically allows for more opening of the nares than other techniques that only allow movement in one direction (Figure 2). In a study of 34 dogs undergoing this procedure, no major complications were noted in the 85% of dogs presented for a recheck examination at a median of 402 days. On an owner survey, it was noted that one dog experienced collapse of one naris secondary to self-trauma, and another owner reported collapse of both

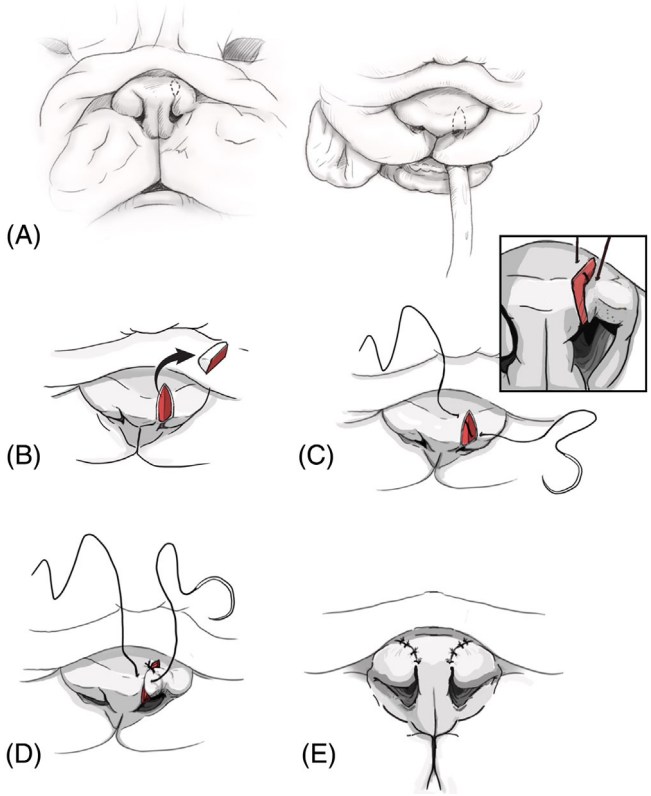

FIGURE 2 Images of a dorsal offset rhinoplasty from Dickerson et al.[34] In this illustration, the planned resection (A) and actual resection (B) of a dorsal wedge from the left naris is demonstrated, with the placement of the first suture shown (C). The remaining simple interrupted sutures are placed (D), and the final outcome of the bilateral rhinoplasty is shown (E).

nares; however, the cause of collapse was unknown. All but one owner that responded to the satisfaction score question reported being very satisfied with the procedure.[34] Neither of these procedures was compared to another technique during the described studies, and comparison of techniques in clinical patients is an interesting area of future study. The ala vestibuloplasty has not been evaluated in a clinical study on its own, though it has been used in other studies as the procedure for correction of stenotic nares.[31,35] An interesting study by Franklin et al. recently compared 3 techniques for correction of stenotic nares using silicone models. A total of 99 silicone models were created based on a CT scan of a single French bulldog's nose with one of the following procedures performed on each model: vertical wedge resection, modified horizontal wedge resection, or ala vestibuloplasty. CT scans were performed before and after the procedure with cross-sectional areas measured from the nares to the nasal vestibules. Increased cross-sectional areas were found with all three procedures, with ala vestibuloplasty having a significantly larger cross-sectional area than the other techniques.[36] Further study evaluating the clinical impact and outcomes of various techniques in dogs with BOAS is recommended to help determine if any technique is superior to another in these dogs.

3.3 | Everted laryngeal saccules

Eversion of the laryngeal saccules is reported to be present in over half of dogs presenting for surgical correction of BOAS and are considered to be grade 1 laryngeal collapse. The presence of this tissue within the airway can contribute to airway obstruction, and removal of everted saccules is recommended by some clinicians at the time of surgery to further decrease airway resistance. However, there is some concern that laryngeal sacculectomy may result in increased postoperative complications, leading some to consider not performing sacculectomy in some cases. Hughes et al. found that dogs undergoing laryngeal sacculectomy were significantly more likely to have postoperative complications; however, this was a retrospective study and breed distribution was not equal between groups indicating that other factors may have contributed to differences in complication rates.[37] Another consideration is whether laryngeal saccules undergo spontaneous resolution of eversion after decreasing airway resistance via performance of other surgical procedures for BOAS. A study by Cantatore et al. evaluating this concept found that none of the everted saccules spontaneously resolved at the time of recheck evaluation.[38] While the number of dogs in this study was small, the findings would indicate that spontaneous resolution of everted laryngeal saccules is unlikely.

3.4 | Everted and/or enlarged tonsils

Removal of the tonsils in dogs with BOAS is recommended by some clinicians to further reduce airway resistance, particularly if tonsillar eversion or enlargement are present. While no studies have specifically looked at the benefit of tonsillectomy in dogs undergoing surgical correction of BOAS, there are some recent studies looking at tonsillectomy technique in dogs. Turkki et al. evaluated a tonsillectomy technique whereby the tonsil is clamped at the base for 20 min then excised using monopolar electrosurgery. In this study, 11/39 had complications of which most were intra- or postoperative bleeding. Two of these dogs required urgent surgical attention for postoperative bleeding. Based on these complications, this technique should be used with some level of caution and with appropriate postoperative monitoring for hemorrhage.[39] Two other studies have evaluated use of a bipolar vessel sealing device for tonsillectomy. Belch et al. looked specifically at dogs undergoing surgical correction of BOAS and comparing use of a bipolar vessel sealing device to a technique involving use of a tonsillectomy clamp, sharp transection, and closure of the tonsillar crypt tissue with a Parker-Kerr oversew pattern. Less hemorrhage and faster surgical times occurred with the bipolar vessel sealing device when compared to the standard technique. Damage to the tonsillar tissue was evaluated via histopathology and showed 1–2 mm of coagulation necrosis at the edge of the tonsils removed with the bipolar vessel sealing device.[40] This is less tissue damage than was noted in a study by Cook et al. using a bipolar vessel sealing device for tonsillectomy where the depth of damage was 3.4 mm.[19] Overall, more information is needed to know if tonsillectomy is a beneficial addition to surgical management of BOAS, though the procedure appears to be safe overall.

3.5 | Aberrant nasal turbinates

Aberrant nasal turbinates are common in brachycephalic dogs with the majority of dogs evaluated being affected in a study by Oechtering et al.[41] These aberrant turbinates are postulated to lead to decreased nasal airflow and increased nasal mucosal contact points.[41] Diagnosis centers on use of computed tomography and rhinoscopy with removal of the aberrant turbinates occurring via a diode laser under rhinoscopic visualization, known as the LATE procedure.[42] This procedure is generally

considered to be safe with the main complication being intraoperative hemorrhage which is usually self-limiting. In one study, regrowth of the aberrant turbinates 6 months after the initial removal leading to potential reobstruction and need for a second removal occurred in 15.8% of dogs.[42] While it appears that the majority of brachycephalic dogs have some degree of aberrant turbinates leading to nasal obstruction, not all brachycephalic dogs seem to require a LATE procedure to have a good quality of life following traditional surgery for BOAS correction. In a study by Liu et al., a BOAS index and BOAS functional grades were obtained from brachycephalic dogs prior to and 2–6 months after conventional BOAS surgery. Dogs with a BOAS index >50% and a BOAS functional grade of 2–3 at the postoperative follow-up were considered candidates for the LATE procedure. Using those criteria, 29/57 dogs were candidates for LATE, with all of those dogs being Pugs or French bulldogs. In the dogs that underwent LATE, there was a significant improvement in their BOAS index when compared pre- and post-procedure. The amount of soft tissue present at the rostral end of the choanae as measured on computed tomography was a predictor of dogs that would benefit from the LATE procedure in Pugs and French bulldogs.[43] The availability of preoperative objective measurements and potential predictors which would indicate which dogs would benefit from the LATE procedure may allow for more confidence in recommendation of this procedure at the time of initial surgical correction for BOAS in dogs that would likely benefit from the procedure.

4 | POSTOPERATIVE MANAGEMENT AFTER SURGICAL MANAGEMENT OF BOAS

A variety of complications can arise in the immediate postoperative period in dogs undergoing multi-level surgery for BOAS, including upper airway obstruction and regurgitation which can lead to aspiration pneumonia. Careful monitoring and controlled recovery from anesthesia are imperative to limit the risks of these complications occurring; however, even with the most intensive monitoring, complications can occur. In a study by Lindsay et al. evaluating postoperative respiratory complications in 248 dogs undergoing surgery for BOAS, respiratory complications were noted in 23.4%, with an overall mortality rate of 2.4%. Risk factors for developing a complication included older age, presence of airway pathology that was not a primary component of BOAS (such as laryngeal collapse or tracheal collapse), and presenting in an emergent fashion for surgery, with the odds of developing a complication being over 30 times higher for dogs with an emergent presentation.[44] This study highlights the importance of early surgical intervention for dogs with BOAS while dogs are younger, before they present on an emergent basis, and/or before they develop additional airway pathology, which may limit postoperative respiratory complications. Interestingly, Fenner et al. evaluated postoperative regurgitation in dogs undergoing surgery for BOAS and found that younger dogs were more likely to experience regurgitation in the postoperative period, with the odds of postoperative regurgitation reduced 28.8% for every one-year increase in age. Dogs with a history of regurgitation prior to surgery were also more likely to experience regurgitation postoperatively.[45] This study highlights the importance of discussing this complication with owners preoperatively, especially in dogs with a prior regurgitation history and in younger dogs undergoing this procedure. An additional study by Ree et al. looking at short-term complications after BOAS surgery found a major complication rate of 7%, and the only factor that was found to be associated with development of a major complication was postoperative radiographic evidence of pneumonia, with age not being identified as a significant risk factor for complications in this study.[46] Filipas et al. evaluated respiratory complications in 199 brachycephalic dogs undergoing BOAS surgery and found an overall respiratory complication rate of 15%. The only risk factors associated with various respiratory complications were associated with the need for tracheostomy postoperatively and were increasing BOAS grade and the presence of pre- and postoperative aspiration pneumonia.[47] This is consistent with the Ree et al. study in that postoperative development of pneumonia was associated with development of major complications, indicating that prevention of postoperative pneumonia is an important factor in limiting complications after surgery in these patients.

One idea for limiting postoperative anxiety and possibly complications is the concept of owner-assisted recovery and same day discharge from the hospital for dogs undergoing BOAS surgery. In a retrospective study by Camarasa et al. evaluating this concept, one group of dogs was recovered in ICU with the owner present in the kennel with the dog throughout recovery. Dogs were discharged within a few hours after surgery once they were able to walk around the room and had a normal breathing rate and effort. The other group had a standard postoperative recovery without the owner present and were hospitalized for at least 24 h. Dogs that underwent standard recovery had a significantly higher rate of complications (28%) compared to dogs undergoing owner-assisted recovery (2%). Additionally, none of the dogs in the owner-assisted recovery group required additional

veterinary assistance after discharge.[48] This study indicates that early discharge and owner-assisted recovery of these cases may yield a benefit in postoperative morbidity and should be evaluated further in larger studies to determine if a true benefit exists.

Nebulized epinephrine has also been evaluated as a way to decrease postoperative upper airway obstruction in dogs undergoing BOAS surgery. It was evaluated for use both pre- and postoperatively in a study, where 0.05 mg/kg epinephrine was diluted in 0.9% saline. A significant decrease in BOAS index was noted pre- and postoperatively in this population of dogs. All dogs received this treatment; therefore, comparisons could not be made between complication rates in dogs receiving the treatment versus those that did not. Five dogs in this study did not tolerate nebulization, and nausea was noted in four dogs that did undergo nebulization.[49] Another larger study by Fenner et al. evaluated 0.5 mg epinephrine in 4.5 mL of saline nebulized to patients that were experiencing stertor or dyspnea after surgery. In this study, they found that only 4/90 dogs experienced agitation after nebulization, and there were no significant differences in heart rate or respiratory rate 60 min after nebulization. There was no control group in this study, so there were no comparisons made between outcomes and complications in dogs that received this treatment to those that did not.[50] Future studies evaluating this treatment in a prospective, randomized manner would be beneficial to show the impact this may have for dogs in the postoperative period.

Another device that is becoming more available in veterinary hospitals is high-flow oxygen therapy. This modality uses a specific nasal cannula system that allows for very high oxygen flow rates to the patient and is considered an option for some conditions prior to intubation and ventilation. This modality was evaluated in brachycephalic dogs recovering from general anesthesia, and dogs were enrolled if they showed signs of stertor or stridor accompanied by hypoxia or increased respiratory rate in the 2 h after extubation. In the five dogs enrolled, none required reintubation, and all were discharged from the hospital. One dog experienced aerophagia that required orogastric intubation.[51] This modality is a very promising option for brachycephalic dogs when needed during recovery from general anesthesia for any reason. Heliox, a mixture of helium and oxygen, has been used to improve air flow and reduce airway obstruction in people. In a study by Benavides et al., heliox was administered to healthy mesocephalic and brachycephalic dogs with tidal breathing flow-volume loops recorded and compared to those obtained when the dogs were breathing room air. It was found that in brachycephalic dogs, peak inspiratory and expiratory flow were significantly increased when heliox was administered.[52] This is another compelling option, and more research is needed to determine the effect in dogs undergoing surgery for BOAS. Another option that is more readily available which can be considered is nasotracheal intubation, which bypasses the upper airway obstruction that can occur postoperatively in brachycephalic dogs. With this technique, a 5–10 French tube is inserted through the naris and exteriorized through the oral cavity. The patient is extubated, and the tube is inserted into the trachea to the level of the thoracic inlet. Oxygen flow is delivered through this tube. In a retrospective evaluation of 36 dogs undergoing BOAS surgery, nasotracheal tubes were placed in 20 of the dogs, with the remaining dogs receiving oxygen supplementation in another way or no oxygen supplementation at all. Complication rates were similar between groups; however, no dogs with a nasotracheal tube experienced respiratory distress postoperatively as compared to five dogs without nasotracheal tubes.[53] This is a readily available option that is easily placed and can prevent reintubation in some dogs undergoing surgery for BOAS. It should be considered as an option for brachycephalic dogs that are experiencing hypoxia or upper airway obstruction after general anesthesia.

Despite novel interventions and advanced monitoring, some dogs undergoing surgery for BOAS will unfortunately need a temporary tracheostomy in the postoperative period due to upper airway obstruction. A study by Worth et al. evaluating risk factors for dogs that required a postoperative temporary tracheostomy identified a 30% increased odds of needing a temporary tracheostomy for each 1 year increase in age, further highlighting the importance of early surgical intervention in brachycephalic dogs.[54] Placement of a temporary tracheostomy tube in these patients often results in positive outcomes, with 40/42 dogs surviving to discharge in a study by Stordalen et al. with no long-term complications related to placement of the temporary tracheostomy. In that study, the temporary tracheostomy tube was in place for a median of 2 days, though the tube remained in place up to 7 days in some patients.[55] Permanent tracheostomy is also necessary in some brachycephalic dogs, typically in those dogs diagnosed with grade 3 laryngeal collapse. A study by Grimes et al. found that brachycephalic dogs were significantly more likely to require revision surgery after having a permanent tracheostomy as compared to non-brachycephalic dogs.[56] Additionally, Gobbetti et al. evaluated long-term outcome after permanent tracheostomy specifically in brachycephalic dogs with severe laryngeal collapse. Of 15 dogs in the study, eight died secondary to a major complication, with major complications occurring in 80% of dogs. Long-term survival of over 5 years after surgery with a good quality of

life occurred in 5/15 dogs, indicating that positive outcomes can be achieved with this surgery; however, owners should be made aware of the risks associated with the procedure and be well educated on the postoperative care and lifestyle changes required in these dogs.[57]

5 | OUTCOME IN DOGS AFTER SURGICAL MANAGEMENT OF BOAS

Dogs with BOAS can have a significant improvement in their quality of life and a decreased incidence of emergent respiratory distress after surgical management of BOAS. However, not all abnormalities associated with BOAS can be addressed surgically, such as hypoplastic trachea or macroglossia, or may not completely improve with surgical management. Preoperatively, it can be challenging to know which dogs with improve with surgical management and what that degree of improvement will be. Some studies have attempted to evaluate prognostic factors associated with outcome in these dogs. In a study by Seneviratne et al. evaluating outcome at 6 weeks after surgery for BOAS, it was noted that almost 71% of dogs showed improvement in respiratory signs following surgery with the only factors associated with improvement being the severity of inspiratory effort preoperatively and the preoperative Poncet score.[58] Liu et al. evaluated dogs 1–6 months after surgery and found that the median BOAS index decreased after surgery, though the median postoperative BOAS index was still in the clinically affected range. In this study, younger age, a normal body condition score, and the presence of laryngeal collapse were all negative prognostic factors after surgical treatment for BOAS. Additionally, modified multilevel surgery, consisting of an ala-vestibuloplasty, modified folded flap palatoplasty, removal of everted laryngeal saccules (when indicated), removal of everted tonsils (when indicated), and a partial cuneiformectomy in dogs with grade 2 or 3 laryngeal collapse, was found to be associated with a positive outcome more often than traditional multilevel surgery, consisting of a cut-and-sew staphylectomy, vertical wedge resection for stenotic nares, removal of everted laryngeal saccules (when indicated), and removal of everted tonsils (when indicated).[35] Based on this information it is worth considering that dogs that are at a higher risk of a negative outcome may benefit from the modified multilevel surgery for BOAS; however, more research is needed to show this definitively.

Nasopharyngeal collapse is also seen in some dogs with BOAS with little known about the effect surgical treatment for BOAS has on the severity of the collapse present. A recent study by Clarke et al. evaluated this via fluoroscopy in dogs with BOAS before and after surgery and compared the results preoperatively to a group of control dogs without BOAS. The study found that dogs with BOAS had a significantly higher reduction in the dorsoventral dimensions of the pharynx during respiration when compared to the control dogs. Unfortunately, no significant improvement was noted in this measurement after surgery in a cohort of the dogs with BOAS, though if more dogs had been evaluated a difference may have been seen.[59] Interestingly, nasopharyngeal collapse with a pharyngeal diameter change of greater than 50% has been documented using fluoroscopy in a small percentage of normal Beagles without evidence of cardiopulmonary disease indicating that the visualization of this collapse on imaging modalities may not correlate to clinical disease.[60] This remains an area of interest for future research to determine if different surgical procedures may result in additional improvement in these dimensions and the impact of this condition on clinical outcome with BOAS dogs.

An area where improvement is thought to occur in many dogs postoperatively is in gastrointestinal signs in dogs undergoing BOAS surgery. This was evaluated in a recent study by Mayhew et al. where dogs were compared pre- and postoperatively via a standardized owner questionnaire and via endoscopy to evaluate for gastroesophageal reflux and presence and severity of a sliding hiatal hernia. Owners perceived improvement postoperatively in regurgitation after eating and in regurgitation during increased activity or exercise. Unfortunately, no differences were noted in endoscopic evaluation of gastroesophageal reflux or incidence and severity of sliding hiatal hernia in these dogs after surgery.[61] Poncet et al. evaluated owner perception of improvement in gastrointestinal signs after BOAS surgery in dogs that were also receiving medical management for gastrointestinal disorders and found that owners noted excellent or good improvement in gastrointestinal disorders in over 90% of dogs.[8] While clinical improvement or at least perceived improvement by the owner is an important metric, it is important for clinicians to recognize that we may not be seeing a true improvement in the incidence of these gastrointestinal sequelae of BOAS in some or all dogs undergoing BOAS surgery.

One area where improvement was seen after BOAS surgery was in the incidence of post-anesthetic complications. Doyle et al. compared dogs that had undergone anesthesia before and after BOAS surgery and compared the complication rates at each procedure. Dogs that had undergone BOAS surgery had 79% decreased odds of having a post-anesthetic complication at subsequent anesthetic events.[62] As many, if not all, dogs with BOAS will need to undergo general anesthesia more than once in their life, the importance of decreased complications

associated with having undergone BOAS surgery is very high.

6 | CONCLUSIONS

BOAS is a frequently encountered issue in dogs with a brachycephalic conformation. As brachycephalic breeds continue to grow in popularity, veterinarians will encounter dogs with these abnormalities with more frequency. Additionally, client education about BOAS and the possible advantages of early surgical intervention will continue to be of importance to improve the overall quality of life for these dogs while understanding that not all components or sequelae of BOAS can be addressed surgically. Further research is needed to better delineate the best surgical procedures for each individual dog and if there are preoperative factors that could predict outcome or risk of complications. Additionally, research focused on breeding strategies that may improve conformation and limit negative outcomes in these breeds, along with research on best strategies for education of the general public and owners of brachycephalic dogs, may also be worthwhile.

CONFLICT OF INTEREST STATEMENT

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

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REFERENCES

1. Haid M. The Most Popular Dog Breeds of 2022. https://www.akc.org/expert-advice/dog-breeds/most-popular-dog-breeds-2022/
2. Platt S. Is banning breeds the answer? *Today's Vet Pract*. 2022;12(3):8.
3. Tansino M. New Hampshire Bill would ban breeding, sale of dogs and cats with known birth-deformities. https://www.wmur.com/article/new-hampshire-bill-pets-breeding-deformities-ban/60023059
4. Pichetto M, Arrighi S, Roccabianca P, Romussi S. The anatomy of the dog soft palate. II. Histological evaluation of the caudal soft palate in brachycephalic breeds with grade I brachycephalic airway obstructive syndrome. *Anat Rec*. 2011;294(7):1267-1272. doi:10.1002/ar.21417
5. Jones BA, Stanley BJ, Nelson NC. The impact of tongue dimension on air volume in brachycephalic dogs. *Vet Surg*. 2020;49(3):512-520. doi:10.1111/vsu.13302
6. Song A, Phillips H, Oliveira CR, McCoy AM. CT volumetric analysis permits comparison of tongue size and tongue fat in different canine brachycephalic and mesaticephalic breeds. *Vet Radiol Ultrasound*. 2023;64(3):429-438. doi:10.1111/vru.13221
7. Siedenburg JS, Dupré G. Tongue and upper airway dimensions: a comparative study between three popular brachycephalic breeds. *Animals*. 2021;11(3):1-13. doi:10.3390/ani11030662
8. Poncet CM, Dupre GP, Freiche VG, Bouvy BM. Long-term results of upper respiratory syndrome surgery and gastrointestinal tract medical treatment in 51 brachycephalic dogs. *J Small Anim Pract*. 2006;47(3):137-142. doi:10.1111/j.1748-5827.2006.00057.x
9. Poncet CM, Dupre GP, Freiche VG, Estrada MM, Poubanne YA, Bouvy BM. Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with upper respiratory syndrome. *J Small Anim Pract*. 2005;46(6):273-279. doi:10.1111/j.1748-5827.2005.tb00320.x
10. Conte A, Morabito S, Dennis R, Murgia D. Computed tomographic comparison of esophageal hiatal size in brachycephalic and non-brachycephalic breed dogs. *Vet Surg*. 2020;49(8):1509-1516. doi:10.1111/vsu.13521
11. O'Neill DG, Jackson C, Guy JH, et al. Epidemiological associations between brachycephaly and upper respiratory tract disorders in dogs attending veterinary practices in England. *Canine Genet Epidemiol*. 2015;2(1):10. doi:10.1186/s40575-015-0023-8
12. Gruenheid M, Aarenes TK, McLoughlin MA, et al. Risk of anesthesia-related complications in brachycephalic dogs. *J Am Vet Med Assoc*. 2018;253(3):301-306.
13. De Gennaro C, Vettorato E, Corletto F. Evaluation of bilateral maxillary nerve block in dogs undergoing surgery for brachycephalic obstructive airway syndrome. *Can Vet J*. 2022;63(1):67-73.
14. Williams PJ, De Gennaro C, Demetriou JL. Evaluation of the addition of adrenaline in a bilateral maxillary nerve block to reduce hemorrhage in dogs undergoing sharp staphylectomy for brachycephalic obstructive airway syndrome. A prospective, randomized study. *Vet Surg*. 2024;53(1):67-74. doi:10.1111/vsu.14039
15. Mcnally EM, Robertson SA, Luisito PS. Comparison of time to desaturation between preoxygenated and nonpreoxygenated dogs following sedation with acepromazine maleate and morphine and induction of anesthesia with propofol. *Am J Vet Res*. 2009;70(11):1333-1338.
16. Costa RS, Abelson AL, Lindsey JC, Wetmore LA. Postoperative regurgitation and respiratory complications in brachycephalic dogs undergoing airway surgery before and after implementation of a standardized perianesthetic protocol. *J Am Vet Med Assoc*. 2020;256(8):899-905. doi:10.2460/javma.256.8.899
17. Kirsch MS, Spector D, Kalafut SR, Moore GE, Mcdougall R. Comparison of carbon dioxide laser versus bipolar vessel device for staphylectomy for the treatment of brachycephalic obstructive airway syndrome. *Can Vet J*. 2019;60(2):160-166.
18. Dunié-Mérigot A, Bouvy B, Poncet C. Comparative use of CO_2 laser, diode laser and monopolar electrocautery for resection of the soft palate in dogs with brachycephalic airway obstructive syndrome. *Vet Rec*. 2010;167(18):700-704. doi:10.1136/vr.c5107
19. Cook DA, Moses PA, Mackie JT. Clinical effects of the use of a bipolar vessel sealing device for soft palate resection and tonsillectomy in dogs, with histological assessment of resected tonsillar tissue. *Aust Vet J*. 2015;93(12):445-451. doi:10.1111/avj.12384
20. Tamburro R, Brunetti B, Muscatello LV, Mantovani C, De Lorenzi D. Short-term surgical outcomes and

histomorphological evaluation of thermal injury following palatoplasty performed with diode laser or air plasma device in dogs with brachycephalic airway obstructive syndrome. *Vet J*. 2019;253:105391. doi:10.1016/j.tvjl.2019.105391
21. Conte A, Berlato D, Rasotto R, et al. Comparison of harmonic shears, diode laser, and scissor cutting and suturing for caudal palatoplasty in dogs with brachycephalic obstructive airway syndrome. *Vet J*. 2022;280:105802. doi:10.1016/j.tvjl.2022.105802
22. Gilman O, Moreira L, Dobromylskyj M, Doran I. A comparison of harmonic and traditional sharp staphylectomy techniques in 15 brachycephalic dogs. *J Small Anim Pract*. 2023;64(1):31-34. doi:10.1111/jsap.13548
23. Palierne S, Meynaud P, Bilmont A, et al. Plasma-mediated bipolar radiofrequency ablation of overlong soft palate in the dog: a pilot study. *J Am Anim Hosp Assoc*. 2018;54(5):267-275. doi:10.5326/JAAHA-MS-6668
24. Jones SA, Kennedy SC. Comparison of mortality of brachycephalic dogs undergoing partial staphylectomy using conventional incisional, carbon dioxide laser, or bipolar vessel sealing device. *Vet Surg*. 2024;53(1):122-130. doi:10.1111/vsu.14002
25. Findji L, Dupré G. Folded flap palatoplasty for treatment of elongated soft palates in 55 dogs. *Vet Med Austria*. 2008;95:56-63.
26. Haimel G, Dupré G. Brachycephalic airway syndrome: a comparative study between pugs and French bulldogs. *J Small Anim Pract*. 2015;56(12):714-719. doi:10.1111/jsap.12408
27. Khoo TX, Yates G, Chambers B, Ng J. Wound healing complications following folded flap palatoplasty in brachycephalic dogs. *Aust Vet J*. 2022;100(12):571-578. doi:10.1111/avj.13204
28. Miller AK, Regier PJ, Colee JC. Complications and outcome following staphylectomy and folded flap palatoplasty in dogs with brachycephalic obstructive airway syndrome. *Vet Surg*. 2024;53(1):29-37. doi:10.1111/vsu.13994
29. Grimes J, Wallace M, Sutherland B, Reed R, Perlini M, Schmiedt C. Objective evaluation of changes in airway size, exercise tolerance, and arterial blood gas after two different palatoplasty techniques in the treatment of brachycephalic obstructive airway syndrome. *ACVS Surgery Summit Abstracts. Vet Surg*. 2023:023.
30. Holloway GL, Higgins J, Beranek JP. Split staphylectomy to address soft palate thickness in brachycephalic dogs: 75 cases (2016-2018). *J Small Anim Pract*. 2022;63(6):460-467. doi:10.1111/jsap.13485
31. Carabalona JPR, Le Boedec K, Poncet CM. Complications, prognostic factors, and long-term outcomes for dogs with brachycephalic obstructive airway syndrome that underwent H-pharyngoplasty and ala-vestibuloplasty: 423 cases (2011-2017). *J Am Vet Med Assoc*. 2022;260(S1):S65-S73.
32. Hostnik ET, Scansen BA, Zielinski R, Ghadiali SN. Quantification of nasal airflow resistance in English bulldogs using computed tomography and computational fluid dynamics. *Vet Radiol Ultrasound*. 2017;58(5):542-551. doi:10.1111/vru.12531
33. Huck JL, Stanley BJ, Acvs D, Hauptman JG. Technique and outcome of nares amputation (Trader's technique) in immature shih tzus. *J Am Anim Hosp Assoc*. 2008;44:82-85.
34. Dickerson VM, Dillard CMB, Grimes JA, Wallace ML, McAnulty JF, Schmiedt CW. Dorsal offset rhinoplasty for treatment of stenotic nares in 34 brachycephalic dogs. *Vet Surg*. 2020;49(8):1497-1502. doi:10.1111/vsu.13504
35. Liu NC, Oechtering GU, Adams VJ, Kalmar L, Sargan DR, Ladlow JF. Outcomes and prognostic factors of surgical treatments for brachycephalic obstructive airway syndrome in 3 breeds. *Vet Surg*. 2017;46(2):271-280. doi:10.1111/vsu.12608
36. Franklin PH, Riggs J, Liu NC. Comparison of the effectiveness of three different rhinoplasty techniques to correct stenotic nostrils using silicone models: a case study. *Vet Surg*. 2024;53(1):104-112. doi:10.1111/vsu.14041
37. Hughes JR, Kaye BM, Beswick AR, Ter Haar G. Complications following laryngeal sacculectomy in brachycephalic dogs. *J Small Anim Pract*. 2018;59(1):16-21. doi:10.1111/jsap.12763
38. Cantatore M, Gobbetti M, Romussi S, et al. Medium term endoscopic assessment of the surgical outcome following laryngeal saccule resection in brachycephalic dogs. *Vet Rec*. 2012;170(20):518. doi:10.1136/vr.100289
39. Turkki OM, Bergman CE, Lee MH, Höglund OV. Complications of canine tonsillectomy by clamping technique combined with monopolar electrosurgery – a retrospective study of 39 cases. *BMC Vet Res*. 2022;18(1):242. doi:10.1186/s12917-022-03342-0
40. Belch A, Matiasovic M, Rasotto R, Demetriou J. Comparison of the use of LigaSure versus a standard technique for tonsillectomy in dogs. *Vet Rec*. 2017;180(8):196. doi:10.1136/vr.103873
41. Oechtering GU, Pohl S, Schlueter C, et al. A novel approach to brachycephalic syndrome. 1. Evaluation of anatomical intranasal airway obstruction. *Vet Surg*. 2016;45(2):165-172. doi:10.1111/vsu.12446
42. Oechtering GU, Pohl S, Schlueter C, Schuenemann R. A novel approach to brachycephalic syndrome. 2. Laser-assisted turbinectomy (LATE). *Vet Surg*. 2016;45(2):173-181. doi:10.1111/vsu.12447
43. Liu NC, Genain MA, Kalmar L, Sargan DR, Ladlow JF. Objective effectiveness of and indications for laser-assisted turbinectomy in brachycephalic obstructive airway syndrome. *Vet Surg*. 2019;48(1):79-87. doi:10.1111/vsu.13107
44. Lindsay B, Cook D, Wetzel JM, Siess S, Moses P. Brachycephalic airway syndrome: management of postoperative respiratory complications in 248 dogs. *Aust Vet J*. 2020;98(5):173-180. doi:10.1111/avj.12926
45. Fenner JVH, Quinn RJ, Demetriou JL. Postoperative regurgitation in dogs after upper airway surgery to treat brachycephalic obstructive airway syndrome: 258 cases (2013-2017). *Vet Surg*. 2020;49(1):53-60. doi:10.1111/vsu.13297
46. Ree JJ, Milovancev M, Macintyre LA, Townsend KL. Factors associated with major complications in the short-term postoperative period in dogs undergoing surgery for brachycephalic airway syndrome. *Can Vet J*. 2016;57:976-980.
47. Filipas MC, Owen L, Adami C. A retrospective observational cohort study on the postoperative respiratory complications and their risk factors in brachycephalic dogs undergoing BOAS surgery: 199 cases (2019-2021). *J Small Anim Pract*. 2024;65:329-337. doi:10.1111/jsap.13707
48. Camarasa JJ, Gordo I, Bird FG, Vallefuoco R, Longley M, Brissot HN. Owner-assisted recovery and early discharge after surgical treatment in dogs with brachycephalic obstructive airway syndrome. *J Small Anim Pract*. 2023;64(11):680-686. doi:10.1111/jsap.13647
49. Franklin PH, Liu NC, Ladlow JF. Nebulization of epinephrine to reduce the severity of brachycephalic obstructive airway

syndrome in dogs. *Vet Surg*. 2021;50(1):62-70. doi:10.1111/vsu.13523

50. Fenner JVH, Henderson CC, Demetriou JL. Nebulised adrenaline in the post-operative management of brachycephalic obstructive airway syndrome in dogs: short-term outcomes in 90 cases (2014–2020). *N Z Vet J*. 2023;71(6):329-336. doi:10.1080/00480169.2023.2248053
51. Jagodich TA, Bersenas AME, Bateman SW, Kerr CL. Preliminary evaluation of the use of high-flow nasal cannula oxygen therapy during recovery from general anesthesia in dogs with obstructive upper airway breathing. *J Vet Emerg Crit Care*. 2020;30(4):487-492. doi:10.1111/vec.12971
52. Benavides K, Rozanski E, Anastasio JD, Bedenice D. The effect of inhaled heliox on peak flow rates in normal and brachycephalic dogs. *J Vet Intern Med*. 2019;33(1):208-211. doi:10.1111/jvim.15385
53. Senn D, Sigrist N, Forterre F, Howard J, Spreng D. Retrospective evaluation of postoperative nasotracheal tubes for oxygen supplementation in dogs following surgery for brachycephalic syndrome: 36 cases (2003-2007). *J Vet Emerg Crit Care*. 2011;21(3):261-267. doi:10.1111/j.1476-4431.2011.00612.x
54. Worth DB, Grimes JA, Jimenez DA, Koenig A, Schmiedt CW. Risk factors for temporary tracheostomy tube placement following surgery to alleviate signs of brachycephalic obstructive airway syndrome in dogs. *J Am Vet Med Assoc*. 2018;253(9):1158-1163.
55. Stordalen MB, Silveira F, Fenner JVH, Demetriou JL. Outcome of temporary tracheostomy tube-placement following surgery for brachycephalic obstructive airway syndrome in 42 dogs. *J Small Anim Pract*. 2020;61(5):292-299. doi:10.1111/jsap.13127
56. Grimes JA, Davis AM, Wallace ML, et al. Long-term outcome and risk factors associated with death or the need for revision surgery in dogs with permanent tracheostomies. *J Am Vet Med Assoc*. 2019;254(9):1086-1093.
57. Gobbetti M, Romussi S, Buracco P, Bronzo V, Gatti S, Cantatore M. Long-term outcome of permanent tracheostomy in 15 dogs with severe laryngeal collapse secondary to brachycephalic airway obstructive syndrome. *Vet Surg*. 2018;47(5):648-653. doi:10.1111/vsu.12903
58. Seneviratne M, Kaye BM, Ter Haar G. Prognostic indicators of short-term outcome in dogs undergoing surgery for brachycephalic obstructive airway syndrome. *Vet Rec*. 2020;187(10):403. doi:10.1136/vr.105624
59. Clarke DL, Reetz JA, Drobatz KJ, Holt DE. Severity of nasopharyngeal collapse before and after corrective upper airway surgery in brachycephalic dogs. *Vet Surg*. 2022;51(6):982-989. doi:10.1111/vsu.13841
60. Na H, Lee SK, Choi H, Lee Y, Lee K. Nasopharyngeal collapse can be identified on radiography in healthy male beagle dogs without cardiopulmonary diseases. *Vet Radiol Ultrasound*. 2022;63(5):546-551. doi:10.1111/vru.13094
61. Mayhew PD, Marks SL, Pollard R, Balsa IM, Culp WTN, Giuffrida MA. Effect of conventional multilevel brachycephalic obstructive airway syndrome surgery on clinical and videofluoroscopic evidence of hiatal herniation and gastroesophageal reflux in dogs. *Vet Surg*. 2023;52(2):238-248. doi:10.1111/vsu.13906
62. Doyle CR, Aarnes TK, Ballash GA, et al. Anesthetic risk during subsequent anesthetic events in brachycephalic dogs that have undergone corrective airway surgery: 45 cases (2007-2019). *J Am Vet Med Assoc*. 2020;257(7):744-749.

How to cite this article: Wallace ML. Surgical management of brachycephalic obstructive airway syndrome: An update on options and outcomes. *Veterinary Surgery*. 2024;53(7):1173-1184. doi:10.1111/vsu.14131