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ORIGINAL ARTICLE – RESEARCH

Objective effectiveness of and indications for laser-assisted turbinectomy in brachycephalic obstructive airway syndrome

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Abstract

Objective: To evaluate the effectiveness of laser-assisted turbinectomy (LATE) in treating brachycephalic obstructive airway syndrome (BOAS) and to investigate the potential indications.

Study design: Prospective clinical study.

Sample population: Client-owned pugs, French bulldogs, and English bulldogs (n = 57).

Methods: A BOAS index was obtained from whole-body barometric plethysmography before BOAS conventional multilevel surgery (CMS) and 2–6 months post-CMS. Dogs with BOAS index >50% and BOAS functional grades II-III after CMS were considered candidates for LATE. A BOAS index was repeated 2–6 months after LATE. Intranasal lesions and a measurement of soft tissue proportion at the rostral entrance of choanae (STC) were recorded on the basis of computed tomography images. Logistic regressions were used to assess the intranasal predictors for being LATE candidates.

Results: Twenty-nine of 57 dogs were candidates for LATE, all of which were pugs or French bulldogs. The median BOAS index of dogs that were operated on (20/29 candidates) decreased from 67% post-CMS to 42% after LATE ($P < .001$). Soft tissue proportion at the rostral entrance of choanae was the only predictor for candidacy for LATE. Pugs ($P = .021$; cutoff = 64%) and French bulldogs ($P = .008$; cutoff = 55%) with higher STC were more likely to be candidates for LATE. After LATE, 12 of 20 dogs had temporary episodes of reverse sneezing, and nasal noise was noted in 8 of 20 dogs when sniffing and excited.

Conclusion: Laser-assisted turbinectomy was an effective treatment for dogs with intranasal abnormalities and a poor response to CMS. Soft tissue proportion at the rostral entrance of choanae was a predictor of candidacy for LATE in pugs and French bulldogs.

Clinical significance: Computed tomography-based measurement of STC can be used to predict whether LATE is required in addition to CMS in pugs and French bulldogs with BOAS.

Results of this report were presented in part at the annual scientific meeting of the European College of Veterinary Surgeons; July 14, 2017; Edinburgh, United Kingdom.

1 | INTRODUCTION

Conventional multilevel surgery (CMS) to treat brachycephalic obstructive airway syndrome (BOAS) focuses on

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lesions of the pharynx, larynx, and the nasal planum.[1] The technique of laser-assisted turbinectomy (LATE) to address intranasal obstruction in dogs was first reported as an integral part of CMS for BOAS in 2007.[2] Laser-assisted turbinectomy has been widely used in human medicine[3] but is not yet commonly used in dogs. A systematic assessment of intranasal lesions has been described to evaluate caudal aberrant turbinates (CAT), rostral aberrant turbinates (RAT), septal deviation, and mucosal contact points.[4–6] These characteristics complement the description of lesions in BOAS and led to the development of surgical treatment options. These intranasal abnormalities are highly prevalent in brachycephalic dogs, and some of these lesions have been found in asymptomatic brachycephalic dogs as well as mesaticephalic dogs.[7,8] The role of these intranasal abnormalities as indications for LATE remains unclear. Moreover, the outcome of LATE has been evaluated mechanically only by measurement of intranasal resistance by rhinomanometry[9] and subjectively with an owner questionnaire after a combination of CMS and LATE.[10] The improvement of dynamic respiratory function after LATE independently from CMS has not been documented.

In the first descriptions of LATE, the increased number of mucosal contact points was linked to the severity of intranasal obstruction and was used as an indication for LATE.[5,7,11] In our experience, consistent quantitation of intranasal mucosal contact points is challenging during initial examination. In severe cases, most of the turbinates are compressed, complicating the identification of isolated contact points. Moreover, only the rostral nasal cavity was visible in rhinoscopy because the 1.9-mm rhinoscope often could not be passed through the compressed turbinates. We also failed to calculate the mucosal contact points on computed tomography (CT) images[7] corresponding to the rhinoscopic images because the mucosa is too thin to be visualized correctly on CT. Thus, we documented all the previously reported intranasal abnormalities[4] in this study except for intranasal mucosal contact points. From observations of a few patients' CT images before and after LATE, we noticed that the soft tissue lining at the choanae was consistently thinner after LATE[12] (Supporting Information Figure 1A). This change was not seen in dogs treated only with CMS (Supporting Information Figure 1B).

We therefore hypothesized that dogs with high soft tissue proportion at the rostral entrance of choanae (STC) would have a poor outcome (BOAS index >50% and BOAS functional grade II/III) after CMS due to nasal obstruction and that LATE would provide additional improvement in respiratory function. The objectives of the study were twofold: (1) to evaluate the additional effectiveness of LATE in dogs that had been previously treated with CMS, as assessed with whole-body barometric plethysmography (WBBP) and (2) to determine the value of STC and other intranasal lesions as predictors of CMS failure and LATE candidates.

2 | MATERIALS AND METHODS

2.1 | Dogs

Pugs, French bulldogs, and English bulldogs that had been referred to the Queen's Veterinary School Hospital for CMS were included if they underwent CT of the head between October 2014 and August 2017. Dogs treated with a combination of CMS and LATE were excluded from this study because of the inability to isolate the surgical outcome of LATE from CMS. Dogs with airway diseases in addition to BOAS were also excluded from this study. All dogs were included with informed consent from their owners.

2.2 | Study design

Figure 1 provides a visual illustration of the study design. This study was approved by the Ethical and Welfare Committee, Department of Veterinary Medicine, University of Cambridge, under informed ethical consents CR62 and CR63.

On the day of admission, each dog underwent clinical examination and an exercise tolerance test to obtain a BOAS functional grade (grade 0-III, severity increases in an ascending order, grades II-III are considered clinically affected).[13] Each dog also had a WBBP respiratory function test and a baseline BOAS index (0%–100%, severity increases in an ascending order, >50% is considered clinically affected in this study). The detailed protocols of WBBP and BOAS index calculation were described previously.[14] On the following day, the dog underwent a head CT scan and rhinoscopy prior to CMS under the same general anesthesia. A grade (0–3) of laryngeal collapse[15] was assigned prior to intubation. The CMS procedures were standardized and performed as required: modified folded-flap palatoplasty, tonsillectomy, ventriculectomy, laryngoplasty, and rhinoplasty.[16] The postoperative reassessments were undertaken between 2 and 6 months post-CMS, and a post-CMS BOAS index was obtained. Laser-assisted turbinectomy was advised and performed with the owner's consent when dogs (named *candidates for LATE* in this study) had all of the following 3 elements: diagnosis of abnormal intranasal structures according to pre-CMS CT and rhinoscopy; post-CMS BOAS index >50%; assessment of functional grade II-III post-CMS. Endoscopically guided LATE and equipment setting followed the detailed description described by Oechtering and coworkers.[11] Premedication, anesthesia, postoperative medication, and details of intensive care are described in Supporting Information Document 1. Dogs were reassessed between 2 and 6 months after LATE, and the post-LATE BOAS index obtained. Owners were requested to complete a questionnaire (Supporting Information Document 2). Five questions from the owner questionnaire were included in this study, focusing on improvement of exercise tolerance (question [Q]3), regurgitation (Q6), disruptive sleep patterns (Q7),

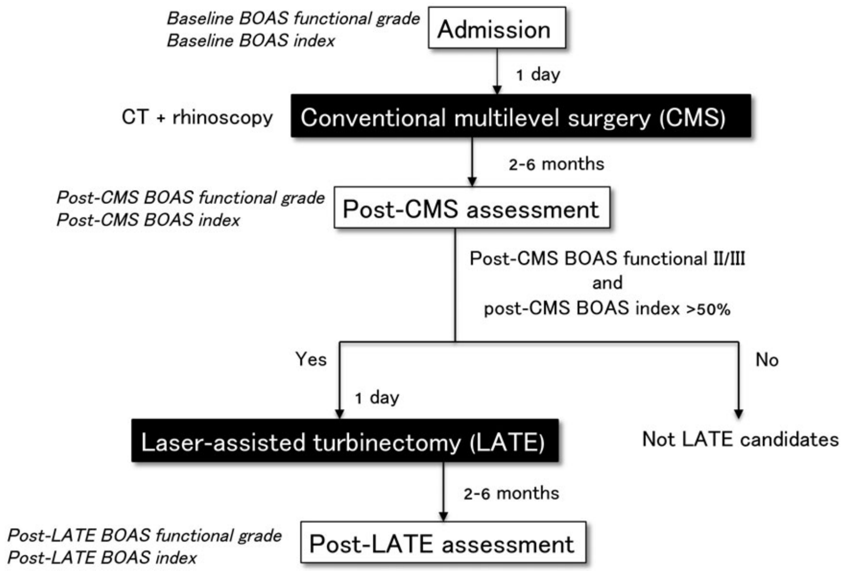

FIGURE 1 Study design and clinical procedures. BOAS, brachycephalic obstructive airway syndrome; CMS, conventional multilevel surgery; CT, computed tomography; LATE, laser-assisted turbinectomy

quality of life (Q8), and general satisfaction (Q9). We decided to use a BOAS index of 50% as the cutoff value in this study rather than use the breed-specific cutoff values for disease screening[14] (these aim for the maximum sum of specificity and sensitivity) to avoid overtreating the dogs (use of the 50% value gives relatively higher specificity with slightly lower sensitivity). Some dogs from the treated group were included in our previous study comparing different types of CMS.[16]

2.3 | Intranasal lesion identification and measurements

Intranasal lesions were assessed and measured with CT with a 16-slice multislice CT scanner (Aquilion 16; Toshiba America Medical Systems, Tustin, California). The images were acquired in helical mode, with a slice thickness of 0.5 mm and a standard 512 × 512 matrix. Tube rotation time was 0.5 seconds and KVp = 100, mAs = 150. The images were acquired with a bone algorithm (window width = 3500 Hounsfield units [HU], window level = 1500 HU). Image analysis was performed in commercially available software (Horos v2.2.0; Horos Project, http://horosproject.org/). Anatomical bony landmarks were defined under the predetermined contrast bone scale (window width = 2500 HU and window level = 500 HU, range = −750-1750 HU). The interactive multiplanar reconstruction option was used to align the 3 planar axes and reconstruct the project by using a slice thickness of 0.5 mm prior to measurement. The detailed criteria used in reslicing were referred from a previously published article (see Figure 1 in Liu et al[17]).

Four intranasal lesions and measurements were recorded:

1. Rostral aberrant turbinates. The term was defined previously as "conchal lamellae from the concha nasalis media or the concha nasalis ventralis spreading rostral to the point of first branching of the plica alaris into the concha nasalis ventralis."[4] Data were coded as 0 = absence of RAT and 1 = presence of RAT
2. Caudal aberrant turbinates. The term was defined as a previously developed grading system[8] in which grade 0 = normal (no turbinates visible in the ventral nasal meatus), grade 1 = minimal (turbinates visible in the ventral nasal meatus but not extending into the nasopharyngeal meatus), grade 2 = mild (turbinates visible in the nasopharyngeal meatus but not extending through the choanea), grade 3 = moderate (turbinates visible in the choanea but not extending caudal to the caudal border of the nasal border [vomer] that is the rostral opening of the nasopharynx), and grade 4 = severe (turbinates visible in the nasopharynx)
3. Septal deviation. Data were coded as 0 = absence of septal deviation and 1 = presence of septal deviation
4. Cross-sectional area of the soft tissue proportion at the rostral entrance of choanae (Figure 2). Cross-sectional area of the soft tissue proportion at the rostral entrance of choanae was measured on the first slice at the level where the bony frame of the entrance of the choanae is complete. Pencil Tool (Horos v2.2.0; Horos Project) was used to draw the inner margin of the bony frame and the margin of the air passageway. The surface area of the bony frame and the surface area of the airway passageway were measured automatically by the software. The STC was measured as the soft tissue surface area on both sides of the nasal cavity (surface area of the bony frame minus surface area of the air passageway) divided by the surface area of the bony frame. Soft tissue proportion at the rostral entrance of choanae data were recorded as percentage.

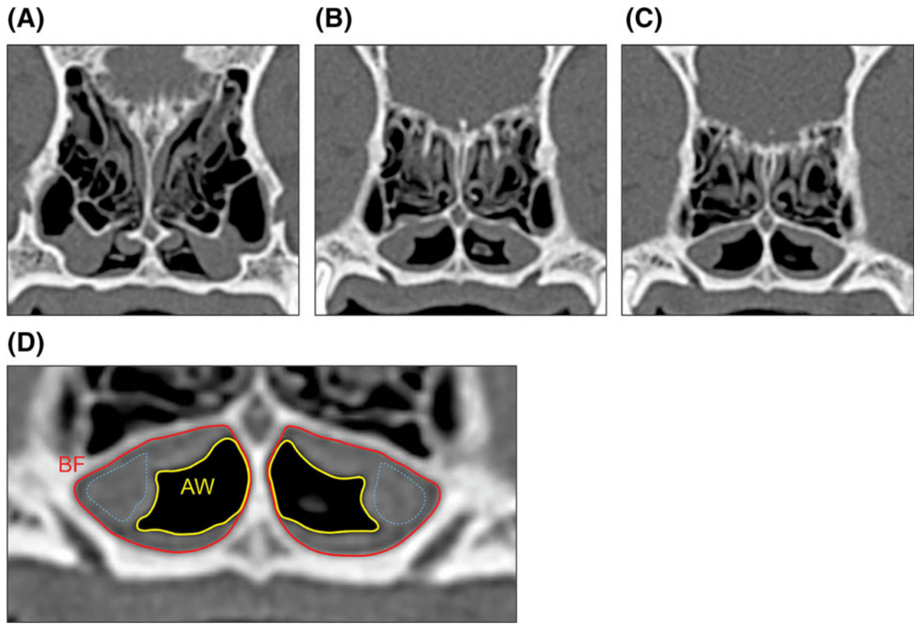

FIGURE 2 Measurement of the cross-sectional area of the soft tissue proportion at the rostral entrance of the choanae (STC) on computed tomography (CT) images. **A-C,** Three slices of cross-sectional CT images illustrating the identification of markers to measure STC. **A,** The lateral nasal gland first migrates from the maxillary recesses medially into the entrance of the choanae. **B,** The dorsal bony frame is about to close (the last slice rostrally to the STC measurement slice). **C,** First CT slice with a complete bony frame at the entrance of the choanae, used to measure STC. **D,** Magnification of the image from **C** to illustrate the measurement of STC. The STC was calculated as (BF − AW) / BF × 100(%). The caudal extents of the lateral nasal gland are marked with light blue dotted margins. AW, surface area of the airway passageway on both sides of nasal cavity; BF, surface area of the bony frame on both sides of nasal cavity

2.4 | Statistical analyses

All statistical analyses in this study were performed in software R version 3.3.0 for Mac (http://www.r-project.org). Significance level was set at .05. Bonferroni corrections were used in analyses with multiple comparisons.

The Kolmogorov–Smirnov test and a frequency histogram were used to examine continuous variables for normality (age, body weight, baseline BOAS index, post-CMS BOAS index, post-LATE BOAS index, and STC). Results are presented as mean ± standard deviation for normally distributed data or median with range or interquartile range (IQR) for nonnormally distributed data. Categorical variables are reported as numbers and percentages. The Wilcoxon signed-rank test was used to assess the effectiveness of CMS and LATE on the basis of BOAS indices (paired samples between baseline BOAS indices and post-CMS and between post-CMS and post-LATE indices).

Comparisons of parametric continuous variables between breeds were performed by using ANOVA with a post hoc test for pairwise comparison. Categorical variables were compared by using Fisher's exact test, followed by multiple pairwise comparisons.

Because of the low number of English bulldogs and the fact that none were candidates for LATE, they were removed from further analysis. Initial data mining revealed that pugs had substantially different upper airway lesions compared with French bulldogs. Therefore, the analyses of the intranasal predictors of candidate for LATE were performed separately for pugs and French bulldogs. Candidates for LATE were coded as "1," and noncandidates for LATE were coded as "0." Predictive variables were sex (male/female, binary variable), neuter status (neutered/entire, binary variable), body weight (kilograms, numeric variable), age (months, numeric variable), obesity (obese [body condition score ≥ 7/9]/not obese [body condition score < 7/9], binary variable), baseline BOAS index (%, numeric variable), laryngeal collapse (yes/no, binary variable), RAT (yes/no, binary variable), CAT (grade 0–4, ordinal variable), septal deviation (yes/no, binary variable), and STC (%, numeric variable). Each predictive variable was included in a breed-specific univariate logistic regression model initially where candidates for LATE (yes/no, binary variable) was the outcome variable. Variables that had a Wald test $P < .25$ on univariable logistic regression were selected as candidates for the multivariate analysis by using the method of purposeful selection. Backward stepwise model-selection based on Akaike's information criterion was used to obtain the final best-fit model. Receiver operating characteristic curves were used to determine the cutoff values of STC when the sum of sensitivity and specificity was maximum.

3 | RESULTS

Fifty-seven dogs (23 pugs, 27 French bulldogs, and 7 English bulldogs) were included.

Median age was 22 months (range, 6–60), and median weight was 9.5 kg (range, 5.55–31). Female dogs accounted for 47.4% of the study population. Approximately half (29/57) of the dogs were neutered. Seventeen of 57 (29.8%) dogs were obese (ie, body condition score ≥ 7), including 14 pugs. Laryngeal collapse (91.3%) and septal deviation (100%) were more common in pugs (Table 1). Rostral aberrant turbinates were identified in about half the pugs and French bulldogs and only 1 English bulldog. Caudal aberrant turbinates were present in all dogs of each breed. Grade 2 CAT was more prevalent in pugs and English bulldogs, whereas more French bulldogs had grade 3 CAT. Pugs had higher STC than French bulldogs ($P < .001$) and English bulldogs ($P = .001$), but STC did not differ between French bulldogs and English bulldogs ($P = .478$; Figure 3).

The median BOAS index decreased from 80.7% before surgery to 56.9% after CMS ($P < .001$; Figure 4). Among the 29 of 57 (50.9%) dogs considered as candidates for LATE, 20 underwent LATE, whereas owners of the other 9 dogs declined the treatment because of satisfaction with the CMS and personal preference. Dogs that underwent LATE had a median BOAS index post-CMS of 66.7% (IQR = 3.8%), which was lower than the preoperative BOAS index of 88.8% (IQR = 23.4%; $P < .001$). This index further decreased after LATE by about a 1/3 (median = 42.3%, $P < .001$).

In pugs, the baseline BOAS index ($P = .068$) and STC ($P = .021$) were initially included in modelling, but only STC remained in the final best-fit model ($P = .021$). In French bulldogs, sex ($P = .103$), baseline BOAS index ($P = .157$), laryngeal collapse ($P = .077$), and STC ($P = .008$) were initially included in modelling, but only STC remained in the final best-fit model ($P = .009$; Table 2). The best cutoff values of STC as an indicator for LATE were 64.3% (sensitivity = 88.9%, specificity = 85.7%) and 55.3% (sensitivity = 91.7%, specificity = 80%) for pugs and French bulldogs, respectively (Figure 5).

Dogs were in the intensive care unit (ICU) after LATE for a median of 1 day (range, 0–2) and were hospitalized for a median of 1.5 days (range, 1–2.5 days). Six of 20 dogs treated with LATE did not require ICU monitoring postoperatively. Complications during LATE were considered minor (bleeding, arousal requiring an unplanned intravenous bolus of anesthetic or analgesia) except in 2 dogs. One dog developed bradycardia associated with a second degree atrioventricular block that required conversion with atropine. One dog suffered a cardiopulmonary arrest toward the end of the procedure but was resuscitated after cardiac compressions, intermittent positive pressure ventilation, and the administration of atropine. Five of 20 dogs had regurgitation that responded to medical management immediately postoperatively; 6 of 20 dogs became dyspneic, 2 of which required temporary tracheostomy for 48 hours. These 2 dogs were both pugs with grade 3 laryngeal collapse.

Twelve of 20 (60%) owners reported frequent reverse sneezing for 4–7 days after LATE, which was resolved in all dogs at the time of reevaluation. Eight of 20 (40%)

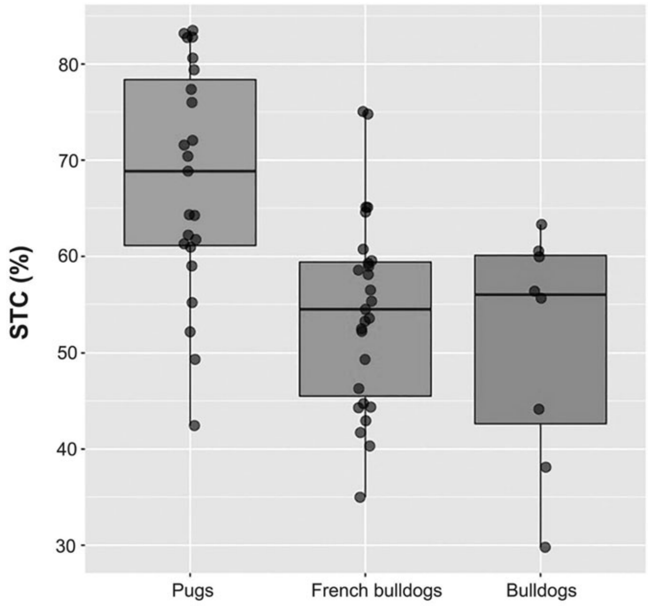

FIGURE 3 Distribution of the cross-sectional area of the soft tissue proportion at the rostral entrance of the choanae (STC) before surgery

TABLE 1 Measurements of laryngeal and intranasal lesions[a]

Lesion	Total, n = 57	Pug, n = 23	French bulldog, n = 27	English bulldog, n = 7
Laryngeal collapse, n (%)[b]	36 (63.2)	21 (95.7)	12 (44.4)	3 (42.9)
RAT, n (%)	28 (49)	12 (52.2)	15 (55.6)	1 (14.3)
CAT, n (%)[c]				
Grade 1	5 (8.8)	4 (17.4)	0 (0)	1 (14.3)
Grade 2	25 (43.9)	12 (52.2)	10 (37)	3 (42.9)
Grade 3	19 (33.3)	2 (8.7)	15 (55.6)	2 (28.6)
Grade 4	8 (14)	5 (21.7)	2 (7.4)	1 (14.3)
Septal deviation, n (%)	25 (43.1)	23 (100)	2 (7.4)	0 (0)
STC, median % (IQR)	59.2 (12.9)	68.9 (17.3)	54.5 (13.9)	55.7 (17.5)

CAT, caudal aberrant turbinates; IQR, interquartile range; RAT, rostral aberrant turbinates; STC, cross-sectional area of the soft tissue proportion at the rostral entrance of the choanae.
[a] Data are number of dogs and the percentage of each group for laryngeal collapse, RAT, CAT, and septal deviation.
[b] Laryngeal collapse was defined as grade II-III laryngeal collapse[15] in this table. Eversion of laryngeal saccules (grade I laryngeal collapse) was not included.
[c] No dogs were assigned grade 0 CAT.

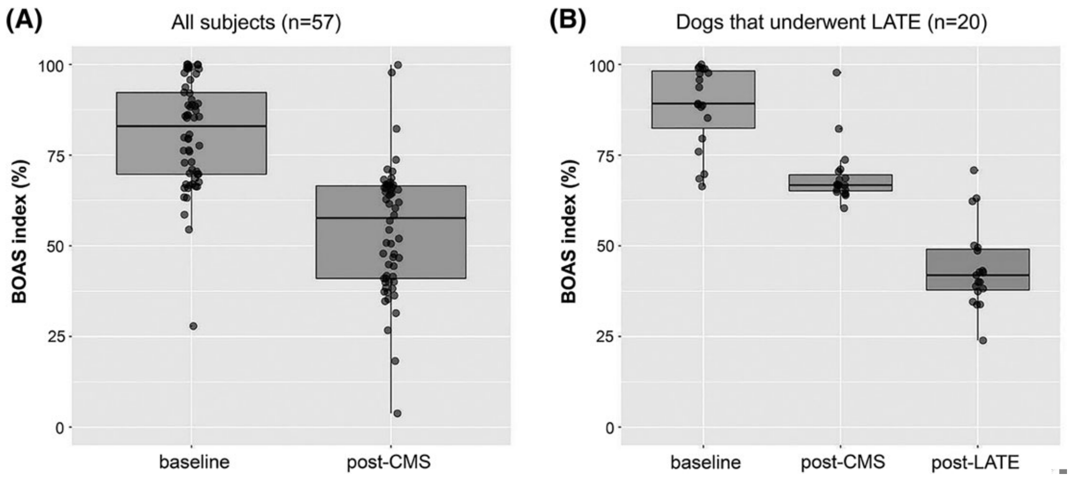

FIGURE 4 Distribution of brachycephalic obstructive airway syndrome (BOAS) indices before surgery, after conventional multilevel surgery (CMS), and after laser-assisted turbinectomy (LATE)

TABLE 2 Logistic regression model of STC predicting being LATE candidates in pugs and French bulldogs

Breed	Coefficient (SE)	Wald test statistics	Estimated OR (95%CI)	*P* value
Pugs				
(Intercept)	−16.919 (7.374)	−2.294	…	.022
STC (%)	0.264 (0.114)	2.311	1.302 (1.107–1.796)	.021
French bulldogs				
(Intercept)	−12.441 (4.795)	−2.595	…	.009
STC, %	0.237 (0.089)	2.653	1.267 (1.1–1.575)	.008

…, not applicable; CI, confidence interval; LATE, laser-assisted turbinectomy; OR, odds ratio; STC, cross-sectional area of the soft tissue proportion at the rostral entrance of the choanae.

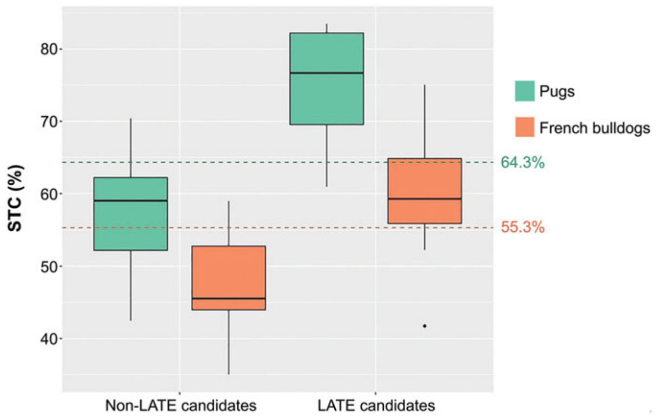

FIGURE 5 Distributions of the cross-sectional area of the soft tissue proportion at the rostral entrance of the choanae (STC) based on the candidacy of dogs for LATE. The dashed lines indicate the cutoff values of STC for pugs (green) and for French bulldogs (orange) with the highest sensitivity and specificity in predicting a dog as a candidate for LATE

dogs were found to have intermittent nasal noise when sniffing and excited during the veterinary examination at the time of recheck. The BOAS index remained >50% after LATE in 4 of 20 (20%) dogs. Two were pugs with grade 3 laryngeal collapse. The other 2 dogs were French bulldogs, 1 of which had grade 2 laryngeal collapse and an undersized trachea and the other grade 1 laryngeal collapse.

Questionnaires after LATE were returned for 18 of 20 dogs. Only 1 owner reported an unchanged exercise level, whereas 17 reported that their dog was able to walk/play longer after LATE. In the 4 dogs in which the post-LATE BOAS index remained >50%, 2 owners reported that their dog could walk/play much longer, 1 reported a slight improvement, and 1 owner did not notice any change. Six of 18 dogs had a preoperative history of frequent regurgitation/vomiting, which resolved in 5 of 6 dogs and reduced in frequency in 1 dog. The preoperative sleeping problems noted in 4 dogs resolved post-LATE. In general, 10 of 18 owners were very satisfied with the outcome of LATE, and 8 of 18 owners were satisfied with the outcome.

4 | DISCUSSION

Conventional multilevel surgery (CMS) improved the respiratory function of dogs with BOAS, although objective measurements were unsatisfactory in 50% of dogs after CMS. Dogs that responded minimally to CMS and had intranasal abnormalities benefited from LATE. Soft tissue proportion at the rostral entrance of choanae is a newly proposed CT-based intranasal measurement that can serve as a relatively objective and sensitive indication for LATE.

The effectiveness of CMS varies among studies, with owners noticing postoperative improvement in 45%–94% of cases.[18–22] The discrepancies in surgical outcome among studies could reflect different surgical techniques, patient populations, and the subjectivity of evaluating the surgical outcome. Our previous study used WBBP to quantitate respiratory function before and after 2 types of CMS (ie, traditional and modified). In this study, WBBP improved after surgery, but 68% of dogs still had a BOAS index consistent with an unsatisfactory respiratory function.[16] In the present study, CMS (ie, modified) improved the BOAS index from 4%–98%, with English bulldogs generally responding better than the other 2 breeds. Nevertheless, although all English bulldogs in this study had post-CMS functional grade 1 (mild clinical signs, clinically unaffected), their median post-CMS BOAS index was just below the threshold of affectedness, at 47%. All LATE candidates in this study were pugs and French bulldogs. The outcome of LATE is promising because 16 of 20 dogs had satisfactory respiratory functions after surgery. The unsatisfactory results in the remaining 2 pugs and 2 French bulldogs remain unclear.

Intranasal structures were evaluated with a 5-point grading system[8] of CAT adapted from a previous definition.[6] We did not detect any association between the severity of CAT and the status as a candidate for LATE. Our preliminary study[12] also found no association between the originally defined CAT[6] and whether a dog was a candidate for LATE. Caudal aberrant turbinates result from abnormal growth of conchal lamellae extending caudally into the meatus nasopharyngeus. Caudal aberrant turbinates did not have contact points with the surrounding wall in some cases (Supporting Information Figure 2). One study proposed the feasibility of LATE solely for the CAT, in which only the CAT was removed, leaving the nonobstructing ventral nasal conchae intact.[23] However, it is unclear whether CAT truly cause obstruction or are a compensational extension into the relatively wider space of nasal cavity. Rostral aberrant turbinates similarly were not a predictor of candidacy for LATE in our study. Originally, RAT was defined as the abnormal growth of turbinates in the rostral nasal cavity, where the "5 folds" should be identified.[24] At this level, the nasal cavity occupies a relatively wider volume compared with further caudally. Although RAT did not obstruct the airway in our study population, RAT were not only identified rostral to the first branch of the plica alaris as defined but also beyond the first branch, where turbinates are more crowded, potentially exacerbating an obstruction.

Deviation of the nasal septum was not an indication for LATE. However, all pugs in this study had some degree of nasal septal deviation, whereas this finding was rare in bulldogs included here. One study found no difference in the prevalence of septal deviations between brachycephalic dogs and normocephalic dogs.[7] In man, deviation of the nasal septum is a common cause of nasal obstruction but often remains asymptomatic. Internal nasal asymmetry due to nasal septal deviation may prompt compensation, such as hypertrophy of the turbinates in the concave side of the nasal cavity. These changes are assumed to protect the more patent side from excess airflow and mitigate drying and crusting.[25,26] Moreover, human patients with nasal septal deviation may have signs of paradoxical nasal obstruction due to the nasal cycle.[27] The normal nasal cycle could also be affected by septal deviation.[28]

The STC was the only intranasal predictor of candidacy for LATE in our study. Pugs and French bulldogs that did not respond to CMS and had abnormal intranasal structures were more likely to have a higher STC. The site of STC measurement is not included in the laser operating field during LATE. Therefore, the STC was not directly altered by the LATE but responded to the LATE. The lateral part of soft tissue lining at the choanae consists of nasal mucosa and part of the lateral nasal gland (glandula nasalis lateralis)**.** The main body of the lateral nasal gland is located in the mucosa of the maxillary recess. The secretions drain rostrally via a duct along the lateral wall of the nasal cavity and open on the lateral wall of the vestibule.[29] Schmidt-Nielsen et al[30] proposed that the lateral nasal gland in dogs plays an important role in thermoregulation. The gland provides fluid, which is essential for heat dissipation during thermal panting, functionally similarly to human sweat glands. The theory was further supported by Blatt et al.[31] The rate of secretion from the lateral nasal gland rises with increasing respiratory evaporation as a result of thermal panting. We suspect that enlargement of the lateral nasal gland could be a compensatory change in response to the compromised thermoregulation due to intranasal obstruction in affected dogs. To the best of the authors' knowledge, no report of a study on the lateral nasal gland in brachycephalic dogs has ever been published. The mechanism of STC swelling and reduction in size before and after LATE is still unclear. Although intranasal obstruction and thermoregulation are difficult to quantify, STC could indirectly measure both variables. Another possibility is that rhinomanometry could help quantitate the intranasal resistance and further justify LATE. However, the equipment and technique are not widely available, and a CT-based measurement may be more practical in a clinical setting.

Intraoperative complications in this study were similar to those in a previous study. The 2 major intra-anesthetic complications that occurred were likely associated with the trigeminal-vagal reflex.[32] This is the first published study reporting the short-term clinical outcomes after LATE, providing a guide to inform owners of the potential side effects. Postoperative reverse sneezing was a relatively common self-limiting complication. The development of a different type of nasal noise to the preoperative noise has not been previously reported. This noise was present in some dogs without obvious nasal obstruction at follow-up. We believe that the relatively rapid airflow passing through the narrowed and collapsible nasopharynx during sniffing may cause vibration of the soft tissues. No other long-term complications were noted. In human patients, postoperative complications include dry nose and empty nose syndrome.[33,34] Such symptoms are usually identified via patients' complaints, which is impossible in dogs. Although LATE has been confirmed to give a patent airway and improve the nasal airflow, additional studies on the function of the turbinates and the potential effect of the change in intranasal structure are warranted.

Our study is limited by the duration of follow-up (6 months) after CMS and LATE. Longer term follow-up will be valuable in future studies to assess regrowth of the turbinates. The unsatisfactory outcome of CMS for dogs classified as LATE candidates could also be attributed to other abnormalities of the airways, such as hypoplastic trachea, narrow nasopharynx, and hypoplastic larynx. A more direct and specific measure of the intranasal obstruction may help refine indications for LATE. The study was conducted over 3 years, and LATE has a steep learning curve; improvement in surgeons' skills with time may have affected the outcome. However, the surgery was standardized, and all dogs had clear patency of the ventral nasal meatus at the end of the surgery. Finally, the sample was small and may have led to type II error. The inclusion criteria were set to control variables that could affect the results. Nevertheless, our current clinical impression is that the number of dogs presenting for LATE because of poor response to CMS is increasing, with the majority consisting of French bulldogs. The incidence of dogs that require LATE in addition to CMS must be refined with a larger scale study.

In conclusion, LATE was effective in BOAS-affected dogs with intranasal obstruction that had little response to CMS. Soft tissue proportion at the rostral entrance of choanae was a reliable predictor of candidacy for LATE in pugs and French bulldogs that did not respond to CMS.

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CONFLICT OF INTEREST

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

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SUPPORTING INFORMATION

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

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