Obstructive Lesions and Traumatic Injuries of the Canine and Feline Tracheas

Abstract: Tracheal obstruction and tracheal injury can be life-threatening conditions in dogs and cats. Early identification of associated clinical signs and the use of appropriate diagnostic and therapeutic techniques are important to patient survival. Common causes of tracheal obstruction reported in the veterinary literature include tracheal foreign bodies and tracheal tumors. Tracheal injury has been associated with endotracheal intubation and external trauma. Radiography and tracheoscopy are effective diagnostic modalities, and tracheal repair or resection and anastomosis are the most common treatments.

Physiology
The trachea allows the movement of air to and from the lower airways and the removal of particulate material from the respiratory tree via the mucociliary escalator and coughing. Goblet epithelial cells move particulate matter and excessive bronchial secretions toward the larynx at 12.6 mm/min. During a cough, the dorsal tracheal muscle contracts, decreasing the tracheal lumen by 50% and increasing air velocity, which aids in removal of particulate matter from the trachea.

Irritation of the tracheal mucosa results in increased mucus secretion, influx of inflammatory cells, hyperemia, and edema. Superficial mucosal injuries heal relatively quickly, with epithelial cell migration occurring as early as 2 hours. Small defects are covered with transitional epithelium within 48 to 72 hours, and differentiation to ciliated or goblet cells occurs within 96 hours. Full-thickness injuries that lead to gaps in the tracheal mucosa result in granulation tissue and scarring, which impairs the mucociliary escalator and may cause stenosis of the tracheal lumen. However, up to 50% of the normal diameter of the airway lumen can be obstructed before clinical signs are evident.
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Obstruction

Airway obstruction can be life threatening. It may be caused by stenosis, foreign bodies, neoplasia, torsion of the trachea, collapsed tracheal rings, granulomas, external compression, or a complication of tracheostomy. Reported cases of tracheal foreign bodies in dogs and cats are rare but have involved mineral oil, hair, bullets, bones, plant material, an open safety pin, and an acorn. Generally, when foreign bodies do enter the trachea, they are small enough to pass into the bronchial tree and cause small airway disease such as aspiration pneumonia. Foreign bodies that are too large to pass into the bronchi and beyond usually lodge at the carina.

Primary tracheal neoplasia is uncommon in dogs and cats, with only 37 cases reported in the veterinary literature. Of the 18 dogs reported, eight were 2 years of age or younger and diagnosed with osteochondroma or echondroma/osteochondromal dysplasia. The other 10 dogs diagnosed with primary tracheal neoplasia were 6 years of age or older, indicating a bimodal age distribution in dogs. The mean age of the 19 cats reported as having primary tracheal neoplasia was 9.5 years, with lymphoma and adenocarcinoma being the most common tumors diagnosed. Other types of primary tracheal neoplasia in cats and dogs include chondrosarcoma, mast cell tumor, squamous cell carcinoma, adenocarcinoma, osteosarcoma, extramedullary plasmacytoma, leiomyoma, and fibrosarcoma.

Clinical Signs

Clinical signs on presentation depend on the degree of tracheal obstruction. Patients with tracheal foreign bodies commonly present with an acute onset of coughing, inspiratory stridor, and, occasionally, rhonchi. Large tracheal foreign bodies often cause acute dyspnea and can cause cyanosis. Most animals with tracheal tumors present with chronic coughing, stridor, and exercise intolerance. Change in bark, dysphonia, intermittent cyanosis, collapse, or weight loss may also be noted. Cats may present with open-mouthed breathing.

Upper airway obstruction may also precipitate pulmonary edema because of the marked negative intrathoracic pressure during the increased inspiratory effort.

Emergency Stabilization

Patients in severe respiratory distress should be stabilized before further diagnostics are pursued. Oxygen support with a mask or nasal catheter is the mainstay of initial therapy. Sedation with acepromazine in combination with an opioid, such as butorphanol, is generally safe and effective at relieving anxiety. If swelling and edema are contributing to airway obstruction, short-acting corticosteroids, such as dexamethasone sodium phosphate at an antiinflammatory dose, should be administered. Monitoring temperature is important because animals with airway obstruction may become hyperthermic due to the increased work of breathing. Continuous assessment of the patient is important to determine the effectiveness of treatment. Patients that cannot be stabilized should be intubated with ventilatory support. Emergency tracheostomy may be required in patients in which intubation is unsuccessful in order to bypass the airway obstruction.

Diagnosis

The patient’s condition should dictate the extent and timing of the initial diagnostic workup, with priority given to minimizing the amount of stress on the patient. Radiography is the initial diagnostic procedure of choice, and a lateral view of the cervical and thoracic region is generally adequate if the patient cannot tolerate dorsal or ventral recumbency. Depending on the opacity of the object, radiography may detect the presence of a foreign body within the tracheal lumen. Tracheal tumors can often be seen as soft tissue masses within the tracheal lumen on survey radiographs due to the natural negative contrast medium provided by the air within the trachea (Figure 1). Three-view thoracic radiography and regional lymph node aspiration are also important diagnostic tools for staging a suspected tracheal tumor.

Obstruction in the proximal trachea results in underaeration of the lungs, a high and domed diaphragm, indrawing of the intercostal muscles or the sternum, pulmonary edema, tracheal narrowing or collapse, and distention of the pharynx. Patients with distal tracheal obstruction may have overexpanded lungs, a flattened diaphragm, and prominent pulmonary vasculature secondary to air trapping caudal to the obstruction as the trachea narrows during expiration.
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Tracheoscopy allows direct visualization of the tracheal obstruction and is the method most commonly used for diagnosis of radiolucent tracheal foreign bodies\(^{10,11}\) (FIGURE 2). It also allows sampling of tracheal tumors for cytology and histopathology, with the former potentially providing an immediate diagnosis.\(^{13}\) However, care must be used when anesthetizing patients with tracheal foreign bodies. During tracheoscopy, inhalation anesthesia is preferred, with the scope passed through the endotracheal tube. If this is not possible, then preoxygenation with intravenous anesthesia is used, with supplemental oxygen provided to the airway through the bronchoscope.\(^{19}\)

Treatment

The treatment for tracheal obstruction depends on the etiology of the lesion. The treatment of choice for removal of tracheal foreign bodies is endoscopy because it is minimally invasive and allows visualization of secondary injuries to the trachea.\(^{11}\) The small luminal diameter of puppy or cat tracheas makes endoscopic removal of some foreign bodies difficult. There is one report of a tracheal foreign body being removed by a Foley catheter technique.\(^{22}\) The Foley catheter is passed distal to the foreign body, and the balloon is inflated and retrieved with the foreign body. It is important to note the risks involved with this procedure, including obstructing the airway with the inflated Foley catheter balloon. The surgical options for removal of tracheal foreign bodies, tumors, and stenotic lesions are tracheotomy and tracheal resection and anastomosis, with the latter being the most common technique.

Tracheal Resection and Anastomosis

The surgical approach to the cervical trachea requires the patient to be positioned in dorsal recumbency with the head in a relaxed position. The skin and subcutaneous tissue are incised from the larynx to the manubrium, and the paired sternocleidomastoid muscles are separated on midline with blunt dissection.\(^{23}\) The surgical approach for intrathoracic tracheal resection and anastomosis is a right lateral thoracotomy between the third to fifth intercostal spaces. The adjacent lung lobe(s) is retracted caudally or ventrally with moist sponges, the azygous vein ligated and transected, and the vagus nerve retracted.\(^{19}\)

Once the trachea is visualized and the lateral pedicles are dissected, traction sutures are placed in the proposed proximal and distal segments of the trachea to prevent retraction after the resection and to facilitate rotation of the segments for placement of the anastomosis sutures.\(^{23}\) The tracheal segment containing the tumor, trauma, or stenosis is then resected. The split-ring technique (circumferentially splitting the cartilage rings and then apposing the two half rings) has been shown to result in less postoperative stenosis at the anastomosis site than the annular ligament technique (cutting through the annular ligament and anastomosing the two intact adjacent rings).\(^{24}\) If the
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obstructed tracheal segment was preventing the endotracheal tube from passing distal to the obstruction, the endotracheal tube is now passed into the distal segment to provide positive-pressure ventilation.23

The anastomosis is performed with simple interrupted 3-0 to 5-0 monofilament nonabsorbable sutures.19,23 The sutures go through the split cartilages and may enter the tracheal lumen. The endotracheal tube is withdrawn proximal to the anastomosis, and the site is submerged in saline as positive-pressure ventilation is applied to check for leaks and the need for additional sutures. Muscle or mediastinal tissues are closed over the trachea, and the surgical site is closed routinely. A thoracostomy tube is placed to evacuate the pleural space if a thoracotomy was required.19

Few short- and long-term complications have been associated with tracheal resection and anastomosis.25 However, anastomotic stenosis is a significant complication associated with excessive tension or poor alignment at the anastomosis site. If too many tracheal rings are removed, the tension at the anastomosis site will exceed the suture-holding strength of the cartilaginous tissue, leading to dehiscence and stenosis of the tracheal ends.19

The amount of trachea that can be safely resected without excessive tension on the anastomosis site varies with patient age. It has been reported that only three to 10 tracheal rings in puppies 6 to 8 weeks of age, and fewer than 14 tracheal rings in puppies 12 to 18 weeks of age, can be safely removed without excessive tension at the anastomosis site. This is in comparison to the reported eight to 23 tracheal rings that can be removed in an adult dog. The tracheas of younger animals are more elastic, containing less collagen and more water than the adult trachea, making them more susceptible to tension. Separation, which occurs at the anastomosis site as the tension increases, heals with granulation tissue, resulting in varying degrees of tracheal stenosis.19

Tension is greatest near the anastomosis site because fascial and vessel attachments prevent the tension from being dispersed over the entire tracheal length. Therefore, freeing the trachea from these attachments both cranially and caudally to the resection site allows anastomosis under less tension. However, dissection of the trachea should be limited to avoid disrupting the segmental blood supply.4 Also, using tension sutures that encircle a tracheal ring two to three rings from the anastomosis in the proximal and distal segments helps relieve tension on the primary suture line.19 Maintaining cervical flexion with a martingale-style neck brace during the first 2 weeks postoperatively also decreases the number of stress points that can lead to dehiscence.19,26

Accurate mucosal alignment at the anastomosis site is important because mucosal defects may lead to formation of granulation tissue and possible stenosis.19 Tracheal anastomosis using monofilament nonabsorbable sutures in a simple interrupted pattern is preferred because simple continuous suture patterns have been associated with less precise apposition and greater luminal stenosis.14,23,25 (FIGURE 3). Penetrating the cartilaginous rings with the suture needle is indicated in all but young, small, or old animals. Older animals may have mineralized tracheal rings that can fracture, and younger animals have less rigid tracheal rings that may tear when penetrated by a needle. Using a fine cutting needle reduces this risk. Otherwise, tracheal ring-encircling sutures can be used in these cases, although this technique has been associated with overriding or telescoping of the anastomosed rings.19 During tracheal resection and anastomosis, it is also important to visualize and protect the recurrent laryngeal nerves to avoid iatrogenic laryngeal paralysis.25

Perioperative broad-spectrum antibiotics are administered because the surgery is performed
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in a contaminated airway. Postoperatively, sedation and confinement are used to lessen the chances of trachea dehiscence. Providing supplemental oxygen and careful monitoring is also important. Postoperative evaluation should include survey lateral thoracic radiographs and tracheoscopy at 2 to 3 months to monitor for tracheal stenosis.\textsuperscript{25}

Other Options
In addition to the tracheal resection and anastomosis described above, treatment options for tracheal tumors include surgical excision, chemotherapy, radiation therapy, or a combination of these.\textsuperscript{13} There are reports of surgical excision by blunt dissection\textsuperscript{15,16} and endoscopic snaring.\textsuperscript{13,14,17} Staging the disease before definitive treatment is recommended; however, tracheal neoplasia causing respiratory compromise is an indication for immediate intervention.\textsuperscript{13}

Prognosis
The short-term prognosis after surgical excision of tracheal tumors is favorable.\textsuperscript{13} However, long-term follow-up has been conducted for few canine and feline primary tracheal tumors after surgical resection. Osteocartilaginous tracheal tumors in young dogs with active osteochondral ossification are usually benign and do not recur once the patient has reached skeletal maturity.\textsuperscript{13,14} Therefore, complete resection of benign tumors of the trachea, such as benign osteochondral tumors, have a good prognosis because excision is usually curative.\textsuperscript{14,16} Malignant tracheal tumors have a guarded prognosis, and advanced lesions may not be surgically resectable.\textsuperscript{14}

Incompletely excised tumors may require adjunctive treatment.\textsuperscript{16} Palliative intraluminal stenting may provide temporary relief for unresectable neoplasms causing tracheal obstruction.\textsuperscript{27} Feline tracheal lymphoma may respond to radiation, systemic chemotherapy, or a combination of both. Overall, prognosis with primary tracheal neoplasia in dogs and cats depends on the tumor type and stage and the degree of respiratory compromise.\textsuperscript{6,13}

Tracheal Injury
Tracheal injury can be caused by intraluminal or external trauma. The former is associated with endotracheal intubation, while the latter is most commonly seen secondary to a dog fight or automobile accident.\textsuperscript{28-30} Tracheal injuries can range from small lacerations to tracheal avulsions.

The dorsal tracheal membrane is protected dorsally by the cervical spine, laterally by the neck musculature, and ventrally by the tracheal rings.\textsuperscript{35} Disruption of the dorsal tracheal membrane is most commonly a result of intraluminal tracheal damage, such as from overzealous endotracheal intubation, overinflation of the endotracheal tube cuff, inappropriate use of a stylet in an endotracheal tube during intubation, a change in head position without disconnecting the endotracheal tube, or removal of the endotracheal tube without deflating the cuff. These tracheal ruptures are commonly located at the dorsolateral junction of the tracheal rings and trachealis muscle at the thoracic inlet and are 2 to 5 cm long (corresponding to the length of an endotracheal tube cuff).\textsuperscript{29} However, there is one report of a pericarinal tracheal laceration produced during tracheal intubation of a cat.\textsuperscript{32}

Tracheal rupture associated with endotracheal intubation has been well documented in cats.\textsuperscript{39,39,39} One review determined that the volume of air needed to obtain an airtight seal in a feline endotracheal tube was 0.9 to 2.3 mL and that inflating the cuff with more air increased the risk of tracheal rupture.\textsuperscript{39} To avoid iatrogenic tracheal rupture, it is essential that endotracheal tube cuffs be inflated to effect and not with an arbitrary amount of air. Several studies have attempted to determine which types of endotracheal tubes are most likely to cause tracheal rupture.\textsuperscript{29,33} Low-pressure endotracheal tube cuffs should be safer to use than high-pressure cuffs. However, it appears that proper use of endotracheal tubes and cuff inflation is more important than which type of endotracheal tube is used.\textsuperscript{29,30}

The intrathoracic trachea is protected by the thoracic wall; therefore, rupture from external trauma is most likely a result of luminal and longitudinal traction.\textsuperscript{25} Intrathoracic tracheal avulsion in cats has been well documented and is caused by a sudden, dramatic increase in intratracheal luminal pressure during impact with the glottis closed or with blunt trauma that causes whiplash extension of the neck. The carinal region is a fixed point and is stronger than the tracheal wall, which makes the trachea more prone to tearing cranial to the carina.\textsuperscript{28}
Clinical Signs

Tracheal injuries characteristically result in subcutaneous emphysema over the cervical and thoracic areas due to air escaping from the trachea into the subcutaneous tissue.\(^5\)\(^,\)\(^29\)\(^,\)\(^34\) Patients that present in respiratory distress due to a compromised upper airway develop dyspnea, mild to moderate increases in respiratory and heart rates, and inspiratory stridor with a prolonged inspiratory phase followed by a variable expiratory phase.\(^8\) Other clinical signs include coughing, exercise intolerance, gagging, exertional distress, fever, and cyanosis.\(^11\)\(^,\)\(^30\)\(^,\)\(^35\) Dyspnea can also be caused by restrictive respiratory diseases, such as pneumothorax, which can be concurrent with tracheal injuries. Trauma is a primary cause of tracheal injury; therefore, it is important to evaluate the entire patient for other problems. Injuries of the cervical trachea due to external injury may or may not have overlying skin lacerations.

Tracheal avulsion injuries in cats produce two distinct clinical presentations. One is acute onset of dyspnea and respiratory compromise. The second is a more chronic onset of dyspnea, exercise intolerance, and exertional respiratory distress days to weeks after the traumatic episode, caused by severe circumferential luminal stenosis of the proximal and distal ends of the avulsed trachea.\(^35\) In one report of seven cats presented for respiratory signs with a known history of trauma, only one cat presented within 24 hours of the traumatic episode. The other six cats presented 1 to 3 weeks after the injury. In another report of 16 cats with intrathoracic tracheal avulsion, most cats had no obvious respiratory signs at the time of the traumatic episode.\(^36\) Onset of dyspnea in these cases ranged from 1 to 28 days, with a median of 12.5 days. In chronic cases, the airway lumen is maintained after the avulsion injury by either intact tracheal adventitia or thickening of the mediastinal tissue leading to development of a pseudotrachea that provides continuity of the airway.\(^25\)\(^,\)\(^28\) However, granulation and scar tissue eventually narrow the lumen at both ends of the tracheal avulsion.\(^25\)\(^,\)\(^28\) (FIGURE 4). Patients may develop anorexia, open-mouthed breathing, cyanosis, and marked inspiratory and expiratory effort with progression to suffocation as the free ends of the trachea narrow.\(^28\)

Diagnosis

Radiography can be used to identify changes consistent with tracheal injury. Radiographs of the cervical region typically show subcutaneous emphysema but may not display an obvious disruption of the trachea. In a study of 20 cats with tracheal rupture associated with intubation, radiographs showed pneumomediastinum and subcutaneous emphysema in all the cats.\(^29\) Thoracic radiographs of an animal with an acute tracheal avulsion may show a pneumomediastinum because air is leaking from the tracheal rupture and dissecting along muscles into the thoracic inlet.\(^28\)\(^,\)\(^34\) If a pseudotrachea is maintained, radiographs may reveal loss of continuity of the thoracic trachea, with a gas-filled diverticulum between the separated tracheal rings.\(^36\) The tracheal lumen may be obscured by a soft tissue opacity if there is stenosis at each end.\(^28\) Tracheoscopy can also aid in diagnosing tracheal injury by providing direct visualization of the lesion (FIGURE 5). In one review of tracheal rupture due to endotracheal intubation, tracheoscopy was the diagnostic method of choice.\(^50\) However, in another study, tracheoscopy did not detect tracheal rupture associated with endotracheal intubation in two cats that was later confirmed at surgery.\(^29\) As mentioned previously, it is important to realize the risks associated with anesthesia and tracheoscopy in critical respiratory patients.
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Treatment
Tracheal injuries can be treated with supportive medical care or surgical intervention, depending on the clinical status of the animal, the extent of the tracheal damage, and the cause of the tracheal disruption. Appropriate monitoring for tracheal injury requires serial evaluations of respiratory status and progression of subcutaneous emphysema. Most cats with tracheal injury associated with intubation showing mild to moderate signs of dyspnea and subcutaneous emphysema can be treated medically. Subcutaneous emphysema can take 1 to 6 weeks to resolve, with a median of 2 weeks. If significant secondary stenosis occurs following medical management of a tracheal injury, surgery is indicated to avoid worsening of the stenosis and inevitable progression to death.

Dogs and cats with severe dyspnea should be evaluated and treated for pneumothorax before being considered for surgery. Patients with continued dyspnea or worsening subcutaneous emphysema should be treated with immediate surgical intervention. Caution should be used when anesthetizing critical patients with tracheal injuries. Smaller patients should be placed in an induction box and preoxygenated before the anesthesia is added. When the patient is intubated, the endotracheal tube should not pass beyond the tracheal lesion. Positive-pressure respiration is also avoided to prevent rupture of the airway.

The trachea is approached gently to avoid damage to the tracheal blood supply and recurrent laryngeal nerves, using the surgical approaches to the cervical or thoracic trachea described for the treatment of tracheal obstruction. The injured site may not be evident but can be located by filling the surgical field with saline and applying positive-pressure ventilation. Bubbles will appear at the location of the injury. The trachea is repaired by direct suturing. If the tracheal wound is irregular, then debridement of the edges should precede suturing. Ruptured dorsal tracheal membranes have been repaired with various suture patterns, including simple interrupted or continuous patterns. In one case report, an airtight seal was obtained with a horizontal mattress pattern that was oversewn with a simple continuous pattern.

Tracheal resection and anastomosis is the only effective treatment for stenosis of an avulsed trachea in cats. Once the tracheal lesion is resected, the endotracheal tube is passed into the distal trachea with the surgeon’s guidance. Perioperative antibiotics are administered to prevent contamination from the injury or the airway. Drains are often placed due to the contamination of the surgical site and to prevent the formation of seromas. Any subcutaneous emphysema is absorbed over several days to weeks. Postoperative care includes confinement and sedation to avoid disrupting the surgical repair.

References
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1. **Tracheal obstruction has been reported to occur with**
   - foreign bodies
   - neoplasia
   - all of the above

2. **For suspected tracheal obstruction,_____ is the initial diagnostic modality of choice.**
   - bronchoscopy
   - radiography
   - tracheal wash
   - d. bronchoalveolar lavage

3. **Options for treatment of tracheal tumors include**
   - chemotherapy
   - surgical excision
   - radiation therapy
   - all of the above

4. **The short-term prognosis after tracheal tumor resection is generally**
   - good
   - fair
   - poor
   - grave

5. **The number of tracheal rings that can be safely removed during resection and anastomosis in a 6- to 8-week-old puppy is**
   - >10
   - 12
   - 14
   - >16

6. **Tracheal rupture in cats is most commonly associated with**
   - gunshot wounds
   - coughing
   - esophageal rupture
   - endotracheal intubation

7. **_____ is a common clinical sign of tracheal rupture.**
   - Hemoptysis
   - Subcutaneous emphysema
   - Inspiratory stridor
   - Head tilt

8. **After traumatic tracheal avulsion, cats may show no significant respiratory compromise if the _____ is/are intact.**
   - tracheal adventitia
   - sternohyoideus muscles
   - sternocophalicus muscles
   - skin

9. **Animals with suspected tracheal rupture should go immediately to surgery if subcutaneous emphysema is**
   - unchanged
   - resolving
   - worsening
   - absent

10. **_____ is/are the only effective treatment for stenosis of avulsed tracheal ends.**
    - Cage rest
    - Bronchodilators
    - Cough suppressants
    - Tracheal resection and anastomosis