Brachycephalic Airway Syndrome: Pathophysiology and Diagnosis

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Abstract: Brachycephalic airway syndrome (BAS) is a group of abnormalities that result in upper airway obstruction. Primary malformations include stenotic nares, elongated soft palate, and hypoplastic trachea, which cause an increase in negative pressure within the upper airways that can eventually lead to secondary abnormalities such as everted laryngeal saccules, everted tonsils, and laryngeal and tracheal collapse. Abnormal nasopharyngeal turbinates are also encountered, but have not been classified as primary or secondary. BAS is readily diagnosed, and quality of life is improved with appropriate medical and/or surgical management.

In brachycephalic breeds, the lower jaw is of normal length, but the upper jaw is much shorter in proportion to body size than normal. This is a result of early ankylosis of the basicranial epiphyseal cartilage, leading to a shortened longitudinal skull axis. All of the associated oral tissues are still present in the shortened maxilla; however, they are compressed into a smaller area, resulting in a narrowed upper respiratory tract lumen and increased airway resistance. Brachycephalic airway syndrome (BAS) refers to a group of upper respiratory tract abnormalities that can include stenotic nares, an elongated soft palate, and tracheal hypoplasia. Abnormal nasopharyngeal turbinates, or nasal turbinates that extend caudally into the nasopharynx from the choanae, have also been observed in brachycephalic dogs and cats with upper airway disease. These abnormalities lead to secondary changes, including mucosal edema, everted laryngeal sacculles, laryngeal collapse, and tonsil eversion. In affected dogs, airway resistance and inspiratory effort increase, leading to increased negative pressure and air turbulence, which cause mucosal inflammation and edema. Excessive negative pressure also everts laryngeal sacculles and weakens laryngeal cartilages, further obstructing the laryngeal lumen. Other abnormalities that may be associated with BAS include a hyperplastic tongue and gastrointestinal (GI) abnormalities.

Anatomy
The nares comprise the alae, or wings, as well as the dorsal lateral nasal cartilages, the ventral lateral nasal cartilages, and the accessory cartilages (FIGURE 1). The wings of the nares contain maxillary levator labii and nasolabial levator muscle fibers, allowing them to be maneuvered and widened. The nasal cavities house the dorsal, ventral, and ethmoid conchae, which form the common nasal, dorsal, middle, and ventral meatuses that house the nasal turbinates. These meatuses form the nasopharyngeal ducts and terminate as caudal choanae (FIGURE 2).

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The size and shape of the choanae determine the path of airflow through the nasal cavities.¹ Air travels through the ventral and middle meatuses toward the nasopharynx during inspiration.³ A strong inspiratory effort allows the dorsal meatus to become involved and the olfactory epithelium to be stimulated.¹ On expiration, air flows past the caudal choanae, through all the meatuses, and out of the respiratory tract.¹ In nonbrachycephalic animals, airflow through the nasal cavities is responsible for 76.5% of total airflow resistance; the larynx contributes 4.5%, and the bronchi and bronchioli contribute 19%.¹,³ These values do not differ significantly between inspiration and expiration.¹ Nasal cavity resistance increases up to 80% when the airflow is increased.¹ In brachycephalic breeds, resistance to airflow is affected by the narrowed airway, which causes an increase in the intraluminal pressure gradient during inspiration.¹ When this pressure is excessively greater than the atmospheric pressure, the tissues become inflamed, taut, and laryngeal saccules evert, and the cartilaginous larynx and trachea become compromised and can collapse, decreasing the tracheal luminal size and further increasing resistance to airflow.¹,³ This increased resistance causes turbulent airflow, edema, and, thus, inspiratory noise.¹,²⁵

Panting also increases airflow turbulence within the narrowed airway lumen, leading to inflammation and subsequent swelling of the airways.¹⁴ This, in turn, results in obstruction, distress, and potential overheating.¹⁸ For this reason, avoidance of heat, humidity, and excessive activity or excitement is important for brachycephalic breeds.¹⁸

GI lesions have been recognized in some dogs with BAS. At this time, the relationship between these lesions and the respiratory signs of BAS is unknown.²⁴,²⁶,²⁷ It has been hypothesized that (1) an abnormal inspiratory effort results in low negative intrathoracic pressure, which could be sufficient to worsen or even cause a hialtal hernia and gastroesophageal reflux; (2) gastroesophageal disorders, including pylial, regurgitation, vomiting, and gastroesophageal reflux, exacerbate the respiratory signs through further impairment of the pharyngeal region, resulting in persistent inflammation; or (3) chronic respiratory depression leads to gastroesophageal reflux.²⁴,²⁶ One study²⁸ evaluated 30 brachycephalic dogs with BAS and digestive disorders and found that 25 dogs (83%) had concurrent esophagitis, most commonly located in the distal third of the thoracic esophagus; some dogs, however, had esophagitis throughout the entire thoracic esophagus. Another study²⁹ evaluated 73 brachycephalic dogs that presented with upper respiratory signs and found that 71 dogs (97.3%) had esophageal, gastric, or duodenal abnormalities. A third study³⁰ found that 98% of examined brachycephalic dogs with BAS had histologic evidence of chronic gastritis. It has been concluded that there is a correlation between the severity of GI signs and respiratory signs among dogs with BAS.³¹

History and Clinical Signs

Typical clinical signs of BAS include stertor, stridor, inspiratory dyspnea, increased respiratory effort, exercise intolerance, vomiting and/or regurgitation, salivation, and, in severe cases, syncope.¹,²,³,⁴,⁶,⁸,¹²,¹⁴ Another common clinical sign is hyperthermia due to the patient’s inability to cool itself efficiently, making it prone to heat stress.¹⁶,¹⁸ BAS is usually diagnosed in dogs aged 2 or 3 years; however, puppies younger than 6 months have been diagnosed with BAS and severe secondary laryngeal changes, demonstrating the need to evaluate immature brachycephalic dogs.¹¹ Additionally, males are typically represented more than females.⁵,⁵,¹¹

Signs of respiratory distress may be mild, moderate, or severe. Animals that present in mild respiratory distress have pink mucous membranes, a normal attitude or restlessness when disturbed, and normal posture.¹⁶ Animals that present in moderate respiratory distress have pink mucous membranes, are anxious and restless when undisturbed, and occasionally demonstrate abduced elbows.¹⁶ Animals that present in severe respiratory distress may have pale, dusky, or cyanotic mucous membranes; can be disoriented, obtunded, or semicomatose; and have abduced elbows with a generalized use of accessory abdominal musculature.¹⁶

Diagnosis

BAS abnormalities are often tentatively diagnosed when the dog is first heard and examined. Definitive diagnosis is based on the history, physical examination, diagnostic imaging, blood gas analysis, and upper airway and GI endoscopy findings.⁴,⁵,⁶,¹²,¹⁸ Plethysmography and tidal flow volume loops have been used in
research settings to further evaluate BAS and how obstruction affects respiration.1,3,4,6,17,21 Early diagnosis of BAS is beneficial because surgical intervention to improve airflow can minimize the progression of secondary changes.4,5,6,16,18,22

**Physical Examination Findings**

Stenotic nares are easily diagnosed by visualizing the malformed dorsolateral cartilages.5,7,16,21 Thoracic auscultation is impaired by referred upper respiratory noise, which obscures lower airway sounds and limits evaluation of the lungs, but mild to moderate tachycardia and tachypnea have been reported.10,13 Mucous membrane color can be assessed, along with general posture, respiratory pattern, and employment of accessory muscles.16

**Radiographic Findings**

Thoracic radiography is recommended for evaluation of lower airway disease, including tracheal hypoplasia, cardiac, and pulmonary abnormalities (i.e., aspiration pneumonia and noncardiogenic pulmonary edema).5,7,18,21 Noncardiogenic pulmonary edema and aspiration pneumonia should be treated preoperatively to reduce the anesthetic risk and postoperatively to aid in recovery.5,7,18,21 On a properly positioned lateral neck and thoracic radiograph, the distance from the thoracic inlet (TI) at the ventral aspect of the vertebral column at the midpoint of the first rib to the inner surface of the manubrium at its narrowest point is the TI measurement5,18,21 (FIGURE 3). The diameter of the tracheal lumen perpendicular to the long axis of the trachea where the TI line intersects the midpoint of the tracheal lumen provides the tracheal diameter (TD) measurement.5,21 When the TD:TI ratio on a lateral thoracic radiograph is <0.16, the trachea is considered to be hypoplastic.1,6,16,21 This measurement is not influenced by phase of respiration.21 The TD can also be assessed by measuring the diameter of the thoracic trachea at the third rib and the diameter of the third rib at this site.21 If the TD is three times the width of the third rib, it is considered normal.21

**Blood Gas Analysis**

Arterial blood gas analysis is important when evaluating BAS patients because it provides information that will direct treatment (i.e., oxygen supplementation).13,18 If an arterial blood gas sample cannot be obtained, a venous sample can be used to provide the pH and bicarbonate levels and partial pressure of carbon dioxide, or pulse oximetry can be employed as an indirect method of gaining information on oxygen saturation to determine the need for supplemental oxygen.13,18 Blood gas levels may be normal in stable patients.18 Animals may suffer from syncope and collapse when the oxygen saturation falls acutely below 80%; these patients benefit from immediate intervention with oxygen support.18

**Upper Airway Endoscopy**

Endoscopic visualization is the best means of identifying abnormalities associated with BAS. A complete and thorough examination of the upper airway is performed under anesthesia before surgery.21,13,18 An elongated soft palate, everted laryngeal sacculae, laryngeal collapse, everted tonsils, and nasopharyngeal turbinates can all be diagnosed endoscopically.1,4,6,7,8,11,17,20,21 In one study,17 partial collapse of the left mainstem bronchus was a finding in 70% of dogs with BAS; this finding has not been previously described as a component of BAS.

**Gastrointestinal Endoscopy**

Performing esophagoscope and gastroduodenoscopy may reveal concurrent abnormalities in the GI tract, even in dogs not exhibiting clinical signs of digestive disorders.24 Lesions and physiologic abnormalities have been found in the esophagus, stomach, and duodenum, including esophagitis, esophageal deviation, cardiac atony, gastroesophageal reflux, axial hiatal hernia, gastric stasis, mucosal hyperplasia of the pylorus, pyloric stenosis, pyloric atony, inflammation of the corpus or antrum, and diffuse inflammation of the duodenum.24–26

**Conclusion**

BAS can be diagnosed and successfully managed with knowledge of the abnormalities and treatment options. Animals that have BAS can lead a more normal life with medical and surgical management.

**References**


1. Which is not considered a primary BAS abnormality?
   a. hypoplastic trachea
   b. everted laryngeal saccules
   c. stenotic nares
   d. elongated soft palate

2. Which of the following measurements is considered indicative of a hypoplastic trachea?
   a. a TD that is three times the width of the second rib
   b. a TI:TD of 0.13 on a ventrodorsal thoracic radiograph
   c. a TD:TI of <0.16 on a lateral thoracic radiograph
   d. a TD that is twice the width of the third rib

3. The narrowest area(s) of the upper airway is/are the
   a. conchae.
   b. meatuses.
   c. choanae.
   d. rima glottis.

4. Nasal cavity resistance increases up to ____ when airflow is increased.
   a. 19%
   b. 50%
   c. 76.5%
   d. 80%

5. Endoscopic evaluation is the best means of identifying
   a. an elongated soft palate.
   b. everted laryngeal saccules.
   c. nasopharyngeal turbinates.
   d. all of the above

6. In nonbrachycephalic breeds, the soft palate normally extends
   a. to the front of the tip of the epiglottis.
   b. just past the tip of the epiglottis.
   c. beyond the epiglottis.
   d. to the last molar.

7. If oxygen saturation falls acutely below ____, animals may suffer from syncope and collapse.
   a. 60%
   b. 80%
   c. 88%
   d. 95%

8. GI lesions have been found in the ___________ of brachycephalic dogs.
   a. esophagus, stomach, and jejunum
   b. pharynx, stomach, and jejunum
   c. esophagus, stomach, and duodenum
   d. pharynx, stomach, and duodenum

9. Which GI conditions have been found in brachycephalic dogs?
   a. hiatal hernia
   b. gastroesophageal reflux
   c. esophagitis
   d. all of the above

10. The size and shape of the __________ determine the path of airflow through the nasal cavities.
   a. ventral and middle meatuses
   b. conchae
   c. nares
   d. choanae