Minimally Invasive Surgery for Advanced Practitioners Mini Series

Session One: Introduction to Interventional Radiology and Tracheal Collapse

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Introduction to Interventional Radiology

Fluoroscopy

Digital fluoroscopy is commonly used in the majority of interventional radiology procedures. It is essential to have a standard C-arm digital fluoroscopy system and an appropriate table to allow and adequate and comfortable. Not only, but especially for endovascular procedure digital subtracton angiography (DSA) is an essential tool. This is a technique by which an initial mask image is subtracted from subsequent serial images following injection of contrast into a vessel or organ. After subtraction, the static anatomical structures are removed from the screen and the structures containing the contrast are opacified. Any motion during the image acquisition may induce artifacts therefore temporarily controlled apnea by suspension of mechanical ventilation is recommended especially for abdominal interventions.
Interventional radiology procedures involve significant radiation exposure and associated risks for both staff and patients. Radiation protection is one of the main concerns in interventional radiology. Wearing lead apron and thyroid collar is mandatory as well as maintaining distance from the radiation source.

Access needles

Percutaneous access to vessels of abdominal structure are performed using needles with thin wall and large lumens to allow passage of guide wires. The common needles used range from 18 to 21 gauge. It is important to ensure that the guide wire ca pass through the needle. For example a 18G needle allows for passage of a 0.038” and 0.035” guide wire however a 19G needle can accommodate a 0.035” wire but not a 0.038”. Needles and catheters have an outer cannula and an inner stylet. When the tip of the stylet is in the right position the stylet is retracted and the cannula is advanced and the wire is passed through it. There are some other specific needles called single-wall puncture needles without cannula. After puncturing the vessel or the target area the tip is advanced in the correct position and the wire passed through it.

Guide wires

Guide wires are used to select a particular route and to facilitate and support the placement of catheters. The outer diameter is expressed in inches; the standard wires are 0.035” in diameter and 145cm in length. Different diameters are available, and wires of 0.018” or less are called micro-wires. The guidewires should be twice as long as the catheter used. When a catheter needs to be exchanged the guide wire should be long enough to allow removal and preplacement of the catheter without losing access. Guide wires can have different soft leading tip such as straight, angled or “J” configuration. Normally the “J” shape is designed to be less traumatic when within a vessel. The mandrel of the wire determines the rigidity of the shaft and ranges from regular, stiff, extra stiff, super stiff and ultra stiff. Generally, a less stiff wire is useful to access different vessels or small branches whereas stiffer wires allow a better manipulation and give more support for passage of catheters and stents. Guide wires can also have different types of coating however the majority of them have a nitinol alloy core and a hydrophilic polymer coating. These wires are elastic and resistant to kinking because of the nitinol and they have a low coefficient of friction and they are less trombogenic because of their coating. It is extremely important to completely wet the guide wire to take advantage of their low friction property.

Sheaths

Once the access is established an introducer sheath should be placed, this is important for vascular or urethral access. This is a thin wall catheter that facilitates insertion of other catheters, wires, contrast or other devices. It usually comes with a dilator, a sheath and a guide wire. The dilator is stiff tube with a tapered end, it is inserted into the sheath before the placement and over the guide wire. In contrast with all the other equipment the sheath are described by their inner diameter. For example if a catheter is 4 French (Fr) this would describe the outer diameter. If a sheath is 4 Fr this would describe the inner diameter. A 4 Fr sheath can accommodate a 4Fr catheter. One French is equal to 3 millimeters. The sheath is important to protect the access and to allow the exchange of different catheters or other devices. A haemostatic valve (for catheter exchanging) and a side port (for injection of contrast, pressure measurements, blood-sampling) are present at the end of the sheath.

Catheters

Catheters can be angiographic, balloon or drainage catheters. The catheters have three parts: the hub, the shaft and the tip. They are measured in French for the outer diameter of the shaft. The most common catheters used are 4 or 5 Fr and they accept 0.035” or 0.038” guidewires. The catheters can be used for diagnostic or therapeutic purposes. The angiographic catheters can be used for delivery of contrast medium, administration of therapeutic agents or passage of other devices. Balloon catheters have a balloon incorporate at the end and it can be inflated for therapeutic or diagnostic procedures. Drainage catheters are used for peritoneal or pleural drainage, nephrostomy or cystostomy drainage and biliary drainage.

They are generally large-bore (6-12 Fr) with a single large lumen. The tip has a pigtail or mushroom configuration to prevent migration of dislodgment.

Stents

Stents are tubular devices made of plastic, metal or bioabsorbable materials with the aim to restore or preserve luminal patency. Most of stents are metal whereas plastic stents are commonly used only in ureters, biliary duct and trachea. Currently available metal stents are made of nitinol or stain-less steal alloy. They can be balloon-expandable or self-expanding stents and they are further divided into bare stents (uncovered) or stent-graft (covered). Balloon-expandable stents are most commonly used for nasopharyngeal stenosis. Self-expanding stents are compressed within a delivery system and divided into mesh/woven types or laser-cut types. They are implanted by retracting the outer sheath while holding the stent delivery system in place. Most stents require oversizing of 1-2mm greater than the target lumen. They are most commonly placed within the trachea, urethra, and within blood vessels. Lasercut stents are generally nonreconstrainable, meaning they cannot be reconstrained into the delivery system once deployment is initiated. They also have minimal foreshortening during deployment, therefore the length of the stent when implanted is the same as its manufactured length. Woven stents are most often reconstrainable, although nonreconstrainable versions also exist, so the operator must confirm reconstrainability before placement. Another property of woven stents is that they foreshorten, which causes shortening of the length of the stent as it expands. Reconstrainable stents offer flexibility during placement because they can be reconstrained into the delivery system and repositioned.
A typical plastic stent is the ureteral stent that works as an internal drainage catheter with multiple side holes and two pigtail-loop ends.

Endoscopes

Rigid and flexible endoscopes are used for interventional endoscopic procedures. A light and camera box are needed to visualize the images on a monitor. The room should be set up in a way that the operator can have easily access to all the equipment and, at the same time, looking straight to the monitor. A variety of endoscopes are available with specific usages and all of them have working channel to allow access for guide wires, catheter or other devices. Common devices used in interventional endoscopy procedures are snares, baskets, needles and lasers. Snares, connected to an electrocautery unit, are commonly used for polypectomies. Baskets are helpful fir stone or foreign body removal. Injection needles are used for injection of triamcinolone in case of strictures or bulking agents such as collagen in the urethral tissue. Different type of lasers can be used for lithotripsy or ectopic ureter ablation.

Seldinger Technique

It is the mainstay of vascular and other luminal access in interventional radiology. It can be used for insertion of central venous catheters, chest drains, pacemaker leads, PEG tubes, and others. It is mandatory to used an aseptic technique when this technique is used. So the area has to be clipped and aseptically prepared. The desired vessel of cavity is punctured using an hollow needle or and over-the-needle catheter. In the latter the stylet is then removed. A soft curved tip guide wire is inserted through the needle or catheter and advanced into the lumen. Holding firmly the guidewire the catheter is removed and a dilator can be introduced over the guide wire and removed. A large-bore sheath/cannula/catheter is passed over the guide wire into the lumen and the guidewire is withdrawn leaving the catheter in situ. Finally, the catheter is sutured to the skin. Possible complications are haemorrhages, infection, perforation of viscus, air embolism, failed access.

Cystoscopy

Cystoscopes can be rigid or flexible. The rigid cystoscope has the advantage of having a larger lumen for water flow, hence improving visualisation. It also has a larger working channel for the passage of instruments. Rigid cystoscopes are more readily available compare to flexible cystoscopy. Rigid cystoscopes normally used in dogs are 2.7mm, 2.4mm and 1.9mm and 30°. The cystoscope should have three ports: one biopsy port for instruments and two accessory ports to infuse (ingress) and to remove (egress) fluids. A fluid line attached to 1L bag is connected to one of the accessory port, this is be helpful to dilate urethra and bladder and to increase the visualization. Bladder overdistention has to be avoided either calculating the volume infused or to palpate the bladder during procedure. The dog is placed in dorsal recumbency and in females, the vulva is gently clamped with an hand after initial insertion of the cystoscope to distend the vaginal vault with fluid for better visualization.

The urethral opening will be ventral to the vaginal lumen and appear as a longitudinal slit, it is important to remember than on the monitor, if the dog is in dorsal recumbency, the vagina will be toward the “floor” and the urethra will be toward the “ceiling”. Vestibule, vagina, urethra, bladder and ureteral opening should be evaluated.

Once in the urethra, fluid should distend the folds and the urethra lumen is kept as dorsal as possible on the monitor to avoid damage the urethra (the cystoscope is 30° oblique). Once in the bladder the urine should be removed and replaced with saline to maximise visualization. When the bladder is relatively distented fluids should be stopped. The normal bladder wall when distended should be light pink with visible sub-mucosal blood vessels. On entering the urinary bladder the light source of the cystoscope should be tilted downwards (180°) to enable the operator to visualise the neck and the trigone of the urinary bladder.

At this point also the ureteral openings can be identified. They are located at the dorsolateral aspect of the trigone area where the bladder mucosa begins and the urethra ends. Urine should normally be seen "jetting" from both ureters. At the end of the procedure the dorsal aspect of the urethra should be evaluated for the presence of ectopic ureters.

Introduction to laparoscopy

The most basic video endoscopy imaging system consists of a light source, light-transmitting cable, endoscope, camera and monitor. The light generated by the light source is transmitted by the fiber-optic light cable, and farther down the telescope, by fiber optics to illuminate the anatomy being observed. The images are transmitted through a series of lenses from the distal end of the telescope to the eyepiece; then to the camera head, to the camera control unit and finally to a monitor for viewing.

Rigid endoscopes are more convenient than flexible endoscopes for examining and performing procedures in the body cavity. The appropriate sized telescope should be selected based on the surgical procedure, size and morphology of the patient and surgeon’s experience and preference. The most versatile telescope in small animal are 5mm in diameter and 30cm in length. Smaller endoscopes (2.7 or 3mm) are ideal for cats, puppies and toy breeds. The viewing angle of a telescope is an important consideration because it affects both orientation and visual access. Standard forward-viewing telescopes (0 degrees) provide the simplest spatial orientation but limit the viewing field. A 30 degree viewing angle allows to view a wider area rotating the shaft of the telescope. For laparoscopic procedures an insufflator is necessary: a CO_2 insufflator is used to create and maintain a working space between the telescope and the target tissue. It automatically controls CO_2 flow rate and pressure throughout the procedure. An antibacterial sterile filter should be coupled inline, which prevents contamination from the CO_2 tank.

Instruments necessary for laparoscopy include scissors, tissue retractors, forceps and needle holders. Their shafts are long and thin to allow them to pass through an instrument port into a body cavity. Straight instruments are the basic instruments for minimally invasive surgery in multiple port surgery. A variety of instruments are available and their choice is based on the procedure to be performed. In this section specific instruments will be described with the specific procedure.

Trocar, cannula and sheath

The trocar is a pen-shaped instrument with a sharp triangular point at one end, used inside a cannula which provide access into a cavity. A cannula is a tube-shaped metal or plastic shaft placed in the patient to allow access into a cavity. They can be sutured in place, they can be screwed into a cavity or locked in placed by inflatable balls or plastic flanges. A seal is located at the top of the cannular which allows instruments to pass through the cannula preventing CO_2 from escaping from the abdominal cavity. A gas-tight valve is located at the top of the cannula to allow instruments to be inserted, removed or exchanged. An obturator (sharp or blunt) is a tool that allows the cannula to be inserted into the abdomen for initial placement. Creating a pneumoperitoneum allows for separation between the body wall and internal organs and allows for increased internal working space for manipulation of organs by surgical instruments. Cannula placement can be done by one of three methods: Veress needle, direct trocar insertion or the open Hasson method. After the laparoscope has been introduced, secondary trocars can be placed under direct visualization to minimize the risk of injury and internal organ damage.

Trocar-cannula placement
The initial placement can be done before or after the insufflation of the peritoneum.

Veress needle technique
It is the most traditional technique. It is a specially designed instrument with an outer diameter of 2mm . the outer cannula has a beveled needle point for cutting through the tissue and an inner spring-loaded dull-tipped stylet. After the outer needle passes through the abdominal wall the spring loaded stylet springs forward to protect the internal organs. The needle is then attached to the insufflator and CO2 is used to inflate the cavity. The placement is done blindly which is an important factor for complications. There are many tests to confirm correct positioning before insufflation including the double click sound, aspiration test, hiss sound test, waggle test and hanging drop test. However most of these tests remain unreliable. After an adequate volume of gas has been insufflated the Veress needle is removed. At this point a trocar is inserted, the insufflation tubing is connected to the cannula port and the laparoscope is inserted to confirm successful placement and to rule out intraabdominal injury from the Veress needle and/or cannula placement.

Direct insertion technique
The initial cannula is placed without pre-insufflation. This technique is not normally performed in small animals. It can be performed either with a bladed trocar blindly or with an optical trocar under direct visualization. One of the advantages is the decrease time to establish access but disadvantages included an higher rate if intraabdominal injuries. For inexperienced surgeons the direct access is associated with unnecessary increased risk compare to other techniques.

Hasson technique
This is a mini-laparotomy technique. In the open technique the peritoneal cavity is entered under direct visualization decreased the likelihood of injury to adherent bowel or major vascular injury during trocar insertion. Potential disadvantages include an increase surgical time and increased risk of late port-related complications such as haematoma, wound infection or hernia. Leakage of gas around the port can be a problem. In this situation sutures in the fascia can be used to anchor the outer sleeve and to create a airtight seal.

Complications
Most of them can be avoided and do not usually required conversion to open surgery. Complications include intraabdominal and vascular damage, subcutaneous insufflation, air embolism, insufflation of the falciform fat. Insertion of the Veress needle remains the most hazardous part of the laparoscopy accounting of 40% of all laparoscopic complications. Overall the morbidity and mortality rates related to laparoscopic access are low. Vascular injury can occur regardless of the method of access and it is higher for close techniques compared to the Hasson technique. Injury due to the trocar are usually more obvious than injury due to the Veress needle and they cab require a conversion to open surgery. The incidence of visceral injury is about 0.5% of all the open access procedures. Damage to small and large intestine can lead to peritonitis.

Pneumoperitoneum
After successful entry into the abdominal cavity the pneumoperitoneum provides the visual field. Normally the pneumoperitoneum is hyperbaric, so higher than atmospheric pressure resulting from gas insufflation. Carbon dioxide (CO2) is the most commonly used gas for laparoscopy as safe and inexpensive. The absorption of CO2 causes hypercapnia and acidosis which have to be avoided by hyperventilation. Various complications such as tachycardia, arrhythmias and pulmonary oedema and postoperative pain (due to peritoneal irritation) are possible adverse effects of capnoperitneum. The pneumoperitoneum will exert effects on physiological parameters (increased heart rate, systemic vascular resistance, arterial and central venous pressure and decreased pulmonary compliance) and these effects can be severe in dogs especially when the pressure exceeds 15mmHg. In addition, pressures of 12-14mmHg can have negative effects on intraabdominal organ perfusion. A pressure of 8-10mmHg should be advocated.

Patient positioning
The body positioning of the patient is of great importance for visualization. Intraabdominal organs are heavily influenced bt gravity and changes in position during surgery can improve the ability to visualize the target organs. Laparoscopy is often performed with the patient in the Trendelenburg position (head lower than the abdomen). This would move the organs cranially improving the working space but reducing the pulmonary compliance. The general recommendation is to not use a steeper angle than 15 degrees to the horizontal plane. A reversed Trendelenburg position would affect venous return and the animal needs to be monitored for cardiovascular changes. In genera a dorsal recumbency provides best exposure for liver, gallbladder and pancreas. A dorsal Trendelenburg position provides best exposure for stomach, pancreas, pylorus, bladder, cervix and liver.

Left lateral recumbency: right liver lobes, cystic duct, duodenum, right kidney, right ovary and uterine horn. Right lateral recumbency: left liver lobes, spleen, left kidney, left ovary and uterine horn. The position may need to be change also several times during the same procedure. It is important to have a table that allow adjustments of the position of the patient to improve visualization and for a more comfortable surgeon position.

Contraindications

Contraindications to laparoscopy can be divided in relative or definitive and anatomic or physiologic. Definitive contraindications are those that eliminate a patient from a laparoscopic procedure completely. Relative contraindications are those in which exceptions are made when taking into account varying factors related related to the patient. Anatomic considerations can include difficulty accessing the cavity, obliterationg of the peritoneal or thoracic space, organomegaly, intestinal distension, congenital abnormalities and potential for dissemination of cancer. Physiologic considerations include pregnancy, increase intracranial pressure, abnormal cardiac output and gas exchange in the lung, chronic liver disease and coagulopathy. Another major limitation is surgeon skills and experience, inadequate training and experience can lead to serious injuries.

Conversion to open surgery

It is defined as elective or emergent. Elective conversion are cases that are converted because of factors that preclude safe and timely laparoscopic completion of procedures. Normally in absence of complications; failure to progress occurs because of factors that include poor exposure, surgeon’s experience or previous surgeries (adhesions). Emergent conversions require immediate conversion to open laparotomy and include uncontrollable bleeding or rupture/damage of intraabdominal organs or hollow viscus.

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Management of tracheal collapse

Anatomy and pathophysiology

The trachea is a relatively non-collapsible tube that extends from the cricoid cartilage of the larynx to its bifurcation into the two main bronchi, also called tracheal carina, dorsal to the cranial part of the base of the heart. The cricotracheal junction marks the border of the upper and lower respiratory airways. The trachea consists of a series of parallel, incomplete (C-shaped) hyaline cartilages rings. The space left dorsally is bridged by fibers of the smooth, transversely running tracheal muscle (trachealis muscle) and connective tissue. The arched shape of the tracheal cartilages exerts outward pressure against the trachealis muscle maintaining the tracheal lumen. Between the rings there is the annular ligament, formed by bands of fibroelastic tissue which allowed some movement of the trachea without breakage or collapse. There are approximately 35 ring presents (up to 46 reported) and tracheal lumen is widest at the level of the cricoid and progressively tapers to its narrowest point at the thoracic inlet. In cross-section the lumen of the trachea is circular in shape with a width-height ratio of 1:1. At the level of the thoracic inlet the tracheal rings have the thinnest cartilage and the lumen has the smallest cross-sectional area.

The trachea has a segmental blood supply from the cranial and caudal thyroids arteries whereas at the level of the carina the blood supply comes from the brochoesophageal arteries. Venus drainage is provided by the thyroid, internal jugular and bronchoesophageal veins. The innervation is from the right vagus and the recurrent laryngeal nerves.

Tracheal size does not increase proportionately with the size of the dog and normally it has a trachea:thoracic inlet ratio of 0.2 for non-brachycephalic dogs, 0.16 of brachycephalic dogs and 0.13 for English Bulldogs.

The trachea has multiple functions such as conduit for gases to and from the lungs, assists the upper airway in conditioning of inspired air, provides warmth and humidification as well as mucosal hydration. One of the main functions remain mucociliary escalator, transporting inspired particles to the larynx via ciliary action.

Diagnostic

Radiographs are very valuable as they are able to identify most of the lesions and they can evaluate the thorax at the same time. The trachea is easily to visualized because of the sharp interface of air and soft tissue. On lateral radiographs the trachea v roughly parallel to the spine deviating ventrally at the level of the carina. The lumen of the trachea should remain approximately uniform along the entire trachea and in all phases of respiration. On survey radiographs an estimation of the tracheal diameter should be calculated (tracheal diameter: thoracic inlet diameter ratio). One thing to bear in mind is that radiographs underestimate the presence and severity of changes in the intrathoracic region. Fluoroscopy is another helpful tool to evaluate dynamic changes in tracheal and bronchial diameters. Fluoroscopy is also at the base of interventional techniques.

Computed tomography (CT) is another valuable tool with a very good resolution to evaluate the pulmonary parenchyma and it has been recently validated as method for diagnosing tracheal hypoplasia, collapse and stenosis.

As fluoroscopy, tracheobronchoscopy can be used for diagnosis of functional lesions but also for biopsies, removal of foreign bodies and document disease progression/response to treatment. It is considered the most reliable method for diagnosing and grading tracheal and bronchial collapse. Bronchoalveolar lavage can be done at the same time under endoscopic guidance or blind.

Tracheal collapse

Tracheal collapse is a common disease process in dogs and represent a progressive and irreversible condition of the airway cartilages secondary to chondromalacia. The collapse is initially due to laxity of the trachealis muscle which progress, with time, to weakness of the cartilaginous rings. The ultimate cartilage collapse leads to obliteration of the tracheal lumen usually in a dorsoventral manner. Continuous collapse of the cartilages and repeat luminal contact results in chronic inflammation which leads to cough which exacerbate the inflammation creating a vicious cycle of inflammation and cough. The persistent inflammation causes also loss of ciliary epithelial component leading to squamous metaplasia and the loss of ciliary function causes coughing to because the main mechanism of tracheobronchial clearance.

Tracheal collapse is a condition that affects small and toy breed dogs with 85.5% of dogs weighting less than 7.3kg and included Yorkshire Terrier, Chihuahua, Pomeranian, miniature Poodle and Pug. No sex predisposition has been reported but there is an age predisposition for middle to old-aged dogs. Younger dogs are commonly more severely affected compared to the ones presented in middle age. Up to 55% of cases presented with tracheal collapse have some other concomitant diseases.

Diagnosis is achieved by signalment, history, and clinical signs, in conjunction with diagnostic evaluation to document the location and degree of collapse.

A thorough history and physical examination are essential in all dogs presented for tracheal collapse evaluation, Typical clinical signs include cough (varying degrees and types), dyspnea, exercise intolerance

and cyanosis and syncopal episodes. Many dogs have issues on multiple locations in the upper and lower airway (nasopharynx, larynx, trachea, and bronchi). A complete medical history and specific questions are important to determine the disease location.
Visual assessment of the patient breathing especially at rest is important to evaluate the type cough, the phases of respiration, any increased, any abdominal effort on expiration.
Assessment of the nature of abnormal respiratory noises (honking, high pitched, wheezing moist, stertor, or stridor). Auscultation of the larynx, trachea, and thorax should be very helpful to detect fluid sounds, wheezes, and crackles. Tracheal palpation can elicit a characteristic coughing episode, but this is not a reliable test (positive in only 41% of surgical patients). Obesity is a common finding reported in up to 74% of the cases. As a guideline tracheal collapse on the cervical trachea causes increased inspiratory effort due to the weakened airway's inability to withstand negative intraluminal pressure generated on inspiration. When the collapse is isolated to the intrathoracic portion of the trachea results in expiratory noise and effort due to airway collapse from an inability to withstand increased thoracic pressures upon exhalation. If the collapse is at the thoracic inlet the clinical signs are either or both inspiratory and expiratory. Bronchial collapse is very common in dogs with tracheal collapse documented in 83% of dogs. Location of the collapse and presence or absence of concurrent bronchial collapse, determines the clinical signs and severity of respiratory compromise. The classic "honking" noise is typically seen with obstructive airway disease, generally with collapse of the cervical or thoracic inlet trachea. Stress, activity, and excitement commonly exacerbate the severity of the clinical signs. Conversely, pure cough that tend to have a dry, hacking cough and may or may not be productive in normally identified in dog with thoracic collapse. These dogs do not tend to have exercise intolerance or respiratory distress when mildly to moderately affected but can with more advanced disease or concurrent pulmonary parenchymal disease. It is important to bear in mind that many patients will have components of both coughing and obstruction, and determination of the primary problem can help guide diagnostics and therapy.

Diagnostic testing
Haematology, serum biochemistry, blood-gas analysis, pulse oximetry should be considered as general screening as well as to evaluate both oxygenation and ventilation. Before anesthesia a thorough laryngeal examination for structure and function should be performed to rule out laryngeal paralysis and varying degrees of laryngeal collapse. Three-view thoracic radiographs (including neck and larynx) would be important to rule out other cardiorespiratory diseases and to evaluate tracheobronchial collapse. The sensitivity is variable, with diagnostic radiographs in fewer than 60% to up to 90% of cases; false-positive have been reported in 25% of patients. This is because tracheal collapse is a dynamic disease process and it can be difficult to evaluate presence and extent of the process using a static investigation. For this reason, fluoroscopy is an excellent tool which allows direct visualization of abnormal tracheal dynamics during all phases of respiration. Recently, fluoroscopy was demonstrated to detect significantly more sites of collapse during induction of cough when compared with radiography and bronchoscopy. However, false-positive are still possible.
Tracheobronchoscopy is the gold standard for evaluating and grading tracheal and brochial collapse should be performed in association of fluoroscopy as provides the most significant diagnostic information: direct visualization of collapse during inspiration and expiration.
Tracheoscopy is also valuable in documenting other abnormalities such as thickening and inflammation of the dorsal tracheal membrane. Samples may be obtained concurrently for cytology and bacterial culture and sensitivity. The grading system is from I to IV and represent 25%, 50%, 75%, and 100% collapse, respectively. Echocardiography should also be considered to assess for secondary pulmonary hypertension. There are many concerns for recovery from general anaesthetic after diagnostic procedure in dogs with tracheal collapse therefore it was important to outweight the benefits and the risks of the investigations.

Medical management
It is important to remember that medications only control clinical signs of the tracheal collapse (coughing and inflammation) but they do not directly address airway collapse or obstruction. However medical management should be attempted before considering surgical or interventional options. Up to 71% of dogs can be effectively managed with a correct medical management for more than 12 months and the majority of dogs with cough will continue to require medications after surgery or stenting.
Initial medical management in case of acute exacerbation of clinical signs includes administration of sedatives, cough suppressants, and short-acting corticosteroids. In animals presented in respiratory distress, oxygen should be administered immediately either with masks, nasal tubes, or oxygen cages. Intravenous sedation with acepromazine/acepromazine+opioid can be extremely helpful in easing respiratory effort.
Corticosteroids serve to treat airway swelling and to reduce the inflammation. In the most severe, nonresponsive or critical cases, endotracheal intubation may be necessary to secure the airway before intervention.

When and if the patient is stable, chronic therapy can be instituted to control clinical signs. The majority of the drugs used in the acute stage can be continued orally. Corticosteroids should be used at antiinflammatory doses (prednisolone 0.5 to 1.0 mg/kg/day per os) for short periods of time.
The role of bronchodilators in tracheal collapse alone is controversial, although they may be indicated in patients with bronchial collapse. If respiratory infection is suspected, antibiotics can be prescribed, based on the bacteriology results. Obesity management remains an important factor to be addressed. During cool periods of the day, regular controlled short exercise can be introduced if tolerated. For leash walks, a harness around the chest should be used rather than a collar or any device that restricts or compresses the neck. Environmental modification is also important and smoke, dust, scented candles, carpet freshener, and other potential irritants should be avoided and removed from the house.

Tracheal stenting
Tracheal stenting has become an important alternative to conventional surgical techniques. This approach to treating tracheal collapse has the advantages of shortening anesthetic time, providing immediate relief of respiratory distress, and allowing minimally invasive access to the intrathoracic trachea and an earlier surgical intervention has the advantage to have less deformed tracheal cartilages with less debilitated tissue and fewer secondary cardiac and pulmonary changes or secondary disease processes. It is very important to understand what can and cannot be accomplished with tracheal stenting. For dogs with airway obstruction and respiratory distress secondary to tracheal collapse, tracheal stenting is a life-saving procedure to alleviate the obstruction and improve respiratory comfort. For dogs whose only clinical sign is coughing secondary to lower airway disease and/or bronchial collapse, tracheal stenting is likely to provide limited relief. The majority of dogs with tracheal stents will continue to require lifelong cough suppression.
The intraluminal stents address also the issue of providing simultaneous support when the thoracic and the cervical trachea are affected. Various stents are available, each with its own inherent strengths and weaknesses. Currently, nitinol wire, wound, reconstrainable, foreshortening stents are recommended. These stents are collapsed on a delivery system and can be recaptured after partial deployment (reconstrainable), and because of their woven nature, they undergo measurable shortening with placement as they reach maximum diameter (foreshortening). Laser-cut stents (which are cut from a single piece of material rather than constructed of individual woven wires) are available and do not foreshorten. However, these stents have an unacceptable rate of fracture.

Stent size
Measurements for stents are determine under general anesthesia because of relaxation of the dorsal tracheal membrane and positive pressure ventilation to maximally expand the airway. There is no method to predict the appropriate stent size and measurement can be obtained with radiography, fluoroscopy, tracheobronchoscopy, CT, or a combination of these. In critical patients who cannot recover from general anesthesia without relief of the airway obstruction, a variety of stent sizes (both length and diameter) should be readily available for placement immediately after measurements. Most tracheal stent complications result from issues with sizing, therefore it is imperative to size the stent as precisely as possible based on the measurements obtained.
To perform measurements for tracheal stent sizing, the patient is placed under general anesthetic in right lateral recumbency position. The endotracheal tube has to be placed at the larynx and a marked catheter is used for reference in the oesophagus. The tracheal boundaries (cricoid cartilage and carina) are identified. Positive-pressure ventilation is administered to 20-30 cm H_2O. The diameter of the inflated trachea is measured at various levels: 2 to 4 measurements made at each segment of the trachea (2–4 intrathoracic measurements, 2–4 thoracic inlet measurements, and 2–4 cervical tracheal measurements) and the length is measured from the cricoid cartilage to the carina.
The selected stent is chosen so that it exceeds the widest measured diameter of the trachea on positive-pressure thoracic films by 10% to 20%. A stent length is chosen so that at least the stent will cover all of the collapse and provide an additional 1 cm of stent contact cranial and caudal to the collapse. It is important to remember that the stent will be longer than advertised if it does not open fully along the length of the trachea (foreshortening charts are provided by the manufacturer). Given the progressive nature of tracheal collapse, it is preferable to span as much of the tracheal length as possible with the stent. Tracheal diameter is not always uniform (larger cervical and cranial thoracic inlet diameter compared with the intrathoracic tracheal diameter) in these cases the cervical trachea is undersized to accommodate the intrathoracic trachea or the thoracic trachea is oversized to accommodate the cervical trachea. A self-expanding, woven nitinol stent with a tapering diameter where the cervical tracheal diameter stent portion is larger than the intrathoracic portion has been designed (VetStent Duality; Infiniti Medical, Menlo Park, CA).

Stent placement

They can be placed quickly and minimally invasively, using a variety of techniques (fluoroscopy, radiography, or endoscopy). Fluoroscopy allows for constant assessment of stent positioning, degree of opening, and evaluation of stent
proximity to the boundaries for placement (cricoid cartilage and carina). Tracheal stents are placed through an endotracheal tube and care must also be taken to retract the endotracheal tube during deployment to ensure the stent is not inadvertently opened into the endotracheal tube. Most tracheal stents are reconstrainable and can be recaptured up to 75% of the stent. Tracheoscopy should be repeated after placement to evaluate the stent and the areas of poor contact. If the position is suboptimal removal of the tracheal stent and placement of a larger size or second stent may be considered. The stent will begin to become incorporated into the mucosa within several days, after which point the stent cannot be removed.

Postoperative cares
After the procedure, dogs are recovered under direct observation in the intensive care unit, preferably in an oxygen cage. Patients are often discharged after 24-48 hours from stent placement; thoracic radiographs should be taken before discharge to confirm positioning and evaluate for pneumonia that may have developed secondary to anesthesia. Patients are discharged with antibiotics (10-14 days) pending bacteriology results, a 2 to 3 week tapering course of steroids, and cough suppression. A dry, self-limiting cough is to be expected for 4 to 6 weeks, this should be discussed with the owner. Long-term routine thoracic radiographs are important to be able. For the first year after stent placement, radiographs are checked every 3 to 4 months to detect migration or fracture of the stent. For every year
after that, radiographs are taken every 6 months.

Outcome and complications
Recorded complications include stent fracture, stent migration, tracheitis, progressive collapse in unstented regions of the trachea, obstruction of the stent lumen with granulation tissue, and tracheal rupture. Other uncommon complications after stent placement include rectal prolapse and perineal hernia, presumably from refractory paroxysmal cough. Complications are thought to be greatly reduced with precise sizing. Oversized stents are at increased risk of fracture because stents are strongest when fully expanded. Whereas, undersized stents are at risk of migration and poor incorporation into the tracheal mucosa, leading to mucous accumulation, inflammation, and likely infection. Unequal tracheal mucosal contact can lead to granulomatous/inflammatory tissue formation.
In case of a stent fracture radiographs easily demonstrate the fracture, and aggressive medical management should be initiated. If the patient remains severely symptomatic, a new stent can be deployed within the lumen of the fractured stent, or the stent can be removed and replaced. Inflammatory/granulomatous tissue formation in dogs is poorly understood. It may be related to areas of poor mucosal ingrowth into the stent, resulting in mucous accumulation and chronic infections. Patients with excessive inflammatory tissue have responded to treatment with antiinflammatory doses of corticosteroids (6 to 8weeks). In 60% of cases tracheatis was reported and it should be medical addressed.-Immediate improvement has been reported in around 83 to 96% of dogs, for longer than 1 year. Complications can be severe.

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