311 (2025) 106345

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Diode Laser Epiglottidectomy (DLE) for management of epiglottic disease in 35 dogs

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ARTICLE INFO

Keywords:
Endoscopy
Diode laser epiglottidectomy
Epiglottic diseases
Minimally invasive surgery
Dog

ABSTRACT

Veterinary literature on epiglottic disorders and their treatment in dogs is limited. The objective of this study is to report the clinical features, diagnosis, surgical treatment, and outcomes of dogs with epiglottic conditions treated using diode laser epiglottidectomy (DLE). This was a single-institution observational prospective study. Thirty-five dogs diagnosed with epiglottic disease underwent DLE. In all cases, an epiglottic disease was documented with combined laryngoscopic examination, when needed, fluoroscopy, computed tomography (CT) scan, and biopsy. Sub-total (SDLE) and total (TDLE) diode laser epiglottidectomy was performed under endoscopic guidance according to the diagnosis. Follow-up was performed by a re-examination visit and endoscopy, and telephone follow-up with the owner. The most common epiglottic disorder was epiglottic retroversion (ER) (57.1 %). SDLE was performed in 32/35 (91.4 %) dogs, while 3/35 (8.6 %) dogs underwent TDLE. Intraoperative complications occurred in 11.4 % surgeries, primarily involving bleeding. Postsurgical complications were reported in 8.5 % cases post-SDLE and were represented by transient airway obstruction caused by local edema. Follow-up (median 18 months, minimum 3 months – maximum 21 months) consultations revealed prolonged resolution of upper airway obstruction without signs of respiratory tract compromise or dysphagia. The surgical techniques described in this study have proven to be effective and minimally invasive for the treatment of epiglottic-related airway obstruction.

Introduction

Despite its prominent location at the entrance of the laryngeal airway, little is known regarding the function and condition of the epiglottis. During the swallowing reflex, the epiglottis protects the lower airways from the aspiration of liquids and solids as it covers the laryngeal inlet by acting as a hinged lid. The role of the epiglottis in the mechanism of breathing is not completely understood (De Lorenzi et al., 2015; Amis et al., 1998).

Veterinary literature regarding epiglottic disorders and medical treatment in dogs is minimal (De Lorenzi et al., 2015; Flanders and Thompson, 2009; Skerrett et al., 2015; Mullins et al., 2014; Mullins et al., 2019; Shoieb, 2014). Only a few studies have been published concerning the incidence of epiglottic diseases, and their treatment was limited to 79 cases in total, 77 of which were affected by the same disorder (epiglottic retroversion) (Flanders and Thompson, 2009; Skerrett et al., 2015; Mullins et al., 2014; Mullins et al., 2019). Only two studies described the surgical treatment of a primary epiglottic malignant tumour (De Lorenzi et al., 2015; Shoieb, 2014). Although epiglottic retroversion (ER) is increasingly recognized as a cause of continuous or intermittent upper airway obstruction in dogs, its etiology remains unknown. Possible causes include hypothyroidism-associated peripheral neuropathy, epiglottic fracture, epiglottic malacia, and hyoepiglottic muscle failure to drag the epiglottis rostrally and ventrally to oppose the negative pressure generated during inspiration (Skerrett et al., 2015; Mullins et al., 2019). However, in the current literature, only 3 cases

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https://doi.org/10.1016/j.tvjl.2025.106345
Received 4 January 2025; Received in revised form 10 March 2025; Accepted 2 April 2025
Available online 3 April 2025

diagnosed with ER undergone histopathological examination of the epiglottis, although no attempt has been made to assess the histological features of the cartilage as has been done in tracheal collapse syndrome (Dallman et al., 1988).

Therapeutic management of ER can be medical or surgical; in dogs, epiglottopexy and subtotal or total epiglottidectomy are described as surgical treatments of ER (Skerrett et al., 2015; Mullins et al., 2014; Mullins et al., 2019). Total epiglottidectomy is also used for surgical resolution of primary epiglottic malignant tumours in dogs (De Lorenzi et al., 2015; Shoieb, 2014). Epiglottidectomy is well tolerated and associated with a lower rate of postsurgical complications than incisional or non-incisional epiglottopexy (Mullins et al., 2019). A high incidence of surgical complications and failures has been reported. In one study, approximately one-third of a cohort of 19 dogs were euthanized after surgery due to respiratory complications (Skerrett et al., 2015). Another study of 50 surgically treated dogs reported that 48.7 % had major postsurgical complications, and 24 % of dogs died as a consequence of clinical conditions or were euthanized (mean 301.5 days, range 3–1212 days) (Mullins et al., 2019). In human medicine, video-assisted laser epiglottidectomy is the standard surgical procedure for treating epiglottic-related airway obstruction, as in neoplastic or chronic inflammatory diseases, and for sleep apnea. Surgery is usually well tolerated by patients, with no significant postoperative complications or worsening of swallowing, breathing, or phonation (Zeitels et al., 1990; Golz et al., 2000; Kanemaru et al., 2007).

The purpose of this study were to: 1) to characterize the signalment, history, clinical signs, endoscopic features, comorbidities, complications, and outcomes of a cohort of 35 dogs with an epiglottic disease treated with DLE; 2) describe a standardized surgical technique, and 3) describe the pathological features of the epiglottic cartilage related to the different diagnosed diseases.

Materials and methods

Dogs with obstructive epiglottic disease were evaluated at the Operative Unit (OU) of Interventional Pulmonology at Anicura Hospital I Portoni Rossi from January 2022 to December 2023. Dogs with a history of respiratory distress, without other surgical issues, were considered for the study. Once admitted to the study, clinical and endoscopic evaluations were performed by the same board-certified specialist (Davide De Lorenzi). A final diagnosis of obstructive epiglottic disease was confirmed by the concurrent presence of respiratory distress and endoscopic abnormalities of the epiglottis. In relation to endoscopic findings, epiglottic disorders were classified into four major categories: epiglottic verticalization (EV), characterized by a normally shaped epiglottis that is permanently displaced posteriorly, partially or completely obstructing the view of the glottis (Fig. 1); ER, characterized by a normally shaped epiglottis that is displaced posteriorly during inspiration, partially or completely obstructing the glottic space; epiglottic deformation (ED), characterized by an abnormally shaped epiglottis that partially obstructs the glottis; and epiglottic neoplasia (EN), characterized by an epiglottic mass that partially obstructs the glottis. SDLE was the preferred procedure for all dogs with ER, EV, and ED; TDLE was the surgery of choice for the treatment of EN. All surgical procedures were performed by the same board-certified specialist (Davide De Lorenzi). Dogs with respiratory comorbidities potentially causing dyspnea (ex. III° laryngeal collapse, laryngeal paralysis, laryngeal neoplasia, cervical IV° tracheal collapse) were excluded from the study if they underwent concurrent surgical management for other airway disorders along with epiglottic surgery. Another exclusion criterion was the presence of severe heart disease (class B2 or higher, according to the American College of Veterinary Internal Medicine Consensus on degenerative mitral valve disease) and organ failure (renal or hepatic). For each dog, the recorded information included signalment, history, clinical signs, cervical and thoracic radiographs (and, when available, computed tomography scans and fluoroscopy of the affected area) findings, upper and lower airway endoscopic findings, histological findings, surgical procedures, and outcomes. All dog owners gave informed consent.

Endoscopic procedure

All dogs underwent complete endoscopic examination, including pharyngoscopy, laryngoscopy, and tracheobronchoscopy. All endoscopic procedures were performed with the dogs in sternal recumbency; the jaw was held open with a gag and with gentle traction of the tongue (Fig. 2). Laryngoscopy, pharyngoscopy, and cervical tracheoscopy were performed under sedation or light intravenous anaesthesia via a 2.7 mm× 18 cm rigid telescope (Telescope K Storz 64018BS, Karl-Storz-Endoscopy, Tuttlingen, Germany) with a halogen light supply. Bronchoscopy was performed under inhalation anaesthesia by passing a 2.7 mm× 67 cm flexible endoscope (Fiberscope K Storz 11278AK, Karl-Storz-Endoscopy) through a T-adapter inserted between the tracheal tube and the tubing of the anesthetic machine, using the same halogen light supply.

Laryngeal collapse was graded as proposed by Leonard (Leonard, 1960), tracheal collapse was graded as proposed by Tangner and Hobson (Tangner and Hobson, 1982), and bronchial collapse was graded based

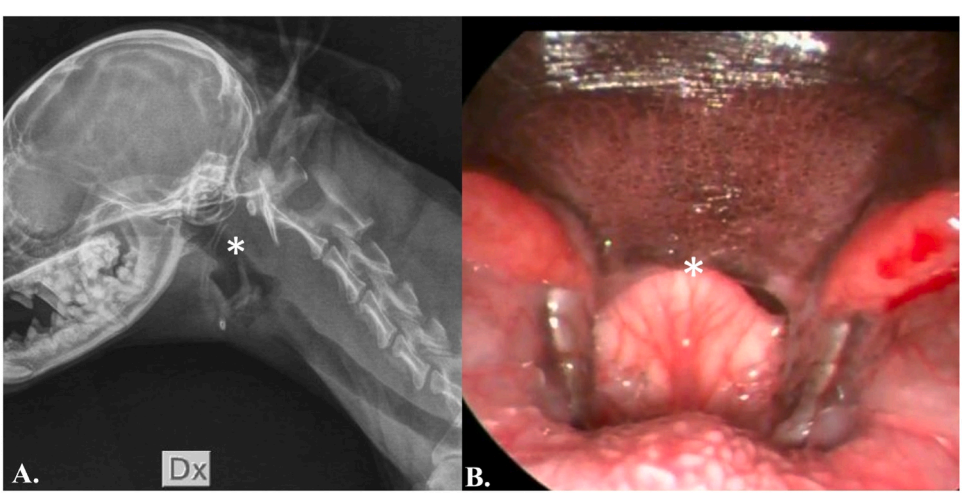

Fig. 1. Epiglottic verticalization (EV). A) Lateral neck radiographic view reveal the caudal shift of the epiglottis, indicated by the asterisk; B) Endoscopic view of EV, the epiglottis is indicated by the asterisk.

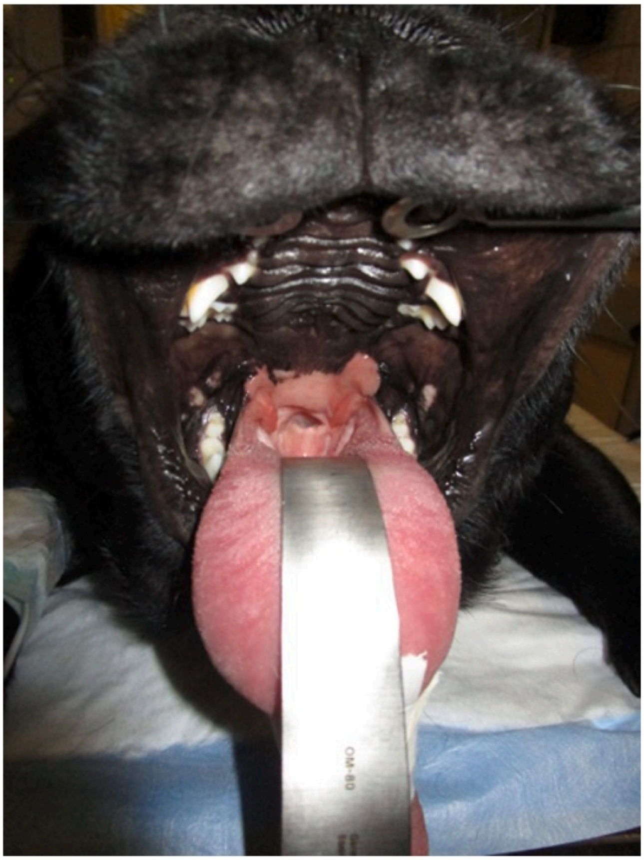

Fig. 2. Patient positioning during the endoscopy and diode laser epiglottidectomy (DLE).

on the bronchial diameter reduction, as proposed by De Lorenzi et al. (2009).[14]

Surgical procedure

All surgical procedures were performed with the dogs in sternal recumbency, the jaw was held open with a gag and with gentle traction of the tongue (Fig. 2). The dogs underwent surgery using general total intravenous anesthesia technique (TIVA). The dogs were premedicated with 2 μg/kg dexmedetomidine and 0.2 mg/kg methadone intramuscularly, and anesthesia was induced with intravenous propofol (4 mg/kg). Anesthesia was maintained with propofol administered as a bolus, fentanyl administered as a bolus of 2 μg/kg, or fentanyl in a constant rate infusion (CRI) at a dosage of 5 μg/kg/h. Due to the constant risk of the laser coming into contact with the endotracheal tube, all surgical procedures were performed in extubated dogs, with oxygen supplementation administered through a nasotracheal cannula. The inspired oxygen fraction (FiO_2) was kept below 30 % to prevent the risk of fire, as recommended by the FUSE (Fundamental Use of Surgical Energy) program.

All dogs were placed in sternal recumbency with the neck extended, the head suspended from a frame, and the jaw held wide open with a zinc oxide tape placed from around the tongue to the surgical table. Better visualization of the surgical field was obtained by placing a malleable retractor (BT752R, B Braun Aesculap, Milan, Italy) with the tip positioned anterior to the epiglottis to expose the vallecula and base of the tongue, thus allowing optimal exposure (Fig. 2). Once positioned, the retractor was held in place by fixing it to the table using zinc oxide tape.

SDLE and TDLE were performed using a 270 nm or a 350 nm diameter fiber, 4 W power, and a 980 μm wavelength diode laser (Quanta System, Milan, Italy) in the contact, continuous wave mode. A 2.7 mm× 18 cm, 30° oblique rigid endoscope (HOPKINS II Forward-Oblique Telescope 30°, 64018 BA, Karl Storz) and a sheath 14.5 Fr x 15 cm sheath with three different ports (67065 C, Karl Storz) were used. A central port was used to insert the laser fiber, and two lateral ports were used for continuous smoke and fluid aspiration. The procedure was performed by starting from the left side of the epiglottis. The first incision was performed in contact mode. Excision was performed after applying traction force in the mid-lateral portion of the epiglottis using cup laryngeal forceps (Dufner 27970–01, Dufner instruments GmbH, Tuttlingen, Germany). To maintain maximum traction on the epiglottis, a U-shaped wedge was incised at the level of the suprahyoid portion of the epiglottis if SDLE was performed. When TDLE was performed, the entire cartilage, including the epiglottic stalk (petiolus epiglottidis), was removed by resecting it from the dorso-caudal surface of the thyroid cartilage. A diode laser was used to cut through both aryepiglottic folds and to incise the lateral edge of the epiglottis. These incisions were then united across the vallecular surface of the epiglottis, resulting in *en bloc* cartilage excision. Careful dissection of the lingual surface of the epiglottis was necessary to avoid bleeding.

Immediately after the surgical procedure, the dogs were intubated, and a refrigerated saline-soaked sponge was placed on the surgical area and left in place for 3–5 minutes. The tissue defect healed by secondary re-epithelization without primary closure. To prevent traumatic edema of the operative field, 0.5 mg/kg of dexamethasone sodium phosphate (Dexadreson 2 mg/ml, MSD Segrate, Milan, Italy) was administered intravenously before induction of anesthesia, and a second dose of 0.5 mg/kg was given 12 hours post-surgery. Perioperative antibiotics (amoxicillin + clavulanic acid, 12,5 mg/kg twice daily subcutaneously) were also administered to all the dogs. Ranitidine chlorhydrate (Zantadine 3 gr/100 ml, CEVA S.p.A, Milan, Italy) at a dose of 2 mg/kg twice daily orally was used as an antiacid to prevent delayed healing in any dog exhibiting clinical signs such as hypersalivation, grass ingestion, vomiting, or swallowing without food, which are suggestive of gastroesophageal reflux disease (GERD). After surgery, the dogs were hospitalized in the Intensive Care Unit of the hospital for postoperative monitoring. Usually, postoperative alimentation was provided ad libitum, with soft food, starting 12 hours after surgery. Discharge occurred after 24 hours of clinical observation.

Histological findings

All histological specimens of epiglottis, obtained from normal and abnormal appearing tissues, were fixed in 10 % neutral-buffered formalin, processed, and embedded in paraffin wax; 4-μm sections were stained with hematoxylin and eosin (H&E), and then evaluated by a single board certificate pathologist. Histological specimens were classified into three groups: 1) nonspecific findings (when only mixed inflammation was present), 2) necrosis (when severe degenerative cartilage changes were evident), and 3) neoplasia (when neoplastic cells were present).

Follow-up

Follow-up consultations were performed at 1 month postoperatively (short-term follow-up) through clinical visit and laryngoscopic examination, and at 3 months postoperatively (long-term follow-up) solely through clinical check. No specific rubric for the evaluation of outcomes was provided to the owners. Instead, during these visits, owners were administered a questionnaire to assess the outcome of the surgery. They were asked whether the dog showed an improvement or worsening of respiratory function, whether there was persistence of pre-operative clinical signs, and whether the dog exhibited new clinical signs. Based on the information collected by the owners during clinical checks (short and long term follow-up), the outcome was classified as follows:

Poor: when the dog presented unchanged or worsened clinical signs;

Fair: when the dog showed good improvement in respiratory function with the disappearance of some clinical signs but persistent limitations in physical activity;

Good: when the dog showed complete improvement in respiratory function and the disappearance of clinical signs.

If owners did not authorize a laryngoscopy examination, follow-up was conducted only by clinical visit, and endoscopy was performed during intubation for another procedure (if necessary in a period between 1 and 6 months after SDLE or TDLE). In addition, throughout the study period, information on the outcomes (clinical aggravation, death, etc…) was obtained through telephone contacts with dog owners. Further visits or endoscopic checks were scheduled based on the outcomes discussed during these telephone conversations.

Statistical analysis

Only descriptive statistics are provided. The results were expressed as median (range) for continuous variables and as number (%) for qualitative and semi-quantitative variables.

Results

Thirty-five dogs diagnosed with epiglottic disease and undergoing DLE at the Operative Unit (OU) of the Interventional Pulmonology of the Anicura Hospital *I Portoni Rossi* during the study period (January 2022-December 2023) were included. Thirty-two out of 35 dogs underwent SDLE (91.4 %) and 3 TDLE (8.6 %). The individual assignments are presented in Table 1. The most common breeds included were Pomeranian (n = 7, 20 %), Chihuahua (n = 7, 20 %), and Yorkshire Terrier (n = 4, 11,4 %). Also, there were eight brachycephalic breed dogs: pug (n = 3, 8.5 %), CKCS (n = 2, 5.7 %), french bulldog (n = 2, 5.7 %), boxer (n = 1, 2.8 %). Other breeds present were mongrels (n = 5, 14.2 %) and german shepherds (n = 1, 2.8 %). There were 16 (45.7 %) spayed females, 1 (2.8 %) intact female, 15 (42.8 %) intact males and 3 (8.5 %) neutered males. The mean age was 66 months (12–120 months, median 61.4 months).

The most frequent pre-operative clinical signs were dysphagia (n = 33, 94.2 %), exercise intolerance (n = 33, 94.2 %), dyspnea (n = 33, 94.2 %) and breath sounds (n = 30, 85,7 %). Other clinical signs reported were hypersomnolence (n = 11, 33.4 %), discomfort during sleeping (n = 11, 33.4 %), and cough (n = 6, 17.14 %). Clinical signs suggestive of GERD were reported in the medical histories of 8 out of 35 dogs (22.8 %). Individual pre-operative clinical signs are listed in Table 1.

Diagnostic findings

Epiglottic abnormalities seen during the laryngoscopy were 20 ER (57.1 %), 6 EV (17.1 %), 6 ED (17.1 %), and 3 EN (8.6 %). Nineteen dogs (54.2 %) were affected by additional respiratory abnormalities observed endoscopically: 5 dogs (26.3 %) had 1 concomitant respiratory tract abnormality, 10 dogs (52.6 %) had 2 concomitant respiratory tract abnormalities, and 4 dogs (21.0 %) had 3 or more concomitant respiratory tract abnormalities. Additional upper and lower respiratory tract abnormalities (Table 1) included tracheal collapse (n = 10, 28.6 %), bronchial collapse (n = 9, 25.7 %), arytenoid collapse (n = 7, 20 %), soft palate hyperplasia (n = 5, 14.3 %) and arytenoid immobility (n = 2, 5.7 %).

Radiographic abnormal findings were recorded in 23 dogs (67.7 %). These included gastric dilation (n = 8, 22.8 %), abnormal epiglottic shape (n = 6, 17.1 %) (Fig. 3), caudally displaced epiglottis (n = 6, 17.1 %) (Fig. 2), bronchointerstitial pattern (n = 6, 17.1 %), and soft palate hyperplasia (n = 5, 14.2 %).

Fluoroscopy was performed in 7 (20 %) alert and awake dogs to confirm the clinical and endoscopic diagnosis of ER. In all cases, fluoroscopy was used to confirm the abnormal caudal movement of the

Table 1
Signalment (breed, sex, age), pre-operative clinical signs, and diagnostic (endoscopic and radiographic) findings of 35 dogs included in the study.

Case number	Signalment (breed, sex, age in months)	Pre-operative clinical signs	Endoscopic findings	Radiographic findings
1	Pomeranian, NF, 18	IS; Dy; EI;	ER	/
2	Chihuahua, M, 48	IS; Dy; EI;	ER	CDE
3	Yorkshire Terrier, M, 60	GERD; IS; Dy; EI;	ER, TC (II°)	/
4	Chihuahua, NF, 86	IS; Dy; EI; DDS; H; Co;	ER, TC (III°), BC (III°)	BIP
5	Pomeranian, NM, 74	IS; Dy; EI;	ER, TC (III°), BC (II°)	TC, BIP, GD
6	Poodle, NF, 48	IS; Dy; EI;	EV	/
7	Pug, NF, 36	GERD; Dy; EI; DDS; H; Ds;	EV, SPH, LC (II°), BC (III°)	SPH
8	French Bulldog, NF, 96	GERD; IS; Dy; EI;	ED, SPH, LC (II°)	AES, SPH
9	Chihuahua, M, 84	IS; Dy; EI; DDS; H;	ER, TC (III°), BC (III°), LC (II°)	TC, BIP
10	Mongrel, M, 120	Co;	EN	/
11	Boxer, M, 24	GERD; IS; Dy; EI;	ER	/
12	Chihuahua, NM, 72	IS; Dy; EI; DDS; H; Co;	ER, TC (II°), BC (II°)	TC, GD
13	Pomeranian, M, 36	IS; Dy; EI; DDS; H;	ER	CDE, GD
14	Pomeranian, NF, 54	IS; Dy; EI; DDS; H;	ER	/
15	Mongrel, NF, 74	Dy; EI;	ED	AES
16	Pug, M, 48	IS; Dy; EI; DDS; H; Ds;	EV, BC (III°), LC (II°)	SPH, BIP, GD
17	Pomeranian, M, 12	IS; Dy; EI;	ER, LC (II°), AI	/
18	Mongrel, NF, 60	IS; Dy; EI;	EV	/
19	Poodle, F, 84	GERD; IS; Dy; EI;	ER, TC (III°)	CDE
20	Yorkshire Terrier, NF, 78	IS; Dy; EI; Co;	EV, TC (III°), BC (III°)	TC, BIP, GD
21	Pomeranian, M, 54	IS; Dy; EI;	ER	/
22	German Sheperd, NF, 108	GERD; Co;	EN	/
23	Pug, NM, 42	IS; Dy; EI; DDS; H;	ER, BC (II°), LC (II°)	SPH
24	Yorkshire Terrier, NF, 12	IS; Dy; EI;	ER, TC (IV°), LC (II°), AI	TC
25	Pomeranian, NF, 72	IS; Dy; EI;	ER, TC (II°)	CDE
26	Yorkshire Terrier, M, 24	IS; Dy; EI; Co;	ER, TC (III°)	TC, GD
27	Chihuahua, M, 42	IS; Dy; EI;	EV	CDE
28	CKCS, M, 66	GERD; IS; Dy; EI; DDS; H;	ED, SPH, LC (II°)	AES, SPH, GD
29	Chihuahua, NF, 80	IS; Dy; EI;	ER, TC (III°), BC (II°)	TC, BIP
30	French Bulldog, M, 72	GERD; IS; Dy; EI; DDS; H;	ED, LC (III°), AI	AES, GD
31	Poodle, NF, 42	IS; Dy; EI;	ED	/
32	CKCS, M, 72	IS; Dy; EI; DDS; H; Ds;	ED, SPH	AES, SPH
33	Chihuahua, M, 24	IS; Dy; EI;	ER	/

(*continued on next page*)

Table 1 (*continued*)

Case number	Signalment (breed, sex, age in months)	Pre-operative clinical signs	Endoscopic findings	Radiographic findings
34	Mongrel, NF, 84	Dy; EI;	ER	CDE, GD
35	Mongrel, NF, 120	IS; Dy; EI;	EN	AES

AES: Abnormal Epiglottic Shape; AI: Arytenoid Immobility; CKCS: Cavalier King Charles Sphaniel; CDE: Caudally Displaced Epiglottis; Co: Cough; DDS: Discomfort During Sleeping; BC: bronchial collapse; BIP: Bronco-interstitial pattern; Dy: Dyspnea; Ds: Dysphagia; EI: Exercise Intolerance; ED: Epiglottic deformation; EN: Epiglottic neoplasia; ER: Epiglottic retroversion; EV: Epiglotic verticalization; GERD: Gastroesophageal reflux disease; GD: Gastric dilatation; F: Female; H: Hypersomnolence; IS: Inspiratory stridor; LC (grade): laryngeal collapse; M: Male; NF: Neutered Female; NM: Neutered Male; SPH: Soft Palate Hyperplasia; TC (grade): tracheal collapse (grade).

epiglottis during inspiration (Supplementary material 1).

Computed tomography (CT) was performed in 5 (14.2 %) dogs with an endoscopic suspicion of epiglottic neoplasia. Abnormal findings included moderately to severely deformed epiglottis in all cases (5/5, 100 %), epiglottic mineralization in 4 (80 %) cases, and sub-mandibular lymph node enlargement in 2 (40 %) cases.

Surgical details

The total duration of surgery was approximately 30–40 minutes, with laser application time around 10–20 minutes. Surgical time was slightly longer for TLDE compared to SDLE. In this study, intraoperative complications occurred during 4 out of 35 (11.4 %) surgeries, 2 (7.2 %) during SDLE, and 2 (2.7 %) during TDLE. The only reported intra-operative complication was bleeding. In all cases, bleeding was controlled by grasping the vessel with an alligator forceps and cauterizing it with a bipolar electrosurgical device.

Postsurgical complications were reported in 3 (8.5 %) cases post-SDLE. In this study, the only reported complication was local edema that caused transient airway obstruction and required temporary reintubation; all three dogs were regularly extubated within 2 hours after surgery. This study did not report aspiration pneumonia or temporary tracheostomy as postsurgical complications. No animals required oxygen supplementation while hospitalized in the Intensive Care Unit for postoperative monitoring.

Histological findings

All 35 resected epiglottic specimens were subjected to a pathological evaluation. Nonspecific findings were found in 27 (77.1 %) cases (20 ER, 6 EV, 1 ED), including subepithelial edema (27/27, 100 %), dilated lymphatics (22/27, 81.4 %), mixed inflammatory infiltrate (15/27, 55.5 %), and cartilage mineralization (5/27, 18.5 %). Epiglottic necrosis was found in 5 (14.2 %) cases of ED (Fig. 3). The diagnosis of neoplasia was diagnosed in all 3 (8.5 %) cases of EN; 2 were diagnosed as chondrosarcomas, and 1 identified as an undifferentiated sarcoma.

Follow-up

The median duration of follow-up was 18 months (min 3 months – max 21 months). At the time of drafting, 29 (82.8 %) dogs were alive. Four dogs died of non-respiratory-related conditions (2 with severe cardiac insufficiency, 1 with a road accident, and 1 with adrenal gland adenocarcinoma). Two dogs died of respiratory-related conditions (severe generalized bronchial collapse and grade III° laryngeal collapse).

Of the 32 dogs that underwent SDLE surgery and included in the study, 28 (87.5 %) had a good outcome, 3 (9.3 %) had a fair outcome, and 2 (6.2 %) had a poor outcome. All the 3 dogs that underwent TDLE surgery had a good outcome. No difference was observed in the short-term (1 month) and long-term (3 months) outcomes recorded during interviews with the owners at clinical examination. No differences in outcomes were reported by the owners during the telephone contacts following the examination visit performed at 3 months.

A follow-up laryngoscopy was performed in 17 (48.5 %) dogs either electively (1 months after surgery) or at the time of intubation for another procedure (1–6 months after SDLE or TDLE). In 15 cases, the larynx displayed no cicatrix retraction, granulation tissue, or twisting, and there was no distortion other than the defect in the treated area (Fig. 4). In 2 cases, a small area of residual epiglottic cartilage was exposed and not covered by the mucosal layer, apparently with no functional consequences.

Discussion

To the best of our knowledge, few veterinary medicine studies have investigated video-assisted diode laser epiglottidectomy in dogs with epiglottic diseases. During the 3 years of the study, 35 dogs diagnosed with obstructive dyspnea secondary to epiglottic pathology were treated with either subtotal (SDLE) or total epiglottectomy (TDLE).

Exact identification of the respiratory tract obstruction site is essential for selecting the best therapeutic strategy. The epiglottis is a thin lamella of elastic cartilage shaped like a leaf. It projects obliquely behind the root of the tongue and ventrally towards the entrance of the larynx. The epiglottis protects the lower respiratory tract by acting as a valve during the swallowing reflex. Concurrent adduction of the arytenoid cartilages and the vocal folds assists in its function. Even though epiglottic physiology remains largely unknown, its active movement during breathing is regulated by a complex interaction of muscles and

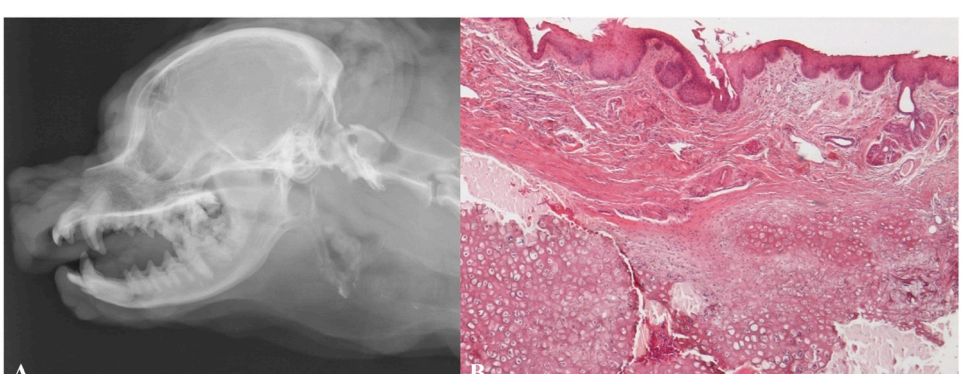

Fig. 3. Epiglottic necrosis. A) Lateral neck radiographic view reveal alterations in the shape and radiodensity of the epiglottis; B) Histological findings in hematoxylin and eosin (H&E) colouration during epiglottic necrosis.

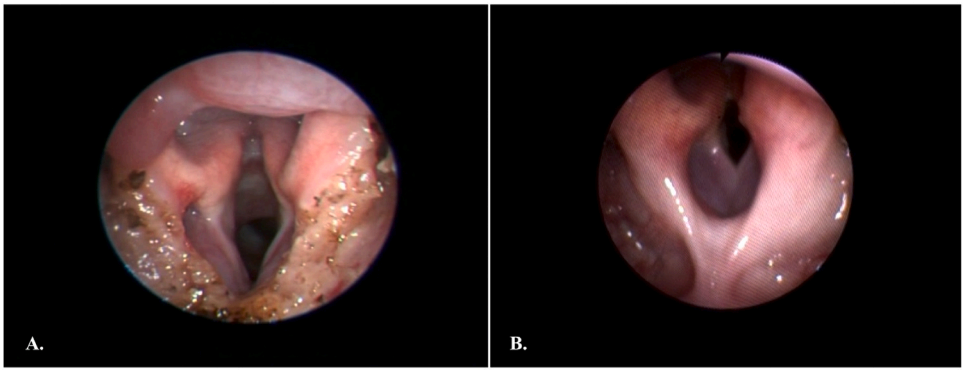

Fig. 4. Post operatory videoendoscopic images of surgical site. A) Videoendoscopic image taken immediately after the surgery; B) Videoendoscopic image taken 1 month after surgery reveal the larynx displaying no defects in the treated area.

airway cartilages, predominantly driven by the contraction of the hyoepiglottic muscle (Amis et al., 1998).This muscle originates from the ceratohyoid bone and inserts into the ventral aspect of the epiglottis; thus, its contraction moves the epiglottis ventrally, providing a mechanism for the active control of the epiglottic position during breathing (Amis et al., 1998; Amis et al., 1996). Early research on upper airway obstructive breathing disorders largely ignored the epiglottis. However, more recent studies have shown, both in human and veterinary medicine, that the epiglottis plays a vital role on its own and in combination with other respiratory structures (Flanders and Thompson, 2009; Skerrett et al., 2015; Mullins et al., 2014; Mullins et al., 2019).

ER was the study's most common epiglottic disorder (20/35 cases, 57.1 %). The same condition, both in pediatric and in adult human patients with obstructive sleep apnea, could be the cause of severe and life-threatening complications due to associated respiratory difficulties (Zeitels et al., 1990). Both in dogs and humans, an unusually flaccid epiglottis (so-called "floppy epiglottis") is displaced posteriorly against the posterior pharyngeal wall during inspiration. In extreme cases, the negative pressure developed within the laryngeal inlet may cause the epiglottis to prolapse downward and inward, resulting in subtotal or total airway obstruction (Mullins et al., 2019; Zeitels et al., 1990). In all the cases of ER reported in this study, an abnormally flaccid epiglottis was perceived to cause respiratory symptoms, although epiglottic prolapse was not observed in all cases during the endoscopic inspection. In some dogs, an aberrant craniocaudal movement was only detected in a light anaesthesia plane, possibly due to the increased air volume and speed during inhalation if compared with a more deeper anaesthesia plane, as previously described in humans (Kanemaru et al., 2007). This could explain the intermittent clinical signs in dogs clinically normal between obstructive respiratory episodes precipitated by stress or exercise. Indeed, the most frequently recorded clinical sign in this study was exercise intolerance (33/35 cases, 94.2 %). Due to intermittent symptomatology, the diagnosis of ER may be significantly underestimated. Moreover, veterinary clinicians should be aware that a missed diagnosis of ER when performing an upper airway examination could result not only from excessive tongue traction or downward pressure on the epiglottis, but could be secondary to a deep anaesthesia plane (Skerrett et al., 2015; Mullins et al., 2014). In uncertain cases, fluoroscopy should be performed on awake dogs to confirm the clinical and endoscopic suspicion of ER. In this study, fluoroscopy was performed in 7 (20 %) awake dogs, and in all cases, it was possible to confirm the abnormal caudal movement of the epiglottis during the inspiratory act.

ER is the only epiglottic displacement disorder described in veterinary medicine (Flanders and Thompson, 2009; Skerrett et al., 2015; Mullins et al., 2014; Mullins et al., 2019). However, in this study, we have identified another type of pathological epiglottic displacement that can be differentiated from ER. In our opinion, EV can be defined as the posterior displacement of the epiglottis against the posterior pharyngeal wall, independently of the respiratory phase. Although these disorders are similar, the constant presence of EV regardless of the inspiratory phase affects clinical and endoscopic findings. For this reason, we prefer to distinguish between these two conditions. During the endoscopic investigation, no substantial changes in the epiglottic position were noticed in correlation to the anesthesiologic stage in the presence of EV. Moreover, no anatomical abnormalities of the epiglottis were observed in any of the dogs with EV. The causes of EV in these dogs may be challenging to determine because several possibilities exist, such as congenital abnormalities or laryngeal trauma. We hypothesized that, in some cases, a hypertrophic tongue may play a role in EV. In our theory, the base of a hypertrophic tongue may exert positive pressure on the lingual aspect of the epiglottis, displacing it posteriorly and causing epiglottic back positioning and subsequent verticalization; however, further investigation is warranted. In our study, 2 out of the 6 cases of EV involved brachycephalic dogs, which seems to support our thesis, although it highlights the possible presence of many unknown pathogenetic causes. Additional hypotheses regarding the etiology of EV in dogs could include epiglottic fracture or malacia, hypothyroidism-associated peripheral neuropathy, and denervation of the hypoglossal nerve, the glossopharyngeal nerve, or both, as already suspected for ER (Mullins et al., 2019). In our study, the histological findings in cases of ER and EV were nonspecific, mostly indicative of inflammation. Epiglottic fractures were not found in any of the cases. No specific coloration, histochemical analysis or electron microscopy studies, similar to those previously described for TC, was performed for the identification of malacia (Dallman, 1988; Dallman, 1985). However, the possibility that generalized malacia is a predisposing factor for epiglottis pathologies such as EV and ER is supported by the prevalence of small breeds (Pomeranian, Chihuahua, and Yorkshire Terrier), known to be predisposed to conditions such as tracheal and bronchial collapse (Della Maggiore, 2020). The small number of cases, particularly for EV, is insufficient to draw definitive conclusions about the pathophysiology of these conditions. Further studies should focus on histological and microscopic details regarding the epiglottic cartilage, muscles (especially the hyoepiglottic muscle), and nerve tissue, as previously described for laryngeal paralysis (Shelton, 2010).

ED can be defined as a congenital or acquired anatomical alteration of the epiglottis that can obstructs the glottis. This study found 6 cases of severe epiglottic deformation, 4 of which were in brachycephalic breed dogs (CKCS and French Bulldogs). The epiglottis was markedly distorted shape in these dogs, which partially obstructed the laryngeal inlet. Two cases demonstrated that both left and right borders folded dorsally and axially, approximately mid-body, with the rostral portion deviated ventrally, and the cartilage thickened with the micro-nodular aspect of the mucosa of the laryngeal surface of the epiglottis (Fig. 5 A). In three cases, endoscopic examination revealed a transverse kink in the mid-body of the epiglottis with the rostral portion deviated caudoventrally and to the left in two dogs and to the right in one dog (Fig. 5B). In the last case, the epiglottis curled on itself and was omega-shaped, probably secondary to severely shortened aryepiglottic folds (Fig. 5 C). In all these cases, the apex was nodular and thickened. Histopathological examination of specimens collected from the ED of these dogs revealed tissue necrosis in 5 out of 6 cases. Epiglottic necrosis is an unusual condition rarely described in human medicine that may occur as a potential complication of epiglottitis in immunocompromised patients (Sengör et al., 2004). The causes of epiglottic deformity in these dogs may be difficult to determine; our theory is that the epiglottic deformation could be congenital or acquired secondary to a chronic inflammatory condition. Our six dogs had no medical history of immunodeficiency disease, laryngeal infection, or chronic inflammation, which corroborates our hypothesis.

Concomitant upper or lower airway disorders were diagnosed in 54.2 % of cases, suggesting that epiglottic conditions are either a component of these disorders or occur secondary to chronic increased inspiratory airway pressures that may occur with these processes. The altered airway pressure balance could be responsible for GERD, which was suspected in some dogs. The majority of animals with medical histories reporting gastrointestinal clinical signs suggestive of GERD belonged to brachycephalic breeds. Moreover, as evidenced in other upper airway tract disorders, GERD could also be an unrecognized etiopathogenic factor responsible for chronic epiglottic inflammation (Grobman and Reinero, 2023). Furthermore, ER, EV, and ED may represent unrecognized components of brachycephalic airway obstructive syndrome (BAOS), or this population may be at risk for epiglottic conditions due to abnormal inspiratory pressures. An additional area of research could be the epiglottic position in relation to the tongue and other airway cartilages in brachycephalic dogs, to evaluate if there is a breed predisposition linked to anatomical factors. However, brachycephalic breeds represented only 22.8 % of the study's population; therefore, no statistical conclusions could be drawn. To investigate the hypothesis, further research remains needed.

In veterinary medicine, laryngeal neoplasms are rarely reported in small animals, including epithelial and mesenchymal types, with the epiglottis being the most unusual primary neoplastic subsite (Meuten, 2002; Salk et al., 1986; Witham et al., 2011). To the best of our knowledge, few cases of primary malignant epiglottis neoplasms have been reported (De Lorenzi et al., 2015; Shoieb, 2014; Muraro et al., 2013); in two of these cases, the conclusive diagnosis was low-grade chondrosarcoma microscopically characterized by well-developed chondroid lobules, which primarily originate from the elastic cartilage of the epiglottis. The inadequate number of reports regarding cartilaginous tumours of the epiglottis in the veterinary medical literature imposes some diagnostic and therapeutic challenges.

Various surgical techniques have been described in humans for the treatment of benign epiglottic obstructive diseases such as ER, EV, and ED. These treatments include epiglottopexy, laser epiglottoplasty, epiglottis stiffening operation, and sub-total laser epiglottidectomy (Salamanca et al., 2019). Moreover, both conventional surgery and video-assisted laser epiglottidectomy are used to treat supraglottic airway obstruction secondary to neoplastic diseases (Zeitels et al., 1990). In veterinary medicine, epiglottectomy and epiglottopexy have been described for treating benign epiglottic obstructive conditions (Mullins et al., 2014; Mullins et al., 2019). Total epiglottectomy, traditional, and laser guidance, have also been described for the treatment of epiglottic neoplasms (De Lorenzi et al., 2015; Shoieb, 2014). To the best of our knowledge, no surgical treatments has been described for ED in dogs. In this study, we proposed video-assisted DLE as a treatment for all obstructive epiglottic diseases. SDLE was the preferred procedure for all dogs with benign epiglottic conditions such as ER, EV, and ED, while TDLE was the surgery of choice for the treatment of EN. TDLE was favored for suspected neoplasms of the epiglottis because, when feasible, surgery with curative intent is preferred. In all cases of EN in our series, no metastatic lesions were detected by CT scan, and we opted for total excision of the neoplasm with curative intent. Diode laser is easy to manipulate, shortens surgical time, and provides a high degree of precision, maintaining hemostasis and minimizing postoperative edema. We performed the same procedure described in humans by Catalfumo et al. (1998) by resecting the suprahyoid portion of the epiglottis. Anesthesia was maintained with propofol and fentanyl administered in bolus. Although displaced posteriorly, the endotracheal tube could impede surgical maneuvers; its bulk impedes the manipulation of the epiglottic, and the traction and exposure of the epiglottis are less than ideal. Furthermore, the endotracheal tube is at constant risk of being struck by the laser beam. For these reasons, all the surgical procedures described in our study were performed in an extubated dog with oxygen supplementation administrated through a nasotracheal cannula. This procedure was safe, effective, and tolerated by all our dogs. No severe intra- or postsurgical complications were observed. The only reported intraoperative complication was bleeding. The diode laser provides a dry operative field during most of the procedures. However, branches of superior laryngeal vascularization may be encountered, and careful dissection along the lingual surface of the epiglottis is necessary to avoid bleeding. In 4 cases, bleeding of the superior laryngeal vessel branches was controlled by grasping them with alligator forceps and applying a coagulating electric current, with no further complications. In a retrospective study aimed at reporting intraoperative and major postoperative complications in dogs treated surgically for ER by comparing the incidence of major postoperative complications between procedures, authors found that although intraoperative complications were uncommon, major postoperative complications were common, especially after epiglottopexy procedures (Mullins et al., 2019). More specifically, major postoperative complications were documented after 36 of 74 (48.7 %) procedures. Postoperative complications occurred in 7 of 12 (58.3 %) non-incisional epiglottopexies, 23 of 43 (53.5 %) incisional epiglottopexies, 2 of 4 (50 %) partial epiglottomectomies, 2 of 12 (16.7 %) subtotal epiglottomectomies, and 2 of 3 (66.7 %) other surgical

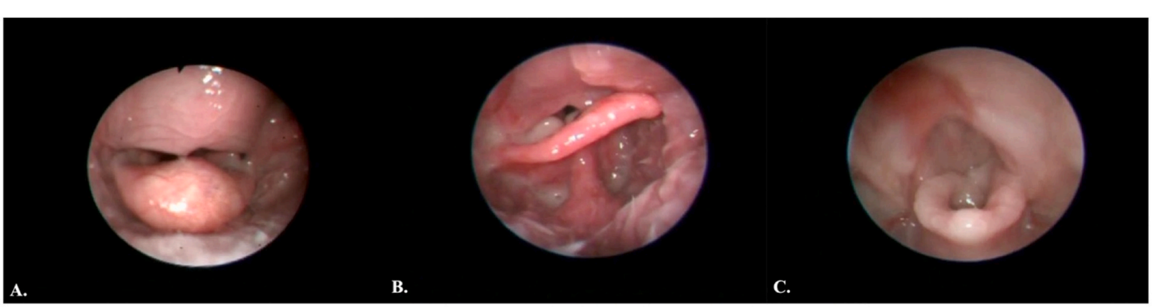

Fig. 5. Endoscopic view of epiglottis deformation (ED). A) Epiglottis exhibits folding along its borders in both dorsal and axial directions. The rostral portion of the epiglottis is bent or deviated ventrally. The mucosa appears to have a micro-nodular aspect; B) Epiglottis had a transverse kink in the middle portion, and the rostral portion deviated caudo-ventrally; C) Epiglottis is folded on the same "omega"-shaped.

procedures. The authors concluded that surgical treatment of ER is associated with a high rate of major postoperative complications. This statement is in contrast with the results of the present study: postsurgical complications were reported in 3 cases post-SDLE, with the only reported complication being immediate local edema that caused transient airway obstruction and required temporary reintubation. All 3 dogs were regularly extubated within 2 hours after surgery. No animals required oxygen supplementation while hospitalized in the Intensive Care Unit for postoperative monitoring. The latter could be associated with a lower rate of complications from the laser technique, as proposed by the authors of this study.

Epiglottectomy in infants and adult patients with epiglottic obstructive disease results in the relief of symptoms of airway obstruction in 85–90 % of cases (Holinger and Konior, 1989). This is consistent with the results of our study, which revealed a substantial improvement in both short and long-term respiratory function without developing a swallowing disorder. To prevent misinterpretation of the dog's clinical status by the owner, improvement of respiratory function was evaluated through regular clinical visits and questionnaires administered by clinicians at each follow-up. Only two dogs had a poor outcome and died due to pre-existing comorbidities (III° laryngeal collapse and bronchial collapse, respectively), which worsened their clinical signs. Although these pathological conditions were identified preoperatively, surgical treatment wasn't considered necessary. In fact, bronchial collapse is typically managed medically (Reinero and Masseau, 2021). In contrast, if III° laryngeal collapse causes obstructive dyspnea, lateralization or arytenoidectomy can be performed as a surgical treatment (White, 2012). While some cases required simultaneous surgical management of epiglottic disease and other airway disorders, the authors prefer, when the animal's clinical condition allows it, to adopt a staged surgical approach. Specifically, they opt to address the most severe obstructive disorder first or, in cases of equal severity (e.g. III° laryngeal collapse or IV° cervical collapse), the most rostral one. This approach aims to reduce anesthesia time and procedural invasiveness while allowing for clinical evaluation after treating the primary obstructive pathology. In animals where the epiglottic condition is the main cause of airway obstruction, this strategy could leads to symptom resolution and significant clinical improvement. However, in cases where multiple airway conditions contribute to obstruction, additional surgeries may be required, negatively impacting the overall prognosis. Based on their personal experience and previously published literature, the authors believe that there are currently no less invasive alternatives to the proposed gradual surgical approach (Mullins et al., 2019). However, further studies are needed to better define therapeutic options for these cases.

A limitation of our study was the poor standardization of follow-up. Laryngoscopy examinations were inconsistently performed at various postoperative times. Although follow-up examinations were recommended one month post-surgery, in some cases they were conducted based on the owner's preference or the clinical necessity of the animals. Because upper laryngoscopy was not performed regularly after surgery, postoperative complications may have been underestimated, although most animals showed improvement in respiratory function without dysphagia. Another limitation of this study is the presence of only descriptive statistics.

SDLE or TDLE with a 980 μm diode has been proven to be a safe and relatively simple procedure by a well-trained surgeon and provides a high degree of precision and hemostasis, minimizing postoperative edema. Accurate clinical evaluation, medical history collection, and adequate diagnostic endoscopy are fundamental for proper selection of dogs for surgical procedures. Following the successful outcomes of previously published case and those included in our case series, it can be concluded that with careful patient selection and adequate knowledge of laser surgery, TDLE is a suitable treatment for epiglottic cancer, while SDLE is a viable option for treating obstructive benign epiglottic disease. The results obtained in this study are promising: 85 % of the dogs had an adequate outcome. No significant respiratory discomfort or swallowing disorders were reported during the postoperative evaluation. However, further investigation is necessary to assess the outcome in a more significant number of cases.

CRediT authorship contribution statement

De Lorenzi Davide: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Maggi Giulia:** Writing – review & editing, Writing – original draft, Validation, Resources, Formal analysis, Data curation. **Mantovani Chiara:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Conceptualization. **Marchesi Maria Chiara:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization. **Bottero Enrico:** Writing – review & editing, Visualization, Validation, Methodology, Conceptualization.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

We have nothing to declare.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2025.106345.

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