COMPANION OR PET ANIMALS

Airway management for tracheal resection proximal to carina in a cat

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SUMMARY
Tracheal tumours in cats are rare, and most primary tumours respond well to complete surgical excision. Providing secure airway management during resection of the trachea is particularly challenging and in some cases represents a limitation to surgery. We present the case of a cat with a primary tracheal neoplasm located close to the carina, undergoing complete resection. Successful management of the airway was accomplished by intubating the distal tracheal stump with a modified polyvinyl chloride endotracheal tube. Effective seal of the airway and adequate ventilation of both lungs were achieved. We describe a reliable, simple, low-cost technique which provides control of the airways even in situations where the distal stump of the trachea is either too short or non-existent.

BACKGROUND
Tracheal resection as treatment for rupture, avulsion or for tumour removal has been largely described.1–6 Although tracheal neoplasia is uncommon in cats, cases of lymphoma, squamous cell carcinoma and adenocarcinoma have also been reported. The prognosis depends on the type, size and location of the tumour. More extensive resection and localisation close to the carina are associated with poorer outcome as anaesthetic airway management in these cases may be particularly challenging.1 4–7 Animals are usually presented with dyspnoea, cough, wheezing and intermittent cyanosis as most common clinical signs.8–10 Diagnostics include thoracic radiographs which often reveal the mass, bronchoscopy to allow direct visualisation and sampling of the mass, and CT which is usually used for surgical planning. Most primary tracheal tumours respond well to complete surgical excision and additional chemo therapy and/or radiation therapy is often used in combination.

Resection of a tracheal neoplasm requires a similar anaesthetic approach as for tracheal avulsion or laceration repair surgery. Anaesthetic and surgical management of tracheal resection in the proximal or mid-thoracic part of the trachea is well documented, but to our knowledge only three case reports describe the management of the airways close to or involving the carina in cats.11 4

We present a case of successful airway and anaesthetic management in a cat undergoing extensive tracheal resection for a tumour located just cranial to the tracheal bifurcation.

CASE PRESENTATION
A 14-year-old castrated male domestic shorthair cat presented to our institution with a two-week history of persistent progressive coughing and dyspnoea. For two-and-a-half years, the cat was under treatment for asthma with prednisolone, 1 mg/kg orally once a day, and with fluticasone propionate/salmeterol xinafoate inhaler (250/25 µg per actuation inhaler, Seretide forte Accuhaler inhaler, GlaxoSmithKline, UK), one nebulisation two to three times per day. The symptoms were mostly under control, with the exception of sporadic acute episodes.

At presentation the cat was quiet and alert, with a bodyweight of 5.3 kg and a body condition score of 7/9. On physical examination, the cat showed a moderately increased respiratory effort during both inspiration and expiration, and a respiratory rate of 44 breaths per minute. High-pitched stridor was auscultated over the trachea and referred airway sounds were heard over the entire thorax. Other vital parameters were within normal range, with a heart rate of 160 beats per minute, a strong and synchronous femoral arterial pulse and a rectal temperature of 38.8°C.

INVESTIGATIONS
Complete blood count and serum chemistry did not reveal any abnormalities. Thoracic radiographs, bronchoscopy and CT identified chronic bronchiectasis, bronchomalacia and a round, homogenous mass, 1.6 cm in radius, located on the intrathoracic portion of the trachea, three tracheal rings oral from the carina and protruding into the tracheal lumen.

TREATMENT
Differential diagnosis included mediastinal neoplasia, granuloma, abscess, cyst or haematoma. The clinician in charge of the case together with the owner decided against further investigations of the nature of the mass by fine-needle aspiration (FNA)/biopsy during bronchoscopy, bronchoalveolar lavage and CT-guided or ultrasound-guided sampling due to technical limitations, size of the mass, anticipated difficult control of bleeding as well as the location of the mass in the vicinity of sensitive structures (major vessels, heart and lungs). Other conservative therapy options were discontinued due to the rapid deterioration in patient health.

The patient was therefore scheduled for surgical resection of the mass. After clinical examination, a peripheral venous catheter (22 G) was placed in
the right cephalic vein. The cat’s lungs were preoxygenated for approximately five minutes with 100 per cent oxygen via a face mask using an oxygen flow of 3 l/minute. Premedication consisted of sufentanil 0.8 µg/kg (Sufenta-Ampullen, Janssen-Cilag Pharma, Austria) administered slow intravenously. Induction of general anaesthesia was accomplished using midazolam 0.2 mg/kg (Midazolam Hameln, Hameln Pharma Plus, Germany), and alfaxalone 2 mg/kg intravenous (Alfaxan, Jurox UK) and subsequently maintained with sufentanil (1 µg/kg/hour) and alfaxalone (10 mg/kg/hour) constant rate infusion (CRI). Orotracheal intubation with a 4 mm inner diameter (ID) cuffed polyvinyl chloride (PVC) endotracheal (ET) tube (Rüschelit, Teleflex Medical, Ireland) was performed without any difficulty. The patient was then connected to a circle breathing system and 100 per cent oxygen was delivered at 1 l/minute. A total volume of 1 ml bupivacaine 0.5 per cent (Carbostesin 0.5 per cent, AstraZeneca, Germany) was used to perform an intercostal block from the second to the seventh intercostal space with a blind technique. Intravenous balanced crystalloid solution (ELO-MEL OP, Fresninius Kabi, Austria) was infused at a rate of 5 ml/kg/hour.

Monitoring consisted of a lead II ECG, pulse oximetry, expired and inspired anaesthetic gases and carbon dioxide, spirometry, oscillometric non-invasive blood pressure and rectal temperature (IntelliVue M60 patient monitor, Philips, Germany).

The cat was initially allowed to breathe spontaneously, but as the thoracotomy was started it was shifted to mechanical ventilation using a pressure-limited modality with a peak inspiratory pressure (PIP) of 10 cmH₂O, while the frequency was adjusted to maintain an end-tidal CO₂ (EtCO₂) of 45–55 mmHg.

A right lateral thoracotomy was performed through the fourth intercostal space. Once the trachea was exposed, the mass appeared to be infiltrating the tracheal wall and extended further than expected based on previously obtained CT images. The decision was taken to proceed with a palliative excision, involving the resection of the four to five tracheal rings just cranial to the tracheal bifurcation.

The airway management was adapted to the different phases of surgery over time. After incision of the tracheal wall at its distal part close to the bifurcation, a cuffed sterile 3.5 ID, 17 cm long PVC ET tube was inserted by the surgeon into the distal tracheal stump. Before insertion, the ET tube was shortened by cutting its distal end close to the cuff as already described by Ng et al in 2003 (figure 1B).¹¹

The ET tube was then connected to a circle system which was covered with a sterile sleeve (Foliodrape, Hartmann, Germany). After an initial phase when manual ventilation was used while adjusting the tube in the trachea in order to ventilate both lungs, we proceeded with mechanical ventilation (PIP of 13 cmH₂O, tidal volume (Vₜ) of 12 ml/kg, respiratory frequency (fₚ) of 17 breaths per minute, EtCO₂ 45–47 mmHg). Approximately half of the inflated tube’s cuff protruded out of the distal stump of the trachea. The remaining part provided an effective seal of the airway, as confirmed by the possibility to ventilate both lungs and absence of any detectable leak.

After surgical resection of the affected tracheal rings, the proximal tracheal stump was mobilised and prepared for the anastomosis with the distal stump. Since a cuffed tube long enough to bridge the anastomosis and thin enough to fit into the cat’s trachea was not available, a duodenal feeding tube (Duodenal tube, Levin/x-ray, Unomedical, UK) was adapted by cutting off both extremities and by shortening it to an approximate length of 30 cm (figure 2). One extremity was then inserted through the surgical field in the proximal stump of the trachea and advanced out of the mouth, where it was reconnected to the circle system using a size 3.5 ET tube connector. After uncuffing and removing the modified ET tube, the extremity of the feeding tube was inserted into the distal tracheal stump to bridge the resected area. During anastomosis of the trachea, which lasted approximately 10 minutes, a leak was inevitable. The PIP was increased from 10 to 14–16 cmH₂O in the attempt to maintain a Vₜ of 12–13 ml/kg.

Finally, after the closure of the anastomosis, the tube was disconnected from the circle system and a guidewire was advanced through its lumen. The modified feeding tube was in turn withdrawn orally, and a cuffed PVC 4.0 ID ET tube was advanced over the guidewire to quickly reintubate the trachea with a blind technique.

Intraluminal tracheal secretions were intermittently suctioned during the procedure. EtCO₂ tensions before tracheotomy ranged from 33 to 50 mmHg. Following the first reintubation manoeuvre by transtracheal approach, EtCO₂ had increased to 46–55 mmHg. During the time the cat was intubated with the non-cuffed duodenal tube to bridge the area of anastomosis, EtCO₂ readings showed a value of 30–35 mmHg. As soon as the ET tube was reintserted over the guidewire and cuffed, EtCO₂ rose to 59–62 EtCO₂ mmHg and was subsequently corrected with ventilation. Pulse oximetry, initially showing an SpO₂ of 100 per cent, dropped to 80–92 per cent for two to three minutes after the transtracheal intubation. Thereafter, and for the rest of the intervention, SpO₂ remained over 95 per cent. Non-invasive mean arterial blood pressure measurements varied between 60 and 80 mmHg. The heart rate varied between 100 and 130 beats per minute and the ECG showed a sinus rhythm.

The cat recovered uneventfully in a heated oxygen cage (FiO₂ approximately 40 per cent). Postoperative analgesia consisted of methadone (Methadone Streuli, Streuli Pharma, Switzerland) 0.2 mg/kg intravenous every four hours for the first 24 hours, followed by buprenorphine (Buprenovet, Bayer, Germany) 20 µg/kg intravenous every eight hours and ketamine CRI 5 µg/
and reconstruction. Meticulous planning and communication between the anaesthesia and surgical teams are pivotal for the safe and successful outcome of the surgery.

The challenges of airway management during the tracheal resection can be summarised in three phases: (1) initial ET intubation, complicated by potential obstruction of the airway, which depends on the location of the mass (intrathoracic or extrathoracic); (2) the resection of the mass or avulsion repair, when a distal part of the tracheal stump has to be intubated separately; and (3) finally, the end-to-end anastomosis: when bridging of the free tracheal ends is necessary.

During the first phase, location of the lesion in the extrathoracic part of the trachea might complicate orotracheal intubation. The anaesthetist faces the challenge to find a thin but long enough tube to bypass the mass or lesion without causing further damage or bleeding. Ideally, the tube should still have a cuff large enough to provide a seal of the airways caudal to the lesion. In the case described here the mass was located just before the bifurcation of the trachea. Therefore, initial intubation did not involve bypassing the surgical site and was achieved without difficulty and with an adequately sized tube.

There are a number of reports of tracheal repair after tracheal avulsion, rupture or stenosis in cats due to trauma, overcuffed ET tube or inadvertent traction of theuffed ET tube. However, the majority of published case reports describe anaesthetic and surgical management of the tracheal resection in proximal or mid-thoracic part of the trachea.1 2 4–7 12 13 In these cases, a distal stump of the trachea is usually intubated with a sterile ET tube through the thoracic wound by a surgeon. The breathing circuit tubing can then be threaded through a sterile sleeve to prevent contamination of the surgical field. White and Burton, Lawrence et al and White and Milner have described the management of this type of intrathoracic tracheal injury in cats. 2 3 12 However, if the resection area is close to the carina like in the case described here, it is much harder to secure the airway due to the small space left to safely position the tube’s tip and cuff before the tracheal bifurcation.

To our knowledge, only three case reports describe the airway management for a resection close or involving the carina in cats. Schmierer et al described the avulsion of the caudal thoracic trachea involving the carina.1 The authors use manual jet ventilation without intubation. The human medicine literature also suggests the use of manual jet ventilation or high-frequency jet ventilation in situations when only a small lumen tube could be passed over a stenosis or the airtight seal of the airways is not possible.14 This technique ensures bilateral ventilation in absence of ET tube with minimal haemodynamic consequences as well as a clear view of the operating field.14 15 However, some limitations have to be taken into account. The continuous airflow exiting the lungs helps, but does not guarantee to prevent blood or other fluids entering the airways.15 Furthermore, standard capnography cannot be used and monitoring the effectiveness of ventilation by arterial blood gas analysis becomes necessary. The equipment for jet ventilation was not available at our institution, prompting us to look for a feasible alternative. Sayre et al describe a case of tracheal diverticulum repair close to the carina in a cat. The authors use two independent anaesthetic machines, circuits and tubes to ventilate each lung separately.4 This approach is resource and space consuming, and technically demanding. Even so, ventilating both lungs was not possible throughout the whole procedure, and the surgery had to be paused when severe desaturation required adequate bilateral ventilation. Kästner et al describe a case similar to ours by location of the resection area.5 The authors tried to intubate transtracheally the main bronchus,

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**Figure 2** A feeding tube (top) is adapted for transtracheal retrograde intubation of proximal tracheal stump by shortening and added endotracheal tube connector size 3.5; original (bottom).

**Figure 3** Endotracheal tube (top) and endotracheal tube adapted to allow intubation of proximal tracheal stump by shortening the tip (bottom).
but the tube became dislodged and could not be advanced due to its excessive diameter. The authors postulate that the main stem bronchus in cats is short in relation to the cuff size of available ET tube. Hammer et al 14 also describe that an effective seal of the trachea is only possible when the length from the tube’s distal tip to the proximal cuff edge is less than the length of the main stem bronchus (figure 1).16 Additionally, problems can arise if the tip of the ET tube occludes early branching bronchi, in which case one lung lobe cannot be ventilated properly.1

The tube modification we adopted was intended to preserve a functional cuff to seal and protect distal airways from aspiration, and at the same time to make ventilation of both lungs possible, despite the extreme proximity of the tracheal bifurcation. The tip of the cuffed PVC ET tube was shortened until its distal cuff edge (figure 1B). Ng et al were the first in 2003 to suggest modifying normal ET tube by shortening its tip in people.17 The technique described is relatively simple and does not require any expensive equipment while proving to be effective also in cats. In our case, pulse oximetry readings decreased (SpO2, 80–92 per cent) as a consequence of the reintubation manoeuvre, but were promptly corrected and maintained at a value of at least 95 per cent after placing the modified tube. However, changes in the arterial oxygen tension may have gone unrecognized because arterial blood gas measurements were not available.

The adaptation of the ET tube as mentioned is relatively simple, however when cutting the tube it has to be taken into consideration that the cuff or the inflating lumen of the cuff could be damaged. In many different types of ET tube, inflation line extends the whole length of the tube, that is, beyond the cuff itself. Therefore, to be able to inflate the cuff after shortening of the tube, care needs to be taken not to damage the inflation line. The inflation line should be visualised and the tube cut at an angle (figure 3).

It would be also very important to emphasize that during the procedure the tube cannot be easily secured. It is held in position only by the pressure of the cuff to the walls of the distal tracheal stump and can be easily retracted and dislodged. For that matter continuous monitoring of the EtCO2, spirometry, position of the tube and support of the surgical team are essential.

The human literature also emphasizes the importance of good cooperation between surgical and anaesthetic teams and suggests other alternatives for managing surgeries involving the carina. One option consists of bypassing the tracheal defect using a one-lung ventilation technique. Different management strategies like the use of double lumen ET tube, bronchial blockers and single lumen tube for single bronchus are used to achieve one-lung ventilation. However, both in humans and in dogs one-lung ventilation was shown to lead to significant decrease in PaO2 resulting from deoxygenated blood from non-ventilated lung going back to the left side of the heart. Ventilation perfusion mismatch of the ventilated lung is also increased.17–19 Moreover, commercially available systems and tubes are rarely available in sizes fitting the length and diameter of cats’ trachea. Another alternative option described in human medicine is the use of cardiopulmonary bypass.20 Unfortunately, the necessary equipment and trained personnel are rarely available in veterinary hospitals.

For the final end-to-end anastomosis and reconstruction of the trachea, the transtracheal intubation has to be removed. It is normally suggested to shift back to ET intubation. Usually a cuffed tube long enough to overbridge the tracheal defect by positioning the cuff distal to the resected area is used.11–14 In our case, the location of the resection made it impossible to have a cuffed ET tube thin enough but at the same time long enough to reach the tracheal bifurcation. For this reason we adapted a feeding tube as described above (figure 2). Although this made possible to ventilate the lungs, it has to be remarked that this solution cannot guarantee the protection of the deep airways against the penetration of blood or other fluids due to the absence of the cuff. A high-volume leak is also inevitable, making ventilation less effective and capnography reading unreliable, as shown in our case by the falsely low EtCO2 readings (30–35 mmHg). After the cuffed ET tube was placed the EtCO2 reading was around 60 mmHg.

Resection of the trachea close to the carina is associated with poor outcomes, in part due to the challenge encountered in managing the airways, often due to the absence and/or limitations of specific equipment and techniques. The simple modification of easily available material, like a common ET tube and a feeding tube as suggested in this case report, can help the clinician in the successful management of similar cases.

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