AUSTRALIAN VETERINARY JOURNAL
AUSTRALIA'S PREMIER VETERINARY SCIENCE TEXT
SMALL ANIMALS

ORIGINAL ARTICLE

Brachycephalic airway syndrome: management of post-operative respiratory complications in 248 dogs

B Lindsay,[†,*] D Cook, J-M Wetzel, S Siess and P Moses

SMALL ANIMALS

Objective As ownership of brachycephalic dog breeds rises, the surgical correction of components of brachycephalic airway syndrome (BAS) is increasingly recommended by veterinarians. This study's objective was to describe the incidence of, and strategies for the management of post-operative respiratory complications in brachycephalic dogs undergoing surgical correction of one or more components of BAS.

Methods Medical records of 248 brachycephalic dogs treated surgically for BAS were retrospectively reviewed for demographic information, procedures performed, post-operative complications and treatment implemented, hospitalisation time, and necessity for further surgery.

Results Pugs, Cavalier King Charles Spaniels and British Bulldogs were the most commonly encountered breeds. Dogs which experienced a complication were significantly older (mean was 5.5 years, compared with 4.1 years [$P < 0.01$]). Fifty-eight dogs (23.4%) had complications which included: dyspnoea managed with supplemental oxygen alone (7.3%, n = 18), dyspnoea requiring anaesthesia and re-intubation (8.9%, n = 22), dyspnoea necessitating treatment with a temporary tracheostomy (8.9%, n = 22), aspiration pneumonia (4%, n = 10), and respiratory or cardiac arrest (2.4%, n = 6). Five of the 22 dogs requiring anaesthesia and re-intubation deteriorated 12 or more hours after post-surgical anaesthetic recovery. The overall mortality rate in this study was 2.4% (n = 6). Age, concurrent airway pathology, and emergency presentation significantly predicted post-operative complications.

Conclusion Our data show the importance of close monitoring for a minimum of 24 h following surgery by an experienced veterinarian or veterinary technician. Surgical intervention for BAS symptomatic dogs should be considered at an earlier age as an elective procedure, to reduce the risk of post-operative complications.

Keywords airway obstruction; dogs; dyspnoea; post-operative complications

Abbreviations BAS, brachycephalic airway syndrome; CKCS, Cavalier King Charles Spaniel

Aust Vet J 2020;98:173–180 doi: 10.1111/avj.12926

*Corresponding author. drbarbaralindsay@gmail.com
[†]**Present address:** Center for Veterinary Specialty + Emergency Care, 2700 Lake Vista Drive, Lewisville, Texas 75067.
Part of this work was presented in abstract form at the Australian and New Zealand College of Veterinary Scientists Science week, Gold Coast, Queensland, Australia, July 2013.
Department of Neurology, Veterinary Specialist Services, Underwood, Queensland, 4119, Australia; drbarbaralindsay@gmail.com

Brachycephalic airway syndrome (BAS) describes a combination of anatomical abnormalities which cause upper respiratory tract obstruction in brachycephalic dogs. Commonly affected breeds include British Bulldogs, Boston Terriers, Pugs and Pekingese.[1–3] Cavalier King Charles Spaniels (CKCSs) are over represented in the UK and Australia.[4,5] Shortened maxillary morphology in brachycephalic dogs contributes to the primary components of BAS which include stenotic nares, elongated soft palate, abnormal nasopharyngeal turbinate morphology, hypoplastic trachea and redundant pharyngeal folds.[4,6,7] Increased airway resistance and airflow turbulence leads to mucosal inflammation and development of secondary BAS changes; everted laryngeal saccules, laryngeal collapse, bronchial collapse and tonsillar hyperplasia.[1,4,7–10]

Concurrent abnormalities also seen in brachycephalic dogs include abnormal respiratory patterns,[11] gastrointestinal abnormalities including hiatal hernia, pyloric stenosis, gastritis, regurgitation and vomiting[12] as well as ophthalmologic and dental malformations.[1,4,8,9,12–14] Compared with mesocephalic or dolichocephalic dogs, brachycephalic dogs have been reported to have decreased arterial oxygen saturation, increased arterial carbon dioxide levels, hypertension and elevated packed red cell volume.[15]

Stertor or stridor, snoring, excessive panting, exercise intolerance and gastrointestinal signs such as gagging, vomiting or regurgitation are common clinical signs of BAS[4] which may progress to dyspnoea, hyperthermia, cyanosis, syncope or collapse when severe.[1,9] Oxygen therapy, active cooling if hyperthermic, anti-inflammatories, sedation and cage rest are the recommended conservative treatment options for acute respiratory distress.[4,9] In severe cases, it may be necessary to bypass the upper respiratory tract via endotracheal intubation or placement of a temporary tracheostomy tube to allow effective oxygenation and ventilation.

BAS surgery is advised to reduce the degree of upper respiratory tract obstruction. Options include staphylectomy, alarplasty, resection of everted laryngeal saccules and excision of hyperplastic tonsillar tissue. Previous reports have discussed the favourable long-term results of surgery for brachycephalic airway disease.[1,3,4,9,14,16–18]

Complications described following BAS surgery include respiratory distress, pharyngeal oedema, post-operative haemorrhage, regurgitation, aspiration pneumonia and death.[1,2,4,9,14,19,20] Major complications (death or requirement for upper airway bypass) have been reported to range from 0% to 6.8%.[1,4,5,9,14,18,19,21] The management of complications has not been reported in detail previously. This report aims to describe the incidence of and a strategy for the management of post-operative respiratory complications in brachycephalic dogs undergoing surgical correction of one or more components of BAS.

Materials and methods

Medical records from a multi-site private veterinary specialty hospital were examined from January 2001 until December 2012 to identify brachycephalic dogs who had at least one primary component of BAS surgically treated. Cases included dogs who had elective surgery and those who presented in acute respiratory distress.

Information collected included demographic information, procedures performed, post-operative complications and treatment implemented, hospitalisation time, and necessity for further surgery. Concurrent airway and non-airway pathology was also recorded. Dogs were removed from the study if they were not a brachycephalic breed or if they did not have primary BAS surgically treated components. Hospitalisation time was not evaluated for dogs that underwent a second, non-related procedure while in hospital.

Diagnosis of BAS components was made based on signalment, presenting signs, physical examination, and oropharyngeal and laryngeal exam following induction of anaesthesia. Assessment was undertaken after induction of anaesthesia but prior to intubation in order to assess laryngeal morphology and function before a surgical plane of anaesthesia was reached.

Prior to anaesthesia, food and water were withheld for 12 h. Thoracic radiographs prior to surgery were taken to assess tracheal size and the presence of aspiration pneumonia. Dogs were premedicated with intramuscular or subcutaneous methadone (0.3 mg/kg) then pre-oxygenated immediately prior to anaesthetic induction. Intravenous anaesthetic induction agents used were thiopentone (8–12 mg/kg) (in earlier cases), alfaxalone (2 mg/kg) or propofol (4 mg/kg) each given to effect. Prior to intubation, the soft palate and tonsils were examined, the larynx was assessed and if laryngeal collapse was present, it was assigned a stage from 0 to 3.[10] Dogs were intubated with a cuffed endotracheal tube and maintained on isoflurane in 100% oxygen for the remainder of the anaesthetic. Dogs were positioned in sternal recumbency and a tape sling positioned around the upper canines that was held by an assistant to keep the head in an elevated position. Prior to surgical intervention, bupivicaine was applied as a local analgesic splash block in the caudal pharynx (up to 2 mg/kg).

Stenotic nares were corrected using a vertical wedge resection technique.[22] Staphylectomy was performed using sharp dissection; the palate was typically resected at a level cranial to the caudal border of the tonsillar crypt by a distance of a third the length of the crypt. Cut mucosal edges were opposed using a synthetic, absorbable, monofilament suture in a simple interrupted pattern (5–0 poliglecaprone 25). The endotracheal tube was removed for sacculectomy if required and then replaced prior to recovery. Everted laryngeal saccules were grasped and amputated using Metzenbaum scissors. Enlarged tonsils were grasped with Debakey forceps and withdrawn from their crypts, a mosquito hemostat was applied to the base of the tonsil and left for 5 min. The tonsillar tissue was then sharply excised with Metzenbaum scissors. Haemorrhage was addressed by suturing with 4–0 or 5–0 poliglecaprone 25.[23–25]

For dogs which presented with a tracheostomy in place, the tracheal stoma and tube were assessed and the stoma surgically revised or tube replaced if needed. The upper airway structures were subsequently reviewed under anaesthesia prior to surgical treatment. For some dogs judged to be high risk of developing post-operative upper respiratory obstruction, a tracheostomy tube was placed before recovery. High-risk dogs included emergency patients such as dogs transported from other clinics intubated or those who presented in acute respiratory distress, dogs who had evidence of aspiration pneumonia before surgery or if severe pharyngeal oedema was noted at the end of surgery.

Following completion of surgery, dogs were transferred to an intensive care unit to recover from anaesthesia. Dogs were placed in sternal recumbency and remained intubated for as long as possible while being supplemented with oxygen via an oxygen line into the endotracheal tube. After recovery, dogs were closely monitored in a quiet environment for at least 24 h. Analgesia was achieved using methadone (0.1–0.3 mg/kg subcutaneously every 4 h) or fentanyl (2–5 μg/kg/h intravenously as a constant rate infusion) until dogs were able to tolerate oral analgesia. Acepromazine was used judiciously for sedation (0.01–0.03 mg/kg subcutaneously or intravenously) if required. Dogs received isotonic crystalloid intravenous fluid therapy during surgery (10 mL/kg/h) and recovery (2–4 mL/kg/h) until the dog was eating and drinking appropriately. Water was withheld for 12 h following surgery and until the animal's respiratory effort was stable. Soft food was offered only after a successful water trial. Dogs with normal appetite were discharged with oral amoxicillin-clavulanic acid (10–15 mg/kg q12h) and tramadol (2–4 mg/kg q8–12h), with or without a non-steroidal anti-inflammatory at the attending surgeon's discretion (meloxicam; 0.1 mg/kg q24h or carprofen; 2.2 mg/kg q12h).

Complications were defined as dyspnoea requiring oxygen therapy or more intensive care, development of respiratory or cardiac arrest, or development of aspiration pneumonia in the post-operative period.

During recovery, patients were monitored for dyspnoea. Dyspnoea was assessed by evaluating the dog's respiratory rate and effort, pulse oximetry and/or arterial blood gas measurements (partial oxygen pressure). If the dog developed dyspnoea that did not improve with administration of analgesic, sedative or anxiolytic medication, then supplemental oxygen was supplied via flow-by oxygen, placing the dog in an oxygen cage, or placing nasal oxygen lines. The method for supplementing oxygen was made by the clinician on an individual patient basis. Determining factors included: the demeanour of the patient (for example some patients may not tolerate a flow-by mask and did better in an oxygen cage), the size of the patient (for example larger dogs may better tolerate nasal oxygen lines), response to initial oxygen therapy and estimated time oxygen would be required for.

If dyspnoea was unresponsive to supplemental oxygen, dogs were anaesthetised using propofol, the pharynx was assessed and then the dog was reintubated. Any haemorrhage was controlled with hemostat application and ligation with 4–0 poliglecaprone 25 or by applying pressure using a surgical gauze sponge until bleeding ceased. Dogs which were dyspnoeic on initial recovery due to anxiety were re-anaesthetised and kept under a very light plane of anaesthetic for a further 2–4 h and slowly recovered from anaesthesia. If dyspnoea was due to pharyngeal swelling, the dog remained intubated and maintained on continuous intravenous anaesthetic (propofol 3.5–10 mg/kg/h and midazolam 0.25–1 mg/kg/h after initial loading dose 0.1 mg/kg). Dogs were also given a single dose of corticosteroid (dexamethasone 0.1 mg/kg subcutaneously) and the pharynx was packed with mannitol-soaked gauze swabs in the oropharynx to help decrease tissue oedema. The dogs were kept under a light plane of anaesthesia so that spontaneous ventilation continued. Monitoring was via clinical signs of anaesthetic depth (eye position, palpebral reflex and response to stimuli), heart rate and rhythm, blood pressure, pulse oximetry, capnography and arterial blood gas measurement. Dogs with severe pharyngeal oedema were kept anaesthetised for up to 72 h with assessment of the oropharynx every 3–4 h. Extubation was attempted when oedema had decreased, by a gradual reduction of constant rate infusion. Nasal oxygen supplementation or flow-by oxygen was continued as required following extubation. A temporary tracheostomy was performed if multiple extubation attempts were unsuccessful. The specific number of attempts varied between dogs.

Aspiration pneumonia was diagnosed in patients with deteriorating oxygenation despite adequate ventilation, using thoracic auscultation in conjunction with findings of thoracic radiography. Treatment was broad-spectrum antibiotic therapy (cefazolin 22 mg/kg intravenously q8h, enrofloxacin 5–10 mg/kg subcutaneously q24h and metronidazole 10 mg/kg intravenously q12h).

Dogs which went into respiratory or cardiac arrest were resuscitated following the current cardiopulmonary resuscitation guidelines available at that time,[26] with most dogs receiving a combination of adrenaline, atropine, endotracheal intubation with manual ventilation, and external thoracic compressions. Owners were notified and had the option of euthanasia if they did not wish to proceed with resuscitation.

Statistical analysis was performed using commercially available statistic software (Graph Pad Prism 5 for Windows, Version 5.03, GraphPad Software, Inc. San Diego, CA, USA, and IBM SPSS Statistics 23, IBM Corp, 2015, Armonk, NY, USA). Data were analysed for normality using a D'Agostino normality test. Comparisons for normal data were made using a two-tailed t-test, or where data were not normally distributed a Mann-Whitney U test was used. Comparisons between where complications occurred and cases where complications did not occur, and the procedures performed were made using χ^2 contingency tables. Fisher's exact test was used for comparisons of mortality between elective and emergency cases as well as the relationship between vomiting or regurgitation and the occurrence of respiratory complications. Findings were considered significant if $P < 0.05$. In order to determine the effects of age, non-airway pathology, other airway pathology, emergency presentation, everted saccule surgery, tonsillectomy and stenotic nares surgery on the likelihood that patients develop post-operative complications, a direct logistic regression was performed.

Results

There were 248 dogs included in the study (120 [48.4%] male and 128 [51.6%] females). The predominant breeds represented were Pugs (n = 44, [17.7%]), CKCS (n = 42, [16.9%]) and British Bulldogs (n = 31, [12.5%]); other breeds frequently represented were the Staffordshire Bull Terrier (n = 19, [7.7%]), French Bulldog (n = 13, [5.2%]) and Shih Tzu (n = 13, [5.2%]).

Table 1. **Number (%) of dogs with various components of brachycephalic airway syndrome treated surgically**

	Number of dogs
Elongated soft palate	242 (97.6%)
Hyperplastic tonsillar tissue	106 (42.7%)
Everted saccules	103 (41.5%)
Stenotic nares	97 (39.1%)

Age ranged from 31 days to 15.8 years (mean = 4.4 years, SD = 3.36). British Bulldogs presented significantly earlier for surgery compared with the rest of the population (mean age 1.97 years, SD = 1.93 [$P < 0.001$]). CKCSs were found to present significantly older than the rest of the population (mean age 5.8 years, SD = 2.3 [$P < 0.001$]). Dogs which experienced a complication were significantly older than cases where complications did not occur (mean = 5.5 years, SD = 3.56 compared with 4.1 years, SD = 3.24 ($P < 0.01$)).

The mean weight of dogs at the time of surgery was 11.8 kg (SD = 7.54) (the precise weight of 14 dogs was unable to be located). When comparing breed weight averages of British Bulldogs, CKCS or Pugs, there was no significant difference in weight when comparing cases where complications occurred and cases which did not have complications.

Elongated soft palate was the most common abnormality identified and treated surgically (Table 1). The mean number of abnormalities treated was 2.2 (range 1–4) (Table 2). There was no relationship found between the number of procedures performed and the occurrence of complications.

There were 47 dogs that also had concurrent airway pathology with the majority having varying grades of laryngeal collapse (n = 16) and tracheal collapse (n = 15). Other types of airway disease included epiglottal or periepiglottal masses, laryngeal paralysis, tracheal hypoplasia or lower airway disease.

Of the 248 dogs in the study, 190 recovered without complications while 58 dogs (23.4%) had complications. Eighteen dogs (7.3%) were treated with supplemental oxygen alone for dyspnoea (and did not require intubation or tracheostomy, or did not develop aspiration pneumonia). Nasal oxygen catheters were the most common method of supplementing oxygen in all the cases requiring it, (n = 17). Duration of oxygen supplementation ranged from 30 min to 144 h (mean = 19.86 hours, SD = 41.97) (the time of oxygen supplementation was not recorded for five patients).

Table 2. **Number (%) of dogs with the number of surgically treatable brachycephalic airway syndrome abnormalities present**

Number of abnormalities	Number of dogs
One abnormality	63 (25.4%)
Two abnormalities	97 (39.1%)
Three abnormalities	61 (24.6%)
Four abnormalities	27 (10.9%)

Table 3. Summary of aspiration pneumonia cases

Aspiration pneumonia	Initial treatment	Outcome
Aspiration pneumonia present prior to surgery (n = 4)	Pre-emptive temporary tracheostomy (n = 2)	No other complications (Australian bulldog and a pug)
	Presented in respiratory distress and had an emergency tracheostomy (n = 1)	Remained oxygen-dependent on day 4 after surgery, owners elected to euthanase (British bulldog)
	Presented in respiratory distress and was diagnosed with aspiration pneumonia. Staphylectomy performed the following day (n = 1)	Required one dose of acepromazine following anaesthetic recovery but otherwise unremarkable recovery (pug)
Developed aspiration pneumonia post-operatively (n = 6)	Diagnosed 48 h post-operatively and treated with IV antibiotics (n = 2)	No other complications (n = 1) (CKCS)
		Required supplemental oxygen during treatment but survived to discharge (n = 1) (Pomeranian)
	Required re-intubation (n = 3)	Survived to discharge (n = 2) (Staffordshire terrier and a Shih Tzu)
		Arrested and was euthanased (n = 1) (British bulldog)
	Remained oxygen-dependent (n = 1)	Euthanased 4 days post-operatively (Boston terrier)

CKCS, Cavalier King Charles Spaniel.

Twenty-two dogs (8.9%) were treated with anaesthesia and re-intubation. Duration of intubation ranged from 1 to 72 h (mean = 19 h, SD = 18.78). Pharyngeal oedema was the most common reason for re-intubation (n = 12). Other causes were respiratory/cardiac arrest (n = 4), dyspnoea associated with haemorrhage from surgical site (n = 3), anxiety on recovery (n = 2) or dyspnoea associated with laryngeal collapse (n = 1). Five of these 22 dogs deteriorated 12 h or more after post-surgical anaesthesia recovery. Eleven of the 22 dogs were successfully managed with re-intubation alone.

Twenty-two dogs (8.9%) were treated with a temporary tracheostomy. Nine of the 22 were placed after the dogs had decompensated and were re-anaesthetised and re-intubated. Five of the 22 presented from the referring veterinarian with a temporary tracheostomy tube in place; these dogs had BAS surgery and were recovered with the temporary tracheostomy tube. One dog was intubated at the referring veterinarian and transported to the specialty hospital with an endotracheal tube in place and anaesthetised with a propofol constant rate infusion; this dog had a temporary tracheostomy placed at time of surgery. Six of the 22 dogs had a temporary tracheostomy tube placed at the time of surgery as they had been deemed to be at risk of poor anaesthetic recovery. Concurrent respiratory pathology was the major reason cited for increased risk of poor anaesthetic recovery, such as the presence of epiglottal scar tissue, subjectively assessed severe pharyngeal oedema, presence of an epiglottal mass that was biopsied at time of surgery, and pneumonia diagnosed prior to surgery. The presence of dyspnoea prior to surgery was also a major determining factor. One dog had a tracheostomy tube placed during surgery; however, the patient arrested during anaesthesia and was unable to be resuscitated. Two of the 22 dogs had complications attributed to the temporary tracheostomy tube; one dog's tracheostomy tube repeatedly became dislodged and required replacement with a modified endo-tracheal tube and the other dog developed subcutaneous emphysema around the tracheostomy site. Successful recovery following temporary tracheostomy tube placement was made in 19/22 cases.

One dog had a temporary tracheostomy tube replaced with a permanent tracheostomy after multiple extubation failures and surgical revision by further shortening of the soft palate.

Ten cases (4.0%) were diagnosed with aspiration pneumonia (Table 3). Four of the ten had clinical evidence of pneumonia prior to surgery; one dog (British Bulldog) required an emergency tracheostomy on presentation, the other two (Australian Bulldog and a Pug) each had a tracheostomy performed pre-emptively at time of surgery. The final dog (Pug) presented in respiratory distress and had surgery performed following 7 days of hospitalisation; one dose of acepromazine was required during the post-surgical recovery period; however, the remainder of the recovery was unremarkable. Six of the ten cases were diagnosed with aspiration pneumonia post-operatively. One case was a Staffordshire Bull Terrier mix who had a concurrent left arytenoid lateralisation surgery at the same time as staphylectomy and alarplasty. Two dogs (CKCS, Pomeranian) had aspiration pneumonia diagnosed 48 h post-operatively, treated accordingly and did not require further intervention for respiratory distress.

Six cases (2.4%) developed respiratory or cardiac arrest. Times varied: before anaesthetic recovery (n = 1), during recovery (n = 2), after recovery but within 12 h of surgery (n = 1) or 12–24 h after surgery (n = 2). One dog was unable to be resuscitated (Pug), three of six dogs were euthanased during resuscitation or shortly afterwards (one Pomeranian and two British Bulldogs). The remaining two dogs (Shih Tzu and Chihuahua) were successfully resuscitated and survived to discharge.

The immediate post-operative mortality rate in this study was 2.4% (n = 6) (Table 4). Twelve dogs in the study presented as an emergency or following an acute exacerbation of respiratory effort; of these cases, one dog died (8.33%). Of the 236 cases which were elective procedures, five dogs died or were euthanased (2.16%). The immediate perioperative mortality rate was not

Table 4. Summary of perioperative causes of death

Number of dogs	Reason for death
n = 4	Respiratory or cardiac arrest (Pomeranian, pug and two British bulldogs)
n = 1	Presented in respiratory distress with aspiration pneumonia prior to surgery. A temporary tracheostomy tube was placed at time of surgery, dog remained dependent on the tube 2 days post-surgery, owners elected not to continue with further treatment (British bulldog)
n = 1	Diagnosed with aspiration pneumonia, remained dependent on nasal oxygen 4 days post-operatively, owners elected not to continue with further treatment (Boston terrier)

statistically significant between dogs who presented as an emergency and those which presented for surgery as an elective procedure ($P = 0.26$).

Four dogs were euthanased within 8 weeks of discharge; all for ongoing respiratory difficulties. One dog did not have complications following surgery but was euthanased 2 weeks post-operatively for episodic dyspnoea. One dog who also had a laryngeal tie-back at time of surgery and required extended intubation followed by nasal oxygen for 5 days, re-presented for euthanasia 16 days post-operatively for ongoing wheezing and inappetence. One dog continued to have repeated episodes of dyspnoea; on repeat airway exam under sedation, he was found to have bilateral laryngeal paralysis. Surgery was not performed and the owners elected to euthanase the following day. Finally, one dog who was discharged home with a permanent tracheostomy presented on emergency for acute respiratory distress. This dog arrested and although initial resuscitation was successful, the owners elected euthanasia.

Hospitalisation time for cases where complications did not occur ranged from 1 to 7 days (mean = 2.5 days, SD = 0.99). Cases with complications were hospitalized for a significantly longer time (mean = 4.2 days SD = 2.35 [$P < 0.0001$]).

Of the 24 dogs that were recorded to have vomited or regurgitated following surgery, half (12) had respiratory complications. Of the 215 dogs which had not vomited or regurgitated, 38 of these had respiratory complications. The incidence of vomiting or regurgitation was found to be significantly ($P < 0.001$) related to the incidence of respiratory complications.

A direct logistic regression was performed to ascertain the effects of age, non-airway pathology, other airway pathology, emergency presentation, everted saccule surgery, tonsillectomy and stenotic nares surgery on the likelihood that patients develop post-operative complications. The logistic regression model was statistically significant, χ^2 (7) = 41.57, $P < 0.001$. The model explained 23.3% (Nagelkerke R^2) of the variance in post-operative complications and correctly classified 81.4% of cases. Sensitivity was 24.1%, specificity was 84.6%, positive predictive value was 87.5%, and negative predictive value was 80.95%. Table 5 shows regression coefficients, Wald statistics, odds ratios and 95% confidence intervals for odd ratios for each of the seven predictors. According to the Wald criterion, age, other airway pathology and emergency presentation significantly predicted post-operative complications, χ^2 (1) = 6.20, $P < 0.05$, χ^2 (1) = 6.42, $P < 0.05$, and χ^2 (1) = 9.66, $P < 0.01$, respectively. The odds of developing a post-operative complication increased 1.15 times with each increase in age of 1 year. The odds of developing a post-operative complication increased 2.75 times with the presence of other airway pathology. The odds of developing a post-operative complication increased 30.30 times with emergency presentation.

Discussion

The common clinical signs of BAS (stertor, stridor, snoring, exercise intolerance and dyspnoea) have already been well reported.[4,9] Breed prevalence in this report is similar to other reported breed prevalences.[1,4,9] British Bulldogs presented significantly younger for surgery whereas CKCS presented at a later age, similar to other

Table 5. Logistic regression analysis of post-operative complications as a function of age, non-airway pathology, other airway pathology, emergency presentation, everted saccule surgery, tonsillectomy and stenotic nares surgery

Variables	B	Wald Chi-square	Odds ratio	95% confidence interval for odds ratio	
				Lower	Upper
Age (years)	0.14	6.20*	1.15	1.03	1.27
Non-airway pathology	0.40	0.80	1.48	0.62	3.54
Other airway pathology	1.01	6.42*	2.75	1.26	6.01
Emergency presentation	3.41	9.66**	30.30	3.53	260.47
Everted saccule surgery	0.51	2.01	2.67	0.82	3.39
Tonsillectomy	0.19	0.30	1.21	0.61	2.42
Stenotic nares surgery	0.49	1.49	1.63	0.74	3.56
(constant)	−2.81	31.62			

*P < 0.5. **P 0.01.

reported results.[4,5] Dogs having post-operative complications were significantly older than those who did not; the odds of developing complications increased (1.15 times) with each year of age. This emphasises the importance of early intervention in BAS dogs before the development of severe secondary changes.

The aim of BAS surgery is to decrease airflow resistance via surgical correction of abnormal anatomical obstructions in the upper respiratory tract.[27] Within the reported literature, there are differences in the type of procedures performed; however, most dogs improve after BAS surgery.[4,5,9,14] Previous studies report the use of alarplasty (in 43%–87% of dogs) and laryngeal saccule resection (in 1.6%–59% of dogs), with good or excellent clinical outcomes reported in 88%–94% of cases although many dogs in these reports also had concurrent soft palate resection performed.[4,9,14]

This study found that the number of BAS components surgically corrected was not correlated to the risk of post-operative complications similar to Fasanella et al.[1] Many studies use the caudal pole of the tonsils as a landmark for soft palate resection[3,9,28,29]; in this study, the palate was resected at a more rostral level. More rostral resection of the soft palate may further decrease resistance to airflow by removing more tissue that potentially obstructs the larynx. While more rostral resection of the soft palate may increase the risk of nasopharyngeal reflux and subsequent nasal discharge, this complication was not observed in this cohort of patients prior to discharge from hospital nor at follow up examination. Recently new techniques to assess and treat intranasal airway obstruction have been published; however, this technique was not used in the dogs of this study.[30,31]

Of the 47 dogs with concurrent airway pathology, 31 had either tracheal collapse or laryngeal collapse or both. Other types of airway disease included epiglottal or periepiglottal masses, laryngeal paralysis, tracheal hypoplasia or lower airway disease. Dogs with other airway pathology were at greater risk of developing post-operative complication (odds increased 2.75 times). Pre-operative radiographs and assessment of the larynx under a light plane of anaesthesia are essential to identify patients which are at higher risk of post-operative complications. Laryngeal paralysis has been described in small breed dogs[32] in conjunction with other brachycephalic airway abnormalities in some patients. Anaesthesia protocols have been shown to influence laryngeal motion under anaesthesia.[33] While a consistent induction agent was not used, the plane of anaesthesia was consistently light, which the authors propose is a key component of laryngeal function assessment. The incidence of laryngeal collapse and laryngeal paralysis as well as ideal assessment of laryngeal function in brachycephalic dogs could be further investigated in a study designed to achieve this outcome.

This study illustrates the importance of close post-operative monitoring, ideally in a facility which has the capacity for 24-h care. For example, of the 22 dogs requiring re-anaesthetising and re-intubation, five of these deteriorated more than 12 h after surgery (which in most cases was the night after surgery). Of the six dogs who developed respiratory or cardiac arrest, three of these dogs arrested the night after surgery or the following day.

There are few reports specifically describing the management of post-operative complications following BAS surgery. Reported rates of complications following canine BAS surgery range from 0% to 29.5%.[1,4,9,14,18,19,21] Complications include respiratory distress, pharyngeal swelling, regurgitation, aspiration pneumonia, and death.[1,2,4,9,14,19,20] In this study, 7.3% of dogs were treated with supplemental oxygen alone for dyspnoea, while 16.1% of dogs had major complications requiring extended endotracheal intubation, a temporary tracheostomy tube, treatment for aspiration pneumonia, or they had cardiac or respiratory arrest.

The optimal method of managing dyspnoeic dogs after BAS surgery is yet to be defined. Re-anaesthetising the dog and re-intubating with a cuffed endotracheal tube permit complete control of the airway while pharyngeal oedema and inflammation resolve and allowing respite for fatigued respiratory muscles. The slow and relatively controlled recovery allowed by gradually reducing constant rate infusions of propofol and midazolam reduced stress and anxiety that may worsen post-operative dyspnoea.

Senn et al[20] discussed the use of nasotracheal tubes as a less invasive measure, compared with intubation, to supply a high fraction of inspired oxygen. While nasotracheal tubes supply oxygen to the trachea, the nasotracheal tube does not relieve any upper respiratory tract obstruction. In the Senn et al's study, dogs with nasotracheal tubes were more frequently observed coughing; it may be possible that the presence of the nasotracheal tube could add to the airflow turbulence within the pharynx and larynx and may slow the resolution of inflammation in these areas.

Nasal oxygen lines do not bypass upper respiratory tract obstruction; however, they were used frequently in this study for dogs with oxygen responsive dyspnoea that were not severe enough to warrant anaesthesia and re-intubation. Nasal oxygen lines are easy to place, well tolerated by the patient and do not require an anaesthetic for placement as nasotracheal tubes do.[20,34]

Temporary tracheostomy tubes effectively bypass the upper airway; however, the potential for tube occlusion necessitates close supervision. Complications include obstruction of the tube or airway, tube dislodgment, inflammation at the stoma site, coughing, gagging, emphysema, pneumomediastinum, aspiration pneumonia or less commonly tracheal stenosis or tracheal malacia.[35,36] Reported range of complications is 43%–87%.[37–40] Stout conformation of the neck leading to tube displacement, redundant skin folds causing tube occlusion and concurrent lower airway collapse may complicate the use of temporary tracheostomy tubes in brachycephalic dogs. In this study, 2/21 dogs had complications attributed to the temporary tracheostomy tube. The authors hypothesize that there were more minor complications associated with the temporary tracheostomy tubes; however, they were not noted explicitly in the medical record. All dogs were under 24 h hospital monitoring allowing rapid intervention in the case of complications, along with intensive maintenance of an adequate tube lumen and stoma. Successful recovery following temporary tracheostomy tube placement was made in 19/21 cases.

Aspiration pneumonia results from inhalation of gastrointestinal or oropharyngeal contents causing chemical, bacteriologic and immunologic damage to the airways.[36] Increased negative intrathoracic pressure while breathing with a compromised upper airway predisposes dogs to gastroesophageal reflux, vomiting or regurgitation which increases the risk of aspiration pneumonia.[12,41] Aspiration pneumonia may be an underlying cause for patients requiring mechanical ventilation.[41] In dogs with upper respiratory tract obstruction, the placement of a tracheostomy tube may decrease the risk of gastroesophageal reflux by decreasing respiratory effort and negative intrathoracic pressure, thereby decreasing the risk of aspiration and further damage to the airways.

The incidence of vomiting or regurgitation following surgery appeared to be significantly related to the incidence of respiratory complications. Reliance on medical records makes it difficult to ascertain whether the act of regurgitation or vomiting was the inciting cause of the respiratory complications post-operatively in each individual dog. Poncet et al[12] identified an association in brachycephalic dogs between severe respiratory signs and the pathology in the gastrointestinal tract. The use of prokinetics, anti-acids, or anti-emetics and the incidence of post-operative regurgitation were not explicitly studied here. There are mixed reports on benefits of using metoclopramide in dogs to reduce incident of regurgitation during or shortly after anaesthesia.[42–44] Further studies focused on the use of these medications in brachycephalic dogs undergoing airway surgery would be beneficial.

The primary indications for mechanical ventilation are severe hypoxemia despite oxygen therapy, hypercapnia (hypoventilation) or excessive work of breathing.[45] The reported success rates for dogs and cats who have been weaned off mechanical ventilation range from 22% to 39%.[41,45] Mechanical ventilation is not a benign procedure and is associated with complications such as pneumonia, cardiovascular impairment, ventilator induced lung injury, pneumothorax, and mouth and corneal ulceration.[41,46] For the 22 dogs in this study which had dyspnoea warranting anaesthetisation and re-intubation, the dogs were kept at a plane of anaesthesia that allowed effective oxygenation and ventilation, without mechanical ventilation. This approach led to successful recovery and discharge in 11/22 of dogs using endotracheal intubation alone; of the remaining 11 dogs who were intubated, 8 required temporary tracheostomy tubes to be placed but also survived to discharge (overall 84.4% survival using these combined methods). Cardiorespiratory complications occur frequently during routine anaesthesia.[47] While this procedure was well tolerated, a light plane of anaesthesia and close monitoring was critical to maintain cardiovascular stability.

This study demonstrates that respiratory distress can develop after an apparently normal recovery from anaesthesia. Five dogs had deteriorated 12 or more hours after post-surgical anaesthesia recovery which highlights the requirement for practices performing upper airway surgery to be able to provide 24-h monitoring and intensive care management of these patients.

Reported mortality following surgical therapy for BAS ranges from 0% to 6.8%[1,4,5,9,14,28]; in these studies, population cohorts range from 20 to 118 dogs. The mortality rate in the current study was 2.4%, which is lower than most other reported figures and represents a heterogeneous group of dogs, some of whom presented in respiratory distress. Although there was not a significant association between the mortality of patients undergoing elective surgery compared with those who presented as an emergency or following an acute exacerbation of respiratory effort, the authors speculate that this may be due to a type II error. A larger number of non-elective cases would be required to verify this. When the logistic regression was performed on the likelihood that a patient would develop post-operative complications, the odds ratio increased markedly (30.30) in patients presented on an emergency basis.

The study is limited by its retrospective nature; there is potential for incomplete information within the medical records and difference in treatment protocols between clinicians. However, it is the authors' belief that this is the largest cohort of dogs who have undergone BAS surgery to be studied. The authors attribute the low mortality rate to relatively rostral resection of the soft palate, 24-h monitoring of dogs post-operatively, early intervention in dogs with post-operative dyspnoea and re-intubation of dogs while pharyngeal oedema resolves. We recommend early surgical intervention in dogs with BAS to prevent development of potentially life threatening post-operative complications.

Conflicts of interest and sources of funding

The authors declare no conflicts of interest or sources of funding for the work presented here.

References

1. Fasanella FJ, Shivley JM, Wardlaw JL et al. Brachycephalic airway obstructive syndrome in dogs: 90 cases (1991-2008). *J Am Vet Med Assoc* 2010;237: 1048–1051. http://doi.org/10.2460/javma.237.9.1048.
2. Monnet E. Brachycephalic airway syndrome. In: Slatter D, editor. *Textbook of small animal surgery*. 3rd edn. Saunders, Philadelphia, 2003.
3. Harvey CE Review of results of airway obstruction surgery in the dog. *J Small Anim Pract* 1983;24:555–559. http://doi.org/10.1111/j.1748-5827.1983.tb00400.x.
4. Torrez CV, Hunt GB Results of surgical correction of abnormalities associated with brachycephalic airway obstruction syndrome in dogs in Australia. *J Small Anim Pract* 2006;47:150–154. http://doi.org/10.1111/j.1748-5827.2006.00059.x.
5. Lorinson D, White RAS, Bright RM Brachycephalic airway obstruction syndrome: a review of 118 cases. *Canine Pract* 1997;22:18–21.
6. Trappler M, Moore K. Canine brachycephalic airway syndrome: pathophysiology, diagnosis, and nonsurgical management. *Compend Contin Educ Vet* 2011; 33:E1–4; quiz E5
7. Ginn JA, Kumar MS, McKiernan BC et al. Nasopharyngeal turbinates in brachycephalic dogs and cats. *J Am Anim Hosp Assoc* 2008;44:243–249. http://doi.org/10.5326/0440243.
8. De Lorenzi D, Bertoncello D, Drigo M Bronchial abnormalities found in a consecutive series of 40 brachycephalic dogs. *J Am Vet Med Assoc* 2009;235: 835–840. http://doi.org/10.2460/javma.235.7.835.
9. Riecks TW, Birchard SJ, Stephens JA Surgical correction of brachycephalic syndrome in dogs: 62 cases (1991-2004). *J Am Vet Med Assoc* 2007;230: 1324–1328. http://doi.org/10.2460/javma.230.9.1324.
10. Leonard HC Collapse of the larynx and adjacent structures in the dog. *J Am Vet Med Assoc* 1960;137:360–363.
11. Bernaerts F, Talavera J, Leemans J et al. Description of original endoscopic findings and respiratory functional assessment using barometric whole-body plethysmography in dogs suffering from brachycephalic airway obstruction syndrome. *Vet J* 2010;183:95–102. https://doi.org/10.1016/j.tvjl.2008.09.009.
12. Poncet CM, Dupre GP, Freiche VG et al. Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with upper respiratory syndrome. *J Small Anim Pract* 2005;46:273–279. https://doi.org/10.1111/j.1748-5827.2005.tb00320.x.

13. Clarke DL, Holt DE, King LG Partial resolution of hypoplastic trachea in six English bulldog puppies with bronchopneumonia. *J Am Anim Hosp Assoc* 2011; 47:329–335. https://doi.org/10.5326/JAAHA-MS-5596.
14. Poncet CM, Dupre GP, Freiche VG et al. Long-term results of upper respiratory syndrome surgery and gastrointestinal tract medical treatment in 51 brachycephalic dogs. *J Small Anim Pract* 2006;47:137–142. https://doi.org/10.1111/j.1748-5827.2006.00057.x.
15. Hoareau GL, Jourdan G, Mellema M et al. Evaluation of arterial blood gases and arterial blood pressures in brachycephalic dogs. *J Vet Intern Med* 2012;26: 897–904. https://doi.org/10.1111/j.1939-1676.2012.00941.x.
16. White RN Surgical management of laryngeal collapse associated with brachycephalic airway obstruction syndrome in dogs. *J Small Anim Pract* 2012; 53:44–50. https://doi.org/10.1111/j.1748-5827.2011.01156.x.
17. Pink JJ, Doyle RS, Hughes JM et al. Laryngeal collapse in seven brachycephalic puppies. *J Small Anim Pract* 2006;47:131–135. https://doi.org/10.1111/j.1748-5827.2006.00056.x.
18. Brdecka DJ, Rawlings CA, Perry AC et al. Use of an electrothermal, feedback-controlled, bipolar sealing device for resection of the elongated portion of the soft palate in dogs with obstructive upper airway disease. *J Am Vet Med Assoc* 2008;233:1265–1269. https://doi.org/10.2460/javma.233.8.1265.
19. Dunie-Merigot 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;167:700–704. https://doi.org/10.1136/vr.c5107.
20. Senn D, Sigrist N, Forterre F et al. 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 (San Antonio)* 2011;21:261–267. https://doi.org/10.1111/j.1476-4431.2011.00612.x.
21. Michelsen J Use of the harmonic scalpel for soft palate resection in dogs: a series of three cases. *Aust Vet J* 2011;89:511–514. https://doi.org/10.1111/j.1751-0813.2011.00846.x.
22. Schmiedt C, Creevy K. Nasal planum, nasal cavity, and sinuses. In: Tobias K, Johnston S, editors. *Veterinary surgery small animal*. Elsevier Saunders, St. Louis, 2012;1691–1706.
23. Dean PW Surgery of the tonsils. *Probl Vet Med* 1991;3:298–303.
24. Anderson AM. Soft tissues of the Oral Cavity. In: Tobias KM, Spencer J, editors. *Small animal veterinary surgery*. Elsevier Saunders, St. Louis, 2012; 1425–1438.
25. Dulisch ML. The tonsils. In: Slatter DH, editor. *Textbook of small animal surgery*. 3rd edn. Saunders, Philadelphia, 2003;1079.
26. Fletcher D, Boller M et al. RECOVER reassessment campaign on veterinary resuscitation: evidence and knowledge gap analysis on veterinary CPR. *J Vet Emerg Crit Care* 2012;22:1–131.
27. Seim H. *Brachycephalic syndrome*. Atlantic Coast Veterinary Conference, Atlantic City, NJ, 2001.
28. Davidson EB, Davis MS, Campbell GA et al. Evaluation of carbon dioxide laser and conventional incisional techniques for resection of soft palates in brachycephalic dogs. *J Am Vet Med Assoc* 2001;219:776–781. http://doi.org/10.2460/javma.2001.219.776.
29. Koch DA, Arnold S, Hubler M et al. Brachycephalic syndrome in dogs. *Compend Contin Educ Vet* 2003;25:48–54.
30. Oechtering GU, Pohl S, Schlueter C et al. A novel approach to brachycephalic syndrome. 1. Evaluation of anatomical intranasal airway obstruction. *Vet Surg* 2016;45:165–172. http://doi.org/10.1111/vsu.12446.
31. Oechtering GU, Pohl S, Schlueter C et al. A novel approach to brachycephalic syndrome. 2. Laser-assisted Turbinectomy (LATE). *Vet Surg* 2016;45: 173–181. http://doi.org/10.1111/vsu.12447.
32. Nelissen P, White RA Arytenoid lateralization for management of combined laryngeal paralysis and laryngeal collapse in small dogs. *Vet Surg* 2012;41: 261–265. http://doi.org/10.1111/j.1532-950X.2011.00917.x.
33. Jackson AM, Tobias K, Long C et al. Effects of various anesthetic agents on laryngeal motion during laryngoscopy in normal dogs. *Vet Surg* 2004;33: 102–106. http://doi.org/10.1111/j.1532-950x.2004.04016.x.
34. Dunphy ED, Mann FA, Dodam JR et al. Comparison of unilateral versus bilateral nasal catheters for oxygen administration in dogs. *J Vet Emerg Crit Care* 2002;12:245–251. http://doi.org/10.1046/j.1435-6935.2002.t01-1-00049.x.
35. Hackett T, editor. *Care of respiratory patients*. 2nd edn. Philadelphia, Saunders, 2003.
36. Mercurio A Complications of upper airway surgery in companion animals. *Vet Clin North Am Small Anim Pract* 2011;41:969–980, vi-vii. http://doi.org/10.1016/j.cvsm.2011.05.016.
37. Nicholson I, Baines S Complications associated with temporary tracheostomy tubes in 42 dogs (1998 to 2007). *J Small Anim Pract* 2012;53:108–114. http://doi.org/10.1111/j.1748-5827.2011.01167.x.
38. Harvey CE, O'Brien J Tracheotomy in the dog and cat: analysis of 89 episodes in 79 animals. *J Am Anim Hosp Assoc* 1982;18:563.
39. Guenther-Yenke CL, Rozanski EA Tracheostomy in cats: 23 cases (1998–2006). *J Feline Med Surg* 2007;9:451–457.
40. Hamilton M, Bird A, Demetriou J. *Tracheostomy in the dog: a review of 23 cases*. Proceedings of the British Small Animal Veterinary Association, Birmingham, UK, 2007.
41. Hoareau GL, Mellema MS, Silverstein DC Indication, management, and outcome of brachycephalic dogs requiring mechanical ventilation. *J Vet Emerg Crit Care (San Antonio)* 2011;21:226–235. http://doi.org/10.1111/j.1476-4431.2011.00635.x.
42. Wilson DV, Evans AT, Mauer WA Influence of metoclopramide on gastroesophageal reflux in anesthetized dogs. *Am J Vet Res* 2006;67:26–31. http://doi.org/10.2460/ajvr.67.1.26.
43. Favarato ES, Souza MV, Costa PR et al. Evaluation of metoclopramide and ranitidine on the prevention of gastroesophageal reflux episodes in anesthetized dogs. *Res Vet Sci* 2012;93:466–467. http://doi.org/10.1016/j.rvsc.2011.07.027.
44. Milovancev M, Townsend K, Spina J et al. Effect of metoclopramide on the incidence of early postoperative aspiration pneumonia in dogs with acquired idiopathic laryngeal paralysis. *Vet Surg* 2016;45:577–581. http://doi.org/10.1111/vsu.12491.
45. Hopper K, Powell L Basic of mechanical ventilation for dogs and cats. *Vet Clin Small Anim* 2013;43:955–969.
46. Hopper K, Haskins SC, Kass PH et al. Indications, management, and outcome of long-term positive-pressure ventilation in dogs and cats: 148 cases (1990-2001). *J Am Vet Med Assoc* 2007;230:64–75. http://doi.org/10.2460/javma.230.1.64.
47. Redondo JI, Rubio M, Soler G et al. Normal values and incidence of cardiorespiratory complications in dogs during general anaesthesia. A review of 1281 cases. *J Vet Med A Physiol Pathol Clin Med* 2007;54:470–477. http://doi.org/10.1111/j.1439-0442.2007.00987.x.

(Accepted for publication 7 January 2020)

