In search of prognostic indicators of short-term outcome in dogs undergoing surgery for Brachycephalic Obstructive Airway Syndrome

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Abstract

Background: The aims of this study were to assess the impact of epidemiological variables, severity of pre-surgical respiratory signs, diagnostic findings from pharyngeal and laryngeal examination using a new grading scheme and CT scan images, on post-surgical outcome in dogs undergoing surgery for brachycephalic obstruction airway syndrome (BOAS).

Methods: An owner-based questionnaire was used to grade dogs based on their respiratory signs prior to surgery and at least 6 weeks after surgery. Epidemiological data and results from pre-surgical pharyngeal and laryngeal examination and CT scan findings for 75 dogs undergoing airway surgery were collected from the medical records.

Results:.70.7% of dogs showed an improvement in respiratory signs following rhinoplasty and palatoplasty. This improvement was associated with the severity of inspiratory efforts and the Poncet score upon presentation, but not with any other clinical sign or anatomical abnormality found during BOAS assessment, nor by the degree of craniofacial shortening as determined by CT-scan. Pre-surgical snoring was positively associated with the degree of narrowing of pharyngeal dimensions.

Conclusions: Dogs presenting with clinical signs of BOAS benefit from rhinoplasty and palatoplasty alone. The degree of narrowing of pharyngeal dimensions appears to be associated with severity of snoring while soft palate length alone was not.

Introduction

Brachycephalic obstructive airway syndrome (BOAS) is a combination of upper respiratory tract abnormalities resulting in varying degrees of upper airway obstruction. The most commonly affected breeds include the English Bulldog, French Bulldog, the Boston terrier and the Pug (1). Brachycephalic dogs have markedly shortened skull bones (2), with a disproportionate reduction in associated soft tissue, which is therefore abundant in mainly the (naso)pharyngeal area. Primary features of BOAS include stenotic nares, an elongated soft palate, redundant pharyngeal soft tissues and tracheal hypoplasia (3). Recent studies have also identified increased mucosal contact of intranasal structures (4) and aberrant conchae, including nasopharyngeal turbinate protrusion (5,6) to contribute to the airway obstruction. Turbinates may become obstructively large as a result of continued turbinate growth despite inhibition of growth of the mid-face (4,5). In addition, narrowing of the nasopharyngeal space (7) due to mucosal hyperplasia and macroglossia, appears to contribute to the syndrome. The increased upper airway resistance generated by the aforementioned features is thought to be responsible for secondary changes such as progressive laryngeal collapse and tonsilar eversion leading to further obstruction (1,8–11). Whereas craniofacial shortening has been proposed as the key etiopathogenic factor responsible for increased airway resistance, a recent paper has shown that muzzle length within 3 extreme breeds was not significant for predicting BOAS status in Pugs, English Bulldogs and French Bulldogs (12).

Clinical signs of BOAS include stertorous breathing, inspiratory dyspnoea, exercise intolerance and episodes of collapse. Concurrent gastrointestinal signs, such as gagging, ptyalism, vomiting and regurgitation are commonly seen (10,13). Whilst the history is highly suggestive of the disease most owners fail to recognise signs and symptoms and perceive respiratory noise as normal for brachycephalic breeds (14–16). CT and endoscopy permit assessment of all brachycephaly related abnormalities. These techniques are mandatory in evaluating the degree of nasopharyngeal turbinate protrusion (6), increased intranasal mucosal contact points (4,17), nasopharyngeal dimensions (7), laryngeal cricoid and tracheal dimensions (18).

Reported surgical procedures include nares and alar fold resection, laser-assisted turbinectomy (LATE), staphylectomy or palatoplasty, and laryngeal sacculectomy or laryngoplasty procedures, and are aimed at permanently reducing airway resistance. Surgical correction of all anatomical anomalies is not possible (eg: narrow (naso)pharyngeal dimensions), thus complete resolution of BOAS is unlikely. Despite these limitations, most authors report a favourable outcome after surgery (1,11,19) with subjective improvement rates of 50-90% (8,9,11,20,21). Objective improvement following surgery measured using whole-body plethysmography was reported in 100% of dogs although respiratory function still remained compromised in 68% of dogs (22). Standard surgical management for options for BOAS include nares resection, staphylectomy and resection of the everted laryngeal saccules (11). Although most surgeons consider nares resection and staphylectomy indicated in patients suffering from BOAS, there is ongoing debate regarding the additional improvement in airflow achieved by sacculectomy, particularly when balanced against concerns regarding increased risk of complications in patients undergoing the procedure. (21,23). A recent study demonstrated a higher complication rate in patients undergoing sacculectomy in addition to nares resection and staphylectomy compared to patients undergoing nares resection and staphylectomy alone (24).

To the authors' knowledge, there is no published data on the effects of nasopharyngeal turbinate protrusion, pharyngeal and laryngeal dimensions, and the degree of facial shortening on the outcome of BOAS surgery. Our objective was to assess the impact of epidemiological variables and diagnostic findings on clinical signs following surgery. Pharyngeal and laryngeal abnormalities were assessed using a novel scoring system developed for this study. Assessment of degree of pharyngeal narrowing by evaluating key pharyngeal structures and dimensions as well as laryngeal narrowing beyond the evaluation of laryngeal collapse alone, was introduced. We hypothesised that 1) an increased degree of nasopharyngeal turbinate protrusion, an increased degree of narrowing of pharyngeal and laryngeal dimensions and a decreased relative facial length would be negative prognostic indicators for improvement of clinical signs after surgery, and 2) a decreased facial length would be associated with a greater degree of nasopharyngeal turbinate protrusion and narrowed pharyngeal dimensions.

Materials and Methods

Dogs and Clinical Data

Medical records of client-owned brachycephalic dogs that presented to a veterinary teaching hospital for investigation of BOAS (2014 – 2015) were retrospectively reviewed. Guidelines of the Science Ethical Review board of the Royal Veterinary College were followed. Only dogs that underwent surgery for nares resection and staphylectomy were included. Dogs were excluded from the study if medical reports were incomplete, e.g. a detailed report of findings on pharyngeal and laryngeal examination was not available, Computed Tomography (CT) scan was not performed, or if other types of airway surgery were performed. Dogs were not excluded from the study if other surgical procedures such as neutering or ophthalmological surgery were performed.

Preoperative evaluation included an owner questionnaire (Appendix 1), based on a previously published scoring system on the severity of several respiratory signs (21). As per the Poncet-Dupre scoring system, each dog was assigned a score prior to surgery (Poncet Score). These scoring sheets were then used to assign a score, grade 1-3, for each individual clinical sign (snoring, inspiratory effort, stress or exercise intolerance and syncope) based on the frequency of occurrence. Telephone interviews using the same questionnaire with owners of the study dogs were conducted more than 6 weeks and less than 6 months following surgery with a median time of 8 weeks. Owners were asked to retrospectively assess the clinical signs of their dogs at predetermined, post-operative time points (T<2 weeks, T=2-6 weeks and T>6 weeks (Appendix 1)). A veterinary surgeon or veterinary student conducted all telephone interviews.

Grading of brachycephaly-related findings

After induction of anesthesia (following IV administration of propofol (Propoflo plus, Zoetis UK) to effect (4 to 6 mg/kg)), nares were evaluated and graded for degree of stenosis upon direct visualization (Table 1, Figure 1). Pharyngeal examination was carried out by suspending the maxilla above the surface where the animal lies, using a bandage strapped behind the canine teeth. The tongue was gently grasped and pulled slightly downward as to open the mouth maximally, but was not pulled rostrally. Evaluation took place before intubation. The pharynx was graded based on the degree of dorsoventral flattening, tonsilar protrusion, pharyngeal oedema and the thickness/position of the base of the tongue (Table 2, Figure 2). The overall degree of pharyngeal narrowing was determined by the two highest grades for the individual parameters. If two or more parameters were moderate, but the other parameters were mild, the overall classification was “moderate”. But if only one parameter was “marked” and the others were “moderate”, the overall classification was “moderate”.

Finally, the larynx was evaluated for secondary collapse (23). Degree of laryngeal narrowing was assessed by determining the overall reduction in size of the rima glottidis, degree of underdevelopment of the laryngeal cartilages and degree of thickening of the laryngeal mucosa. (Table 3, Figure 3). All evaluations were performed by a Board-certified surgeon (GtH).

Dogs were subsequently fully anaesthetised and intubated according to institutional anaesthesia protocols and underwent CT evaluation. CT (Philips Secura, Philips NV, Eindhoven, The Netherlands) was performed with a single-slice helical scanner, and viewed using commercially available software (OsiriX[R] Version 5.8.5 64-bit). Dogs were positioned in sternal recumbency and non-contrast studies were performed in helical acquisition mode with a slice thickness of 3 mm and a pitch of 1. Technical settings were 120 kV, 200 mA, 1 s tube rotation time, 250 mm field of view, 512 × 512 matrix, and with a high spatial frequency algorithm. Images were analysed by the same person (GtH). The degree of extension of caudal aberrant turbinates was graded according to a previously published classification system(6) (Table 1). Transverse images were used primarily for evaluation and classification in all the patients. Both sides of the nasal cavity were evaluated and classified independently. If the score differed on each side, the higher score was used for statistical analysis.

Craniometric measurements were taken from 3D reconstructions of CT scan images. Muzzle length was defined as the distance from the nasal planum to the nasion. Facial length was defined as the distance from the prosthion to the nasion. Cranial length was defined as the distance from the nasion to the inion. The facial length was used for statistical analysis. The craniofacial ratio (CFR) was defined as the facial length divided by the cranial length (Figure 4)

Surgical procedures

The dogs were placed in sternal recumbency, and the head and neck were positioned for an intraoral approach. Nares resection and a staphylectomy were performed by, or supervised by, a Board-certified surgeon. A wide arch-shaped sharp cut and sew technique was used for the staphylectomy (25), reducing the length of the soft palate medially to the level of the rostral third of the tonsils. An interrupted suture pattern with synthetic absorbable 4-0 multifilament suture material (polyglactin 910, Vicryl rapide, Ethicon USA) was used to approximate the mucosa. A modified horizontal wedge resection technique was used for all rhinoplasties (25), and closed with a synthetic absorbable 4-0 monofilament suture material (poliglecaprone 25, Monocryl, Ethicon USA).

Statistical analysis

Statistical analysis was performed using commercially available software (SPSS version 11). Four epidemiological variables were introduced into the database: breed (three modalities: Pug, French Bulldog and English Bulldog), age (units =month), weight (units = kg), and gender (male and female). Results of pharyngeal exam and CT scan were introduced into the database: grade of stenotic nares, nasopharyngeal turbinate protrusion, length of soft palate, narrowed pharyngeal dimensions, narrowed laryngeal dimensions and laryngeal collapse (three modalities: Grade 1,2 and 3). The Poncet score at presentation (three modalities: grade 1,2 and 3) as well as the four individual clinical signs, assessed pre and post-surgery, were entered into the database: snoring, increased inspiratory effort, exercise intolerance, syncope (three modalities: Grade 1,2 and 3). The score at >6 weeks post-surgery was used for statistical analysis.

A total pre and post-surgery grade was calculated as a sum of the individual grades for the four clinical signs assessed. A final variable (post-surgical outcome) was entered based on the change in the total grade pre and post-surgery (two modalities: improved, no change).

Variables were assessed for normality via visual inspection of histograms and the Shapiro-Wilk test. Non- normally distributed variables are presented as median (range), whereas normally distributed variables are presented as mean (SD). Proportions are expressed as percentages. The effects of epidemiological factors (age, weight, breed, sex), grade of stenotic nares, nasopharyngeal turbinate protrusion, overlong soft palate, narrow pharyngeal dimensions, laryngeal hypoplasia, laryngeal collapse and CFRs on pre-surgery clinical signs were assessed using ordinal regression analysis. The effects of the above-mentioned factors and the pre-surgery clinical signs on post-surgical outcome (improved or no change) were assessed using multiple logistic regression analysis. Statistical significance was set at $p=0.05$.

Results

Patient and Clinical Data

One hundred and twelve cases were initially identified, but 37 cases were excluded from statistical analysis due to incompleteness of data, thus, 75 dogs were included in this study. Of the cases excluded, one dog died 24 hours post-operatively (peri-operative mortality rate = 0.9%). The breeds included were French bulldogs (n=31, 41.3%), Pugs (n=31, 41.3%) and English bulldogs (n= 13, 17.3%). The median age was 20.5 months (5 to 82 months). Males were overrepresented (67%, p=0.013). The median weight was 10.5kg (4.5 to 34.6 kg). Male dogs (median 11.85 kg, range 7-34.6 kg) were significantly heavier than female dogs (median 8.1 kg, range 4.5-27.1, p<0.001).

All dogs presented with respiratory signs attributed to BOAS. Grades of individual clinical signs are summarized in Figure 5. Combined clinical signs (Poncet grade) were graded as 1 in 17.3% (n=13), as grade 2 in 38.7% (n=29) and as grade 3 in 44% (n=33) of the dogs. Grades of pre-surgery inspiratory efforts were significantly different between breeds (p<0.001) with English Bulldogs (p=0.001) and Pugs (p<0.001) having a significantly higher grade compared to French Bulldogs (p=0.001).

Grades for nasal, pharyngeal and laryngeal abnormalities are summarised in Figure 6. There were significant differences between breeds in grade of stenotic nares (p=0.026) and narrowed laryngeal dimensions (p=0.002). Grades of stenotic nares were significantly higher in French Bulldogs compared to English Bulldogs (p=0.010). Grades of narrowed laryngeal dimensions were significantly higher in Pugs (p=0.014) compared to English Bulldogs and French Bulldogs (p=0.002).

Figures 7 and 8 demonstrate examples of different grades of narrowed pharyngeal dimensions. A higher grade of narrowed pharyngeal dimensions was significantly associated with an increased frequency of snoring pre-surgery (p=0.016, 95% CI 0.223 - 2.202), while soft palate length alone was not. A higher grade of narrowed laryngeal dimensions was associated with a decreased frequency of snoring pre-surgery (p=0.011, 95% CI -4.327 to -0.558).

Craniofacial ratios of all dogs in this study were found to be <0.5. The median was 0.4 (0.2-0.5). Median CFR was 0.4 for Pugs and French Bulldogs and 0.5 for English Bulldogs. No significant association between the CFR and pre-surgery clinical signs or brachycephaly scores for nose, pharynx and larynx were found.

Change post-surgery

Grades of individual clinical signs post-surgery are summarized in Figure 9. Overall, 70.7% of dogs showed an improvement, manifested as a decrease in total respiratory grade following surgery. An increased exercise tolerance was seen in 56% of dogs, as was a decrease in syncopal episodes in 13.3% of dogs and a decrease in snoring frequency in 9.3% of dogs. There was no significant difference between breeds in their degree of improvement post-surgery.

Predictors of post-surgical outcome

The Poncet score at presentation was associated with outcome post-surgery (p=0.001, 95% CI 1.067 - 4.356) as was the grade of pre-surgery inspiratory effort (p=0.004, 95% CI 0.777 - 4.169), in that the higher the grade prior to surgery, the more likely dogs were to show an improvement post-surgery. Other presenting clinical signs, brachycephaly grades and CFR were not significantly associated with or predictive of outcome. Also, no association was found between the CFR and any of the brachycephaly scores (nose, pharynx and larynx).

Discussion

This large study on outcome after upper respiratory tract surgery in brachycephalic dogs demonstrated an improvement in respiratory tract signs in 70.7% of dogs following rhinoplasty and wide arch-shaped staphylectomy only. A wide variety of epidemiological variables and diagnostic findings, including the use of a novel grading system to assess pharyngeal dimensions and laryngeal hypoplasia, were evaluated as prognostic indicators for outcome, some of which reached significance.

Findings in this study regarding signalment and breeds affected with BOAS are similar to those reported previously with French Bulldogs and Pugs being overrepresented compared to the English Bulldog and male dogs being overrepresented compared to female dogs (1,11,13,14,21,26). Using a previously published clinical grade scoring system (13), 17.3% of the dogs included in our study presented with Grade 1 respiratory tract signs, 38.7% with Grade 2 signs and 44.1% with Grade 3 signs. Our dogs appear to have lower grades compared to a study reported before where much higher clinical grades were found. In that study no dogs presented with Grade 1 signs, 21.3% with Grade 2 signs and 77.3% with Grade 3 signs (21). These differences in clinical presentation could reflect subjective differences in scoring clinical signs or could be due to true differences in study populations. However, the clinical scoring relies on owner assessment of clinical signs, which is inherently subjective and generally underestimates the true severity of disease (15). This problem further highlights the importance of establishing more objective scoring systems, such as those using whole-body plethysmography and assessing individual clinical parameters.

The pre-surgical grade of inspiratory efforts demonstrated significant differences between the three breeds included. The English Bulldog had significantly higher grades for inspiratory efforts than the French Bulldog, as did the Pug compared to the French Bulldog. This may indicate that English Bulldogs are more severely affected by BOAS or it may be related to owner's awareness of the problem with owners of English Bulldogs being more familiar with the airway problems in the breed. Additionally, English Bulldogs seem to suffer from much louder stertor compared to Pugs and French Bulldogs which may contribute to owner awareness. The rapidly increasing popularity of the Pug and French Bulldog may be accompanied by a relatively lower awareness of the problem in the latter breeds and underestimation of the severity of clinical signs (15).

The Poncet grade of respiratory signs (13), and the pre-surgical grade of inspiratory efforts were associated with surgical outcome in this study: higher grades were positively associated with an owner-perceived improvement following surgery. This is in contrast with a previous study that demonstrated post-surgical outcome was not influenced by age, breed or pre-surgery grade of respiratory tract signs (21). Although BOAS is far more complex than just stenotic nares and an overlong soft palate, our results indicate that even clinically severely affected dogs benefit from nares resection and staphylectomy, despite concurrent pathology. However, this result may also be due to the fact that improvement is easier to detect in more severely affected dogs when using subjective scoring systems. Also, the clinical sign 'inspiratory effort' may be difficult to interpret for some owners (26). Despite having its limitations, scoring individual signs makes it easier to establish the effects of surgery on them as some may not respond to surgery at all (syncope in the Poncet score for instance).

Many concurrent nasal, pharyngeal, laryngeal and tracheal factors, however, remain unchanged after surgery. Some of these factors have been evaluated before. For instance, all dogs in this study had some degree of stenosis of the nares. This appears high in comparison with percentages reported by (1,13,14,21), who reported lower frequencies of 77%, 85.2%, 84.9%, 42.5% and 58.1% respectively. An elongated soft palate was also found in 100% of dogs in this study whereas previous studies have reported lower frequencies ranging from 86.3% to 95.9% (1,3,13,14). This most likely reflects differences in subjective evaluation between surgeons and the lack of definite breed-specific criteria. In the author's opinion any degree of stenosis of the nares or overlap of the soft palate with the epiglottis in a brachycephalic dog with increased upper respiratory noise can be considered excessive. Also, this study was derived from a referral population, with one of the inclusion criteria being surgery. Therefore, all dogs in this study are likely to have more severe anatomical abnormalities and findings may therefore not reflect the brachycephalic population as a whole.

There were significant differences between breeds in grades of stenotic nares, narrowed laryngeal dimensions and craniofacial ratio. French Bulldogs had a higher grade of stenotic nares compared to English Bulldogs and Pugs had higher grades of narrowed laryngeal dimensions compared to both other breeds. English Bulldogs also had higher craniofacial ratios compared to both French Bulldogs and Pugs. A recent paper has shown significant differences in nasopharyngeal cross-sectional area between Pugs and French Bulldogs, with Pugs having significantly smaller nasopharyngeal cross-sectional area compared to French Bulldogs based on CT- scan imaging (27). Similarly, the results of our study suggest that laryngeal dimensions may also be breed specific. However, no difference in improvement following surgery among these breeds was found. This again is most likely related to the subjective postoperative assessment performed.

Nearly all (98.7%) dogs in this study had aberrant nasopharyngeal turbinates detected via CT imaging. This is comparable with previous reports where 100% of brachycephalic dogs were reported to have nasopharyngeal turbinate protrusion (5,6). No significant associations between degree of turbinate protrusion and outcome were identified in this study and the clinical significance of these aberrant turbinates therefore remains unclear.

Interestingly, this study showed that an increased degree of pharyngeal narrowing is significantly associated with a greater frequency of snoring, whereas an overlong soft palate alone was not. A study by Grand and Bureau showed that dogs with severe BOAS had significantly thicker soft palates compared to dogs with absent or minimal signs of BOAS, a factor we have incorporated in our pharyngeal dimensions score (28). Our study indicates that defining the degree of pharyngeal obstruction in a pharyngeal dimensions score is more closely associated with degree of snoring than evaluation of just the length of the soft palate. We introduced a scoring system for "narrowed pharyngeal dimensions" in this paper to more accurately reflect the pharyngeal obstruction seen in many brachycephalic animals. All animals included in this study showed a degree of pharyngeal narrowing, but no differences were found between the breeds, nor was the severity of pharyngeal narrowing a predictor of outcome after surgery. A larger study evaluating more animals may be necessary to demonstrate the significance of degree of narrowing of pharyngeal dimensions on outcome.

A similar scoring system for laryngeal abnormalities, beyond evaluation of laryngeal collapse alone, was introduced as well. Three degrees of narrowed laryngeal dimensions are proposed. While narrowing of the laryngeal dimensions are suggestive of laryngeal hypoplasia, histopathology would be required to confirm this. In addition, an acquired contribution to laryngeal narrowing from laryngomalacia as a result of gastroesophageal and gastropharyngeal reflux, could play a role as well. Some narrowed laryngeal dimensions were found in 96% of our animals. Whereas no significant association between degree of narrowed laryngeal dimensions and outcome after surgery was found in this study, the authors feel it is important to categorize abnormalities associated with brachycephaly in more detail for future studies in order to be able to compare results of different surgical techniques. Interestingly, there appeared to be a significant association between degree of narrowed laryngeal dimensions and snoring as well. The higher degree of narrowing, the less frequent the snoring was according to the owner. This may reflect a different type of airflow with higher velocity through the larynx and less vibration of the pharyngeal tissues or maybe a clinically insignificant association. Based on the significant correlations found for pharyngeal narrowing and laryngeal narrowing though, it appears to be important to categorize abnormalities in more detail for future studies in order to be able to compare results of different surgical techniques.

Seventy-six percent of dogs in this study had Grade 1 laryngeal collapse, the other 24% a higher degree. These findings are comparable with previous studies that reported an incidence of laryngeal saccule eversion (grade 1 collapse) ranging from 43% to 66% (1,3,13,14,21,26). No significant correlations between degree of collapse and any of the other parameters, nor with outcome, were found. This is in contrast with a recent study using objective outcome measures (whole-body plethysmography), that showed that presence of Grade 2 or 3 laryngeal collapse was associated with a poorer outcome following surgery (22). Tracheal hypoplasia was not separately assessed in this study. Whereas, especially in English Bulldogs, this undoubtedly has contributed to the degree of respiratory compromise, a previous study indicated that tracheal hypoplasia did not influence post-surgical outcome (3).

Clinical signs of BOAS in brachycephalic dogs have long since been attributed to their skull confirmation, specifically facial length. However, only one study has confirmed the association between facial or muzzle length and severity of BOAS signs (29). All dogs in our study presented for clinical signs of BOAS and it is interesting to note that all dogs had a craniofacial ratio of 0.5 or less, supporting the findings of Packer et al in that dogs showing clinical signs of BOAS have a shorter relative muzzle length. It is important to note though that in Packer's study a random population was used whereas we only analysed animals referred for respiratory disease. Also, our measurements were CT-derived, whereas Packer measured external landmarks. Craniofacial ratio's smaller than 0.5 in our study did not appear to be associated with an increase in clinical signs or a decrease in improvement after surgery. Smaller craniofacial ratios also did not seem to be associated with an increase in nasopharyngeal turbinate protrusion or narrowed pharyngeal dimensions.

In this study, a wide arch-shaped sharp cut and sew technique was used for the staphylectomy. Many different techniques for palate resection have been reported, but differences in outcome between techniques have yet to be demonstrated (3). All dogs included in this study, survived to a minimum 6 week follow up period. Of the cases initially analysed, only one dog didn't survive to discharge indicating a peri-operative mortality rate of 0.89%. This is lower than previously reported mortality rates, 3.3% (21) and 3.2% (3) for palatoplasty, rhinoplasty +/- sacculectomy. The peri-operative mortality for dogs undergoing

LATE in addition to rhinoplasty and palatoplasty was described as 1.6% in one study (30). Whether this reflects differences in techniques used or peri-operative care is unclear.

While many surgeons would consider sacculectomy "standard" treatment for animals suffering from BOAS, sacculectomy was not performed on any of the dogs in our study. Currently, there is no veterinary literature to support this procedure being beneficial in the clinical setting and the need for routine sacculectomy has been questioned before (21). Furthermore, perioperative morbidity appears to be increased with this procedure (24). Whereas one study reported that laryngeal saccule regression did not occur following correction of nares and soft palate (31), the actual contribution to airway signs of everted saccules still needs to be established.

Limitations of this study include its retrospective nature. The reproducibility of the laryngeal and pharyngeal scoring system due to its subjectivity is also a concern. Furthermore, the still relatively small patient numbers imply that these results must be interpreted with caution. The follow-up time used in this study was also variable and the shortest follow-up time of 6-weeks may not be sufficient to assess outcome. The method used to assess post-surgical improvement in this study remains subjective. Owner based questionnaires have several limitations like the necessity of owners to be able to recall pertinent information, influence of the placebo and placebo-by-proxy effect and the necessity of owners to be able to interpret certain clinical signs as abnormal and perceive their clinical significance. It is known that owners of brachycephalic dogs often perceive snoring and abnormal respiratory noise as acceptable for the breed (14,16). While whole body plethysmography has been used to objectively evaluate outcomes following surgery (22), methods that are easier to use in a clinical setting, such as the recently validated exercise tolerance test must be considered (32). Studies evaluating differences between breeds as well as further validation of the proposed scoring schemes are also needed.

This study suggests that brachycephalic dogs affected with BOAS show a significant improvement in respiratory tract signs after rhinoplasty and palatoplasty alone. However, recent work using whole-body plethysmography suggests that despite an improvement, many dogs still remain clinically affected (22). Similarly, even though 70% of dogs in our study showed improvement this does not mean they were clinically normal or that additional improvement could not be achieved with further surgical procedures. None of the anatomical factors assessed in this study nor any patient signalment details were found to be predictors of outcome following surgery. However, the degree of improvement was associated with the severity of inspiratory efforts at presentation. This study proposes the use of scoring systems for pharyngeal dimensions and laryngeal narrowing for more complete evaluation of brachycephaly-associated abnormalities in the throat. However, further work is needed to validate the proposed scoring systems.

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Figure legends

Figure 1: Schematic drawing illustrating the grading of stenosis of the nares. Grades 0 to 3 are illustrated from left to right.

Figure 2: Schematic drawing illustrating the grading of the degree of pharyngeal narrowing Grades 0 to 3 are illustrated from left to right.

Figure 3: Schematic drawing illustrating the grading of the narrowed laryngeal dimensions. Grades 0 to 3 are illustrated from left to right.

Figure 4: A mid-sagittal CT scan image of the skull demonstrating the measurements used for calculation of the craniofacial ratio. The length A represents cranial length (nasion to inion) and the length B represents the facial length (prosthion to nasion).

Figure 5: Pre-surgery respiratory tract signs graded by a modified Poncet-Dupre score

Figure 6: Summary of diagnostic findings from pharyngolaryngoscopy and CT scan in dogs prior to surgery

Figure 7: Moderate degree of pharyngeal narrowing

Figure 8: Severe degree of pharyngeal narrowing

Figure 9: Post-surgery respiratory tract signs graded by a modified Poncet-Dupre score

Tables

Table 1: Definition of the classification system for abnormalities of the nose in brachycephalic dogs (6)

	Grade 0	Grade 1 (mild)	Grade 2 (moderate)	Grade 3 (severe)	Grade 4
Stenotic nares	Normal nose	Mild stenosis of the nares (narrowing of the nostril by <25%)	Moderate stenosis of the nares (narrowing of the nostril between 25-50%)	Severe stenosis of the nares (narrowing of the nostril >50%)	
Nasopharyngeal turbinate protrusion	No turbinates visible in the ventral nasal meatus	Turbinates visible in the ventral nasal meatus, but not extending into the nasopharyngeal meatus	Turbinates visible in nasopharyngeal meatus, but not extending through the choanae	Turbinates visible in the choanae but not extending caudal to the caudal border of the nasal septum (vomer) that is the rostral opening of the nasopharynx	Turbinates visible in the nasopharynx

Table 2: Definition of the classification system for abnormalities of the pharynx in brachycephalic dogs.

		Grade 0	Grade 1 (mild)	Grade 2 (moderate)	Grade 3 (severe)
Overlong soft palate		normal	extension < 5mm over tip of epiglottis	Extension >5 and <10mm over tip of epiglottis	Extension > 10mm over tip of epiglottis
Narrowed Pharyngeal Dimensions					
	Dorsoventral flattening	Normal (complete circle of space present)	Mild oval-shaped flattening of the oropharynx (up to 20%)	Moderate flattening of the oropharynx (between 20-40%)	Severe flattening and narrowing of the oropharynx (>40%)
	Thickness of base of tongue	Normal tongue	Mild thickening; tongue base slightly round, epiglottis visible without need to press tongue down	Moderate thickening; moderately rounded base of tongue that obscures epiglottis in resting position	Severe thickening; severe thickening of base of the tongue leading to significant obstruction of caudal oropharynx and difficulty visualizing the larynx even with use of laryngoscope
	Tonsillar protrusion	No protrusion	Less than half the tonsil is visible from its crypt	Complete tonsil protruded from crypt but no enlargement	Complete protrusion of tonsils from crypt with enlargement
	Diffuse pharyngeal oedema	No mucosal thickening	Mild thickening of the mucosal lining present in all areas including the soft palate	More significant thickening of the mucosal lining leading to an irregular appearance	Severe thickening of the mucosa leading to a ‘wrinkly’ appearance

Table 3: Definition of the classification system for laryngeal abnormalities in brachycephalic dogs

	Grade 0	Grade 1 (mild)	Grade 2 (moderate)	Grade 3 (severe)
Laryngeal hypoplasia	Normally developed larynx of size fitting the size and weight of the animal	Mild hypoplasia of the arytenoid cartilages (reduction in laryngeal size up to 20%). Mild thickening of laryngeal mucosa	Moderate hypoplasia of the arytenoid cartilages (reduction in laryngeal size between 20-40%). Marked thickening of laryngeal mucosa	Severe hypoplasia of the arytenoid cartilages (>40% reduction in laryngeal size)
Laryngeal collapse	No collapse	Eversion of laryngeal saccules	Loss of rigidity and medial displacement of the cuneiform processes of the arytenoid cartilages	Collapse of the corniculate processes of the arytenoid cartilages