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Topical Review

Tracheal Stent Placement for the Emergency Management of Tracheal Collapse in Dogs

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Dogs with tracheal collapse may present with life-threatening upper airway obstruction. In most instances, a conservative approach to treatment including oxygen support coupled with sedation and cooling measures will relieve respiratory effort and thus relieve airway obstruction. Dogs that fail this conservative approach require endotracheal intubation to ensure a patent airway. This population of patients would benefit from a more definitive, yet palliative treatment option to acutely relieve upper airway obstruction. Placement of a self-expanding metallic stent that spans the affected portion of the trachea will acutely provide the patient with a sustained patent airway and optimize the likelihood of a positive outcome.

Introduction

Upper airway obstruction is a common reason for animals to be presented to a veterinarian on an emergency basis. Rapid therapeutic intervention to physically relieve, bypass, or minimize its clinical manifestations is critical to achieving positive outcomes. Tracheal collapse is one of the most common causes of airway obstruction in the small breed dog and is a frequent cause of morbidity and mortality. Tracheal collapse involves a progressive degeneration of the tracheal cartilage (chondromalacia) characterized by dorsoventral flattening of the trachea as well as laxity of the trachealis dorsalis muscle.[1-4] The goal of this article is to provide the reader with a brief review of the clinical manifestations of tracheal collapse and its emergency management with a focus on the utility of self-expanding metallic stent placement as an emergency procedure for animals that fail routine emergency management strategies.

Clinical Manifestations of Tracheal Collapse

The majority of dogs with tracheal collapse would present electively for evaluation of cough or restricted or stridorous breathing pattern. However, a small subpopulation will present on an emergency basis with signs referable to severe airway obstruction. In this patient population, there is almost always some degree of chronic clinical signs that are acutely exacerbated. Chronic manifestations of tracheal collapse may include intermittent cough, honking cough, “noisy” breathing, “snorting,” etc. Often owners remark that these signs are exacerbated by excitement. In the author's experience, the acute exacerbation of dogs with airway obstruction due to tracheal collapse most often is precipitated by excitement, heat, stress, concurrent respiratory pathology (such as pneumonia), or episodes of intubation for other (elective) medical procedures.

Initial evaluation of all animals that present on an emergency basis begins with triage, focusing on the major body systems (cardiovascular, respiratory, and central nervous systems). Animals with airway obstruction will be rapidly identified and moved to the treatment area for immediate stabilization. Clinical signs of dogs in crisis due to airway obstruction may include, but are not limited to extension of the neck, abduction of the elbows, open mouth breathing, paradoxical abdominal movement (inward movement of the abdomen during inspiration), cyanosis, audible inspiratory stridor, inspiratory and expiratory noise, and honking cough. Inspiratory stridor is often identified in dogs with tracheal collapse that affects the cervical trachea and that portion centered on the thoracic inlet because of the dynamic nature of the disease. This is caused by narrowing of the tracheal lumen during inspiration and relative opening of the lumen during expiration. In animals with severe tracheal collapse, inspiratory and expiratory difficulty may be also noted because the tracheal lumen is narrow throughout all phases of the respiratory cycle.

Initial physical examination should continue to focus on the major body systems in dogs with airway obstruction or tracheal collapse. Respiratory auscultation may be challenging in dogs with tracheal collapse due to the severity of the referred upper airway sounds. However, if possible, auscultation of the lungs for the identification of abnormal lung sounds should be performed. Particular attention should be paid to listening for evidence of concurrent respiratory pathology. This may include expiratory wheezes that could be a manifestation of small airway disease, increased lung sounds dorsocaudally that may indicate noncardiogenic pulmonary edema due to airway obstruction, or increased lung sounds ventrally associated with aspiration pneumonia. Gentle palpation of the trachea will often worsen clinical signs, and, on occasion, ventral tracheal ring inversion is palpable. Careful cardiac auscultation is performed to identify evidence of

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concurrent cardiac disease. Assessment of body temperature is critical in animals with clinical evidence of airway obstruction because hypoventilation is associated with decreased ability to dissipate heat. Severe hyperthermia can be life-threatening and may require specific cooling therapy beyond simply managing the airway obstruction. Full physical examination is performed once patient stability is achieved.

Emergency Management of Airway Obstruction due to Presumed Tracheal Collapse

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 and laryngeal examination is also indicated (please see below) at the time of induction or intubation. Monitoring after endotracheal intubation should include a 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 104°F. 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. If these attempts fail, then the patient can be reanesthetized, 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 (0.01-0.04 mg/kg IV or IM) or butorphanol (0.2-0.3 mg/kg IV or IM) or both is often effective at breaking the vicious cycle of airway obstruction due to tracheal collapse. Initiation of corticosteroid therapy with dexamethasone (0.04 mg/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* spp. may also have a place in the management of tracheal collapse.[5] These supportive measures are usually effective in resolving clinical signs of airway obstruction in dogs with tracheal collapse. Some of these measures may also be effective in animals in which the cause of the airway obstruction is unknown.

Diagnosis

Differential diagnoses for dogs that present on an emergency basis for upper airway obstruction may be found in Table 1. It is important to note that dogs with suspected upper airway obstruction due to tracheal collapse may have multiple lesions. For example, dogs with tracheal collapse may also have an elongated palate or some degree of laryngeal collapse. Identification of other respiratory pathology is critical to positive outcomes. The following diagnostic testing is useful in identifying tracheal collapse and concurrent or alternative pathology.

Thoracic Radiographs

Dogs that present on an emergency basis with signs referable to tracheal collapse should be evaluated radiographically or with fluoroscopy after they have been stabilized medically. Thoracic radiographs may aid in the identification of tracheal collapse, but because tracheal collapse is a dynamic condition, radiographs must be interpreted with caution. When acquired during the different phases of respiration, tracheal collapse may be evident based on its anatomic location (Fig 1). Collapse of the cervical and thoracic inlet segments of the trachea will be most evident during inspiration. Conversely, collapse of the intrathoracic trachea and mainstem bronchial/lobar bronchi is most evident at end-expiration or during cough. Thoracic radiographs are useful in the identification of other causes of airway obstruction as well as concurrent respiratory pathology including, but not limited to aspiration pneumonia, noncardiogenic pulmonary edema, and bronchitis. Finally, thoracic radiographs are also effective at diagnosing other comorbid problems (underlying cardiac disease, neoplasia, etc.). Three views of the thorax including peak inspiration and expiration (if possible) images as well as a lateral cervical projection should be acquired for optimal evaluation of the trachea and thorax.

Table 1
Differential Diagnoses for Dogs Presenting with Upper Airway Obstruction. Dogs May Present with Multiple Lesions

Nasal
Stenotic nares
Nasopharyngeal stenosis
Oropharyngeal
Elongated soft palate
Tongue base mass
Tonsilar mass
Other oropharyngeal mass
Hematoma (trauma or rodenticide associated)
Trauma
Pharyngeal collapse
Foreign body
Laryngeal
Laryngeal paralysis
Everted laryngeal saccules
Laryngeal collapse
Laryngeal webbing
Laryngeal neoplasia
Epiglottic retroversion
Foreign body
Tracheal
Tracheal collapse
Tracheal neoplasia
Foreign body
Trauma
Extraluminal compression
Tracheal stenosis
Hypoplastic trachea

Fig. 1. Left lateral thoracic radiograph suggesting tracheal collapse in the cervical region and the thoracic inlet.

Fluoroscopy

Fluoroscopy is the author's preferred method for dynamic real-time evaluation of tracheal collapse because it allows for evaluation of the trachea continuously through all phases of respiration as well as during cough. Based on fluoroscopy, the extent of the collapse should be localized in reference to anatomic landmarks. A determination of the presence of concurrent mainstem bronchial collapse should also be made. These landmarks will aid in subsequent stent placement if indicated.

Tracheobronchoscopy

Tracheoscopy performed under general anesthesia is a technique preferred by some for the identification, localization, and grading the extent of tracheal and mainstem bronchial collapse. Tracheobronchoscopy also allows for sampling of the lower airways with bronchoalveolar lavage (BAL) in dogs with concurrent pulmonary infiltrates. Because tracheoscopy requires general anesthesia, it should be reserved for dogs that have required intubation for life-saving management of airway obstruction due to tracheal collapse or for dogs that are undergoing a palliative treatment, such as tracheal stent placement. Because tracheoscopy is performed under general anesthesia, dynamic evaluation of the trachea during normal respiration is not possible. Tracheoscopy and fluoroscopy should be considered complimentary to one another. Caution should be exercised in that recovery from anesthesia for dogs with airway obstruction due to tracheal collapse could be challenging. The author often performs tracheobronchoscopy just before placement of a tracheal stent.

Oropharyngeal and Laryngeal Examination

Laryngeal examination is a useful technique for the evaluation of upper airway obstruction in dogs. In dogs with tracheal collapse, laryngeal examination is performed at the time of anesthesia induction for stent placement to identify concurrent oropharyngeal and laryngeal pathology (Table 1).

Laboratory Workup

Routine laboratory workup is indicated in dogs with known or suspected tracheal collapse to identify comorbid conditions. Mild hepatic dysfunction has been identified in dogs with tracheal collapse.[6]

Indications for Emergency Tracheal Stent Placement

Most dogs that present with life-threatening tracheal collapse can be managed conservatively (oxygen, sedation, and cooling) as described earlier. Still others require intubation for the emergency relief of airway obstruction but can be successfully slowly recovered and extubated with the aid of sedation. This patient population is at risk of acute life-threatening airway obstruction in the future and, as a result, is considered a candidate for stent placement. A small population of dogs fail attempts to extubate them. This population will require definitive palliation of their airway obstruction. In the past, the only option for this patient population was the surgical placement of prosthetic rings to serve as an external scaffold for the collapsed trachea. This procedure, although successful is associated with a very high incidence of acute complications that include, but are not limited to severe laryngeal dysfunction.[7] In a large retrospective study of dogs undergoing prosthetic ring placement for the management of tracheal collapse, 12% developed laryngeal paralysis, 19% required permanent tracheostomy, and 6% experienced perioperative mortality.[7] Alternatively, placement of an intraluminal self-expanding metallic stent allows for a rapid, minimally invasive treatment option with a low, acute complication rate.[4,8,9] Indications for elective tracheal stent placement include quality–of-life compromise due to respiratory signs, intolerance of medical management of tracheal collapse, and when hospitalization has been necessary in the past for acute airway obstruction due to tracheal collapse. The following paragraphs describe the technique utilized for placement of the tracheal stent most often utilized today (Vet-Stent Trachea, Infiniti Medical LLC., Menlo Park, CA).

Tracheal Stent Placement Technique

Anesthesia

Once the decision has been made to proceed with tracheal stent placement, if not already intubated, the author prefers to premedicate and preoxygenate the patient followed by induction using propofol to effect. Alternative induction protocols tailored to patient needs and concurrent problems are always appropriate. If not performed previously, a thorough oropharyngeal and laryngeal examination should be performed at this time to identify concurrent pathology. A large endotracheal tube ($\geq$4.5 mm inner diameter) with radiopaque marking all the way to the tip should be utilized. Initially, the endotracheal tube may need to be placed relatively distally down the trachea to bypass the area of collapse. Monitoring should include ECG, SpO_2, blood pressure, and $ETCO_2$ whenever possible.

Tracheal Stent Placement

The patient is positioned in right lateral recumbency with the neck extended in such a way that the trachea is straight. If there is a significant bend in the trachea, introduction of the stent delivery system may be challenging. Additionally, the head and neck should be completely lateral. This positioning often aids in identification of the cricoid cartilage. Head and neck positioning can be confirmed fluoroscopically by ensuring that the wings of the atlas are superimposed on one another. Finally, if possible, the entire trachea should be visualized in the field of view (larynx to carina) to aid in measurements. Once optimal patient positioning is achieved, the author prefers to tape the head, neck, and forelimbs in position.

Next, the endotracheal tube is repositioned just beyond the larynx. Fluoroscopy will aid in optimal positioning. This positioning of the endotracheal tube often results in the endotracheal tube cuff being inflated within the larynx. Once the tube is repositioned, the anesthetist must ensure that a positive pressure breath hold at 20 cm H_2O can be achieved without leakage. This step is critical as measurements of the trachea will be performed at this inflation pressure. Using fluoroscopic guidance, a moistened 0.035 in. hydrophilic (standard stiffness) angled-tip guidewire (Weasel Wire, Infiniti Medical LLC., Menlo Park, CA) is advanced down the esophagus and into the stomach and a 5-Fr marker catheter (Marker Catheter, Infiniti Medical LLC., Menlo Park, CA) is advanced over the guidewire. The guidewire is then removed. The marker catheter has radiopaque markings positioned a set distance from one another and is used to calibrate measuring instruments to compensate for the effects of magnification. Without a marker catheter or similar device placed at the level of the trachea, magnification could significantly (and adversely) affect measurements.

Measurements of tracheal length and diameter are performed during a positive pressure, stable breath hold at 20 cm H_2O (Fig 2). Measurements of the tracheal diameter are performed in the midcervical region, at the thoracic inlet, and at the midintrathoracic trachea. A measurement of length of the collapse is also made referencing anatomic landmarks determined during fluoroscopy that detailed the location of the collapse. If the cervical trachea is to be spanned by the stent, the measurement should begin approximately 1 cm distal to the cricoid cartilage and extend, at minimum, 1 cm beyond the area of collapse. If the stent is to span the intrathoracic trachea, it should span a distance 1 cm proximal to the collapse down to a distance 1 cm from the carina. If the stent is to span the entire trachea, the measurement should include the distance from 1 cm distal to the cricoid to 1 cm proximal to the carina. Measurements are most often acquired by calibrating on-screen built-in measuring tools to the marker catheter and then making the measurements (Fig 3A and B). However, if the operator's fluoroscopy system does not have these functions, measurements can be performed using an external software program (OsiriX Imaging Software, http://www.osirixviewer.com) or they can be manually performed. For the latter method, a simple ratio is utilized to account for the effect of magnification (Table 2). The importance of acquiring accurate measurements cannot be overemphasized. If measurements are not precise, the stent may be oversized (and prone to fracture), undersized (and prone to migration), inappropriately long (lodging in the carina or larynx), or inappropriately short (resulting in inadequate coverage of the affected portion of the trachea).

When choosing the optimal stent size, a stent diameter should be chosen that is 10%-20% greater than the maximum tracheal diameter as described earlier. For example, if the maximum tracheal diameter is 10 mm, then a 12 mm stent is generally chosen. The trachea is most often slightly conical with the cervical trachea being wider than the intrathoracic trachea. Because of this, the stent is usually sized appropriately for the cervical trachea, but is technically oversized for the intrathoracic trachea. Oversizing of the stent may be a predisposing cause of stent fracture based on in vitro testing (Personal communication; Infiniti Medical LLC., Menlo Park, CA). In situations where there is significant size discrepancy between cervical and intrathoracic measurements, new tracheal stent options exist to mimic this anatomic difference (Duality Tracheal Stent, Infiniti Medical LLC., Menlo Park, CA). The length of the chosen stent is more challenging to determine. Most woven intraluminal self-expanding metallic stents foreshorten. In other words, as they expand, they shorten. Clinical implications of foreshortening are that a 12-mm × 65-mm stent is 12 mm × 65 mm in its nominal (fully expanded) state. However, because the stent is oversized by 10%-20% at a minimum, it generally will not expand to the "nominal" dimension when placed in the trachea. As a result, it will be longer. That 12-mm × 65-mm stent may only open to 11 mm in which case it will be 74-mm long. If it only opens to 10 mm, it will be closer to be 82-mm long (Vet-Stent Trachea Shortening Chart, Infiniti Medical LLC., Menlo Park, CA). Companies that manufacture stents that foreshorten should

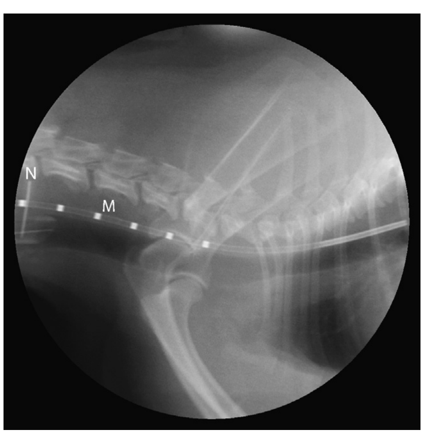

Fig. 2. Right lateral radiograph at 20-cm H_2O inflation pressure delivered during a sustained breath hold by the anesthetist. Note that the trachea is relatively straight and that the entire trachea is in the image. The marker catheter (M) is in the esophagus. Owing to difficulty visualizing the cricoid cartilage, a 25-g needle (N) placed in the overlying skin was used to mark its caudal extent.

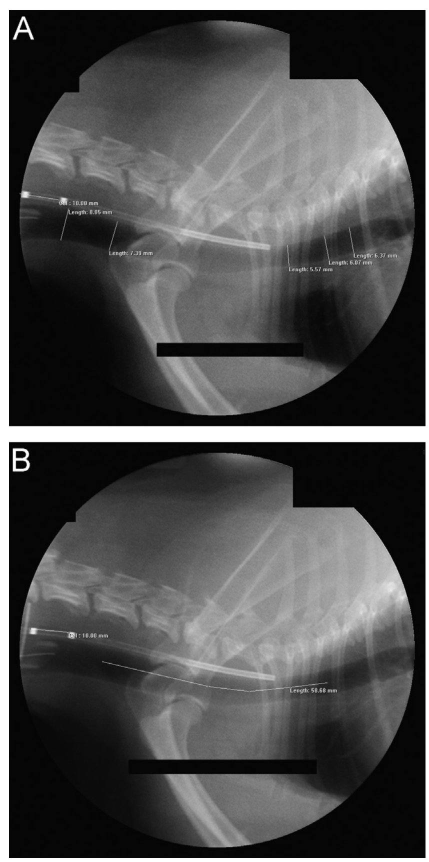

Fig. 3. (A and B) Measurements taken from Figure 2 of the cervical, thoracic inlet, and intrathoracic trachea, and known region of collapse (in relation to anatomic landmarks). This dog had severe tracheal collapse at the thoracic inlet extending from mid-C4 down to the second thoracic vertebra. Because the largest measurement was 8.1 mm, a 10 mm diameter stent was chosen.

Table 2
Ratio for Determining Actual Tracheal Measurements

$$\frac{\text{Actual Marker Catheter Length (AM)}}{\text{Measured Marker Catheter Length (MM)}} = \frac{\text{Actual Tracheal Measurement (AT)}}{\text{Measured Tracheal Measurement (MT)}}$$

Using this formula, the AM length is the actual distance on the marker catheter. Different brands of marker catheter have radiopaque bands different distances apart from one another. MM is the measured distance on the image between radiopaque marker catheter bands. MT is the measured tracheal distance (diameter or length) and AT must be solved for. AT is the actual tracheal measurement.

always provide the operator with a shortening chart that will predict stent length based on how far it opens.

Once the appropriate stent size is chosen, a bronchoscope adapter is applied to the end of the endotracheal tube. This adapter will allow the anesthetist to ventilate the patient and supply anesthetic gases in 100% oxygen while the operator deploys the stent through the port on the adapter.

The tracheal stent should be prepared for deployment as per the manufacturer's instructions. Anatomy of a self-expanding metallic stent is illustrated in Fig 4. This usually involves flushing all ports with sterile saline. Application of a very small amount of sterile water-soluble lubricant to the last 5-10 cm of the stent delivery system may allow it to slide through the endotracheal tube and trachea with greater ease.

The stent is deployed using fluoroscopic guidance. First, the distal aspect of the stent is positioned at the predetermined location that is a minimum of 1 cm distal to the region of collapse or 1 cm from the carina. Next, the hub and "Y" piece are moved toward each other in equal increments to deploy the stent. This maneuver is critical to preserve a fixed location of the distal aspect of the stent. Close attention must also be paid to the proximal end of the stent during deployment. If the stent is to be deployed in the proximal trachea, the endotracheal tube will need to be withdrawn over the delivery system to avoid deployment of the stent into the endotracheal tube. Most tracheal stents are reconstrainable (they can be pulled back into the delivery system) if $<70\%$ has already been deployed. If the operator is not satisfied with the positioning, the motion of the hub and "Y" piece is reversed and the stent is reconstrained, repositioned, and redeployed. After the stent is completely deployed, to maintain a patent airway, the endotracheal tube may be very gently advanced back into the proximal lumen of the stent under fluoroscopic guidance using the delivery system as a stylet. Alternatively, once the stent is deployed, the patient may simply be recovered from anesthesia. The author prefers, if possible, to simply allow the patient to recover immediately after stent placement (without reintubation) because advancing the endotracheal tube into the stent may cause it to move if not performed with caution. The delivery system is then removed under fluoroscopic guidance. Consider recapturing the nose cone of the delivery system using the aforementioned "reconstraining" motion prior to removal to prevent the nose cone from catching on the distal end of the stent. After the procedure is completed, lateral and VD images to determine expanded stent dimensions should be acquired (Fig 5).

Fig 4. Anatomy of a self-expanding metallic tracheal stent. Note the hub (H) or cannula. The "Y" piece (Y), the nose cone (N), and the stent (S to S). (Courtesy Infiniti Medical LLC, Menlo Park, CA) (Color version of the figure is available online.)

Recovery and Discharge from the Hospital

Most dogs that undergo emergency tracheal stent placement are hospitalized for 1 night after the procedure unless comorbid conditions necessitate ongoing hospitalization. Medical management will include a cough suppressant (hydrocodone 0.22 mg/kg PO Q6 hour) to help prevent coughing in the early postplacement period. This medication will be weaned to an "as needed" basis after the first month. A tapering dose of prednisone (0.5 mg/kg PO Q12 hours $\times$ 7 days, then once daily for 7 days, then every other day for 14 days) is also administered. A course of antibiotics that has efficacy against common respiratory pathogens including *Mycoplasma* spp. such as doxycycline, enrofloxacin, or azithromycin is indicated. A dry cough is expected for approximately 1 month as the tracheal stent becomes epithelialized. Additional coughing may be seen, especially if cough was part of the presenting history or if known mainstem and lobar bronchial collapse are present. Persistent coughing should be treated aggressively. Persistent coughing in this population may apply considerable forces to the stent and may be involved in the pathogenesis of stent fracture. Recheck examination including radiography is usually performed 4 weeks after placement and then every 12 months as needed thereafter to evaluate the stent for additional shortening, fracture, etc.

Complications

Like many other medical interventions, tracheal stent placement is not without complications. Acute complications are completely avoidable through careful attention to detail when making measurements and meticulous stent deployment. If the

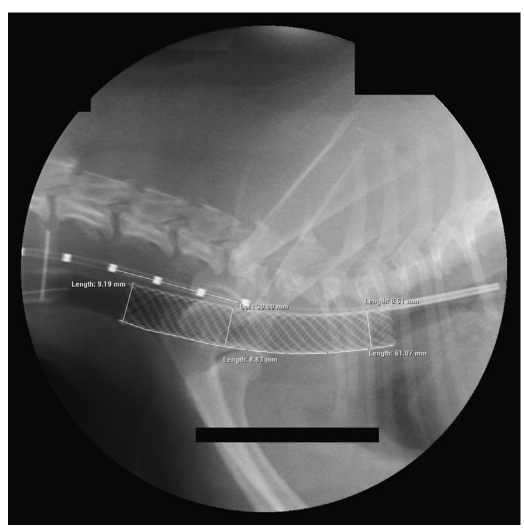

Fig. 5. Postdeployment images of the dog in Figures 2 and 3 illustrating the self-expanding metallic stent spanning the known region of collapse. Note that the stent opened slightly wider than the diameter predicted based on measurements. This is not uncommon.

stent diameter is undersized in relation to the trachea, stent migration will be a problem resulting in persistent cough and possible stent expulsion. Malpositioning of the stent is another acute complication. The stent may be deployed into the carina or mainstem bronchus resulting in persistent coughing and possible partial occlusion of the lobar bronchi. The stent may also be accidentally deployed in the larynx or the endotracheal tube. An undersized stent that has migrated or a malpositioned stent should be removed.

Chronic complications of tracheal stent placement include foreshortening as the outward radial force of the stent results in expansion of the stent over time (usually in the first month).[10] 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 by the stent, clinical signs referable to airway obstruction will occur and placement of a new stent will be necessary.

Stent fracture is a well-recognized problem in dogs with tracheal collapse.[4,10-13] Numerous factors may contribute to stent fracture and research and development efforts by stent manufacturers are always ongoing to optimize design to minimize this complication. It is the author's opinion that persistent cough is the greatest contributor to stent fracture. At the time of this writing, the author has not experienced stent fracture in any stent (Vet-Stent Trachea, Infiniti Medical LLC., Menlo Park, CA) that has been manufactured after 2009. Inflammatory tissue formation that may or may not be associated with bacterial tracheitis has been a documented problem in some dogs undergoing stent placement.[4,10] Some animals with this complication may respond to antibiotic followed by corticosteroid therapy.

Conclusion

Dogs with tracheal collapse presenting with life-threatening airway obstruction refractory to conservative treatment options are candidates for placement of a self-expanding metallic stent. Stent placement is a safe technique with rare acute complications and it will acutely provide the patient with a patent airway allowing for stabilization and discharge from the hospital.

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