Check for updates

Received: 4 February 2025 | Revised: 7 October 2025 | Accepted: 14 October 2025

DOI: 10.1111/vsu.70046

CLINICAL RESEARCH

WILEY

Long-term outcomes of dogs with W-shaped or traditional tracheal collapse treated with a continuous extraluminal tracheal prosthesis: A retrospective study

Masahiro Suematsu DVM[1,2] | **Tomomi Minamoto DVM, PhD**[3] | **Hiroaki Suematsu DVM**[1] | **Shiori Arai DVM, PhD, DACVS (Small Animal)**[4] | **Makoto Fujiki DVM, PhD**[2] | **Manabu Kurihara DVM, DACVR**[5]

[1]AMC Suematsu Animal Hospital, Oita, Japan

[2]Laboratory of Veterinary Surgery, Joint Faculty of Veterinary Medicine, Kagoshima University, Kagoshima, Japan

[3]Evergreen Vet Research & Publication, Aichi, Japan

[4]Department of Clinical Sciences, Colorado State University, Fort Collins, Colorado, USA

[5]Molecular Biomedical Sciences, North Carolina State University, Raleigh, North Carolina, USA

Correspondence
Masahiro Suematsu. AMC Suematsu Animal Hospital. 3-52 Nakajomachi, Hita, Oita 877-0011, Japan.
Email: suematsu.hita@mac.com

Abstract

Objective: To report the clinical characteristics of traditional (TTC) and W-shaped tracheal collapse (WTC) and the long-term outcomes of continuous extraluminal tracheal prosthesis (CETP) placement in dogs with grade IV tracheal collapse (TC).

Study design: Retrospective case series.

Animals: A total of 69 client-owned dogs.

Methods: Medical records of dogs with grade IV TC, subclassified as TTC or WTC, treated using CETP between 2018 and 2021, were retrospectively reviewed. Clinical signs, diagnostic results, intraoperative findings, surgical complications, and clinical outcomes were analyzed.

Results: Of the 69 dogs, 45 had TTC and 24 had WTC. All were discharged after CETP placement. Preoperative stridor ($p < .0001$) and labored breathing ($p = .0419$) were more prevalent in patients with WTC than in those with TTC. The WTC group was 12.1 times more likely to require preoperative oxygen management than the TTC group (OR, 95% CI: 3.2–37.5). The 36-month postoperative survival rates were 75.7% and 90.9% in dogs with TTC and WTC, respectively. Postoperative laryngeal paralysis occurred in three dogs in the TTC group and two in the WTC group. Recurrent TC occurred in one dog in the TTC group and two in the WTC group. Seven of the eight dogs with postoperative complications required surgical intervention or intraluminal stent placement.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2025 The Author(s). *Veterinary Surgery* published by Wiley Periodicals LLC on behalf of American College of Veterinary Surgeons.

Conclusion: Although dogs with WTC showed more severe preoperative respiratory symptoms, their postoperative outcomes were comparable with those of dogs with TTC.

Clinical significance: CETP placement is a viable surgical treatment option for dogs with WTC, even those with severe respiratory symptoms.

1 | INTRODUCTION

Tracheal collapse (TC), a common respiratory disease in dogs, involves dorsoventral flattening of the trachea due to weakening of the cartilaginous rings.[1–3] Mild cases are often asymptomatic, but severe cases can present with goose honking cough, dry harsh cough, and dyspnea, which can lead to respiratory arrest at the end stage.[2] Initial management includes weight loss, avoidance of pressure to the cervical area, elimination of allergens, management of comorbidities, and medical therapy for severe dyspnea.[2,4,5] Medical management can improve clinical signs of TC, but clinical signs often progress, requiring surgical intervention or stenting. The median survival time from the time of diagnosis was previously reported to be 3.7 years in cases with medical management only, and 12 days in severe cases with medical management.[6] Surgical options for refractory or severe TC include endotracheal stent placement,[6–8] tracheal ring placement,[9,10] and continuous extraluminal tracheal prosthesis (CETP) placement.[11]

The type of TC is classified according to severity (grades I–IV).[12] While a subclassification of grade IV based on the presence of malformation of the tracheal cartilage had not been implemented, improvements in the image quality of endoscopic examination allow for clearer visualization and detection of malformations of the tracheal mucosa and tracheal cartilage. Tracheal rings in traditional TC (TTC) are marked by a flattening C shape, whereas in W-shaped TC (WTC) are distinguished by a recently described W-shape, causing obstruction of the tracheal lumen.[6,8] One study found no significant difference between the survival rates of TTC dogs and WTC dogs that underwent endotracheal stent placement.[7] However, static airway obstruction characteristic of WTC is less likely to respond to medical management and more likely to require stent placement or other surgical intervention.[6]

A previous study showed that CETP treatment for severe TC resulted in 98% of dogs surviving to discharge and resolved goose honking cough and dry harsh cough in most dogs.[11] Histologically, CETP placement does not cause chronic inflammation, providing minimal postoperative complications and a good long-term prognosis, with low perioperative mortality.[9–11,13,14] To the authors' knowledge, clinical outcomes of CETP placement in dogs with grade IV WTC have not been reported previously.

This study aimed to evaluate and compare the clinical characteristics and long-term clinical outcomes of CETP placement in dogs diagnosed with grade IV TTC or WTC. We hypothesized that dogs with WTC would exhibit distinct clinical signs, present with more severe preoperative conditions, have a higher incidence of laryngeal paralysis and recurrent collapse, and have lower long-term survival rates compared to those with TTC.

2 | MATERIALS AND METHODS

A retrospective review was performed using the medical records of dogs at AMC Suematsu Animal Hospital that were diagnosed with grade IV TC, as confirmed by radiographs and tracheoscopy, and underwent a CETP placement procedure from October 2018 to September 2021. Grade IV TC was subclassified into TTC and WTC based on the shape of the tracheal cartilage observed by tracheoscopic examination. In this classification, traditional TC was defined as a flattening C shape tracheal rings without malformations of the tracheal cartilage, resulting in dynamic airway collapse. In contrast, TC with a static localized obstruction of the tracheal lumen, where the tracheal rings in the affected segment collapse into a W shape rather than the typical C shape, was defined as WTC (Figure 1). The subclassification was confirmed with radiographic, tracheoscopic, and anatomical findings during surgery (Figure 2). All of the dogs included in this study had at least one of the following clinical signs: goose honking cough, dry harsh cough, stridor, or labored breathing. Preoperative radiographic examination showed severe TC in all cases, and grade IV (TTC or WTC) was confirmed with tracheoscopic examination. The dogs were considered candidates for the surgery when dogs had respiratory signs associated with TC and were refractory to medical management, such as antibiotics, steroids, antitussives, or bronchodilators.

Exclusion criteria included dogs with laryngeal paralysis, laryngeal collapse, laryngeal tumor, chronic valvular

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

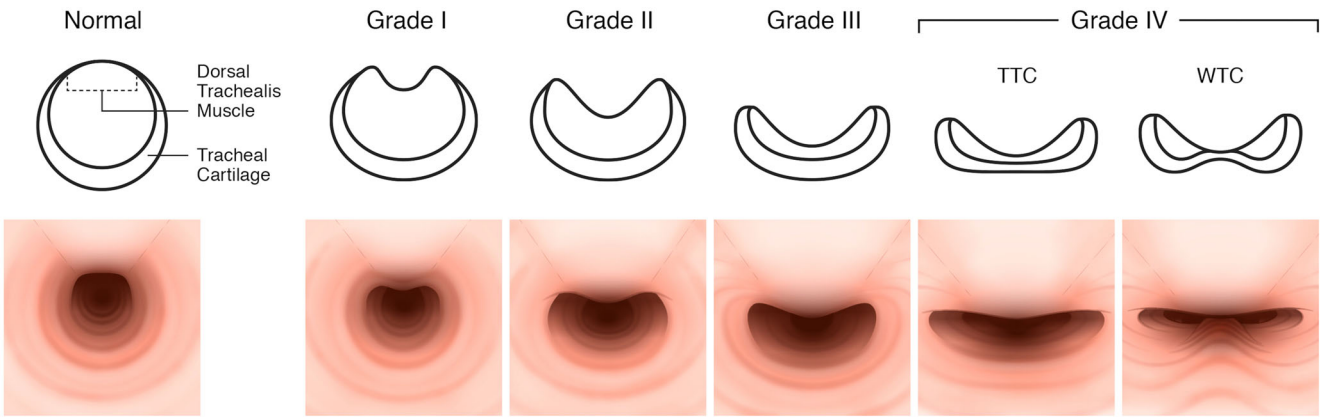


FIGURE 1 Normal canine trachea and severity classification of collapsing trachea. Normal: The tracheal lumen has a round shape, and the cartilage maintains a circular shape. The membranous wall is not pendulous. Grade I: The trachealis muscle is slightly pendulous, and the cartilage maintains a circular shape. The lumen diameter is 25% reduced. Grade II: The tracheal cartilage is partially flattened. The lumen diameter is 50% reduced. Grade III: The tracheal cartilage is nearly flattened. The lateral borders of the cartilage can be palpated during physical examination. The lumen diameter is 75% reduced. Grade IV: The tracheal cartilage is completely flattened, and the membranous wall is severely stretched. The lumen is essentially obliterated. TTC, tracheal cartilage is collapsed, and no malformation of the tracheal cartilage can be seen; TTC, traditional tracheal collapse; WTC, tracheal cartilage is collapsed in a w and reaches the membranous wall; WTC, W-shaped tracheal collapse.

heart disease stage C and D, according to the American College of Veterinary Internal Medicine (ACVIM) consensus guideline, kidney disease, anemia, thrombocytopenia, and any condition that could confer a higher risk of perioperative complications associated with anesthesia and surgical intervention were considered unsuitable candidates for the surgery.

All owners of dogs were informed by the surgeon of the risks associated with the surgical procedures, the materials used in the CETP, and any possible perioperative complications associated with the surgery. All owners agreed to the use of their information for research purposes. Only dogs with complete medical records, including signalment, pre- and postoperative radiographic findings, and tracheoscopic examination findings, were included in the study. To evaluate postoperative clinical outcomes, dogs with at least a 30-day follow-up period were included.

Information retrieved from the medical records included demographic information (e.g., breed, sex, bodyweight, and age at the time of surgery), preoperative clinical signs (e.g., goose honking cough, stridor, dry harsh cough, and labored breathing), the use of an oxygen chamber due to dyspnea and/or cyanosis, radiographic and endoscopic findings, peri- and postoperative complications (e.g., laryngeal paralysis, recurrent dry harsh cough, and recurrent TC), improvement of clinical respiratory signs (e.g., goose honking cough, stridor, dry harsh cough, and labored breathing) after surgery, postoperative hospitalization management, and survival time.

2.1 | Diagnostic tests

Physical examination, complete blood count, chemistry panel, coagulation profile (i.e., prothrombin time and activated partial thromboplastin time), and serum C-reactive protein measurements were performed preoperatively for all patients. Cervicothoracic radiography during inhalation and exhalation, and laryngeal and tracheal endoscopy using an endoscope (BF-XP290 or URF-V3, Olympus Corporation, Japan) with a 3.1-mm outer diameter tip were performed prior to surgery. The site of WTC was classified as the cranial cervical area, middle cervical area, thoracic inlet, or intrathoracic area.[15]

2.2 | Tracheal prosthesis

The CETP was constructed from a 0.75-mm-thick polymer optical fiber, as described in a previous report.[11] The length of the prosthesis was determined by the distance from the cricoid cartilage to the second rib on radiographs. Prostheses with diameters of 8, 9, 10, 12, 15, and 18 mm were prepared and the diameter was selected intraoperatively based on the fit of the prosthesis when placed directly onto the trachea.

2.3 | Preoperative care and anesthesia

Prednisolone (1 mg/kg subcutaneously), ampicillin sodium (20 mg/kg IV), maropitant (2 mg/kg IV), and

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

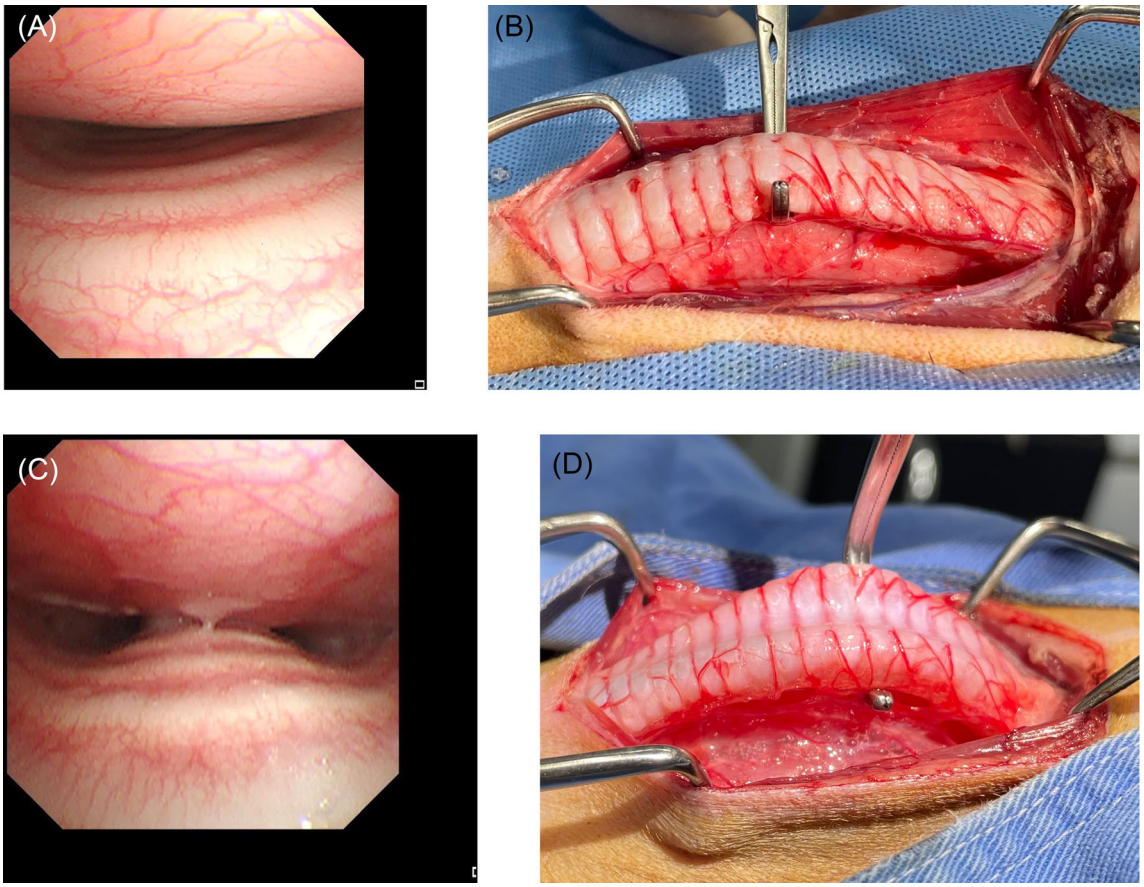


FIGURE 2 (A–D) Radiographs and endoscopy images and gross findings during surgery of TTC and WTC. (A) Endoscopy images of grade IV TTC: The membranous wall is stretched, and the tracheal lumen is severely obliterated. (B) Gross findings during surgery of TTC: The trachea is dorsoventrally collapsed. The trachea is collapsed dorsoventrally, and no W-shaped malformation of the tracheal cartilage is observed. (C) Endoscopy images of WTC: The membranous wall is stretched, and malformation of the tracheal cartilage is observed within the submucosal layer. The tracheal cartilage is inverted and contacts the membranous wall. (D) Gross findings during surgery of WTC: The trachea is dorsoventrally collapsed. The cartilage is partially inverted. TTC, traditional tracheal collapse; WTC, W-shaped tracheal collapse.

buprenorphine hydrochloride (20 μg/kg IV) were administered 30 min before surgery. Propofol (5 mg/kg IV) was slowly administered IV until jaw tension became weak, and laryngoscopy and tracheoscopy were performed to rule out laryngeal paralysis and grade the severity of tracheal collapse. Subsequently, midazolam (0.1 mg/kg IV) was administered, additional propofol (5 mg/kg IV) was infused to induce anesthesia to effect, and then the dogs were intubated. Isoflurane inhalation and a ventilator were used to maintain a surgical plane of anesthesia. Lidocaine hydrochloride (0.5%, 2 mg/kg) was intraoperatively injected into the sternohyoid and sternocephalic muscles for pain management.[11]

2.4 | CETP placement

The CETP was placed as previously described.[11] The dogs were positioned in dorsal recumbency, and a skin incision was made at the midline of the neck. The trachea and perivascular tissues were bluntly dissected to preserve as much of the vascular distribution to the trachea as possible. Extra caution was taken not to damage the recurrent laryngeal nerve. The CETP was placed between vascular segments and securely sutured to the trachea by surgeon's knots using a 5–0 poly hexafluoropropylene-VDF (PRONOVA, Johnson & Johnson Ethicon, USA) with a 13 mm round-bodied needle so as not to entrap vessels or obstruct blood flow. Slight bleeding observed at the time of needle puncture through the membranous wall was controlled by pressure hemostasis. The prosthesis was sutured onto the trachea at seven points per circumference (tracheal cartilage at 4 points and membranous wall at 3 points) using partial-thickness suturing so as not to penetrate the tracheal lumen. For W-shaped malformations, the largest endotracheal tube was inserted and the cuff was inflated to internally support and reshape the trachea during

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

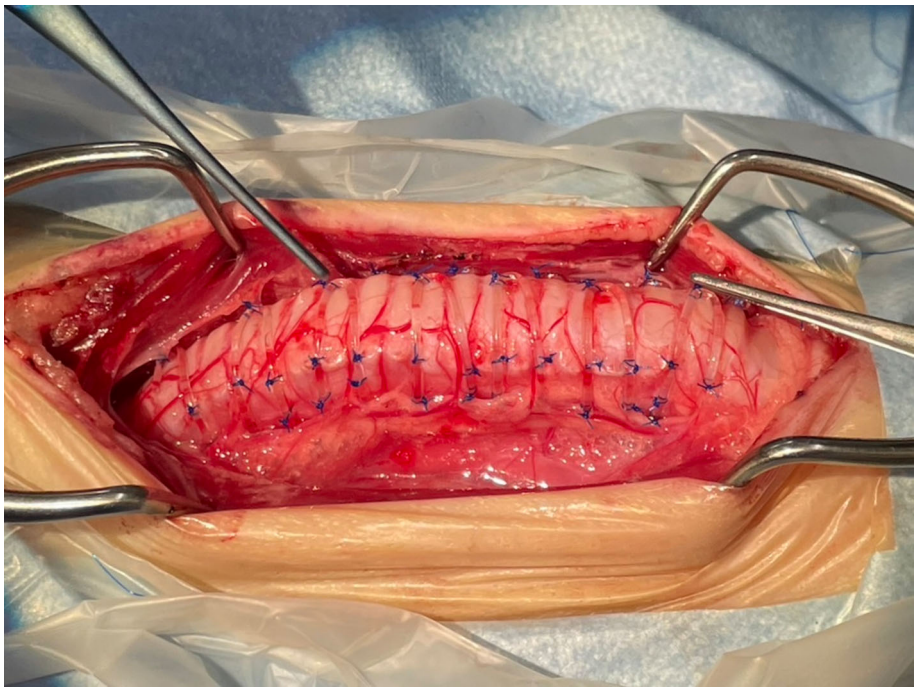


FIGURE 3 Image after CETP placement: The collapsed trachea was corrected to a round shape after CETP. CETP, continuous extraluminal tracheal prosthesis.

suturing. In patients in whom the lateral borders of the tracheal cartilage were severely deformed and could not be corrected with CETP placement alone, the deformed cartilage was excised prior to CETP placement to achieve proper alignment. The CETP was placed in a region between approximately 1-cm caudal to the larynx and the second rib (Figure 3). After CETP placement, a saline solution was irrigated around the trachea, and positive-pressure ventilation was performed several times to check for air leakage from the trachea. After extubation, tracheoscopy was performed to confirm that tracheal collapse was entirely corrected and evaluate the possibility of postoperative laryngeal paralysis (Video Clip S1). After confirmation of normal respiratory status, the dog was monitored in the ICU.

2.5 | Postoperative care

The dogs received the following postoperative medications for 5 days after surgery: prednisolone (0.5 mg/kg subcutaneously, once daily), ampicillin sodium (20 mg/kg IV, twice daily), maropitant (2 mg/kg subcutaneously, once daily), and buprenorphine hydrochloride (20 μg/kg IV, twice daily). Respiratory status was monitored in an oxygen chamber with 0.4 FiO_2. If no respiratory signs were observed, FiO_2 was gradually reduced to 0.3 FiO_2 after 3 days. The dogs were discharged 5–7 days after confirming an improvement in respiratory signs and corrected trachea by radiographic examination (Figure 4).

2.6 | Postoperative follow-up

Postoperative follow-up examinations (physical examination and radiography) were conducted at approximately 1, 3, 6 months, and 1 year postoperatively by the same surgeon. If dogs were not able to visit the clinic, a primary care veterinarian performed the examinations, and the results of the examinations were reported to the author. If a dog was not presented at a primary care veterinary clinic for follow-up examinations, the surgeon contacted the owner via phone and collected current clinical conditions, such as confirmation of survival, presence or absence of coughing or goose honking, and medical treatment, if any.

2.7 | Statistical analysis

Normality of the data was assessed by visual inspection and the D'Agostino–Pearson test. Continuous variables, such as age and bodyweight, and categorical variables, including sex, breed, preoperative clinical symptoms, preoperative oxygen requirements, concurrent heart disease, and postoperative complications, were compared between the groups. Clinical characteristics for the TTC and WTC groups are listed in Table 1. The Mann–Whitney U test was used to compare continuous variables that were not normally distributed. For categorical variables, either chi-square test or Fisher's exact test was performed where appropriate. No multiplicity adjustment was applied for the comparisons in Table 1, which were

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License



FIGURE 4 Postoperative radiograph after CETP placement between 1-cm caudal to the larynx and second rib: WTC at the thoracic inlet has been corrected, and trachea expansion is apparent. CETP, continuous extraluminal tracheal prosthesis; WTC, W-shaped tracheal collapse.

considered descriptive, with the primary statistical inference derived from the Cox proportional hazards model. A significance level of $p < .05$ was used. Data are presented as the median (range) for continuous variables and as counts (percentages) for categorical variables. These analyses were performed using Prism software (GraphPad, Boston, Massachusetts). Univariate time-to-event analyses were conducted using the Kaplan–Meier method, and between-group differences were assessed using the log-rank test. Kaplan–Meier estimates were also used to generate survival curves and calculate survival rates at predefined time points of 1, 5, 16, and 36 months after surgery. To account for the small number of events, Firth's penalized likelihood Cox regression (implemented via the coxphf package) was employed to estimate the hazard ratios and 95% confidence intervals in the uni- and multivariate models. Candidate covariates were specified a priori based on clinical plausibility. At the screening stage, variables with $p < .20$ in the univariable analyses were advanced to the multivariable model; this more lenient threshold was chosen to minimize type II error and to avoid excluding potential confounders in a small dataset. Variables were retained in the final multivariable model if $p < .05$. The proportional hazards (PH) assumption was evaluated using Schoenfeld residuals on an unpenalized multivariable Cox model containing the same covariates as the Firth model. All statistical analyses were performed using R software (version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

3 | RESULTS

3.1 | Clinical characteristics

From the medical records review, a total of 69 dogs with grade IV TC that had undergone CETP placement from October 2018 to September 2021 were identified. Among them, 45 were subclassified into the TTC group and 24 into the WTC group. CETP placement was performed by one surgeon in all dogs. The median follow-up time was 13.5 (1–39) months for the TTC group and 14 (1–39) months for the WTC group.

Breeds included in the TTC group were Chihuahua ($n = 13$), Pomeranian ($n = 14$), Yorkshire Terrier ($n = 8$), Toy Poodle ($n = 4$), Shiba Inu ($n = 4$), Shih Tzu ($n = 1$), and mixed breed ($n = 1$). Sexes included intact male ($n = 13$), neutered male ($n = 15$), intact female ($n = 5$), and spayed female ($n = 12$). The median age was

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 Clinical characteristics of TTC and WTC group treated with CETP.

	TTC ($n = 45$)	WTC ($n = 24$)	p-value
Age (median, years)	10 (1–15)	6 (2–12)	.0562
Bodyweight (median, kg)	3.6 (1.6–15)	3 (1.2–5.8)	.0524
Preoperative clinical signs			
Goose honking	42	22	1
Stridor	3	18	<.0001
Labored breathing	19	17	.0419
Dry harsh cough	30	13	.4413
Preoperative oxygen supplementation	4	13	<.0001
Intrathoracic tracheal collapse (>50%)	15	9	.7937
Concurrent heart disease	3	0	.5465
Postoperative clinical signs			
Laryngeal paralysis	3	2	>.9999
Recurrent tracheal collapse	1	2	.2757
Recurrent dry cough	14	4	.2551
Required medical management after surgery (at 39-months postoperatively)	12	4	.3898

Abbreviations: CETP, continuous extraluminal tracheal prosthesis; TTC, traditional tracheal collapse; WTC, W-shaped tracheal collapse.

10 (1–15) years, and the median weight was 3.6 (1.6–15) kg. Preoperative clinical signs included goose honking cough ($n = 42$, 93%), stridor ($n = 3$, 7%), labored breathing ($n = 18$, 40%), and cough ($n = 29$, 64%). Three dogs (7%) developed cyanosis and respiratory distress before surgery and were managed in an oxygen chamber.

Breeds included in the WTC group were Chihuahua ($n = 8$), Pomeranian ($n = 6$), Yorkshire Terrier ($n = 5$), Toy Poodle (n = 2), Maltese ($n = 1$), and mixed breed ($n = 2$). Sexes included intact male ($n = 9$), neutered male ($n = 9$), intact female ($n = 1$), and spayed female ($n = 5$). The median age was 6 (2–12) years, and the median weight was 3.0 (1.2–5.8) kg. Preoperative clinical signs included goose honking cough ($n = 22$, 96%), stridor ($n = 18$, 75%), labored breathing ($n = 17$, 71%), and dry harsh cough ($n = 13$, 54%). A total of 13 dogs (54%) developed cyanosis and respiratory distress before surgery and were managed in an oxygen chamber.

3.2 | Preoperative tracheoscopy

Preoperative tracheoscopic examination was performed by the same surgeon. All dogs were assessed as grade IV because the tracheal lumen had completely collapsed in all cases. Dogs with WTC had mild to severe W-shaped malformation of the central portion of the tracheal cartilage, and in severe cases, the endoscope with a 3.1-mm outer diameter tip barely passed through.

In the TTC group, all dogs had TC at the thoracic inlet. In the WTC group, 25% (6/24) of dogs had TC at the middle of the cervical area and 75% (18/24) had TC at the thoracic inlet.

3.3 | CETP sizing

The diameters of the CETP used in the TTC group were 8 mm in 2% (1/45), 9 mm in 7% (3/45), 10 mm in 62% (28/45), 12 mm in 18% (8/45), 15 mm in 9% (4/45), and 18 mm in 2% (1/45) of dogs. The diameters of the CETP used in the WTC group were 9 mm in 8% (2/24), 10 mm in 59% (14/24), and 12 mm in 33% (8/24) of dogs. The operation time was 90–150 min. Tracheoscopy immediately after surgery and radiographic examination 3 to 7 days after surgery confirmed no collapse of the trachea from just below the larynx to the second rib, where the CETP had been placed in all dogs.

3.4 | Statistical results

Age, weight, and sex did not differ between the TTC and WTC groups. The number of dogs with preoperative goose honking and dry harsh cough did not differ between the two groups, but preoperative labored breathing ($p = .0419$) and stridor ($p < .0001$) differed. In addition, 9% (4/45) of dogs in the TTC group and 54% (13/24)

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

of dogs in the WTC group required preoperative oxygen supplementation due to dyspnea and/or cyanosis ($p < .0001$), indicating that the WTC group was 12.1 times (odds ratio 95%; CI 3.2–37.5) more likely to require preoperative oxygen management than the TTC group (Table 1). Complications of laryngeal paralysis or recurrent TC were observed in 7% of the TTC group and 8% of the WTC group during the 39-month postoperative period (Table 2). In total, 7% of dogs with TTC and 4% of dogs with WTC died during the follow-up period (Table 3).

The Kaplan–Meier survival curves did not differ significantly between the groups ($p = .5$; Figure 5, Table S1). Univariate Firth's Cox regression analyses identified age, the Yorkshire Terrier breed, and concurrent heart disease as potential predictors of survival ($p < .2$; Table S2). These variables were included in the multivariate models. In the multivariate analysis (Table 4), the Yorkshire Terrier breed (HR = 19.27; 95% CI: 2.36–380.42; $p = .005$) and age (HR = 1.35; 95% CI, 1.00–2.01; $p = .048$) were significantly associated with shorter survival. Although concurrent heart disease had a high hazard ratio (HR = 4.42; 95% CI: 0.56–42.12), this association was not significant ($p = .151$). Schoenfeld residual tests indicated no statistically significant departures from proportional hazards for any covariate (Yorkshire Terrier $p = .48$; age $p = .24$; cardiac disease $p = .48$; global $p = .71$).

TABLE 2 Summary of postoperative complications in TTC and WTC groups.

Breed	Sex	Age (years)	Weight (kg)	Postoperative complication	Onset of complications	Treatment	Outcome
TTC							
Pomeranian	MN	8	3.6	Laryngeal paralysis	9 days	Unilateral arytenoid lateralization	Still alive after 19 months
Pomeranian	IM	9	3.8	Laryngeal paralysis	14 days	Permanent tracheostomy	Still alive after 8 months
Toy Poodle	FS	9	3.6	Laryngeal paralysis	1 month	Unilateral arytenoid lateralization	Still alive after 4 months
Chihuahua	IM	12	3.5	Recurrent tracheal collapse	16 days	Butorphanol tartrate	Still alive after 22 months
WTC							
Chihuahua	IM	10	4	Laryngeal paralysis	15 months	Unilateral arytenoid lateralization	Still alive after 27 months
Maltese	FS	6	1.3	Laryngeal paralysis	3 months	Unilateral arytenoid lateralization	Still alive after 15 months
Pomeranian	MN	5	2.6	Recurrent tracheal collapse	26 months	Endoluminal tracheal stent placement	Still alive after 34 months
Chihuahua	IM	10	4	Recurrent tracheal collapse	14 months	Endoluminal tracheal stent placement	Died 15 months after surgery

Abbreviations: FS, female spayed; IM, intact male; MN, male neutered; TTC, traditional tracheal collapse; WTC, W-shaped tracheal collapse.

TABLE 3 Summary of cause of death after long-term follow-up in TTC and WTC groups.

Breed	Sex	Age (years)	Weight (kg)	Cause of death	Survival time (months)
TTC					
Chihuahua	MN	15	4	Status epilepticus	19
Yorkshire Terrier	FS	13	3.3	Heart failure	0.5
Yorkshire Terrier	FS	13	2.8	Heart failure	5
WTC					
Chihuahua	IM	10	4	Recurrent tracheal collapse	15

Abbreviations: FS, female spayed; IM, intact male; MN, male neutered; TTC, traditional tracheal collapse; WTC, W-shaped tracheal collapse.

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

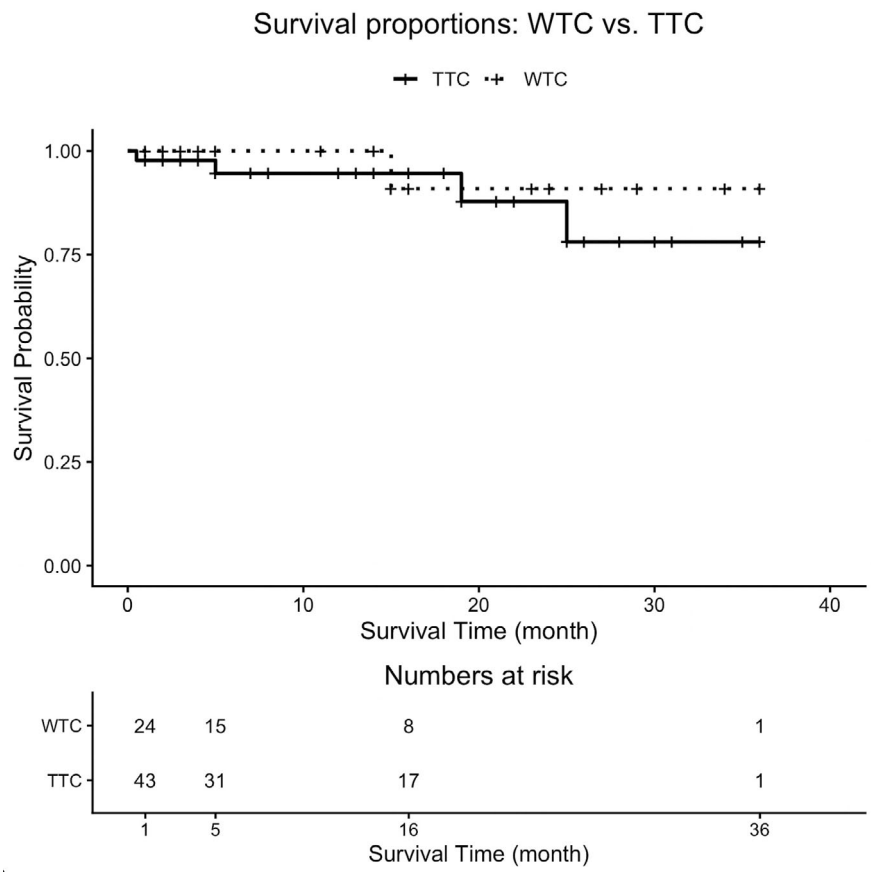


FIGURE 5 Kaplan–Meier survival curves for dogs with TTC or WTC, with a numbers-at-risk table at 1, 5, 16, and 36 months. The solid line represents dogs with TTC, and the dotted line represents dogs with WTC. The survival curves did not differ between the groups ($p = .5$). The tick marks indicate censored values. CETP, continuous extraluminal tracheal prosthesis; TTC, traditional tracheal collapse; WTC, W-shaped tracheal collapse.

Variable	HR (95% CI)	*p*-value	Events (deaths *n*/*N*)
Yorkshire Terrier	19.27 (2.36–380.42)	.005	3/12
Age (per 1 year)	1.35 (1.00–2.01)	.048	4/32 (≧10 years)
Cardiac disease	4.42 (0.56–42.12)	151	2/3

TABLE 4 Multivariate Firth's Cox regression analysis of variables associated with postoperative survival.

Abbreviations: CI, confidence interval; HR, hazard ratio.
HRs and 95% CIs were calculated. Variables were included based on univariate analysis results, with $p < .2$.

3.5 | Short-term follow-up (<1 month after CETP placement)

No intraoperative complications were observed, and all 69 dogs were discharged from the hospital (video clip S2: dogs with WTC before and after surgery). Short-term follow-up data were available for 45 dogs in the TTC group and 24 dogs in the WTC group. The median follow-up period was 1.0 (0.5–1) month for the TTC group and 1.0 (1–1) month for the WTC group.

3.5.1 | Traditional tracheal collapse group

In the TTC group, 3/45 patients (7%) had myxomatous mitral valve disease (MMVD; stage B1 or B2) and were prescribed pimobendan (0.25 mg/kg orally, twice daily) before surgery. Three other dogs required preoperative supplemental oxygen therapy but were clinically well without postoperative oxygen supplementation. Goose honking cough, stridor, and labored breathing resolved in all dogs, whereas dry harsh cough persisted in 16 dogs (36%), for which 12 dogs (27%) were treated with medical management, including theophylline (10 mg/kg orally, twice daily), prednisolone (0.3 mg/kg orally, once daily), butorphanol (0.1–0.2 mg/kg orally, as needed), or maropitant (2 mg/kg orally, every 48 h). Prednisolone was used for 4 days in all dogs after discharge. Postoperative short-term laryngeal paralysis occurred in two dogs (4%) 9 and 14 days after surgery, respectively. Both dogs exhibited labored inspiratory breathing and stridor, and laryngeal paralysis was confirmed by laryngoscopy. One dog

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

underwent a permanent tracheotomy, whereas the other underwent unilateral arytenoid lateralization, and both dogs were clinically well after surgery. One dog developed recurrent TC 16 days after surgery. In this dog, dry harsh cough was observed; thus, prednisolone (0.3–0.5 mg/kg orally, once daily), theophylline (10–15 mg/kg orally, twice daily), butorphanol (0.1–0.2 mg/kg orally, as needed), and maropitant (2 mg/kg orally, every two days) were prescribed. Short-term mortality was 2% (1/45); a 13-year-old Yorkshire Terrier died 2 weeks after surgery, and the cause of death was pulmonary edema.

3.5.2 | W-shaped tracheal collapse group

In the WTC group, all dogs that required preoperative oxygen supplementation were clinically stable without postoperative oxygen supplementation. Goose honking cough, stridor, and labored breathing resolved in all dogs. Dry harsh cough was present postoperatively in four dogs (17%); thus, theophylline (10 mg/kg orally, twice daily), prednisolone (0.3 mg/kg orally, once daily), and butorphanol (0.1–0.2 mg/kg orally, as needed) were administered. There were no cases of laryngeal paralysis, recurrent TC, or death.

3.6 | Intermediate-term period (1–6 months after CETP placement)

The median follow-up period was 6 (2–6) months for both groups.

3.6.1 | Traditional tracheal collapse group

In the TTC group, 41 dogs were identified for the intermediate-term follow-up period. No goose honking cough, stridor, or labored breathing was observed during this period. Dry harsh cough was still present in 15 dogs (37%). Among the 15 dogs, 11 (28%) received pimobendan (0.25 mg/kg orally twice daily), theophylline (10 mg/kg orally twice daily), prednisolone (0.3 mg/kg orally once daily), butorphanol (0.1–0.2 mg/kg orally as needed), and maropitant (2 mg/kg orally every 48 h). One dog (2%) exhibited stridor and inspiratory labored breathing one month after surgery, and laryngeal paralysis was confirmed by laryngoscopic examination. This dog underwent unilateral arytenoid lateralization and remained clinically well after the procedure. Two dogs died 5 months after surgery, and the causes of death were pulmonary edema and pulmonary metastasis of a mammary tumor, respectively.

3.6.2 | W-shaped tracheal collapse group

In the WTC group, 21 dogs were identified for the intermediate-term study period. No goose honking cough, stridor, or labored breathing was observed in this group. Dry harsh cough was present in four dogs (19%) and was managed medically with theophylline, prednisolone, and butorphanol. Laryngeal paralysis occurred in one dog (5%) and was treated with left-sided arytenoid lateralization and remained clinically well after the procedure. No cases of recurrent TC or death were present.

3.7 | Long-term period (>6 months after CETP placement)

The median follow-up period was 16 (7–36) months for the TTC group and 16 (11–36) months for the WTC group.

3.7.1 | Traditional tracheal collapse group

In the TTC group, 28 dogs were identified for the long-term follow-up period. Dry harsh cough was observed in nine dogs (32%) and was managed medically with pimobendan (0.25 mg/kg orally, twice daily), theophylline (10 mg/kg orally, twice daily), prednisolone (0.3 mg/kg orally, once daily), butorphanol (0.1–0.2 mg/kg orally, as needed), and maropitant (2 mg/kg orally, every 48 h). One dog (3.6%) died of tonic seizure 19 months after surgery. No recurrence of TC or laryngeal paralysis occurred.

3.7.2 | W-shaped tracheal collapse group

In the WTC group, 14 dogs were identified for the long-term follow-up study period. Dry harsh cough was observed in three dogs (21%) and was managed medically with theophylline (10 mg/kg orally, twice daily), prednisolone (0.3 mg/kg orally, once daily), and butorphanol (0.1–0.2 mg/kg orally, as needed). One dog (7%) developed laryngeal paralysis. After definitive diagnosis by laryngoscopy, left-sided arytenoid lateralization was performed, and the dog was clinically well after surgery. Recurrent TC was confirmed with endoscopic examination in two dogs (14%), 14 months and 26 months postoperative, respectively. Medical management with steroids was attempted, but both dogs exhibited dyspnea. Thus, an intraluminal stent (Self-Expanding Nitinol Tracheal Stent, Dextronix, Portland, Oregon) was placed. The diameter of the stent used was 10 mm based on the CETP

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

diameter. Of these two dogs, one died 2 months after stent placement, but information about the cause of death was not available at the time of the study. The other dog had persistent dry harsh cough after the stent placement. A nebulizer and butorphanol (0.1–0.2 mg/kg orally, as needed) were used, but granulation tissue formed inside the trachea two months after surgery, resulting in mucus accumulation. Mucus was aspirated endoscopically as needed.

4 | DISCUSSION

Our study showed that dogs with WTC had more severe preoperative clinical signs, such as labored breathing and stridor, and more likely required preoperative oxygen supplementation due to cyanosis and dyspnea compared to dogs with TTC. In WTC, deformation of the tracheal cartilage leads to a more static collapse, resulting in a marked narrowing of the tracheal lumen. Therefore, careful attention should be paid to preoperative respiratory management in these patients. Postoperative laryngeal paralysis can occur immediately or be delayed; thus, close postoperative monitoring of respiratory status is crucial. However, there was no significant difference in the incidence of postoperative laryngeal paralysis between the TTC and WTC groups. Recurrent TC was successfully managed with tracheal stent placement without further surgical intervention. The low recurrence rate may be attributed to the ability of CETP to stabilize the entire cervical trachea. Both groups showed high long-term survival rates and favorable clinical outcomes.

Tangner et al. reported that clinical signs improved in 85% of dogs after placement of total ring prostheses, based on the owners' evaluation.[12] Another study showed that more than 80% of dogs treated with extraluminal polypropylene C-shaped stents were either clinically normal or their clinical signs improved by the 30-month postoperative period.[13] Chisnell et al. reported that respiratory signs improved in all cases that were discharged from the hospital, and a long-term assessment (median 50 months) showed that 65% of dogs did not require medical management after surgery.[10] A previous report by Weisse et al. demonstrated that endoluminal stent placement for tracheal malformations improved goose honking and raspy breathing in 89% of cases, indicating favorable clinical outcomes. While 93% of the dogs were successfully discharged, 56% (20/36) with malformation-type TC (MTC) required re-stenting. These findings suggest that stent placement in cases with tracheal malformations demands a high level of technical expertise.[7] In our present study, goose honking, stridor, and labored breathing improved in all 69 dogs during the long-term postoperative period. No intraoperative complications were observed and all dogs were successfully discharged from the hospital. These favorable outcomes may be attributed to several intraoperative strategies: positioning of the endotracheal tube cuff caudal to the collapsed segment to avoid interference with the surgical field; avoiding needle penetration into the tracheal lumen to minimize intratracheal hemorrhage; and preserving the segmental blood vessels supplying the trachea to reduce bleeding and enhance the visualization of surrounding structures.

Laryngeal paralysis is an important postoperative complication that reportedly occurs in 2%–21% of cases after tracheal ring or CETP placement.[9–11,13,14] In this study, laryngeal paralysis was observed in five dogs after surgery.

In the present study, all five dogs that developed postoperative laryngeal paralysis required surgical intervention, either unilateral arytenoid lateralization or permanent tracheostomy, and all cases showed favorable outcomes. To prevent immediate laryngeal paralysis, all vessels branching to the trachea were carefully dissected, and intraoperative bleeding was meticulously controlled, allowing for clear visualization of the recurrent laryngeal nerve. This approach facilitated precise surgical manipulation, thereby avoiding nerve injury. Three of the five dogs developed delayed laryngeal paralysis, which may have been attributed to factors such as adhesion between the trachea and the recurrent laryngeal nerve, friction or adhesion between the prosthesis or suture and the nerve, granuloma formation around the prosthesis, or idiopathic laryngeal paralysis.[10] In this study, sutures were placed on the tracheal cartilage near the course of the recurrent laryngeal nerve. Therefore, to prevent delayed onset of laryngeal paralysis, reconsideration of suture placement may be warranted in future cases. Furthermore, these results highlight the importance of continuously monitoring respiratory patterns and sounds during the postoperative period.[10]

In the present study, one dog with TTC developed recurrent TC due to sutures affixing the CETP to the trachea coming undone. Possible contributing factors included tracheal mucosal injury and inflammation caused by persistent barking at home after discharge, external compression of the cervical trachea, and the use of suture material that may not have been strong enough to withstand the rigidity of the tracheal cartilage, resulting in loosening or breakage. Two dogs with WTC developed recurrent TC. Two of the three cases with recurrent TC underwent endoluminal tracheal stent placement under fluoroscopic guidance. Although revision surgery was not performed and the exact causes of recurrence could not be confirmed, suture failure was presumed to

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

be the primary factor, based on the tracheal morphology observed on radiographs and endoscopy. In WTC cases, in addition to progression of the disease and severe tracheal cartilage malformation, we speculated that the CETP did not always fit properly to the malformed tracheal cartilage, compromising uniform support of the CETP and consistent suture strength at the malformed segments, which may further contribute to recurrence, highlighting the importance of careful postoperative monitoring. Recurrence may have been prevented by placing additional sutures, increasing the suture size from 5–0 to 4–0, or increasing the CETP diameter from 0.75 to 1.0 mm to enhance its strength. A sedative drug would be necessary for dogs that bark excessively. For the two deceased Yorkshire Terriers due to pulmonary edema, potential causes include MMVD and non-cardiogenic pulmonary edema secondary to airway obstruction. In the multivariable Firth's Cox model, Yorkshire Terrier appeared to have a higher hazard for mortality; however, this estimate is imprecise and susceptible to small-sample instability and therefore should be interpreted as hypothesis-generating rather than definitive. Age was also associated with increased mortality on a per-year basis. These findings support cautious postoperative monitoring in potentially higher-risk groups while emphasizing the need for studies with larger event counts to obtain stable breed- and age-specific estimates.

This study had several limitations, including the retrospective nature of the study. All surgeries were performed by a single surgeon; therefore, treatment outcomes may differ when performed by multiple surgeons. Preoperative medical management was not standardized across the groups, which may have influenced the comparisons. Additionally, the procedure requires advanced surgical techniques, and especially because CETP prostheses are not commercially available, institutions capable of offering this treatment may be limited. Further case accumulation and ongoing evaluation are necessary to validate and refine the procedure.

This study suggests that CETP placement resulted in favorable long-term clinical outcomes for both TTC and WTC cases. Although dogs with WTC exhibited more severe preoperative clinical signs and required more intensive preoperative management, WTC experienced a low incidence of postoperative laryngeal paralysis and recurrence. Their long-term survival rates were comparable to those of the TTC group. Notably, Yorkshire Terrier breed and older age were significantly associated with shorter survival times. These results suggest that CETP placement is a safe and effective surgical option for WTC and could be a promising alternative to endoluminal stenting.

AUTHOR CONTRIBUTIONS

Suematsu M, DVM: Performed the surgeries, collected the data, and drafted the manuscript. Minamoto T, DVM, PhD: Translated and edited the manuscript, performed the statistical analyses, and interpreted the data. Suematsu H, DVM: Advised on patient management and surgical techniques. Arai S, DVM, PhD, DACVS (Small Animal): Advised on surgical techniques and provided intellectual feedback on the manuscript. Fujiki M, DVM, PhD: Gave manuscript and surgical advice. Kurihara M, DVM, DACVR: Provided advice on the manuscript, performed statistical analyses, and interpreted the data. Minamoto T, DVM, PhD, Suematsu H, DVM, Arai S, DVM, PhD, DACVS (Small Animal), Fujiki M, DVM, PhD, Kurihara M, DVM, DACVR: Contributed substantially to the conception or design of the work, drafted the work, and revised it critically for important intellectual content. All authors have approved the final version of the manuscript, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ACKNOWLEDGMENTS

We thank Kojima T, Nakao K, Wada Y, Kimura I, and Nanri M. at AMC Suematsu Animal Hospital; Nakamori M. at Kyoto Animal Medical Center; and Aso T. at Aloha Animal Medical Center for their assistance during surgery and patient management.

FUNDING INFORMATION

The authors received no financial support for the research, authorship, and/or publication of this article.

CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Tomomi Minamoto https://orcid.org/0000-0002-6245-2382

REFERENCES

1. Deweese MD, Tobias KM. Tracheal collapse in dogs. *J Clinic Brief*. 2014;83-87.
2. Tappin SW. Canine tracheal collapse. *J Small Anim Pract*. 2016;57:9-17. doi:10.1111/jsap.12436

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

3. della Maggiore A. An update on tracheal and airway collapse in dogs. *Vet Clin North Am Small Anim Pract*. 2020;50:419-430. doi:10.1016/j.cvsm.2019.11.003
4. Yamaya Y, Sugiya H, Watari T. Methylation of free-floating deoxyribonucleic acid fragments in the bronchoalveolar lavage fluid of dogs with chronic bronchitis exposed to environmental tobacco smoke. *Ir Vet J*. 2015;68:7. doi:10.1186/s13620-015-0035-4
5. White RAS, Williams JM. Tracheal collapse in the dog-is there really a role for surgery? A survey of 100 cases. *J Small Anim Pract*. 1994;35:191-196. doi:10.1111/j.1748-5827.1994.tb01685.x
6. Congiusta M, Weisse C, Berent AC, Tozier E. Comparison of short-, intermediate-, and long-term results between dogs with tracheal collapse that underwent multimodal medical management alone and those that underwent tracheal endoluminal stent placement. *J Am Vet Med Assoc*. 2021;258:279-289. doi:10.2460/javma.258.3.279
7. Weisse C, Berent A, Violette N, McDougall R, Lamb K. Short-, intermediate-, and long-term results for endoluminal stent placement in dogs with tracheal collapse. *J Am Vet Med Assoc*. 2019;254:380-392. doi:10.2460/javma.254.3.380
8. Weisse C. Intraluminal tracheal stenting. *Veterinary Image-Guided Interventions*; 2015:73-82. John Wiley & Sons, Inc. doi:10.1002/9781118910924.ch7
9. Tinga S, Thieman Mankin KM, Peycke LE, Cohen ND. Comparison of outcome after use of extra-luminal rings and intraluminal stents for treatment of tracheal collapse in dogs. *Vet Surg*. 2015;44:858-865. doi:10.1111/vsu.12365
10. Chisnell HK, Pardo AD. Long-term outcome, complications and disease progression in 23 dogs after placement of tracheal ring prostheses for treatment of extrathoracic tracheal collapse. *Vet Surg*. 2015;44:103-113. doi:10.1111/j.1532-950X.2014.12206.x
11. Suematsu M, Suematsu H, Minamoto T, Machida N, Hirao D, Fujiki M. Long-term outcomes of 54 dogs with tracheal collapse treated with a continuous extraluminal tracheal prosthesis. *Vet Surg*. 2019;48:825-834. doi:10.1111/vsu.13229
12. Tangner CH, Hobson HP. A retrospective study of 20 surgically managed cases of collapsed trachea. *Vet Surg*. 1982;11:146-149. doi:10.1111/j.1532-950X.1982.tb00691.x
13. Buback JL, Boothe HW, Hobson HP. Surgical treatment of tracheal collapse in dogs: 90 cases (1983-1993). *J Am Vet Med Assoc*. 1996;208:380-384. http://www.ncbi.nlm.nih.gov/pubmed/8575969
14. Becker WM, Beal M, Stanley BJ, Hauptman JG. Survival after surgery for tracheal collapse and the effect of intrathoracic collapse on survival. *Vet Surg*. 2012;41:501-506. doi:10.1111/j.1532-950X.2011.00945.x
15. Dabanoğlu I, Öcal MK, Kara ME. A quantitative study on the trachea of the dog. *Anat Histol Embryol*. 2001;30:57-59. doi:10.1046/j.1439-0264.2001.00301.x

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Suematsu M, Minamoto T, Suematsu H, Arai S, Fujiki M, Kurihara M. Long-term outcomes of dogs with W-shaped or traditional tracheal collapse treated with a continuous extraluminal tracheal prosthesis: A retrospective study. *Veterinary Surgery*. 2026; 55(1):118-130. doi:10.1111/vsu.70046

1532950x, 2026, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/vsu.70046 by Cochrane France, Wiley Online Library on [08/06/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License