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# Use of nitinol self-expandable stents in 26 dogs with tracheal collapse

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## Summary

A study was designed to describe a novel approach to the treatment of tracheal collapse (TC) in dogs using self-expandable nitinol stents. Medical records were reviewed retrospectively for 26 client owned dogs in which nitinol stents were deployed. The entire length of trachea was supported independently of the extent of TC. Two overlapping stents were used instead of one in cases where one stent was not spanning the entire trachea adequately. The diameter of the cranial radiolucent portion of trachea, just behind the cricoid cartilage, was measured as a specific landmark to select the appropriate size of the stent. Two self-expandable nitinol stents were inserted in 9 of 26 dogs; the trachea in the rest of the cases was supported with only one stent. A follow up tracheoscopy was performed in 10 of 26 cases with recurrent clinical signs. Secondary tracheal stenosis in these cases was caused by stent fracture, granuloma or excessive stent shortening. Additional stents were placed successfully to expand the stenotic lumen. A support of the entire trachea may decrease risk of nitinol fracture at the end of the implant. Long term clinical improvement (25 of 26 dogs, 96 %) is comparable with the results of other studies.

Keywords: tracheal collapse, nitinol, self-expanding, stent, tracheal stenosis

## Verwendung von selbst-expandierenden Nitinol Stents bei 26 Hunden mit Tracheakollaps

Bei 26 Hunden wurde ein Tracheakollaps mit selbstexpandierenden Nitinol Stents behandelt und die Ergebnisse retrospektiv evaluiert. Die Trachea wurde über ihre gesamte Länge unterstützt unabhängig von der Lokalisation des Kollapses. Falls kein Stent mit ausreichender Länge zur Verfügung stand, wurden zwei überlappende Sents gesetzt, um die gesamte Länge der Trachea zu expandieren. Der Durchmesser des Stents wurde anhand des Durchmesseres der Trachea unmittelbar kaudal des Cricoids gewählt. Bei 9 der 26 Patienten wurden zwei überlappende Stents gesetzt. Bei allen anderen Patienten konnte die gesamte Länge der Trachea mit einem Stent unterstützt werden. Bei 10 Patienten wurde eine «second look» Tracheoskopie durchgeführt, da sich erneut klinische Zeichen eines Tracheakollapses zeigten. Eine sekundäre Tracheastenose wurde konstatiert als Folge einer Stentfraktur, Granulation oder einer exzessiven Stentverkürzung. Ein zuätzlicher Stent wurde erfolgreich gesetzt um das eingeengte Lumen zu expandieren. Die Unterstützung der Trachea über die gesamte Länge kann die Bruchgefahr des Nitinols am Ende des Stents vermindern. Die langfristige Verbesserung des klinischen Zustandes in 25 von 26 Fällen (96 %) ist mit Resultaten anderer Studien vergleichbar.

Schlüsselwörter: Tracheakollaps, Nitinol, selbstexpandierender Stent, Tracheastenose

## Introduction

Tracheal collapse (TC) is a chronic progressive acquired disease affecting middle to senior aged miniature and toy breed dogs (White, 1994; Nelson, 2003, 2009). The aetiology is unknown, but is proposed to be multifactorial. Rigid tracheal rings in the healthy trachea maintain an open canal for air flow during inspiration and expiration. A weakening of the tracheal rings results in dorsoventral flattening of the tracheal lumen and movement of the tracheal wall during respiration. A chronic coughing can contribute to further progression of the disease. Thirty percent of affected dogs were found to suffer with concurrent laryngeal collapse at the time of diagnostic endoscopy. Bronchial compression or collapse was found in 50 % of dogs diagnosed with TC (Hedlund, 2007).

Initially conservative treatment is advocated. Medical therapy in conjunction with environmental and social modification resolved clinical signs in 71 of 100 cases for longer than 12 months (White, 1994). Either extraluminal or intraluminal surgical support is recommended for all dogs with clinical signs refractory to medical treat-

ment (Hedlund, 2007). Extraluminal surgery provides good results when used in cervical TC but its use in thoracic TC may require a thoracotomy (Fingland, 1987). Complications related to extraluminal prostheses include severe disruption of tracheal blood flow, laryngeal paralysis, infection and death (Fingland, 1987; Buback, 1996). Tracheal stents are artificial hollow structures introduced to the tracheal lumen with the aim to maintain luminal patency (Nicolai, 2008). Advanced TC in dogs has been managed using stainless steel self-expandable biliary stents (Moritz, 2004). Metal stent fracture or stent migration has been reported (Tanabe, 1993). Nitinol stents are made from a shape memory titanium alloy which shares some physical characteristics with airways and cartilage (Duerig, 1996). Surgical steel can resist deformation of 0.3 %, whereas nitinol can resist deformation of up to 10 % with return to its original shape and size (Duerig, 2000). Additionally nitinol does not corrode when in contact with body fluids (Harris, 1979).

Historically, the placement of intraluminal self-expanding nitinol stents was found to be successful in the palliative treatment for TC in the dogs (Sura, 2008). Material failure was the major complication seen in 5 of 12 dogs. Seven dogs survived longer than 2 years. Three nitinol stents were consecutively placed in the trachea of one dog (Gellasch, 2002). Stent fracture can be successfully treated with a second stent implantation (Mittleman, 2004; Ouellet, 2006). Proper stent size selection and support of the entire tracheal length is considered to be an important factor for successful stenting (Gellasch, 2002). Bronchoscopic placement of nitinol stents was used to improve end-stage clinical signs in 18 dogs (Durant, 2012). We hypothesized that support of the entire length of the trachea independent of the extent of TC can diminish complication rate and results in better clinical outcome. Two overlapping stents were used rather than one in cases where one stent was not able to adequately span the entire trachea.

## Animals, Material and Methods

### Animals

Client owned toy breed dogs referred with chronic upper airway respiratory problems that were non responsive to conservative treatment between July 2000 and February 2009 were evaluated. Extraluminal tracheal surgery was not performed on any of these dogs. Inclusion parameters for this study were complete medical records at the time of stent placement and at any follow up examination. Complete medical records required were the history and clinical examination results, anaesthesia protocol, radiographs of the cervical and the thoracic portion of the trachea (two orthogonal projections, before and after implantation and follow up control), complete record of the upper airway endoscopy (larynx, trachea, mainstem bronchi), and technical parameters of stents used. Bronchial collapse revealed during the initial endoscopy was an exclusion parameter for this study. All cases included in the study received one or more nitinol self-expanding stents SX Expandella (Ella, Hradec Kralove, Czech Republic).

### Diagnosis

The diagnosis of TC was established by endoscopic examination of the upper airways performed under general anaesthesia. Dogs were pre-oxygenated before general anaesthesia and induced directly with propofol (Propofol 1 %, Fresenius Kabi, Germany) until they tolerated laryngeal evaluation. All dogs were intubated immediately after a brief laryngeal inspection. The antibiotic enrofloxacin (Baytril, Bayer, Germany) 10 mg/kg IV was given routinely at the beginning of general anaesthesia.

A brief inspection of the larynx, trachea and bronchi were performed with a video assisted rigid 0° endoscope (Richard Wolf, Germany) with the dog in sternal recumbency. TC was graded according to the extent of luminal compromise (Nelson, 2003). The endotracheal tube was reintroduced behind the collapsed portion after finishing the endoscopy and radiography was performed. Orthogonal projections of the thorax and neck were performed to visualize the larynx, the entire trachea and thoracic structures (lung field, heart). The neck was positioned slightly extended to avoid the possible impact of the distorted position on the measured length of the trachea. The tracheal diameter on the lateral projection just caudal to the radio opaque margin of the cricoid cartilage (consistent with the first tracheal ring) was measured (Fig. 1). The length of the trachea was measured from the lateral radiographs to help with stent length selection (Fig. 2). Radiographic magnification due to projection was corrected using an endotracheal tube of known diameter.

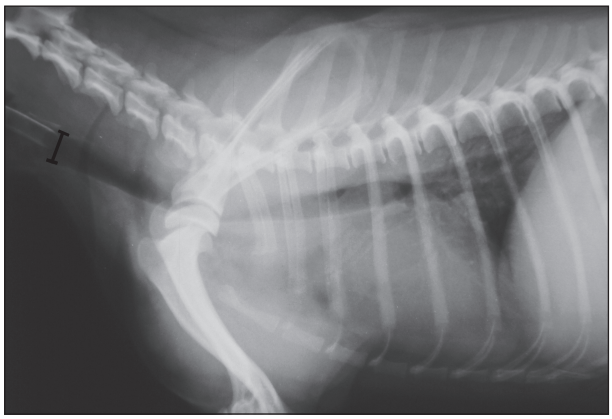

*Figure 1*: Lateral radiograph of the neck and the chest. The tracheal diameter just caudal to the radio opaque margin of the cricoid cartilage (consistent with first tracheal ring) was measured to select an adequate stent diameter.

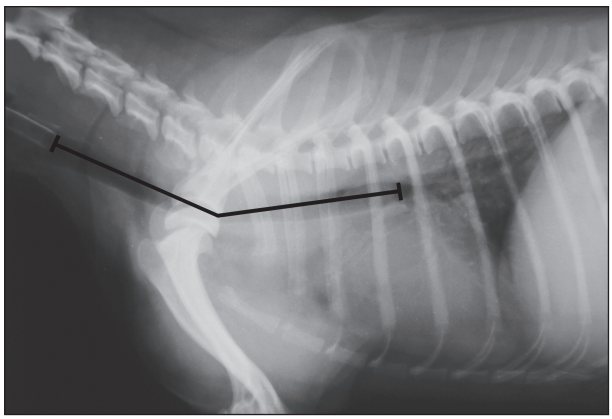

*Figure 2*: Lateral radiograph of the neck and the chest. The length of the trachea was measured to estimate length of the stent.

## Stent selection and placement

The selected stent diameter was larger than the premeasured and corrected tracheal diameter. The stent to trachea diameter ratio 1.2 was the initial selection parameter. However the larger or smaller stent diameter was used if necessary as long as it remained larger than the measured diameter of the trachea. A stent deployed to the trachea cannot be fully expanded and thus remains longer than its nominal length. Furthermore the length of the stent which was finally placed depended on its selected diameter; the larger was the stent diameter, the longer it remained in the trachea. Therefore the final length of the stent was unpredictable until fully released from the guide. Initially a nominal length of the stent was selected to be about one third shorter than the length of the trachea measured from the radiograph. Stent placement was dynamic procedure and its accurate positioning can only be obtained by a visual control during fluoroscopy. Stents of various diameters and lengths were readily available in the clinic allowing instant and accurate stent size selection. The nominal diameters of stents available were 10, 12 or 14 mm, and nominal stent lengths available were 52, 58, 72 and 77 mm. One or two stents were implanted under fluoroscopic guidance after finishing radiography. The entire trachea was spanned regardless of the collapse extent. The cranial end of the stent was positioned accurately just caudal to the larynx. The delivery system, with the compressed stent, was advanced through the endotracheal tube through a T-piece with a sealed working canal. The tip of the delivery guide was positioned in the carina. The endotracheal tube was partially withdrawn to prevent contact with the deploying stent. The origin of the bronchus of the right cranial lung lobe was identified under fluoroscopy as a radiolucent round structure visible in the carina and the caudal stent margin was placed just cranially to this structure. The stent was released up to approximately 2/3 or 3/4 of its length and the position of its cranial end was estimated. The desired position of the cranial margin was just caudal to the larynx. When the position of cranial end did not seem optimal, entire stent was recaptured into the delivery system and removed from trachea. The procedure was then repeated with a stent of a different size until the desired position of the cranial end was achieved.

Preferably two stents were used if a single stent could not reach the caudal border of the larynx accurately and appeared too long or too short. A caudal stent was placed first following the principles described above. The caudal stent length was chosen with the aim to support the caudal two thirds of the trachea. Then the second stent, of the same size, was inserted into the previously placed implant. After placement the caudal stent was not open fully to reach its nominal diameter hence using the cranial stent of the same size should provide adequate contact of both implants. The overlapping part of both stents was adjusted up to one third of tracheal length or up to one half of the stent length. Approximately two thirds of the cranial stent was opened in order to estimate the position of its cranial end. The stent was recaptured into the delivery system and contact area of two stents was changed if the cranial stent did not match precisely with the caudal border of the larynx. Prior to final stent delivery, the endotracheal tube was completely withdrawn from the trachea to prevent any interference during definitive stent placement. The tube was then pushed back after stent placement using the empty delivery system as a guide. Post-placement radiographs were taken immediately after finishing the procedure.

## Postoperative care

Once the dog was deemed stable the endotracheal tube was removed and an immediate tracheoscopy was performed. A small diameter feeding tube was advanced into the trachea at the end of the examination. The feeding tube was glued temporarily to a canine tooth. The feeding tube provided additional oxygen supplementation during the early recovery period. Dexamethasone (Dexadresone, Intervet, Netherland) 0.2 mg/kg IV was administered prior to transporting the dog to ICU. Dogs were discharged from the clinic on the same day or the day after stent/stents implantation. Antibiotics were continued at the same dose for ten days following stent placement. Postoperative coughing was controlled with codeine (1 mg/kg PO q 8 h) or small doses of prednisone (0.1 – 0.3 mg/kg PO q 24 h).

All cases presenting with recurrent clinical signs after the stent placement underwent clinical examination, tracheoscopy and radiography. Stent integrity and position were evaluated on radiographs and compared with post-placement records. Haematology, biochemistry and culture of bronchoalveolar lavage (BAL) were performed if infection was suspected. Recorded complications included stent fracture, excessive stent shortening,

granuloma formation or infection. Additional stenting was performed if the size of the tracheal lumen was markedly diminished due to a stent fracture or recurrent collapse resulting from the excessive stent shortening. Granuloma formation was treated with prednisone administered at an initial dose up to 1 mg/kg PO daily, tapered to a lower dose and alternate day therapy as soon as clinical signs resolved. Infection was treated with appropriate antimicrobials. All owners were contacted by telephone and the animals response to stent placement was evaluated using a questionnaire during February 2009. Results were scored as excellent (animal without clinical signs), good (cough in the morning or after the exercise), moderate (intermittent cough even when quiet, animal life still more comfortable than before stent placement) or poor (no improvement after stent placement).

## Results

The medical records of twenty six miniature breed client owned dogs were included in the study (Tab. 1). All dogs were diagnosed with TC grade III (30.8 %) or IV (69.2 %). Concurrent laryngeal collapse grade I or II was found in 9 cases (34.6 %). Clinical signs reported during the first evaluation at the referral clinic were a honking hacking cough (65.3 %) followed by exercise intolerance (38.4 %), cyanosis (26.9 %) and exercise-induced syncope (7.6 %). Clinical signs had been observed for more than one year before referral.

One stent was placed in 17 dogs and two stents were used in 9 dogs. Tracheal diameter (measured just caudal to the larynx and corrected for radiographic magnification) varied between 7.1 and 11.4 mm (mean diameter 8.5 mm). The ratio of stent size to measured tracheal diameter varied from 1.01 to 1.69 (mean value 1.35). The owners classified the outcome as excellent in 1 dog (3.8 %), good in 12 dogs (46.2 %), moderate in 12 dogs (46.2 %), and poor in one dog (3.8 %). Three dogs died or were euthanatized because of stent related issues (stent fracture in two dogs, granuloma formation followed by laryngeal collapse progression in one dog). Long-term quality of life before developing complications leading to euthanasia was scored by the owners as good in 2 dogs and moderate in 1 case. Five dogs died or were euthanatized within follow up period because of non-upper airway related causes.

Stent fracture, granuloma formation, infection and excessive stent shortening resulted in recurrence of clinical signs and follow up investigations in 10 dogs (38.5 %). Infection was suspected in 3 cases (11.5 %) up to 1 month after the implantation procedure. *Pseudomonas spp.* was cultured in 1 case; a culture&sensitivity testing did not show any growth in the other two dogs. All three dogs responded satisfactorily to antibiotic treatment. Granuloma formation was observed at the cranial or caudal end of the stents in 3 dogs (11.5 %) during the endoscopic re-evaluation. Granuloma formed over the stent fracture in 2 other cases. Granuloma unrelated to the stent fracture responded well to prednisolone treatment. Secondary tracheal stenosis resulting from the stent fracture or excessive stent shortening was treated with additional stent(s) placement. Re-stenting was performed in 8 cases, in two dogs it was performed twice. The time period between first stenting and re-stenting varied from 1 to 24 months. Throughout the course of the study 16 dogs (61.5 %) required more than one stent, two dogs (7.7 %) required four stents. The stent fracture was the most frequent complication, 9 fractures were found in 7 dogs (26.9 %). In two dogs the stent fracture occurred in the replacement stents used as a treatment for the previous stent fractures. The original implant fracture was diagnosed only in dogs where only one stent was placed during the initial stenting. The stent fracture was found in the cranial, caudal or middle part of the stent. The cranial end of the stent was fractured in 2 dogs (7.6 %), caudal end in 3 dogs (11.5 %) and the fracture in the middle portion of the stent occurred in 2 dogs (7.6 %). The time between original stenting and stent fracture ranged from 1 to 24 months (mean time 8.7 months). Minor stent shortening was found in either cranial, caudal or at both ends of stent in every case that underwent follow-up examination. Excessive stent shortening was revealed in 3 dogs (11.5 %) at examinations performed 1, 2 and 24 months after the first stenting. In one dog the cranial end of the stent was pulled out beyond the area of rigid collapse and expanded fully in the caudal portion of trachea. The caudal end of this stent remained in the same position.

All dogs coughed after stent implantation. A hacking cough with intermittent mucous expectoration continued for 3–6 weeks after the initial stent deployment. Some of the dogs needed codeine, low dose of prednisone, or both to control the episodes of non-productive coughing.

## Discussion

There were no early fatal complications recorded after stent placement in our study. These results are consistent with findings of the other nitinol stent study of 12 dogs (Sura, 2008). In another study two of 24 dogs died in the early period after implantation of a stainless steel stent (Moritz, 2004). In these cases sudden death was caused by laryngospasm and emphysema respectively. Struts on the end of the stainless steel stents compared to the smooth margins of the nitinol stents might explain these different results (Sura, 2008).

A nitinol stent supporting only the collapsed portion of trachea did not prevent early progress of TC in a Yorkshire Terrier and second stent had to be implanted 18 hours later (Gelasch, 2002). Nitinol stents were placed

*Table 1*: Medical records of 26 miniature dogs included in the study.

| No | breed | age years | sex M/F | TC | SP/LC | tracheal diameter (mm) | STR | stents | stent size (mm) | restent in (months) | final stent number | survival time till Feb 09 (months) | owner scored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Y | 5 | M | III | SP | 10,2 | 1,18 | 1 | 12–77 | | 1 | † 60 | G |
| 2 | Y | 4 | M | IV | SP | 7,9 | 1,39 | 1 | 11–72 | 24 | 2 | † 48 | M |
| 3 | Y | 4 | M | IV | | 7,1 | 1,69 | 1 | 12–77 | | 1 | 69 | M |
| 4 | Y | 6 | F | IV | | 8,5 | 1,4 | 1 | 12–77 | | 1 | † 43 | M |
| 5 | CH | 9 | F | III | LC I | 8 | 1,5 | 1 | 12–52 | 24 | 3 | † 48 | M |
| 6 | Y | 7 | F | IV | | 7,7 | 1,69 | 1 | 13–77 | 4 | 2 | † 51 | G |
| 7 | Y | 3 | M | IV | SP | 8,6 | 1,28 | 1 | 11–72 | 1 | 2 | 52 | E |
| 8 | Y | 7 | F | III | LC II | 9,9 | 1,01 | 1 | 10–72 | | 1 | 41 | G |
| 9 | Y | 3 | M | IV | | 7,7 | 1,3 | 1 | 10–72 | | 1 | † 32 | G |
| 10 | Y | 3 | F | IV | | 7,2 | 1,39 | 1 | 10–52 | | 1 | 35 | G |
| 11 | Y | 9 | F | IV | LC II | 8,7 | 1,38 | 1 | 12–77 | | 1 | 30 | G |
| 12 | Y | 4 | M | IV | LC I | 8,1 | 1,48 | 2 | 12–52 | | 2 | 28 | G |
| 13 | Y | 3 | F | III | SP | 7,1 | 1,41 | 1 | 10–72 | 4 | 2 | 27 | M |
| 14 | Y | 5 | F | III | LC II | 9,5 | 1,26 | 1 | 12–77 | | 1 | † 20 | M |
| 15 | Y | 5 | F | IV | SP | 10,5 | 1,33 | 1 | 14–58 | 2, 11 | 4 | 23 | M |
| 16 | Y | 4 | F | III | | 8 | 1,25 | 2 | 10–52 | | 2 | 21 | G |
| 17 | Y | 8 | M | IV | | 7,8 | 1,28 | 2 | 10–52 | | 2 | 19 | G |
| 18 | Y | 5 | M | IV | LC I | 7,7 | 1,3 | 1 | 10–72 | 1, 6 | 3 | 19 | M |
| 19 | Y | 8 | M | IV | | 7,8 | 1,28 | 2 | 10–52 | | 2 | 19 | M |
| 20 | Y | 10 | M | IV | LCI | 8,6 | 1,63 | 1 | 14–58 | | 1 | 18 | M |
| 21 | Y | 4 | F | IV | | 8,7 | 1,38 | 1 | 12–77 | | 1 | 15 | G |
| 22 | Y | 8 | M | III | LC II | 7,9 | 1,27 | 2 | 10–52 | | 2 | 10 | P |
| 23 | Y | 6 | M | III | SP | 8,4 | 1,43 | 1 | 12–52 | 2 | 4 | † 8 | M |
| 24 | CH | 8 | M | IV | SP | 11,4 | 1,06 | 2 | 12–52 | | 2 | 8 | M |
| 25 | Y | 6 | F | IV | | 8 | 1,25 | 2 | 10–52 | | 2 | 3 | G |
| 26 | Y | 3 | M | IV | LCII | 9,4 | 1,28 | 2 | 12–52 | | 2 | 1 | G |

**Y** Yorkshire
**CH** Chihuahua
**SP** soft palate elongated
**LC** laryngeal collapse
**STR** stent to trachea ratio

**stent size** diameter-length, ie 12–52
**G** good
**M** moderate
**P** poor
**E** excelent

only to hold up the collapsed area of trachea in a study of 12 dogs; of these five dogs (41.6 %) developed stent fracture at the end of the implant. Bending forces and coughing might potentiate material failure (Sura, 2008). The stent facture at the end of the stent occurred in 5 of 26 dogs (19.2 %) in our study where the entire length of the trachea was supported with the implant. Progressive tracheomalacia and increasing compressive load at the ends of the implant may contribute to stent fractures. Positioning the end of the stent in the stable part of the trachea may decrease material load and the risk of stent fractures if the entire length of the trachea is supported. Furthermore extended contact of the tracheal wall with the stent supporting the entire trachea can decrease risk of stent migration.

Stainless steel stent fracture was not recorded in study of 24 dogs (Moritz, 2004). The cause of nitinol failure is probably multifactorial; axial and bending deformation was investigated in vitro for implants used in human superficial femoral artery (Nikanorov, 2008). Nitinol stents used in our study were originally designed for placement in human arteries. Therefore additional stress resulting from flexion and extension of the neck and subsequent bending forces may have an adverse impact on the durability of stents.

Selection of an appropriate stent size is a crucial part of the procedure (Tanabe, 1993; Fraga, 1997). However TC is a dynamic condition and the diameter of the trachea detected on radiographs can be extremely variable depending on the extent of the disease, the portion of trachea measured, the pressure applied to the upper airways and the phase of respiration (Johnson, 1995; Baroni, 2005; Kneller, 2007; Leonard, 2009). Previous studies have used different methods to minimize difference. The lungs were inflated to a pressure of 20 cm $H_2O$ to calculate maximal tracheal diameter in 12 dogs (Sura, 2008). Rigid 10 mm portions of trachea caudal to larynx and cranial to carina were measured from lateral and dorsoventral radiographs and the lungs were not inflated artificially in 24 dogs (Moritz, 2004). The reference point in our study was the radiolucent tracheal diameter just caudal to the cricoid cartilage. The mineralized cricoid cartilage was identified on the lateral projection as reliable landmark in all dogs in our study. The cricoid cartilage and the attached first tracheal ring are not affected by TC. Therefore the measurement performed at this level should be independent of TC grade or extent but remains individually specific for the trachea of each dog. Similarly, artificial ventilation does not expand the cricoid cartilage and was not performed during radiographic examination in our study. Optimal stent size providing close contact and continuous pressure against tracheal wall is essential to prevent stent migration. The increase in diameter by 1.25 to 1.8 times provides enough mucosal stent compression (Tanabe, 1993). Selection of a stent size 1.25 to 1.5 times larger than the tracheal diameter was reported in a recent study of nitinol stents (Gellasch, 2002). In our study, the stent size used was larger than the measured tracheal diameter with a mean value of stent to trachea diameter ratio of 1.35 (1.01 – 1.69).

The positioning of the cranial end of stent is influenced by many individual factors (tracheal diameter and length, the extent of TC, stent size and stent length). It is probably not possible to predict and objectify these variable factors during stent placement (Moritz, 2004). The use of two stents can simplify accurate positioning of the cranial end just caudal to the larynx. The position of the cranial stent can be finely adjusted by changing the contact area of two overlapping stents whilst the caudal end placed in the carina remains unaffected. Furthermore, the overlapping section may enhance the support of the most dynamic part in the middle portion of the tracheal collapse. A fracture in the middle of a nitinol stent was described in a Pomeranian provided with one stent (Mittleman, 2004). In our study the stent fracture in the middle part of the trachea was found in 2 dogs where only one stent was used to support the trachea. Stent fracture in the overlapping area was not found where two stents had been implanted initially. However, placement of two stents does increase the cost of the procedure.

Stenotic complications after stent deployment can be successfully treated with implantation of an additional stents (Gellasch, 2002; Ouellet, 2006; Sura, 2008). Sixteen (61.5 %) dogs in the present study eventually had more than one stent implanted, two dogs had three, and two dogs had four. We did not recognize any clinically relevant difference between dogs with a different number of stents in the early recovery or long term outcome. The limiting factor might be the increased cost with multiple stents implanted in the same animal.

The authors are aware of several limitations of the presented study. The study is retrospective, the number of dogs in the study is small, and the dogs were not randomized to a control group. Bronchial collapse was an exclusion parameter in our study and it affects any comparisons made with other studies. Long-term outcome was only evaluated from the owner questionnaire and was not validated by clinical, radiographic or endoscopic examination. Also the number of follow up examinations and time period after stent implantation was not standardized. Re-examination was performed only in dogs showing recurrence of the clinical signs.

Self-expanding nitinol stents can provide a viable and minimally invasive method of palliative treatment in dogs with severe TC. Support of the entire trachea may decrease the risk of nitinol fracture at the end of the implant. The use of two stents can simplify accurate positioning of the cranial end behind the larynx. Stent fracture can be effectively treated with an additional stent placement. Further studies evaluating deformation forces acting on implanted tracheal stents would be recommended to better understand and prevent complications.

## Utilisation de stents auto-expansifs en nitinol chez 26 chiens souffrant de collapsus trachéal

Des stents auto-expansifs en nitinol ont été utilisés pour traiter 26 chiens atteints de collapsus trachéal et les résultats ont été évalués rétrospectivement. La trachée a été renforcée sur toute sa longueur, indépendamment de la localisation du collapsus. Si aucun stent d'une longueur suffisante n'était disponible, on a utilisé deux stents se recouvrant pour dilater l'ensemble de la trachée. Le diamètre du stent a été choisi sur la base du diamètre de la trachée directement caudalement au cricoïde. Chez 9 des 26 patients, on a posé deux stents se recouvrant. Chez tous les autres patients, il a été possible de renforcer la trachée sur toute sa longueur au moyen d'un seul stent. On a procédé chez dix patients à une seconde trachéoscopie, car de nouveaux signes de collapsus trachéal étaient apparus. Une sténose trachéale secondaire a été constatée suite à une fracture du stent, à du tissus de granulation ou à un raccourcissement excessif du stent. Un stent supplémentaire a été placé avec succès, pour dilater la lumière trachéale rétrécie. Le renforcement de la trachée sur toute sa longueur peut diminuer le risque de fracture du stent à son extrémité. L'amélioration clinique à long terme obtenue chez 25 des 26 patients (96 %) est comparable aux résultats d'autres études.

## L'uso di stent in nitinol autoespandente in 26 cani affetti da collasso tracheale

Sono stati retrospettivamente valutati i risultati del trattamento con stent in nitinol autoespandente su 26 cani affetti da collasso tracheale. La trachea è stata sostenuta sulla sua intera lunghezza, indipendentemente dalla posizione del collasso. Nel caso non fosse disponibile uno stent sufficientemente lungo, sono stati usati due stent sovrapposti per giungere all'intera lunghezza della trachea. Il diametro dello stent è stato scelto sulla base del diametro della parte caudale della trachea immediata della cricoide. In 9 pazienti su 26 sono stati usati due stent sovrapposti. Per tutti gli altri pazienti, la lunghezza totale della trachea era supportata da una stent. In 10 pazienti è stata eseguita una tracheoscopia «second look» che ha rilevato di nuovo segni clinici di un collasso tracheale. Una stenosi tracheale secondaria è stata costatata come risultato di una frattura dello stent, granulazione o eccessivo accorciamento dello stent. Uno stent supplementare è stato collocato con successo per espandere il lume ristretto. Il sostegno della trachea lungo l'intera lunghezza può ridurre il rischio di frattura del nitinol alla fine dello stent. Il miglioramento clinico a lungo termine in 25 su 26 casi (96 %) è comparabile con i risultati di altri studi.


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