





# Review **Tracheal Injury after Endotracheal Intubation**

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Abstract:

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Endotracheal intubation is a vital procedure in anaesthetized animals to deliver oxygen, volatile anaesthetics, and assist with ventilation. It also protects the airways from aspiration of gastric contents. However, improper intubation techniques or equipment can lead to complications, such as tracheal injury. Cats are particularly prone to tracheal rupture due to their sensitive tracheal anatomy and the overinflation of endotracheal tube cuffs. Dental procedures, which often require repositioning, account for most tracheal injuries in cats. Clinical signs, such as subcutaneous emphysema, coughing, and respiratory distress, may occur hours to days after the procedure. Diagnosis is based on history, clinical signs, radiographs, and tracheoscopy. While mild cases can be managed conservatively with oxygen supplementation and rest, severe injuries require surgical intervention. Proper tube selection, careful cuff inflation, and regular pressure monitoring are essential preventive measures to minimize the risk of tracheal injury. Early diagnosis and suitable management result in favourable outcomes for the affected animals.

Keywords: Endotracheal intubation; subcutaneous emphysema; dogs; cats; tracheal injury; tracheoscopy; dental procedures







### 1. Introduction

Endotracheal tubes are made of plastic, siliconized rubber, or red rubber and can be cuffed or uncuffed. Some tubes are reinforced with a metal spiral to prevent kinking or compression during extreme neck flexion. The size of the tube is determined by its internal diameter (in millimetres), while the external diameter determines its fit within the trachea.

The external diameter can vary depending on the material and whether the tube is cuffed. Selecting the correct tube size is critical (Dugdale et al., 2020). Endotracheal tubes with an internal diameter of 3.5 - 4.5 mm are appropriate for most cats (Hardie et al., 1999).

It is crucial to select the largest possible diameter that can still be used safely and allows for minimal inflation of the cuff. This is especially important for low-volume, high-pres sure cuffs, as minimal inflation helps to seal the trachea while reducing the cuff pressure and thus minimizing the risk of damaging tracheal mucosa. A tube that is too small may increase breathing resistance or become obstructed with mucus, while a tube that is too large can cause tracheal damage.

Proper tube placement extends from the level of the incisors to the proximal third of the trachea, below the cricoid. The cuff should be inflated evenly on all sides to seal the space between the tube and the tracheal wall, reduce gas leakage into the atmosphere during mechanical ventilation, and prevent passage of contents from the pharynx into the distal trachea. It also helps to position the tube tip more centrally in the trachea, reducing the risk of tube tip obstruction and tracheal wall injury, which most commonly occurs at the tube tip (Dugdale et al., 2020) or cuff (Hardie et al., 1999; Dugdale et al., 2020).

Cats in particular have a sensitive dorsal tracheal ligament, which can rupture if the cuff is overinflated. This risk is increased during procedures that require repositioning, such as dental procedures or multiple x-rays. Most tracheal injuries in cats occur after dental procedures, accounting for 70% of cases (Hardie et al., 1999; Mitchell et al., 2000). Injuries have also been documented after bronchoalveolar lavage and excision of histiocytoma (Hardie et al., 1999), as well as after spaying, castration, oral surgery, and hip and stifle radiographs (Mitchell et al., 2000). More than half of the cats with a tracheal rupture were intubated using a high-volume, low-pressure cuffs (Bauer et al., 2009).

Unlike in cats, tracheal damage from endotracheal tube is very rare in dogs. Only two cases of tracheal stenosis have been reported – one occurring 9 days after surgery (Manabe et al., 2021), and another occurring 5 days after general anaesthesia for arthrodesis (Alderson et al., 2006). Additionally, an experimental study demonstrated tracheal necrosis caused by cuff pressure much higher than the recommended range (Su et al., 2017). Disconnecting the anaesthesia breathing system before repositioning the animal is essential to prevent tube rotation within the trachea, which could cause injury. Low-volume, high-pressure cuffs exert higher localized pressure on the tracheal mucosa, potentially causing necrosis if left in place for prolonged periods. Conversely, high-volume, low-pressure cuffs reduce localized pressure but may increase the risk of trauma during intubation or extubation (Dugdale et al., 2020). The longest tracheal ruptures were observed in cats intubated with high-volume, low-pressure tubes. No differences in occurrence were found between sexes or based on the age of the cats (Hardie et al., 1999).

Relaying solely on palpation of the pilot balloon alone makes it challenging to accurately assess the cuff pressure. However, cuff pressure can be measured with a manometer, especially in high-volume, low-pressure cuffs, where the pressure in the cuff approximately reflects the pressure on the tracheal wall. Ideally, during prolonged procedures, the cuff pressure should be regularly monitored, as the patient's muscle tone can change, as well as the compliance of the cuff as it warms up (Dugdale et al., 2020). Excessive pressure in the cuff can impair tracheal mucosal perfusion, potentially leading to ischemia or necrosis of the tracheal mucosa (Fudge, 2009; Su et al., 2017; Dugdale et al., 2020).

# 2. Causes of tracheal injury by endotracheal intubation

The potential causes of tracheal injury include:

- Overinflation of the cuff (Hardie et al., 1999; Fudge et al., 2009; Quandt, 2017; Dugdale et al., 2020).
- Incorrect tube placement (Hardie et al., 1999).
- Using an improperly sized tube (Hardie et al., 1999; Fudge et al.2009).







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- Failure to deflate the cuff before extubating (Hardie et al., 1999; Mitchell et al., 2000).
- Changing the position without disconnecting the tube from the anaesthetic breathing system (Dugdale et al., 2020; Mitchell et al., 2000).
- Intubation with the stylet (Mitchell et al., 2000).
- Chemical injury from inadequate rinsing of cleaning agents (e.g., glutaraldehyde, chlorhexidine, ethylene oxide (Alderson et al., 2006).

Tracheal injuries are more likely during dental procedures (Dugdale et al., 2020), where the cuff is often overinflated to prevent water aspiration into the lungs (Hardie et al., 1999; Quandt, 2017). It is possible that during a dental procedure, a tracheal rupture may occur due to changes in head position, which could cause excessive manipulation of the tube, leading to tracheal trauma (Mitchell et al., 2000).

Hardie et al. (1999) attempted to simulate a situation on cat cadavers where the endotracheal tube was not disconnected from the anaesthesia circuit, leading to tracheal twisting, but they were unable to induce a linear tear injury in the trachea.

# 3. Clinical signs

Clinical signs of tracheal rupture often develop some time after the procedure because the mediastinum, which closely surrounds the trachea, can initially prevent air from escaping. When coughing or irritation of the trachea occurs, air escapes into the mediastinum and subsequently into the subcutaneous tissues (Hardie et al., 1999).

Severe damage of trachea may result in subcutaneous emphysema or pneumothorax. Pneumothorax can occur if the pressure causes rupture of the mediastinum (Fudge, 2009). Clinical signs of tracheal rupture include subcutaneous emphysema in all affected cats (Figure 1), along with difficulty breathing, coughing, gagging, loss of appetite, and fever (Hardie et al., 1999; Mitchell et al., 2000). Other reported symptoms are vomiting, wheezing, drooling, pharyngeal swelling, submandibular oedema and dehydration (Mitchell et al., 2000).

The time between anaesthesia and the onset of clinical signs ranges from 4 hours to 7 days (Hardie et al., 1999). However, Mitchell et al. (2000) reported that cats were referred 5 hours to 12 days after the procedure, with a median time of 5.5 days. The most common cause of subcutaneous emphysema in cats that have recently undergone a procedure requiring endotracheal intubation is tracheal rupture (Bauer et al., 2009).



Figure 1: Severe subcutaneous emphysema in a cat 8 days after dental procedure.







#### 4. Diagnosis

Most cases are diagnosed based on the history and clinical signs (Bauer et al., 2009). Tracheal rupture is diagnosed using tracheal endoscopy, the preferred method, which reveals linear tears in the trachealis muscle. History along with clinical signs, such as subcutaneous emphysema, dyspnoea, and coughing guide initial diagnosis. Radiographs often reveal pneumomediastinum and subcutaneous emphysema (Hardie et al., 1999; Mitchell, 2000).

# 3. Treatment

Both surgical and conservative treatments can be effective. The choice between conservative medical management and surgical intervention depends on the severity of the clinical signs and the clinician's judgment (Mitchell et al., 2000). Tracheoscopy can be used to determine the most appropriate treatment. Analgesia may be provided with a continuous infusion of ketamine,  $\alpha$ 2-adrenergic receptor agonists, or opioids, such as fentanyl. Alternatively, intermittent boluses can also be administered (Bauer et al., 2009).

# 5.1. Conservative treatment

Conservative management is appropriate for cases with mild dyspnoea and subcutaneous emphysema, that do not worsen. Cats that respond to cage rest and oxygen supplementation should be treated conservatively. Subcutaneous emphysema is monitored through palpation.

Treatment includes:

- Cage rest.
- Oxygen supplementation (Mitchell et al., 2000).
- Sedation with butorphanol, midazolam, acepromazine, buprenorphine, or opioidtranquilizer combinations should be used if needed (Quandt, 2017; Mitchel et al., 2000).
- Close monitoring for 12 to 72 hours (Mitchel et al., 2000).

# 5.2. Surgical treatment

Surgical treatment is required for severe cases involving progressive dyspnoea and cyanosis, that do not improve with oxygen supplementation or in cases where subcutaneous emphysema worsens. Surgical repair is indicated for tears longer than 2 cm, with recovery requiring cage rest for 1 to 4 weeks (Bauer et al., 2009; Mitchel et al., 2000). During tracheoscopy, the animal cannot be intubated. Anaesthesia should be administered intravenously as a constant rate infusion, most commonly with propofol. The dose should be carefully titrated to effect to avoid apnoea. Supplemental oxygen should be provided throughout the procedure to prevent hypoxia. Total intravenous anaesthesia is also used for endoscopy, advanced imaging, and surgical repair of tracheal tears (Bauer et al., 2009).

If an animal with a tracheal rupture requires intubation for oxygenation and ventilation, the tube should be smaller than the lumen of the trachea and extend beyond the rupture. Positive pressure ventilation should be avoided or minimalized (less than 10 cm H<sub>2</sub>O to prevent formation or worsening of subcutaneous emphysema and pneumothorax (Quandt, 2017). Subcutaneous emphysema usually resolves within 1 to 6 weeks, with a median of 2 weeks (Mitchell et al., 2000).

# 4. Prognosis

All cats treated conservatively survived, whereas only two-thirds of those undergoing surgical treatment survived (Hardie et al., 1999). Cats that survived had no subsequent respiratory problems, either after surgical or conservative treatment (Mitchell et al., 2000).

# 5. Preventive measures

To minimize the risk of tracheal injuries:

• Use the smallest effective cuff volume to seal the airway to prevent contamination of the operating room with anaesthetic gases and to ensure adequate ventilation of the cat.







- Gradually inflate the cuff in 0.5 mL increments, using a small syringe and checking for leaks to avoid overinflating the cuff, the cuff is properly sealed when gentle pressure on the reservoir bag no longer causes air leakage past the cuff of the tube.
  - Disconnect the anaesthesia circuit before repositioning the animal.
- Monitor cuff pressure with a manometer during prolonged procedures (Hardie et al., 1999).

# 6. Conclusions

While essential for anaesthesia and airway management, endotracheal intubation carries a risk of tracheal injury if not performed carefully. Proper tube selection, careful cuff inflation, and vigilant monitoring during and after procedures are critical to minimizing complications. Early diagnosis and appropriate management, whether conservative or surgical, ensure a high likelihood of recovery without long-term consequences. In cats, tracheal ruptures most often occur after dental procedures, particularly at the cuff site, due to overinflation of the cuff. These findings highlight the need for precise cuff management and cautious handling during procedures, especially those requiring repositioning, to prevent such injuries.

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