Tracheal Collapse: Emergency Management to Definitive Treatment

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Tracheal Stent Literature Review

Stainless-steel self expanding metallic stents were the first commonly utilized devices for palliation of tracheal collapse in dogs. In early studies, when contrasted with studies of extraluminal prosthetic rings, perioperative death rates were similar, however, the procedure proved to be minimally invasive while being highly effective at relieving airway obstruction of the cervical and thoracic trachea without the high incidence of acute life-threatening complications common to the former technique. Outcomes suggested early clinical improvement in 95.8% of patients. The stainless-steel self-expanding metallic stent used in this study had an “open wire” design (the ends of the stent had wire protruding) which may have contributed to pneumomediastinum in 8.3% of patients. Chronic complications included steroid-responsive inflammatory tissue formation in 27.8% of cases, most often found at the ends of the stent. This inflammatory tissue formation narrowed the tracheal lumen significantly in some patients. The “open wire” design may have contributed to this complication.

In 2008, Sura et al. described a series of dogs with tracheal collapse refractory to medical management that were treated through fluoroscopy-guided placement of a nitinol suture-released knitted tracheobronchial stent system made for humans. This stent is not reconstrinable after partial deployment. In this series of studies, due to available stent sizes, 5/12 dogs required two stents to span the region of collapse. In 5/12 dogs, malpositioning of the stent occurred and this included extension of the stent into the mainstem bronchi, failure to span the region of collapse, and gaps between stents in dogs that required multiple stents. Stent migration, most likely a result of undersizing occurred in one dog. Long-term complications included bacterial tracheitis in 7/12 dogs and stent fracture in 5/12 dogs. Excessive inflammatory tissue formation occurred in 2/12 dogs and responded to antibiotic and corticosteroid administration. Two dogs died within 1-3 months after placement due to tracheal disease. Survival times in this study were variable. Kaplan-Meier survival curves were not provided. The need for placement of multiple devices in numerous patients coupled with the lack of reconstrinability and the high incidence of malpositioning and material failure (fracture) suggest that this stent design may be unsuitable for use in clinical patients.

In 2012, Durant et al. retrospectively described a series of dogs (2004-2008) with tracheal collapse that were treated through endoscopy-guided placement of a self-expanding wire-wound stent. In contrast to the aforementioned device, this device has smooth, atraumatic ends (Figure 1). In addition, in contrast to the other aforementioned device, this device is reconstrinable meaning that it can be withdrawn into the delivery system and repositioned as long as it has not been deployed more than approximately 90%. In contrast to previous studies, the stents in this series were deployed with endoscopic guidance rather than the standard fluoroscopic method. In this series, acute procedural
complications including malpositioning or migration occurred in 3/18 dogs. All of these complications were acutely remedied prior to anesthetic recovery. Acute complications included aspiration pneumonia (3/18) and all dogs survived to discharge. The high incidence of aspiration pneumonia was not addressed, but may have been a consequence of lack of airway protection via and endotracheal tube during the procedure. Long-term complications included stent fracture in 4/18 dogs, development of hyperplastic mucosal tissue in 4/12 dogs available for follow up. Five of twelve dogs developed bacterial tracheitis. Mild stent foreshortening occurred during the follow up period.

A 2019 retrospective study by Weisse et al. (n=75 2009-2015) utilizing the Vet Stent Trachea documented survival to discharge (95%), relief of noisy breathing (89%) and relief of dyspnea (84%). The median survival was 1005 days. Interestingly, 46% of dogs required a second stent placed at a later date due to fracture or tissue ingrowth.

Figure 1: Vet-Stent Trachea. Notice the “closed wire” atraumatic ends of the stent. Image courtesy Infiniti Medical LLC, Menlo Park, CA USA

Evolution of the Vet-Stent Trachea

First released in 2004, the Vet-Stent Trachea has evolved significantly in response to in vitro testing and a better understanding of the forces applied to, and the environment in which the stent resides. Some of the early changes include sourcing nitinol with fewer inclusion bodies and surface imperfections, both of which make stents brittle. Additional improvements include an improved drawing process coupled with pickling and electropolishing to remove additional surface imperfections. Additional proprietary improvements have also been integrated into newer generations of the Vet-Stent Trachea. In the author’s practice, stent fracture has not been observed in dogs receiving stents manufactured after 2009. This may be a result in improved stent design, materials, and manufacturing processes, but could also be influenced by patient selection.

Additional improvements in tracheal stent development include development of a tapered stent (Figure 2). The trachea is very often wider in the cervical region than in the intrathoracic region resulting in more of a tapered appearance. Based on in-vitro testing, this tapered stent in a tapered environment has at least 4x the crush resistance as a tubular (uniform diameter) tracheal stent in the same tapered environment but demonstrates similar chronic outward force. This tapered stent design also provides an increase in fatigue resistance. Although the gain in fatigue resistance varies by stent size and force applied, it averages an approximately 10 fold improvement. When the tapered design is deployed in a tapered trachea it is closer to its fully expanded state which creates greater radial resistance. The tubular (uniform diameter) design in the same tapered trachea is compressed to a point where the stent offers little radial resistance which will lead to lower fatigue resistance.
From a clinical perspective, stents are generally chosen to be approximately 20% oversized compared to the largest tracheal dimension (most often cervical). As a result, the tubular (uniform diameter) stent will often be 20% oversized in the cervical region, but potentially 30% (or more) oversized in the intrathoracic region. As stated above, stents demonstrate improved resistance to compression when they approximate their nominal (maximally expanded) diameter. Consequently, because a tubular (uniform diameter) tracheal stent does not closely approximate its nominal diameter in the thoracic region, it is more susceptible to cyclic compression as may be experienced during coughing. This cyclic compression may contribute to material fatigue and subsequent fracture. This may explain the clinical impression that most fractures that are seen occur in the intrathoracic segment of the stent. A tapered stent “fits” better into the tapered environment of the trachea, and, as a result more closely approximates its nominal diameter throughout its length, making it more resistant to fatigue.

The science behind IR in veterinary medicine is lagging behind device development. While improvements in stent materials, design, and manufacturing methods have made dramatic strides over the past 8 years, it will be critical for more independent prospective bench top and clinical studies to occur that objectively evaluate devices and acute and chronic outcomes in dogs with tracheal collapse undergoing tracheal stent placement.

Clinical Information

Introduction
Tracheal stent placement is a novel treatment option for some dogs presenting with tracheal collapse and signs of airway obstruction. It provides a minimally invasive and somewhat more versatile treatment option than traditional prosthetic ring placement. Despite the rapidly growing popularity of tracheal stents for the management of tracheal collapse, medical management remains a viable therapy. When medical management cannot adequately control clinical signs of tracheal collapse such that quality of life is compromised, signs require hospitalization, or side effects of medical management are unacceptable to the owners, palliative interventions (surgery for prosthetic ring placement or tracheal stent placement) must be considered. It is critical for the client to accept that these interventions
are palliative and will not cure the problem. Instead, the goal of these procedures is an improvement in clinical signs and less reliance on medical therapies.

**Phenotypes of Tracheal Collapse**

Dogs with tracheal collapse may present with a variety of phenotypes.

1. Dogs with airway obstruction (stridor) due to cervical and thoracic inlet collapse. Traditional tracheal collapse or ring malformation may be present in these dogs.
2. Dogs with airway obstruction (stridor) and cough due to diffuse (intrathoracic, mainstem, lobar bronchial) collapse.
3. Dogs with primarily cough due to intrathoracic, mainstem, and lobar bronchial collapse.

Of vital importance is the recognition that stents are used to relieve airway obstruction (stridor, inspiratory dyspnea, noisy inspiration and/or expiration). Stents rarely help cough. As a result, dogs with the 3rd phenotype listed above are not tracheal stent candidates.

**Emergency Management of Tracheal Collapse**

Some dogs present in life-threatening crisis due to tracheal collapse (usually Phenotype 1 above) and airway obstruction. Decisions made in the initial minutes of management of dogs in crisis due to airway obstruction associated with tracheal collapse may impact patient survival. First and foremost, it must be stated that dogs with life threatening airway obstruction require a patent airway. Therefore, it is never wrong to gain vascular access while providing oxygen support and then rapidly inducing general anesthesia (usually with propofol IV to effect) and performing endotracheal intubation. Placement of a tube that is long enough to extend to the level of the third rib will likely bypass the cervical collapse and thoracic inlet collapse that is causing the obstruction. Care must be taken not to intubate one of the mainstem bronchi as this may limit optimal oxygenation and ventilation. Frequent ventilation will resolve hypercarbia and hypoxemia. If time permits, a thorough oropharyngeal / laryngeal examination is also indicated (please see below) at the time of induction / intubation. Monitoring after endotracheal intubation should include, at minimum temperature and oxygen saturation. If possible, blood pressure, ECG, and end-tidal carbon dioxide levels are also desirable. The author will institute external cooling measures (cool water) if the temperature is ≥ 106°F (41°C). Cooling measures should cease when the temperature drops below 104F. Prevention of subsequent hypothermia is also important.

Often, there is hesitancy to take the step of inducing anesthesia and performing endotracheal intubation because of the concern that extubation may be difficult and may be associated with recurrence of severe signs. Although this is a valid concern, the priority must be given to this life-saving procedure. Once the patient is physiologically stable with a patent airway, attempts can be made to slowly recover the patient with concurrent medical management (see below). If these attempts fail, then the patient can be re-anesthetized, reintubated and can undergo a procedure that will provide a patent airway in the long-term such as minimally invasive placement of a self expanding metallic stent (see below) or surgical placement of prosthetic rings.

In dogs with airway obstruction due to tracheal collapse that are not deemed to be in a life threatening situation, a more conservative approach to initial management may be
undertaken. The conservative approach generally includes administration of a high concentration (>40%) of oxygen while minimizing stress through the use of sedation coupled with a cool environment. Administration of acepromazine 0.01-0.04mg/Kg IV or IM and/or butorphanol 0.2-0.3mg/Kg is often effective at breaking the vicious cycle of airway obstruction due to tracheal collapse. Initiation of corticosteroid therapy with dexamethasone 0.04mg/Kg IV, IM, or subcutaneously may help manage tracheal inflammation as well as any other upper airway swelling contributing to the clinical signs. Antibiotics with efficacy against respiratory pathogens including Mycoplasma sp. also have a place in the management of tracheal collapse. These supportive measures are usually effective in resolving clinical signs of airway obstruction in dogs with tracheal collapse.

**Palliative Treatments for Dogs with Tracheal Collapse**

If the signs of tracheal collapse are primarily inspiratory stridor or evidence of fixed airway obstruction and disease is largely localized to the cervical region and at the level of the thoracic inlet, surgical placement of prosthetic tracheal rings or tracheal stent placement is a reasonable consideration. It should be noted however, that the success of prosthetic ring placement is very operator dependent. In addition, a prolonged surgical intervention may not be ideal for a patient that has been in respiratory distress for a protracted period of time. Acute complications such as laryngeal paralysis can be severe and life threatening. Intraluminal placement of a self-expanding metallic stent is a rapid, relatively simple procedure that can restore the patency of the tracheal lumen without the need for open surgical intervention.

**Case Selection for Stent Placement**

Tracheal stent placement is an option for all dogs with tracheal collapse and signs of airway obstruction (phenotypes 1 and 2 above) that have failed medical management, required hospitalization, or experienced adverse effects associated with medical management. Rapid, complete relief of airway obstruction is often achieved in these animals without the risks associated with surgical (prosthetic rings) intervention. Although tracheal stent fracture and subsequent mechanical failure has been a recognized complication of tracheal stent placement, in the authors experience, this is primarily a risk in dogs that present for cough (usually associated with intrathoracic and mainstem bronchial collapse) rather than airway obstruction.

Dogs with collapse of the intrathoracic portion of the trachea or portions of both the cervical and intrathoracic trachea may be treated with a stent placed throughout the length of the trachea. However, the expectations must be that the airway obstruction will be relieved, but that the cough will persist due to concurrent collapse of the mainstem and lobar bronchi.

Dogs presenting with cough due to intrathoracic, mainstem, and lobar bronchial collapse are unlikely to have significant improvement with stent placement.

**Client Expectations**

It is critical that owners of dogs with tracheal collapse undergoing tracheal stent placement recognize that the tracheal stent procedure is palliative in nature and will not CURE their dog. We expect complete relief of airway obstruction signs in near 100% of
cases and significant improvement in other clinical signs. Clients must recognize that medical management will be ongoing, but that the procedure will often result in a decrease in dependence on medical management. Complications (please see below) should also be discussed at length prior to the procedure.

Recovery and Discharge from the Hospital
Most dogs that undergo tracheal stent placement are hospitalized for one night after the procedure. Medical management is ongoing and will include a cough suppressant (hydrocodone 0.22mg/Kg PO Q6-12hrs), prednisone (0.2-0.5mg/Kg Q12hrs x 14 days then gradual weaning to lowest possible dose), and an antibiotic. A dry cough is expected for approximately one month. In addition, if MSB collapse is present, coughing related to MSB collapse will persist. Persistent coughing should be treated aggressively. Persistent coughing may apply considerable forces to the stent and may be involved in stent fracture. Recheck exam including radiography is usually performed 4wks after placement and then every 6-12 months thereafter to evaluate the stent for additional shortening, fracture, etc.

Complications
Like many other medical and surgical interventions, tracheal stent placement is not without complications. Acute complications are generally avoidable through careful attention to detail when making measurements and meticulous stent deployment. If the stent diameter is undersized in relation to the trachea, stent migration will be a problem resulting in persistent cough and possible stent expulsion. An undersized stent that has migrated should be removed. Malpositioning of the stent is another acute complication. The stent may be deployed into the carina or MSB resulting in persistent coughing and possible “caging-off” of the lobar bronchi. The stent may also be accidentally deployed in the larynx or the endotracheal tube necessitating removal. Acute complications are generally a result of operator error.

Chronic complications of tracheal stent placement include foreshortening as the outward radial force of the stent results in expansion of the stent over time. Because the cervical trachea is generally wider than the thoracic trachea, shortening will generally occur here. If the stent shortens to the point that the collapsed area of the trachea is no longer spanned, clinical signs referable to airway obstruction will occur. Foreshortening generally occurs over the first days to weeks that the stent is in place but is rarely of clinical consequence. Stent fracture is a well-recognized problem in dogs with tracheal collapse.5-8 Numerous factors may contribute to stent fracture and research/development efforts by stent manufacturers are always ongoing to optimize design to minimize this complication. The incidence of fracture is decreasing since the initial evolution of the tracheal stent (author’s unpublished data). It is the authors opinion that persistent cough may contribute to stent fracture. Inflammatory tissue formation (especially at the ends of the stent) has been a documented problem in some dogs undergoing stent placement.5-9

Footnotes:
a. Wall –Stent; Boston Scientific, Natick, MA USA.
b. Ultraflex; Boston Scientific, Natick, MA USA
c. Vet-Stent Trachea; Infiniti Medical LLC. Menlo Park, CA USA.
d. Personal Communication; Dr. Jeffrey Solomon, Infiniti Medical LLC, Menlo Park, CA USA

References