Minimally Invasive Management of Urolithiasis

Dana L. Clarke, VMD, DACVECC
Assistant Professor of Interventional Radiology & Critical Care

Andréanne Cléroux, DVM, DACVIM (SAIM)
Assistant Professor of Interventional Radiology & Internal Medicine
University of Pennsylvania School of Veterinary Medicine, Philadelphia, PA

Urolithiasis is a significant cause of morbidity in both human and veterinary medicine, despite growing knowledge about stone prevention and dietary management. Human healthcare has moved towards minimally invasive options for stone removal instead of traditional open surgical procedures. With improved understanding of urolithiasis in dogs and cats and expanding skills in minimally invasive and endoscopic techniques, there is a growing trend toward less invasive techniques for removal of problematic urinary tract calculi.

NEPHROLITHIASIS

In the majority of dogs and cats, nephroliths are often found incidentally and do not require intervention unless there is obstruction of urine outflow at the ureteropelvic junction, compression of the renal parenchyma due to large stone size, pain, hematuria, and recurrent urinary tract infections when the nephrolith is colonized with bacteria.

Ureteral stenting for nephrolithiasis is generally used a temporary measure to provide drainage of the renal pelvis when pyonephrosis is present, when the nephrolith is causing obstruction of the ureteral pelvic junction, or in preparation for ESWL to allow for passive ureteral dilation and passage of stone fragments. For more information on ureteral stenting, see the section below on the management of ureterolithiasis.

Extracorporeal shockwave lithotripsy (ESWL) utilizes a lithotripter to generate high energy shockwaves that are transmitted from the lithotripter to the fixed nephrolith using a dry shockwave delivery head and water filled silicone cushion to maximize contact. The lithotripter is positioned over the stone using fluoroscopy and the stone is gradually fragmented using mechanical forces generated by the shockwaves. The total number of shocks delivered is variable (1000-3500 per treatment), with the ideal treatment shock number in veterinary medicine being unknown. ESWL is effective for calcium oxalate and struvite stones, but is ineffective against cystine nephroliths. Intra-renal hemorrhage, hemorrhage of surrounding tissues, reduction in glomerular filtration rate (GFR), abdominal pain, and shockwave induced pancreatitis are reported complications. Stone fragments created with ESWL are approximately 1 mm, which creates a challenge for the use of ESWL in cats since 1 mm stones are still too large to pass down the undilated feline ureter. In addition to large stone fragment size, feline kidneys appear more sensitive to the hemorrhage and reduction in GFR caused by ESWL; therefore this treatment modality is not recommended for feline nephrolithiasis. ESWL requires general anesthesia for positioning and analgesia and is generally recommended for dogs with nephroliths less than 1.5 cm in size. For stones 1-1.5 cm in size, pre-placement of a ureteral stent to facilitate stone fragment passage and decrease the risk of ureteral obstruction is recommended. ESWL is reported to be successful in up to 90% of canine nephrolithiasis, though some require a second treatment for complete fragmentation, which is generally performed 1-3 months after the initial treatment to allow for complete passage of all stone fragments. The most common complication of ESWL is ureteral obstruction with stone fragments, which occurs in up to 10% of patients, and can be reduced with pre-placement of a ureteral stent. Additionally, because of the ureteral obstruction concerns, patients are monitored in the hospital for 24 hours after the procedure on intravenous fluids, analgesia, and monitoring for any evidence of ureteral obstruction.

For stones with a complex shape or larger than 1.5 cm, complete fragmentation with ESWL can be challenging. Therefore, percutaneous (PCNL) or surgically-assisted endoscopic nephrolithotomy (SENL) can be considered and are treatments of choice in human patients with similar stone burdens. This procedure involves percutaneous or surgically assisted placement of a rigid endoscope into the renal pelvis for lithotripsy with either ultrasonic or laser (holmium:yttrium-aluminum-garnet (Ho:YAG)) lithotripsy and subsequent retrieval of stone fragments. In dogs, ureteral stents are placed after the procedure to allow for passage of stone fragments. When the PCNL is performed, a nephrostomy tube is placed upon completion of the procedure to prevent urine leakage from the access site through the renal parenchyma. When SENL is performed, the capsule of the kidney can be sutured to prevent urine leakage, making a nephrostomy tube unnecessary. Complications reported in human patients and in one abstract describing the use of PCNL/SENL in dogs and one cat include fever, hemorrhage, urosepsis, urine leakage, and secondary ureteral obstruction. Currently, this procedure is only available at limited number of veterinary institutions.

URETEROLITHIASIS

Ureteral stenting can be performed percutaneously, cystoscopically, and surgically; with surgical placement preferred in cats due to the small size of their ureter. The goals of ureteral stenting are to provide immediate urine drainage through the stent and to induce passive ureteral dilation for drainage around the stent, which occurs days to weeks after placement. While ureteral stents are considered a short-term bridge to definitive stone removal therapies in people, ureteral stents have been used as a long-term treatment options for dogs and cats with ureterolithiasis to palliate their ureteral obstruction. Ureteral stents can also be placed as a temporary measure for future ESWL ureterolith treatment in dogs and in patients with ureteroliths and obstructive pyonephrosis. In general, ureteral stents are well tolerated in dogs, with infection, encrustation, tissue proliferation at the ureterovesicular junction, and migration being the most common complications. Up to 30% of cats can develop lower urinary tract irritation and dysuria in response to ureteral stents. This complication can often be managed with supportive care that includes analgesics, alpha-antagonists for smooth muscle relaxation, and anti-inflammatory doses of corticosteroids. Encrustation, infection, and stent migration are also reported in cats.

Given the technical challenges of ureteral stenting in cats, subcutaneous ureteral bypass (SUB) devices are often used to provide an alternative route for urine drainage and bypass of obstructive ureteroliths. These devices are placed via laparotomy, with access to the renal pelvis for placement of the nephrostomy tube, the bladder apex for placement of the cystotomy tube, and the abdominal body wall lateral to the midline incision for placement of the subcutaneous port that connects the cystotomy and nephrostomy tubes. Complications associated with SUBs include infection, dislodgement, occlusion with blood clots, kinking, and long-term encrustation causing occlusion of the drainage system.

CYSTIC & URETHRAL CALCULI

In dogs and female cats with cystic calculi, cystoscopic-guided basket retrieval of stones can be performed to extract stones from the bladder. In general, basket retrieval can be considered in female cats with stones that are less than 2-3mm, male dogs with stones less than 3-4 mm, and female dogs with stones less than 4-5 mm in size. The cystoscope is passed into the bladder to facilitate stone visualization and the stone basket is passed through the scope's working channel. Once in the bladder, the basket is opened to ensnare the stone, closed tightly around the stone, retracted caudally toward the scope, and then removed from the bladder simultaneously with the cystoscope. Care must be taken to prevent extraction of stones that are too large to be safely pulled through the urethra with no more than gentle traction, otherwise the risk of urethral trauma and tearing is increased. This method provides an attractive alternative cystolith removal, however, the procedure requires general anesthesia and the removal and replacement of the cystoscope for each stone that is retrieved. Therefore, in patients with small urethral diameters, large stone size, or significant stone burdens, the risk of urethral trauma and procedural and anesthesia time must be weighed against the advantages of the minimally invasive nature of the procedure.

Cystoscopic-guided laser lithotripsy allows for fragmentation of stones that are too large to be voided with urohydroproulsion or retrieved via stone basketting to still be removed minimally invasively in dogs and female cats. Laser lithotripsy can also be performed successfully on stones lodged in the urethra. The technique is performed in a similar fashion to cystoscopic-guided basket retrieval, with use of a Ho:YAG laser fiber to fragment the stones into small enough pieces for basket retrieval or removal via voiding urohydropropulsion. The procedure has been reported to be effective at complete stone removal in 83-100% of female dogs and 81-87% of male dogs. Reported complications include hematuria, lower urinary tract discomfort, perforation of the bladder, urethral inflammation requiring catheterization, and urethral stricture formation secondary to urethral trauma.

Percutaneous cystolithotomy (PCCL) is a hybrid technique adapted from a procedure designed for children with cystic calculi that utilizes a limited laparotomy approach to the bladder, cannulation of the bladder with a threaded laparoscopic port, and cystoscopic-guided basket retrieval of stones through the port. The main advantage of this procedure is that it can be performed in male and female dogs and cats with stones less than 1 cm in size. For stones larger than 1 cm in size, or those lodged within the urethra that cannot be flushed retrograde into the bladder, laser lithotripsy through the working channel of the scope can be performed to permit stone fragmentation for extraction through the laparoscopic port. This technique also provides excellent visualization due to magnification and saline distension and an ability to use a combination of rigid and flexible cystoscopy to perform a complete examination of the bladder and urethral mucosa for other concurrent lesions and to confirm complete stone removal.

REFERENCES:

1. Lulich JP, Berent AC, Adams LG, et al. ACVIM small animal consensus recommendations on the treatment and prevention of uroliths in dogs and cats. J Vet Intern Med 2016;30:1564-74.
2. Bartges JW, Callens AJ. Urolithiasis. Vet Clin North Am Small Anim Pract 2015;45:747-68.
3. Cannon AB, Westropp JL, Ruby AL, et al. Evaluation of trends in urolith composition in cats: 5,230 cases (1985-2004). J Am Vet Med Assoc 2007;231:570-6.
4. Kyles AE, Hardie EM, Wooden BG, et al. Management and outcome of cats with ureteral calculi: 153 cases (1984-2002). J Am Vet Med Assoc 2005;226;937-944.
5. Low WW, Uhl JM, Kass PH, et al. Evaluation of trends in urolith composition and characteristics of dogs with urolithiasis: 25,499 cases (1985-2006). J Am Vet Med Assoc 2010;236:193-200.
6. Ross SJ, Osborne CA, Lekcharoensuk C, et al. A case-control study of the effects of nephrolithiasis in cats with chronic kidney disease. J Am Vet Med Assoc 2007;230:1854-9.
7. Raza A, Turna B, Smith G, et al. Pediatric urolithiasis: 15 years of local experience with minimally invasive endourological management of pediatric calculi. J Urol 2005;682-5.
8. Muslumanoglu AY, Tefekli A, Sarilar O, et al. Extracorporeal shock wave lithotripsy as first line treatment alternative for urinary tract stones in children: a large scale retrospective analysis. J Urol 2003;170:2405-8.
9. Adams LG, Goldman CK. Extracorporeal shockwave lithotripsy. In: Bartges DJ, Polzin D, editors. Nephrology and urology of small animals. Ames: Blackwell; 2011. p. 340-8.

10. Vachon C, Brisson B, Nykamp S, et al. Passive ureteral dilation and ureteroscopy after ureteral stent placement in five healthy Beagles. Am J Vet Res 2017;78:381-392.
11. Lulich JP, Osborne CA, Albasan H, et al. Efficacy and safety of laser lithotripsy in fragmentation of urocystoliths and urethroliths for removal in dogs. J Am Vet Med Assoc 2009;234:1279-85.
12. Adams LG, Senior DF. Electrohydraulic and extracorporeal shock-wave lithotripsy. Vet Clin North Am Small Anim Pract 1999;29:293-303.
13. Lane IF. Lithotripsy: an update on urologic applications in small animals. Vet Clin North Am Small Anim Pract 2004;34:1011-1025.
14. Lulich JP, Adams LG, Grant D, et al. Changing paradigms in the treatment of uroliths by lithotripsy. Vet Clin North Am Small Anim Pract 2009;39:143-160.
15. Berent AC, Adams LG. Interventional management of complicated nephrolithiasis. In: Weisse C, Berent A, editors. Veterinary image-guided interventions. Ames: Wiley Blackwell; 2015; p. 289-300.
16. Branter, EB, Berent, AB, Weisse, CW. Endoscopic assisted nephrolithotomy in cats and dogs. Abstract presented at ACVIM forum 2012.
17. Donner GS, Ellison GW, Ackerman N, et al. Percutaneous nephrolithotomy in the dog: An experimental study. Vet Surg 1987;16(6): 411-417.
18. Pavia P, Berent A, Weisse C, Bagley D. Outcome following ureteral stenting in dogs with benign ureteral obstruction: 48 Cases. J Am Vet Med Assoc. March 15, 2018, Vol. 252, No. 6, Pages 721-731.
19. Kuntz JA, Berent AC, Weisse CW, Bagley DH. Double pigtail ureteral stenting and renal pelvic lavage for renal-sparing treatment of obstructive pyonephrosis in dogs: 13 cases (2008–2012). J Am Vet Med Assoc. 2015;246(2):216-225.
20. Nicoli S, Morello E, Martano M, Pisoni L, Buracco P. Double-J ureteral stenting in nine cats with ureteral obstruction. Vet J. 2012;194(1):60-65.
21. Culp WTN, Palm CA, Hsueh C, et al. Outcome in cats with benign ureteral obstructions treated by means of ureteral stenting versus ureterotomy. J Am Vet Med Assoc. 2016;249(11):1292-1300.
22. Wormser C, Clarke DL, Aronson LR. Outcomes of ureteral surgery and ureteral stenting in cats: 117 cases (2006–2014). J Am Vet Med Assoc. 2016;248(5):518-525.
23. Horowitz C, Berent A, Weisse C, Langston C, Bagley D. Predictors of outcome for cats with ureteral obstructions after interventional management using ureteral stents or a subcutaneous ureteral bypass device. J Feline Med Surg. 2013;15(12):1052-1062.
24. Berent AC, Weisse CW, Todd K, Bagley DH. Technical and clinical outcomes of ureteral stenting in cats with benign ureteral obstruction: 69 cases (2006–2010). J Am Vet Med Assoc. 2014;244(5):559-576. doi:10.2460/javma.244.5.559
25. Kulendra NJ, Syme H, Benigni L, Halfacree Z. Feline double pigtail ureteric stents for management of ureteric obstruction: short- and long-term follow-up of 26 cats. J Feline Med Surg. 2014;16(12):985-991.
26. Berent A, Weisse C, Bagley D, Lamb K. Subcutaneous ureteral bypass device (SUB) placement for benign ureteral obstruction in cats: 137 cats (174 obstructed ureters) (2009-2015). In: Jackson Hole, Wyoming: Abstract VIRIES; 2016.
27. Livet V, Pillard P, Goy-Thollot I, et al. Placement of subcutaneous ureteral bypasses without fluoroscopic guidance in cats with ureteral obstruction: 19 cases (2014–2016). J Feline Med Surg. 2017;19(10):1030-1039.
28. Berent AC, Adams LG. Minimally invasive treatment of bladder and urethral stones in dogs and cats. In: Weisse C, Berent A, editors. Veterinary image-guided interventions. Ames: Wiley Blackwell; 2015; p360-372.
29. Lulich JP, Osborne CA, Carlson M, et al. Nonsurgical removal of urocystoliths in dogs and cats by voiding urohydropropulsion. J Am Vet Med Assoc 1993;203:660-3.
30. Adams LG, Berent AC, Moore GE, et al. Use of laser lithotripsy for fragmentation of uroliths in dogs: 73 cases (2005-2006). J Am Vet Med Assoc 2008;232:1680-1687.
31. Lulich JP, Osborne CA, Albasan H, et al. Efficacy and safety of laser lithotripsy in fragmentation of urocystoliths and urethroliths for removal in dogs. J Am Vet Med Assoc 2009;234:1279-85.
32. Runge JJ, Berent AC, Meyhew PD, et al. Transvesicular percutaneous cystolithotomy for the retrieval of cystic and urethral calculi in dogs and cats: 27 cases (2006-2008). J Am Vet Med Assoc 2011;239:344-349.

What's New in Tracheal Collapse

Dana L. Clarke, VMD, DACVECC
Assistant Professor of Interventional Radiology & Critical Care
University of Pennsylvania School of Veterinary Medicine, Philadelphia, PA

INTRODUCTION

Tracheal collapse is a common, frustrating disease process in small breed dogs. Once the extent and severity of disease is understood, medical management is attempted in many cases except those so severely affected that discharge without intervention is not possible. Tracheal stenting has become a popular, non-invasive method for treating tracheal collapse in dogs. Initial experience with tracheal stenting was met with significant complications, leading to it being branded a salvage procedure. As experience with stenting has grown, improvements in patient selection, pre-operative work-up and diagnostics, sizing, and post-stent placement monitoring and management have all improved. Design enhancements, progress in sizing protocols, and enhanced patient selection criteria has increased the success of their use. The purpose of this lecture is to discuss updates in patient selection for tracheal stenting, especially using information obtained during history and physical examination, explore additional information that can be obtained from pre-operative imaging, tracheal stent sizing and selection considerations, and post-operative monitoring and management of complications like inflammatory tissue, chronic infections, and stent fractures.

PATIENT EVALUATION

The main goal of the initial consultation for a patient regarding tracheal stenting candidacy should be to determine what portion of their clinical signs are attributable to airway obstruction, since this is what will be addressed with tracheal stenting. In dogs with tracheal collapse and concurrent lower airway disease where coughing is their predominant respiratory complaint, tracheal stenting is less likely to resolve their clinical signs since the lower airway disease will persist after stenting. A thorough history and physical examination, including pointed respiratory questioning and evaluation, is essential since these patients may also have other disease processes affecting the upper and/or lower airway in addition to tracheal collapse. Important historical information that should be obtained during a tracheal collapse consultation includes information regarding the duration of clinical signs, nature of respiratory noise, triggers for a coughing or respiratory event, frequency and duration of events, any respiratory distress induced, snoring, and response to medications.

It is helpful to classify dogs as "honkers" and "coughers", though there are some dogs who have both attributes. For cases with components of both coughing and honking, it may be more difficult to determine how much their signs will be alleviated with stenting. The "honking" noise heard with respiration and panting is characteristic of obstructive airway disease, generally with collapse of the cervical or thoracic inlet trachea. Stress, activity, and excitement can worsen the severity of honking, and exercise and stress intolerance is common. "Coughers" tend to have a dry, hacking cough, which can also be high pitched, and may or may not be productive or associated with a terminal retch. Coughing tends to be the result of bronchial collapse, chronic bronchitis, pulmonary parenchymal disease, and/or intra-thoracic tracheal collapse. These dogs do not tend to have exercise intolerance or respiratory distress when mildly to moderately affected. However, with more advanced lower airway collapse or concurrent pulmonary parenchymal disease, such as pulmonary fibrosis, exercise intolerance may be present. There are patients with components of both coughing and obstruction, making determination of the primary problem and what is affecting the dog the most imperative to guide whether tracheal stenting will be beneficial.

Visual assessment of patient breathing at rest and during a coughing event to evaluate for nature of the cough, prolongation of inspiratory or expiratory phase of respiration, increased respiratory effort, abdominal push on expiration, and herniation of the cranial lung lobes out of the thoracic inlet on expiration should be performed first. Auditory assessment from a distance should assess for nature of abnormal respiratory noises (honking, high pitched, wheezing moist, stertor or stridor). The larynx, trachea, and entire thorax should be carefully ausculted with simultaneous observation of respiratory phase for air movement, fluid sounds, and crackles. The presence of an inducible cough on tracheal palpation is not pathognomonic for tracheal collapse as aggressive palpation can induce patients with normal tracheas to cough. In general, patients with cervical tracheal collapse have clinical signs upon inspiration whereas those with intrathoracic collapse are affected on exhalation. Patients with thoracic inlet collapse can have signs during both or either phase of respiration. Patients with mainstem bronchial collapse are affected mostly during expiration.[1]

DIAGNOSTICS

Thoracic radiographs are an important first line diagnostic in patients with suspected tracheal collapse. They are essential to rule out concurrent bronchopneumonia, bronchiectasis, lower airway disease, cardiomegaly, and to assess pulmonary vasculature size. The presence of tracheal collapse on films does not determine severity, the absence of collapse on films does not preclude a diagnosis of tracheal collapse, and thoracic radiographs cannot determine the dynamic nature of the collapse.[2] Paired inspiratory and expiratory thoracic radiographs improves their utility, but can still underestimate severity and extent of disease. Radiographs misdiagnosed the location of tracheal collapse in 44% of dogs and failed to diagnose tracheal collapse in 8% of dogs when compared to fluoroscopy.[2] Thoracic radiographs may not give a complete assessment of mainstem bronchial disease and nasopharyngeal collapse. Tracheal fluoroscopy is an extremely useful diagnostic for thoroughly assessing the dynamic nature nasopharyngeal, tracheal, and bronchial collapse. It allows for real time understanding of the extent of tracheal collapse during all phases of respiration and during coughing in awake patients. It is especially helpful for determining the presence and extent of mainstem bronchial collapse as well as nasopharyngeal collapse.[3]

Tracheoscopy is a very useful diagnostic in tracheal collapse patients, however, small patient size may mean that some patients must be extubated for tracheoscopy, which can make anesthesia more difficult and dangerous in patients with compromised airways. Tracheoscopy allows for direct visualization of the entire airway and for bronchoscopy if indicated. In patients with suspected or confirmed tracheal collapse where tracheoscopy is being used for staging of collapse and complete airway assessment, the clinician must be prepared for intervention (prolonged intubation, prosthetic ring placement, or endoluminal stenting) should the patient be unable to be extubated due to their disease and/or iatrogenic irritation induced from tracheoscopy.[4] Therefore, in most cases of tracheal collapse, tracheoscopy is reserved for immediate airway assessment before intervention, and in the case of tracheal stenting, immediately post-stent placement to assess position and mucosal contact before recovering the patient from anesthesia.

MEDICAL MANAGEMENT

Medical therapy is a mainstay of tracheal collapse management; efforts should be made to attempt medical therapies before surgical or interventional options are pursued.[5] Oftentimes, “breaking the cycle” of dyspnea, distress, and anxiety with sedation, oxygen, cough suppression, and possibly corticosteroids is adequate to control tracheal collapse symptoms enough to permit discharge with medical management institution or adjustment or referral for further surgical or interventional care. However, there are cases where respiratory distress cannot be controlled or there is significant patient compromise and immediate relief of the airway obstruction is needed.[6]

In the emergency setting when tracheal collapse patients are dyspnic, sedation, anxiolytics, and oxygen are essential. Butorphanol and acepromazine are effective initial anxiolytic and sedative options. Acepromazine should only be used patients for whom cardiovascular compromise is not a concern. The use of an oxygen cage where the percentage of inspired oxygen can be adjusted as dictated by the patient’s comfort is also very helpful during emergency stabilization. Corticosteroids may also be considered if there is concern for airway edema and inflammation secondary to respiratory distress and increased work of breathing.

Hydrocodone and butorphanol are effective antitussives, though it is imperative to educate owners that they better at preventing coughing than stopping an episode, so they should be used regularly in the beginning phases of medical therapy and in some patients, lifelong. Dosing is flexible (0.25-0.5 mg/kg PO q6-12hr) and dependent on patient response and will likely need to be increased over time should tolerance develop. Hydrocodone is available in tablets and an elixir, with the elixir allowing for smaller dose increment changes and titration by the owners.

The use of corticosteroids such as prednisone in the long-term management of tracheal collapse is controversial. In patients recovering from an episode of dyspnea, a tapering course of anti-inflammatory steroids may be necessary to control the airway inflammation that results from cycling of the collapsing trachea during coughing and edema from increased work of breathing. However, when cough is controlled, airway inflammation from tracheal collapse should be minimal and may not require steroids long term.

The use of bronchodilators is also controversial in managing dogs with tracheal collapse. Bronchodilators are generally reserved for dogs with confirmed bronchial collapse or concurrent lower airway disease. Methylxanthine derivatives, such as theophylline or aminophylline may be preferable to B2 agonists such as terbutaline or albuterol due to risk of tachyarrhythmias with sympathomimetic agents. Theophylline and aminophylline have multiple drug interactions, so drug compatibility must be confirmed before initiating therapy.

TRACHEAL STENTING

Tracheal stenting can be performed in dogs with both intra-thoracic and extra-thoracic tracheal collapse as well as those with cervical collapse that are deemed poor surgical candidates for extra-luminal rings or for those whom clients are unwilling to accept the complications associated with tracheal ring placement.[5-14] Since tracheal stenting can be performed quickly and non-invasively, it has has been shown to be beneficial in tracheal collapse dogs that present in respiratory crisis that is nonresponsive to medical stabilization.[6]

Complications when balloon expandable and human biliary wall stents were used in research dogs and clinical tracheal collapse patients, such as foreshortening, migration, fracture, and excessive airway irritation, led to labeling tracheal stenting as a salvage procedure only, and hence the recommendation to exhaust medical management before considering stenting.[15] Stents designed specifically for the canine trachea (VetStent Trachea, Infiniti Medical, Menlo Park, CA, USA) have gone through multiple design enhancements to improve their sizing and placement predictability and risk of fracture. Complications seen with tracheal stenting are believed to be greatly reduced when precise sizing is performed. Oversized stents that do not fully expand are at increased risk of fracture since stents are strongest when fully expanded. Alternatively, undersized stents are at risk of poor incorporation into the tracheal mucosa, leading to mucous accumulation, inflammation, and likely infection. Unequal tracheal mucosal contact, in conjunction with airway inflammation and infection, may also lead to granulation/inflammatory tissue formation but objective data correlating these circumstances is lacking.

Current sizing recommendations include positive pressure breath holds to 20 cmH2O to determine maximal tracheal diameter using digital radiography or fluoroscopy. Stent size is chosen by selecting a stent with a diameter that is 10-20% larger than the maximal tracheal diameter measurement obtained. In some cases, the tracheal diameter is not uniform along its length, with the most common scenario being a larger cervical and cranial thoracic inlet diameter compared to the intrathoracic tracheal diameter. Stent choice in these cases mandates that either the cervical trachea is undersized to accommodate the intrathoracic trachea, or the thoracic trachea is oversized to accommodate the cervical trachea when using traditional tubular stents. Since accurate sizing is thought to be paramount in the success of tracheal stenting, a self-expanding, nitinol stent with a tapering diameter where the cervical tracheal diameter stent portion is larger than the intrathoracic portion was designed. Initial clinical case experience with the tapered tracheal stent (VetStent Duality, Infiniti Medical, Menlo Park, CA, USA) has been very promising.[16] Measurements are performed under general anesthesia at the time of stenting, multiple sizes of tracheal stents should be readily available so that the appropriate size can be placed without having to attempt to recover a compromised patient. Tracheal stents are placed through an endotracheal tube and when a bronchoscope adapter is used, the patient can continue to have oxygen insufflation during stent positioning and deployment.

Patients are often discharged the day following stent placement, unless there is concurrent pneumonia requiring prolonged hospital care. All tracheal stent patients have thoracic radiographs taken prior to discharge. Patients are discharged with antibiotics pending airway culture, a 2-3 weeks tapering course of steroids, and regular (q6-8 hour) cough suppression. A short, dry, self-limiting cough is to be expected for 4-6 weeks post-stent placement and is something about which clients should be educated pre-operatively.

Long-term routine thoracic radiograph monitoring is important to be able to detect migration, early fracture or the development of inflammatory tissue. For the first year post-operatively, radiographs are checked every 3-4 months. For every year after that, radiographs are taken every 6 months. If at any point post-operatively, there is a change in the patient's cough or respiratory comfort, repeat radiographs are taken immediately. If radiographs and/or tracheal fluoroscopy do not reveal the explanation for changes in coughing and respiratory comfort, repeat endotracheal wash and tracheoscopy is indicated. Since tracheal stents are permanent implants, stent fracture causing clinical signs of airway obstruction and coughing can only be managed by placement of an additional stent within the original stent.[17-19] Very limited experience with obstructive intra-luminal granulation tissue has also shown promising response to immunosuppressive steroid therapy, culture-guided antibiotic therapy, and in some cases, repeat stenting.

Portions of the following proceedings were adapted from "Clarke DL. Interventional radiology management of tracheal and bronchial collapse. Vet Clin North America 48(5): 765-779, 2018".

REFERENCES

1. Tanger CH, Hobson H. A retrospective study of 20 surgically managed cases of collapsed trachea. Vet Surg; 1982;11(4):146–9.
2. Macready DM, Johnson LR, Pollard RE. Fluoroscopic and radiographic evaluation of tracheal collapse in dogs: 62 cases (2001–2006). J Am Vet Med Assoc. 2007 Jun 15;230(12):1870–6.
3. Rubin JA, Holt DE, Reetz JA, Clarke DL. Signalment, clinical presentation, concurrent diseases, and diagnostic findings in 28 dogs with dynamic pharyngeal collapse. J Vet Intern Med 2015 May/June 29(3):815-821.
4. Johnson LR, Pollard RE. Tracheal collapse and bronchomalacia in dogs: 58 cases (7 /2001-1 /2008). J Vet Intern Med. 2009 Dec 30;24(2):298–305.
5. White R, Williams JM: Tracheal collapse in the dog-is there really a role for surgery? A survey of 100 cases. J Small Anim Pract 35(4):191-196, 1994.
6. McGuire L, Winters C, Beal MW. Emergency tracheal stent placement for the relief of life-threatening airway obstruction in dogs with tracheal collapse. J Vet Emerg Crit Care 2013; 23(S1):S9.
7. Buback JL, Boothe HW, Hobson HP: Surgical treatment of tracheal collapse in dogs: 90 cases. J Am Vet Med Assoc 1996; 208:380-384.
8. 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 May;41(4):501–6.
9. Gellasch KL, Gomez TDC, McAnulty JF, Bjorling DE. Use of intraluminal nitinol stents in the treatment of tracheal collapse in a dog. J Am Vet Med Assoc. 2002 Dec;221(12):1719–23.

10. Sura PA, Krahwinkel DJ. Self-expanding nitinol stents for the treatment of tracheal collapse in dogs: 12 cases (2001–2004). J Am Vet Med Assoc. 2008 Jan 15;232(2):228–36.
11. Moritz A, Schneider M, Bauer N. Management of Advanced Tracheal Collapse in Dogs Using Intraluminal Self-Expanding Biliary Wallstents. J of Vet Intern Med. 2004;18(1):31–42.
12. Sun F, Usón J, Ezquerra J, Crisóstomo V, Luis L, Maynar M. Endotracheal stenting therapy in dogs with tracheal collapse. Vet J. 2008 Feb;175(2):186–93.
13. Kim JY, Han HJ, Yun HY, Lee B, Jang HY, Eom KD, Park HM, Jeong SW. The safety and efficacy of a new self-expandable intratracheal nitinol stent for the tracheal collapse in dogs. J Vet Sci. 2008 Mar;9(1):91–93.
14. Durant AM, Sura P, Rohrbach B, Bohling MW. Use of nitinol stents for end-stage tracheal collapse in dogs. Vet Surg. 2012 Sep 7;41(7):807–817.
15. Radlinsky MG, Fossum TW, Walker MA, Aufdemorte TB, Thompson JA. Evaluation of the Palmaz stent in the trachea and mainstem bronchi of normal dogs. Vet Surg. 1997 Mar;26(2):99–107.
16. Clarke, DL, Tappin S, de Madron E, Presley R. Evaluation of a novel tracheal stent for the treatment of tracheal collapse in dogs. J Vet Intern Med 2014 July/Aug 2014 (4):1364.
17. Mittleman E, Weisse C, Mehler SJ, Lee JA. Fracture of an endoluminal nitinol stent used in the treatment of tracheal collapse in a dog. J Am Vet Med Assoc. 2004 Oct 15;225(8):1217–21–1196.
18. Ouellet M, Dunn ME, Lussier B, Chailleux N, Hélie P. Noninvasive correction of a fractured endoluminal nitinol tracheal stent in a dog. J Am Anim Hosp Assoc. 2006 Nov;42(6):467–71.
19. Woo HM, Kim MJ, Lee SG, et al. Intraluminal tracheal stent fracture in a Yorkshire terrier. Can Vet J 2007;48:1063-1066.