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Surgical management of epiglottic retroversion

Intraoperative and major postoperative complications and survival of dogs undergoing surgical management of epiglottic retroversion: 50 dogs (2003–2017)

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Objective: Objectives of this study were (1) to report overall and procedure-specific incidence and type of intraoperative and major postoperative complications in dogs treated surgically for epiglottic retroversion (ER), (2) to compare the incidence of major postoperative complications between different procedure types, and (3) to report survival of surgically treated dogs.

Study Design: Multi-institutional retrospective study.

Sample Population: Fifty dogs.

Methods: Medical records of dogs diagnosed with ER that underwent surgery from 2003-2017 at 11 institutions were reviewed. Complications were divided into intraoperative and major postoperative.

Results: Fifty dogs underwent 78 surgical procedures. Intraoperative complications occurred during 2/78 (2.6%) procedures. Twenty-two dogs experienced a total of 36 major postoperative complications following 36 of 74 (48.7%) procedures. Postoperative complications occurred following 7/12 (58.3%) non-incisional epiglottopexy, 23/43 (53.5%) incisional epiglottopexy, 2/4 (50%) partial epiglottectomy, 2/12 (16.7%) subtotal epiglottectomy and 2/3 (66.7%) other surgical procedures. Epiglottopexy failure was the commonest major postoperative complication. No significant difference in incidence of major postoperative complications was identified between procedure types (p=0.1239); however, combined epiglottopexy procedures had a higher incidence of complications than epiglottectomy procedures (p=0.0485). Median survival time was not reached after a median of 716 days.

Conclusions: Overall incidence of major postoperative complications was high. Intraoperative complications were uncommon. Epiglottopexy procedures had the highest incidence of major

postoperative complications. Long-term survival can be achieved in dogs treated surgically for ER.

Clinical Significance: Dogs treated surgically for ER experience a high rate of major postoperative complications, with epiglottopexy procedures associated with the highest rate of complications.

Introduction

Epiglottic retroversion (ER) is increasingly recognized as a cause of intermittent upper airway obstruction in dogs.[1-4] First described affecting two dogs in 2009[1] and subsequently in two case reports and one retrospective case series,[2-4] it is characterized by dynamic or persistent retroflexion/caudal displacement of epiglottis, and obstruction of the rima glottidis.[1-4] The etiology remains unknown, although several theories have been proposed including epiglottic fracture or malacia, hypothyroidism-associated peripheral neuropathy, and hypoglossal/glossopharyngeal nerve degeneration.[1] It is most commonly reported in small-to-medium breeds, with Yorkshire terriers over-represented.[1-4] A condition similar to that recognized as ER in the current literature, epiglottic entrapment, was previously described by Leonard.[5] He described entrapment of the epiglottis against the laryngeal opening as a cause of inspiratory dyspnea in dogs.[5] Failure of the hyoepiglotticus muscles to draw the epiglottis rostrally and ventrally to counteract the negative pressures generated during inspiration was the suspected cause.[5]

Described surgical techniques for management of ER include temporary-epiglottopexy (herein non-incisional-epiglottopexy [NI-EP]), permanent-epiglottopexy (herein incisional-epiglottopexy [I-EP]), partial epiglottectomy (PE) and subtotal epiglottectomy (STE).[1-4] The goal of epiglottopexy is to maintain the epiglottis in a horizontal position by securing it to the tongue base.[1-3] Partial epiglottectomy involves excision of an area of the rostral epiglottis to permit airflow through the dorsal aditus laryngis.[4,5] Subtotal epiglottectomy involves epiglottic excision across its widest base and has been described as a salvage option for recurrent ER.[2,3] The most effective treatment method for ER remains unknown, with the decision to perform any of these procedures based on surgeon preference.

Information regarding the incidence and type of intraoperative and major postoperative complications in dogs treated surgically for ER is limited to case reports[1,2,4] and one retrospective case series,[3] describing a total of 23 surgically treated dogs. Within these reports, a high incidence of complications has been reported with both NI-EP and I-EP procedures.[2,3] In a study involving 19 surgically treated dogs,[3] 36.8% of index temporary-epiglottopexy and 62% of revision permanent-epiglottopexy procedures failed, while 31.6% of those 19 dogs developed aspiration pneumonia (AP). In that study, at time of last follow-up, approximately one third of dogs had been euthanized, most commonly due to respiratory complications.[3] Information regarding complications and outcomes of dogs undergoing PE is limited to four dogs,[4,5] while that related to STE is limited to two.[2,3]

Objectives of this study were (1) to report the overall and procedure-specific incidence and type of intraoperative and major postoperative complications in dogs treated surgically for ER, (2) to compare the incidence of major postoperative complications between different procedure types, and (3) to report survival of surgically treated dogs. Our hypotheses were that (1) the overall rate of major postoperative complications would be high, (2) dogs undergoing epiglottopexy procedures would experience a higher rate of major postoperative complications than those undergoing epiglottectomy procedures, and (3) most dogs would experience long-term survival.

Materials and Methods

Inclusion criteria

Medical records of dogs presented to 11 veterinary institutions from 2003-2017 that underwent NI-EP, I-EP, PE, STE and/or other surgical procedures for management of ER were retrospectively reviewed. Dogs with incomplete medical records and follow-up <6 weeks from diagnosis were excluded.

Data collection

Data retrieved from medical records included signalment, concurrent/historical respiratory and comorbid conditions, details of previous airway surgery, presenting clinical signs, physical examination findings, details of diagnostic investigations performed, epiglottic procedure(s) and additional procedures performed under the same anesthetic, intraoperative and major postoperative complications and follow-up/survival. Duration of clinical signs was recorded as acute (<2 weeks' duration) or chronic (≥2 weeks). Cases were stratified as primary or concomitant ER depending on whether they had concurrent/historical airway (laryngeal, pharyngeal, tracheal and/or bronchial) disorders at diagnosis. Epiglottic retroversion was defined as a persistently upright or caudally displacing epiglottis during inspiration on laryngoscopy, endoscopy or fluoroscopy, resulting in static or dynamic obstruction of the rima glottidis (**Figures 1 and 2**). Non-incisional-epiglottopexy was defined as placement of suture(s) between the lingual surface of the epiglottis and tongue base, without mucosal incision/resection.[1] Incisional-epiglottopexy was defined as mucosal incision/resection in the glossoepiglottic fold, followed by placement of suture(s), to create permanent fibrous adhesion between the epiglottis and tongue base.[1,2] Partial and subtotal epiglottectomy were defined as resection of <50% or ≥50% epiglottis, respectively (**Figures 3-5**).[2]

Intraoperative complications included any unanticipated event that required intervention to resolve. Major postoperative complications included requirement for revision epiglottic surgery; development of AP; development of severe dyspnea deemed directly related to ER/epiglottic surgery or requirement for temporary tracheostomy; and in cases where a non-epiglottic procedure was performed to manage ER (eg, permanent tracheostomy), requirement for revision surgery to address a complication related to that surgery. At last follow-up, if a dog had been euthanized due to dyspnea without further investigation, this was recorded as a major complication unless a cause unrelated to ER/ epiglottic surgery performed could be confirmed. Major postoperative complications were subdivided into short-term (<6 months following a surgical procedure) and long-term (≥6 months). Follow-up data were retrieved from in-hospital records and/or telephone conversations with clients and/or referring veterinarians.

Statistical analysis

Continuous data were tested for normality using the Shapiro-Wilk test. Normally distributed data were presented as mean and standard deviation. Non-normally distributed data were presented as median and range. Categorical data were presented as frequency and percentage. Overall and procedure-specific incidence of intraoperative and major postoperative complications were presented as frequency and percentage (with 95% confidence interval [CI]). Pearson's chi-squared and Fisher's exact tests were used to detect differences in incidence of major postoperative complications between NI-EP, I-EP, PE, and STE, and combined epiglottopexy and epiglottectomy procedures, respectively. Other surgical procedures were not included in these comparisons. For dogs that died of causes unrelated to ER/epiglottic surgery or underwent elective revision epiglottic surgery <2 weeks following an index procedure, that procedure was not included in the statistical analysis concerning major postoperative complications. Due to paucity of published data regarding complication rates with these procedures, a power analysis was not performed. Survival/follow-up time was recorded from index surgery until the date of death/last recorded alive. Kaplan-Meier methodology was used to calculate overall survival time. At last follow-up, dogs were recorded as alive, lost-to-follow-up (LTFU) or dead. If a dog had died, death was recorded as ER-related/possibly ER-related or non-ER-related. Statistical significance was set at $p<0.05$. Statistical analyses were performed using commercially available software.[a]

Results

Signalment

Fifty dogs were included in the study. Individual signalments are listed in **Appendix Table 1**. Details of four dogs have partially been reported previously.[1,2,4] The most common breeds included Yorkshire terrier (n=13), Chihuahua (n=7) and Shih Tzu (n=4). There were 27 spayed females, seven entire females, 11 neutered males and five entire males. Mean age was 72.3 months (SD±35.8). Median weight was 6kg (range, 1.3-43.0kg).

Concurrent/historical respiratory and comorbid conditions

Concurrent/historical respiratory disorders documented prior to ER diagnosis were recorded in 17 (34%) dogs and included tracheal collapse (n=5); elongated soft palate (ESP) (n=5); two each of stenotic nares, bronchitis, bronchial collapse, laryngeal collapse, and rhinitis; and one each of unspecified brachycephalic airway syndrome (BAS), tonsillitis, pharyngeal collapse, aberrant turbinates, and nasal septum deviation. One dog developed AP following partial staphylectomy (PS) five days prior to ER diagnosis and subsequent epiglottic surgery. Non-respiratory comorbidities were recorded in 13 (26%) dogs and included mitral valve disease (n=3), hypothyroidism (n=2), previous cervical bite trauma (n=2); and one each of epilepsy, intestinal leiomyosarcoma, corpora quadrigeminal cyst, meningoencephalitis-of-unknown-origin (MUO), benign splenic nodules, tricuspid insufficiency, food allergy, inflammatory bowel disease, and hepatic microvascular dysplasia.

Previous respiratory tract surgery

Eight (16%) dogs had undergone previous airway surgery a median of 261.5 days (range, 3-618 days) prior to epiglottic surgery. These included PS (n=7), rhinoplasty (n=3), temporary tracheostomy (n=2); and one each of laryngeal ventriculectomy, nasopharyngeal foreign body removal, tonsillectomy, bilateral cuneiformectomy, and laser-assisted turbinectomy.

Presenting clinical signs

Most common presenting clinical signs included dyspnea/tachypnea (n=43); upper respiratory noise (n=30; stridor [n=16], stertor [n=5], other [n=7], unspecified [n=6]), coughing (n=19); exercise intolerance (n=14);sneezing/reverse sneezing (n=11); cyanosis (n=10); syncope/collapse (n=8); gagging/throat-clearing (n=7); five each of lethargy, snoring, regurgitation; retching/vomiting (n=4), and excessive panting (n=3); and two each of dysphonia, wheezing, choking when eating/drinking, nasal discharge, heat intolerance, and anxiety/agitation/restlessness. Overall, six dogs had acute respiratory signs and 43 had chronic signs (not recorded [n=1]).

Physical examination findings

Most common physical examination findings included upper respiratory tract noise (n=34; stridor [n=20], stertor [n=12], other [n=1], unspecified [n=7]), dyspnea/tachypnea (n=26), increased body condition/overweight (n=16), cyanosis (n=8), referred upper airway noise on auscultation (n=5), hyperthermia (n=4), stenotic nares (n=5), cardiac murmur (n=4), increased/adventitious lung sounds (n=4), and excessive panting (n=2). Eight dogs required emergency sedation and/or oxygen supplementation at time of presentation.

Diagnostic-investigations

Upper airway examination was performed by rigid laryngoscopy/flexible endoscopy and a diagnosis of ER was made in all dogs. Individual epiglottic findings are listed in **Appendix Table 1**. Premedication/sedation for upper airway examination varied widely among institutions. Additional upper respiratory tract abnormalities identified at time of laryngoscopy/endoscopy were recorded in 28 (56%) dogs and most commonly included ESP/thickened soft palate (n=20), laryngeal collapse (n=8), everted/enlarged/hyperplastic palatine tonsils (n=4), laryngeal paralysis/paresis (n=4); and two each of pharyngeal collapse, laryngeal edema, pharyngeal edema, and everted laryngeal ventricles. Abnormal nasopharyngoscopic findings were recorded in six dogs (**Appendix Table 2**). Tracheobronchoscopy was performed in 24 (48%) dogs, with abnormalities identified in 11 (45.83%). Radiographs of the thorax and head/neck were obtained at presentation in 38 (76%) and 26 (52%) dogs, with abnormal findings recorded in nine (23.7%) and 12 (46.2%) dogs, respectively. Fluoroscopy of the upper and lower airways was performed in 16 (32%) dogs, with abnormalities identified in 14/16 (87.5%) and findings consistent with ER in 7/16 (43.75%). Specific findings are listed in **Appendix Table 2**.

Overall incidence and type of intraoperative and major postoperative complications

Fifty dogs underwent a total of 78 procedures (**Figure 6**); however, three dogs had NI-EP electively converted to I-EP within four days and a fourth was euthanized three days following

STE due to seizure activity, and were excluded from statistical analysis concerning major postoperative complications. Intraoperative complications occurred during 2/78 (2.6%) procedures (**Table 1**). Twenty-two (44.0%) dogs experienced a total of 36 major postoperative complications following 36 of 74 (48.7%) procedures (**Table 1, Appendix Table 4**). Major postoperative complications occurred following 7/12 (58.3%) NI-EP, 23/43 (53.5%) I-EP, 2/4 (50.0%) PE, 2/12 (16.7%) STE and 2/3 (66.7%) other surgical procedures (**Table 2**). Epiglottopexy failure was the commonest major postoperative complication, having occurred following 23/55 (41.8%) epiglottopexy procedures. Type of failure was not recorded in all cases but most commonly involved stretching of mucosa and suture cut-out. Aspiration pneumonia occurred or was suspected following 4/74 (5.4%) procedures (3/55 [5.5%] epiglottopexy procedures and 1/16 [6.3%] epiglottectomy procedures). No significant difference in the incidence of major postoperative complications was identified between the four surgical procedures (p=0.1239) (**Table 2**); however, epiglottopexy procedures were associated with a significantly higher rate of major postoperative complications than epiglottectomy procedures (p=0.0485).

Primary versus concomitant ER

On the basis of diagnostic investigations and previous airway surgery, 15 dogs had primary ER while 35 had concurrent/historical airway disorders and were classified as concomitant ER. Twenty-eight dogs with concomitant ER underwent ≥1 epiglottopexy procedure and 12 (42.6%) developed failure on ≥1 occasion. Nine dogs with primary ER underwent ≥1 epiglottopexy procedure and five (55.6%) developed failure on ≥1 occasion. The remaining 13 dogs underwent epiglottectomy or other surgical procedures.

Non-incisional-epiglottopexy

Fifteen dogs underwent a total of 15 NI-EP procedures, using absorbable (n=10) and non-absorbable suture (n=3) (not recorded [n=2]). In all cases, NI-EP was performed as an initial step to assess the response to epiglottic fixation and confirm the diagnosis. Conversion to I-EP was electively performed in four dogs after a median of 3.5 days (range, 3-41 days); three performed $\leq$4 days were excluded from statistical analysis concerning major postoperative complications. Six of 12 were classified as primary ER and six as concomitant ER. No intraoperative complications occurred. Seven dogs experienced a total of seven short-term major complications following 7 of 12 (58.3%) procedures; epiglottopexy failure (n=7) (polydioxanone [n=4], polyamide [n=1], not recorded [n=2]). Seventeen days after NI-EP, one dog with severe tracheal collapse underwent extraluminal tracheal ring placement, subsequently developed laryngeal paralysis and severe laryngeal edema, underwent left cricoarytenoid lateralization (CAL), which failed, and resulted in euthanasia (not recorded as a major complication). No long-term major complications occurred in the remaining two dogs after 350 and 1212 days, respectively (one dog LTFU at 43 days, one dog electively converted to I-EP at 41 days). Overall, seven dogs experienced a total of seven major postoperative complications (NI-EP failure) following 7 of 12 (58.3%) procedures, after a median of 27 days (range, 2-113 days). Failure was not recorded following the remaining five procedures after a median of 43 days (range,17-1212 days).

Incisional-epiglottopexy

Thirty-one dogs underwent a total of 43 I-EP procedures. Twenty-one were index procedures, 22 were revision procedures (including four elective). Incisional-epiglottopexy was performed using absorbable (n=26), non-absorbable (n=11), or a combination of both materials (n=2) (not recorded [n=4]). Additional surgery performed in 19 dogs included PS (n=13), rhinoplasty (n=4), folded flap palatoplasty (FFP) (n=3), bilateral tonsillectomy (n=2), laryngeal ventriculectomy (n=2); and one each of CAL, resection of redundant ventral epiglottic mucosa, tracheal stenting, cystotomy, and debridement of a small area of marginal necrosis of rostral epiglottis (following failure of previous index NI-EP and revisional I-EP). Five of 31 were classified as primary ER and 26 as concomitant ER. Intraoperative complications occurred in one dog; excessive hemorrhage following excision of ventral epiglottic and tongue mucosa. Twelve dogs experienced a total of 17 short-term major complications following 17 of 43 (39.5%) procedures, and included epiglottopexy failure (n=12) after median of 20 days (range, 2-154 days); development of AP (n=2); and one each of development of dyspnea/cyanosis and inability to extubate following I-EP and PS in a dog with concurrent grade II laryngeal collapse, which necessitated temporary tracheostomy and ultimately resulted in respiratory arrest four days postoperatively; development of pharyngeal swelling following I-EP and FFP, which necessitated temporary tracheostomy; and I-EP abscessation and requirement for suture removal, which resulted in recurrence of respiratory signs. One dog demonstrated similar but less severe signs two weeks following I-EP; however, repeat laryngoscopic examination/surgery were not advised on the basis of overall improvement. Another dog developed partial mucosal dehiscence after I-EP; however, deeper epiglottopexy sutures remained intact and further surgery was not required. Neither were recorded as major complications. Six dogs experienced a total of six long-term major complications following 6 of 43 (14%) I-EP procedures and included epiglottopexy failure (n=4) after median of 455.5 days (range, 183-733 days); possible aspiration pneumonia (n=1) and one dog that developed dyspnea 704 days postoperatively and was euthanized without further investigation/necropsy. Overall, 16 dogs experienced a total of 23 major postoperative complications following 23 of 43 (53.49%) procedures. Failure occurred following 16/43 I-EP (37.2%) procedures in 12 dogs after a median of 50.5 days (range, 2-733 days). Three failures were converted to STE, one dog was euthanized and the remaining 8 dogs were successfully treated with revision I-EP. Failure was not recorded in 19 dogs after median of 724 days (range, 4-1945), although one dog had the epiglottopexy removed after four days due to abscessation.

Partial epiglottectomy

Three dogs underwent a total of four PE procedures, three as index surgery and one which required revision. Two were classified as primary ER and one as concomitant ER. Additional procedures were not performed in any dog. Intraoperative complications did not occur. Two dogs experienced a total of two short-term major complications following 2 of 4 (50%) procedures and included cyanosis/airway obstruction during recovery in a dog with concurrent laryngeal collapse, and persistence of upper airway noise, which necessitated revision PE 21 days after index surgery to resolve, respectively. Long-term major complications did not occur following 449 and 1690 days in two dogs, and 1058 days after revisional PE in the third.

Subtotal epiglottectomy

Thirteen dogs underwent a total of 13 STE procedures, nine as index surgery and four as revision surgery. Six were classified as primary ER and seven as concomitant ER. Additional procedures performed in four dogs included PS (n=3); and one each of bilateral tonsillectomy, rhinoplasty, and temporary tracheostomy. Intraoperative complications occurred in one dog; difficulty closing mucosa over exposed epiglottic cartilage. One (7.7%) short-term major complication occurred in one dog; airway obstruction after extubation, which resolved with rostral tongue traction until awake. One (7.7%) long-term major complication occurred in one dog; development of severe seizures, AP and death six months postoperatively (STE could not be excluded as the cause of AP in this case). A number of dogs experienced postoperative complications and/or underwent additional surgical procedures not related to ER/epiglottic surgery. These included one dog with concurrent tracheal collapse that experienced difficult anesthetic recovery attributed to collapsing trachea; one dog that was euthanized three days following STE due to seizures (not included in statistical analysis concerning major postoperative complications); one dog with concurrent BAS that underwent STE as well as rhinoplasty, PS, and temporary tracheostomy that developed an episode of dyspnea due to tracheostomy tube blockage; another dog that required additional FFP due to residual upper airway noise attributed to prominent mucosa at nasopharyngeal ostium; and two dogs that required permanent tracheostomy for concurrent bilateral laryngeal paralysis and collapse, and intraluminal tracheal stenting for tracheal collapse, both of whom were subsequently euthanized 280 and 323 days after STE, respectively, due to complications relating to these subsequent procedures. None of these six dogs were recorded as having developed major complications.

Other surgical procedures

Three dogs underwent a total of three other surgical procedures, two as index and one as revision surgery, and included permanent tracheostomy and hyoepiglotticus imbrication, and hyothyropexy, respectively. No additional procedures were performed in any dog. Intraoperative complications did not occur. Short-term major complications occurred in two dogs. This included one dog in whom laryngoscopic examination eight days following hyoepiglotticus imbrication identified persistent ER. This dog was re-presented after 638 days due to ongoing respiratory signs and subsequently underwent I-EP. A second dog with concurrent grade III laryngeal collapse that underwent permanent tracheostomy experienced intermittent tracheostomy obstruction due to redundant skin folds and required temporary skin suture placement. No long-term major complications occurred following these other procedures after 638, 904 and 621 days, respectively.

Anesthesia and analgesia

Anesthetic and postoperative analgesia protocols varied widely depending on the institution and preference of attending anesthesiologist/surgeon but most commonly included partial/pure mu agonist opioids or butorphanol.

Follow-up/survival

Follow-up examinations were inconsistently performed depending on the institution and surgical response. Repeat laryngoscopic examinations were performed at variable postoperative times on ≥1 occasion in 26 (52%) dogs, most commonly at time of revision epiglottic surgery, either electively or due to recurrence/persistence of signs, or at the time of intubation for another procedure/surgery. Follow-up fluoroscopy was performed in seven (14%) dogs. At the time of writing, 30 (60%) dogs were alive after a median of 928 days (range, 114-2805 days), eight (16%) were lost to follow-up after a median of 411 days (range, 43-1158 days) and 12 (24%) were dead/euthanized after a median of 301.5 days (range, 3-1212 days). Overall MST was not reached after a median of 716 days (range, 3-2805 days) (**Figure 7**). Death was classified as ER-related or possibly ER-related in four dogs, and non-ER-related in eight dogs (**Appendix Table 3**). Of those that had not died of ER-/possible ER-related causes, 15 (32.6%; n=7 primary ER, n=8 concomitant]) of 46 were free of respiratory signs at last follow-up/death. Ongoing clinical signs were recorded at last follow-up/death in 31/46 dogs (67.4%; n=7 primary ER, n=21 concomitant) (**Appendix Table 3**).

Discussion

The results of this study support our first hypothesis that dogs undergoing surgical management of ER experience a high overall rate of major postoperative complications. Postoperative major complications occurred following 48.7% of all surgical procedures in our study (**Table 2**). In contrast, intraoperative complications were uncommon. Our second hypothesis, that dogs undergoing epiglottopexy procedures would experience a higher rate of major postoperative complications than those undergoing epiglottectomy procedures was also confirmed. Our third hypothesis, that most dogs treated surgically for ER would experience long-term survival was also supported by our results, with MST not reached after a median of 716 days (range, 3-2805 days).

A high incidence of ongoing respiratory signs was recorded at last follow-up/death in dogs that had not died of ER/possible ER-related causes. However, this should be interpreted in light of the high incidence of concurrent respiratory tract disorders at time of ER diagnosis and their possible contribution to these ongoing signs. In a previous study,[3] cases of ER were stratified as primary or secondary based on the presence of concurrent/historical upper airway disease at presentation. We propose classification of the latter cases as concomitant, as the term secondary suggests a causal relationship between concurrent disorders and ER, which remains unknown. If ER were to occur secondarily to a concurrent upper airway disorder, an epiglottopexy may be considered desirable if treatment of the concurrent disorder were possible (eg, elongated soft palate). In our study; however, 42.6% of dogs with concomitant ER that underwent epiglottopexy developed failure on $\geq$1 occasion.

Complications reported in our study are similar to those reported elsewhere (**Appendix Table 4**).[3] Epiglottopexy failure was the commonest major postoperative complication, occurring following 23/55 (41.8%) epiglottopexy procedures. In a previous study,[3] temporary-epiglottopexy was performed as index surgery in 19 dogs and failure occurred in 36.8% after a mean of six months. In our study, NI-EP failure occurred in 58.3% of dogs after median of 27 days, accounting for all major postoperative complications following NI-EP. Non-incisional-epiglottopexy was most commonly performed using absorbable suture as a therapeutic trial to confirm the diagnosis; however, failure occurred earlier than expected in many cases. Development of AP was the second most common complication in our study, suspected or confirmed following 5.41% of all procedures. These dogs had no other risk factors for development of AP, although one dog experienced uncontrollable seizures, which may have permitted false passage. A significantly higher rate of AP was reported in a previous study,[3] wherein 31.6% of dogs that underwent epiglottopexy developed AP. While it may be anticipated that epiglottectomy procedures, in particular STE, would be associated with a very high risk of AP, this was not supported by our results. Aspiration pneumonia occurred following only 1/16 (6.3%) STE procedures in our study, following initial failed NI-EP. In an experimental study,[6] Medda et al reported no increased incidence of aspiration during swallowing following epiglottectomy in decerebrated cats. In that study, glottal closure, consisting of adduction and approximation of vocal cords and arytenoids, constituted the primary preventative mechanism against aspiration during swallowing, while epiglottis provided no apparent airway protection.[6] The importance of active glottal closure in prevention of aspiration is further supported by the well-recognized risk of aspiration in dogs with laryngeal paralysis, despite a normally functioning epiglottis.[7] In human literature, conflicting reports exist as to whether epiglottectomy increases risk of aspiration.[8-14] Abscessation of I-EP occurred in one dog in our study following initial failed hyoepiglotticus imbrication and has not been reported as a complication in previous studies.

Incisional-epiglottopexy may be seen as a more definitive method of epiglottic fixation on the basis that mucosal resection will result in formation of fibrous union between the epiglottis and tongue base.[1,2] Despite this, failure occurred following 16/43 (37.2%) I-EP procedures in our study. Skerrett et al reported failure of almost two thirds of I-EP procedures; however, all were revision surgeries.[3] It may be anticipated that repeated surgical manipulation/trauma would lead to increased fragility/deformity of epiglottis and increased rate of epiglottopexy failure. This was not investigated in our study due to the relatively small numbers of dogs that underwent individual procedures. Variations in epiglottopexy technique were identified in our study including differences in suture type and whether epiglottopexy was performed with full-thickness bites of epiglottic cartilage, and whether there was incorporation of the basihyoid bone. In humans, placement of epiglottopexy sutures full-thickness through epiglottis and tongue base and tied in a subcutaneous location in ventral neck has been proposed to reduce risk of failure in cases of grade

III laryngomalacia.[15] We did not evaluate the effect of differences in surgical technique on epiglottopexy failure in our study.

Diagnosis of ER in our study was made by laryngoscopy/endoscopy, combined with fluoroscopy in a limited number of cases. Findings related to the epiglottis were quite varied; however, two broad patterns of epiglottic dysfunction were rocognized.[3] In some cases, the epiglottis was observed to spontaneously displace caudally during inspiration (**Video-Clip S1-6**), in others, it was identified in a persistent upright position, appearing "entrapped" caudal to soft palate against the aditus laryngis, similar to that described by Leonard.[5] The caudal aspect of soft palate should be elevated dorsally in suspect cases to confirm that epiglottic displacement occurs independent of soft palate movement/contraction. Strategies to increase the sensitivity to diagnose ER include avoidance of tongue traction and downward pressure of the laryngoscope on the epiglottis.[3,5] Downward pressure in region of epiglottic frenulum should also be avoided. In our study, NI-EP was performed to assess the clinical response to epiglottic fixation in a horizontal position and support a tentative diagnosis of ER. This strategy can also prove useful in cases where diagnosis of ER is uncertain, particularly in dogs with concomitant ER.[1] Depending on response observed, suture(s) can be removed, left in-situ, or converted to I-EP.[1,2] In approximately 50% of dogs, a more definitive surgery was planned if a positive response were observed. In remaining cases, further surgery was not always advised unless recurrence of signs occurred. On the basis of high rate of concurrent airway disorders in these dogs, fluoroscopy may also be useful to evaluate for concurrent pharyngeal and/or tracheal disorders. In our study, findings consistent with ER were recorded in only 7/16 (43.75%) dogs, which may have been due to failure to evaluate for ER in some cases or reflect the intermittent nature of this condition. Abnormal fluoroscopic findings pertaining to epiglottis were similar to those identified during laryngoscopy/endoscopy; the epiglottis was observed to dynamically displace caudally during inspiration, resulting in contact with the dorsal pharyngeal wall (**Video-Clip S7**), or remain in a fixed upright position.

A high rate of major postoperative complications was identified following PE in our study; however, this should be interpreted in light of the small number of dogs that had this procedure performed. Excision of the rostral epiglottic tip, as performed in our study, has been described in only a single case of ER.[4] In that report,[4] epiglottic resection led to long-term resolution of dyspnea without postoperative complication. Leonard[5] described excision of one third of the epiglottis along its abaxial borders for management of epiglottic entrapment in three dogs, which resulted in complete resolution of inspiratory dyspnea in all cases. More extensive epiglottectomy techniques including subtotal/total epiglottectomy have previously been reported in only four dogs, two for management of recurrent ER[2,3] and two for epiglottic chondrosarcoma.[16,17] No major postoperative complications were reported in any case, although follow-up time was not clearly stated in two dogs.[3,17] In remaining two dogs, no significant complications were reported up to 12 and 17 months postoperatively, respectively.[2,16] This procedure has not been performed as index surgery in previously reported cases of ER so our results cannot be compared with others.

A number of alternative techniques were performed in our study including permanent tracheostomy, hyoepiglotticus imbrication and hyothyropexy. These were not included in statistical analysis due to their low individual numbers and heterogeneity. Hyoepiglotticus imbrication was performed in one dog and involved placing a figure-of-eight suture in the hyoepiglottis to shorten it, followed by closure of overlying mucosa. Hyothyropexy was performed as revision surgery in one dog on the basis that by translating the basihyoid bone caudally towards thyroid cartilage, ceratohyoid bones and attached hyoepiglotticus muscles would displace caudoventrally, resulting in epiglottic anteversion. Whether this technique will maintain the epiglottis in an anteverted position or permit further stretching of hyoepiglotticus muscles in the future is unknown.

We acknowledge a number of limitations in this study. Inherent to all retrospective studies, accuracy of recorded data relies on completeness of medical records. Dogs were treated at different institutions by multiple surgeons, with variations in surgical technique and case management. The decision to perform any of these procedures was not randomized but based on surgeon preference. Follow-up examinations were inconsistently performed at various postoperative time-points depending on response to surgery. Follow-up airway examinations were typically performed only if there was recurrence or persistence of clinical signs, and usually immediately prior to revision surgery. In some cases, repeat airway examination and/or revisional surgery may not have been recommended on the basis of a perceived improvement in clinical signs, which may have underestimated the incidence of major complications (e.g., epiglottopexy failure). Timing of major postoperative complications may not always have been accurate as a complication may have occurred but the dog may not have been re-presented immediately. A number of dogs in our study experienced adverse outcomes following a subsequent non-epiglottic surgery. In such cases, a subjective assessment was made as to whether previously performed epiglottic surgery contributed to this outcome. This may have underestimated the incidence of major complications. Conversely, in cases where a dog had died/been euthanized due to respiratory signs postoperatively without further investigation, classification of such cases as having developed a major complication may have overestimated incidence of complications.

In this study, dogs that underwent surgical management of ER experienced a high overall rate of major postoperative complications, particularly those that underwent epiglottopexy procedures. Conversely, intraoperative complications rarely occurred. A significant difference in the incidence of major postoperative complications between individual surgical procedures was not identified; however, combined epiglottopexy procedures had a higher incidence of postoperative complications than epiglottectomy procedures. While the optimal surgical treatment method for ER remains unknown, results of our study emphasize the high possibility of requirement for revision surgery. Epiglottectomy procedures were well tolerated in this study and associated with a relatively low rate of occurrence of AP. Long-term survival can be achieved in dogs treated surgically for ER.

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Disclosure Statement

The authors report no conflict of interest.

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Footnotes

a. GraphPad, USA

Figure 1: Videoendoscopic image of case 26 - The epiglottis contacts the dorsal pharyngeal roof and occludes the rima glottidis. Image courtesy of Dr. Gerhard Oechtering.

Figure 2: Same dog as in Figure 1. The epiglottis can be seen folding into the rima glottidis.

Figure 3: Subtotal epiglottectomy in case 37.

Figure 4: Subtotal epiglottectomy in case 46. Image courtesy of Dr. Bryden J. Stanley.

Figure 5: Same dog as in Figure 1 following partial epiglottectomy - Airflow through the dorsal aditus laryngis is facilitated. Image courtesy of Dr. Gerhard Oechtering.

Figure 6: Flow-diagram illustrating case management and postoperative complications among 50 dogs diagnosed with ER.

Figure 7: Kaplan-Meier survival of 50 dogs treated surgically for ER.

Timing of complications	**Non-incisional-epiglottopexy**	**Incisional-epiglottopexy**	**Partial-epiglottectomy**	**Subtotal epiglottectomy**	**Other**
Intraoperative	▪ None	▪ Hemorrhage (n=1)	▪ None	▪ Difficulty closing mucosa over exposed epiglottic cartilage (n=1)	▪ None
Short-term	▪ Epiglottopexy failure (n=7)	▪ Epiglottopexy failure (n=12) ▪ Aspiration pneumonia (n=2) ▪ Inability to extubate, requirement for temporary	▪ Cyanosis/airway obstruction during recovery (n=1) ▪ Persistent airway noise (n=1)	▪ Transient airway obstruction after extubation (n=1)	▪ Continued ER (n=1) ▪ Permanent tracheostomy obstruction due to skin

		tracheostomy, death (n=1) ▪ Pharyngeal swelling, requirement for temporary tracheostomy (n=1) ▪ Epiglottopexy abscessation necessitating removal, recurrence of signs (n=1)			folds (n=1)
Long-term	▪ None	▪ Epiglottopexy failure (n=4)	▪ None	▪ Severe seizures, aspiration pneumoni	▪ None

		▪ Possible aspiration pneumonia (n=1) ▪ Dyspnea 704 days postoperatively possibly ER-related (n=1)		a and death 6 months postoperatively (n=1)	

Table 1: Timing and type of intraoperative and major postoperative complications among procedures.

Surgical procedure	**Major postoperative complications** **% (95% CI)**
Non-incisional-epiglottopexy (n=15 procedures*)	7/12 procedures* **58.3%** (31.95-80.67)
Incisional-epiglottopexy (n=43 procedures)	23/43 procedures **53.5%** (38.92-67.49)
Combined epiglottopexy procedures (n=58 procedures*)	30/55 procedures* 54.5% (41.53-66.98)

Partial epiglottectomy (n=4 procedures)	2/4 procedures **50%** (15-85)
Subtotal epiglottectomy (n=13 procedures[+])	2/12 procedures[+] **16.7%** (4.7-44.81)
Combined epiglottopexy procedures (n=17 procedures[+])	4/16 procedures[+] 25% (10.18-49.5)
Other surgical procedures (n=3 procedures[†])	2/3 procedures[†] **66.7%** (20.77-93.85)
Overall (n=78 procedures*[+†])	36/74 procedures*[+†] **48.7%** (37.61-59.82)

Table 2: Incidence of major complications among surgical procedures.

*Three dogs converted to I-EP electively <4 days and excluded from NI-EP group.

[+]One dog euthanized after three days unrelated to ER/STE and excluded from STE group.

[†]Not included in statistical comparisons among other four groups.