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CASE REPORT

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Endotracheal tube obstruction due to cuff overinflation or cuff herniation in small equids: A case series

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Summary

Adequate inflation of the endotracheal tube (ETT) cuff is important to avoid leakage of anaesthetic gases or aspiration of gastric contents and to allow positive pressure ventilation. However, overinflation or herniation of the cuff can cause tracheal mucosal damage and in rare cases even obstruction of the ETT. ETT obstruction due to the cuff itself may be an underrecognised phenomenon in equine practice and we aim to create awareness with this retrospective case series ($n = 3$). Cases identified between 2014 and 2021 with (partial) ETT obstruction due to cuff overinflation or cuff herniation at the Utrecht University Equine Clinic were selected. Anaesthesia records were examined and presented. Two cases occurred in foals and one in a pony. In each case, high airway pressure was encountered and no or minimal thoracic excursions were visible. In all three cases, cuff deflation led to immediate normalisation of ventilation parameters. When presented with an intubated patient that is difficult to ventilate and high airway pressures exist, ETT cuff overinflation or herniation should be considered as a possible cause; rapid cuff deflation should be included in algorithms for management of ventilation failure due to suspected airway obstruction.

KEYWORDS
horse, cuff herniation, cuff overinflation, cuff pressure, endotracheal tube obstruction

INTRODUCTION

Endotracheal intubation in horses is a routine procedure to deliver inhalant anaesthetics and oxygen, maintain airway patency and to facilitate positive pressure ventilation. Inflation of the endotracheal tube (ETT) cuff provides a seal between the tube and the trachea, preventing leakage of gases and fluids. Underinflation of the cuff can result in pulmonary aspiration of orogastric contents, while leakage of anaesthetic gases can result in contamination of the room. On the other hand, overinflation of the ETT cuff in horses can lead to tracheal mucosal damage (Heath et al., 1989; Holland et al., 1986; Touzot-Jourde et al., 2005), tracheal necrosis (Wylie et al., 2015) and even tracheal perforation (Saulez et al., 2009). Overinflation should therefore also be avoided. Despite the importance of avoiding under and overinflation, no best practice guidelines for ETT cuff inflation or recommended cuff pressure ranges for horses currently exist.

An underrecognised and rare complication of cuff overinflation is ETT obstruction due to the cuff itself. This may be either due to pressure-induced luminal collapse of ETTs, or due to herniation of the cuff, which then obstructs the ETT outflow including the Murphy eye. There are several case reports in human medicine describing ETT obstruction due to cuff overinflation (Davis et al., 2011; Hofstetter et al., 2010; Zenga et al., 2018) and cuff herniation (Barker & Stotz, 2013; Bar-Lavie et al., 1995; Kumar et al., 2021), but only two reports of cuff herniation in veterinary medicine

(Bergadano et al., 2004; Richardson & McMillan, 2017). The possibility of ETT obstruction secondary to cuff overinflation may be an underrecognised phenomenon in equine practice, but it can be life-threatening if not identified and resolved timely. Therefore, we aim to create awareness of this potential problem with this retrospective case series.

CASE 1

A 4-year-old Shetland pony mare weighing 142 kg was presented for experimental bilateral stifle surgery (DEC 2014.III.11.098). The pony was premedicated with detomidine (Domosedan, 9 µg/kg bwt, Orion Pharma) and butorphanol (Dolorex, 18 µg/kg bwt, MSD Animal Health) and then induced with midazolam (Midazolam, 0.1 mg/kg bwt, Actavis) and ketamine (Narketan, 2.1 mg/kg bwt, Vetoquinol) intravenously (IV) via a 14-gauge catheter (Mila International). Supplemental oxygen was provided intranasally (5 L/min; FiO_2 ~ 0.25) and the pony was hoisted on a surgical table in dorsal recumbency. Seven minutes from the start of induction, the pony was intubated without difficulty with a pretested 14 mm internal diameter silicone ETT tube (Kruuse). The low-volume-high-pressure (LVHP) cuff was inflated as deemed adequate to the anaesthetist by assessing syringe back-pressure; cuff pressure was not measured or recorded. Spontaneous respiration was initially observed by thoracic movements. Five minutes later, head-and-neck movements were observed by the anaesthetist in training and three consecutive top-ups of midazolam and ketamine were given IV (0.01 mg/kg bwt midazolam and 0.46 mg/kg bwt ketamine each). The anaesthetist did not note an obstructive breathing pattern, but a supervisor was called to assist. When the supervisor arrived 1 min later, movement was judged as 'tracheal tugging' (agonal gasping), oral mucous membranes were pale and cyanotic, ictus cordis (apical impulse rate) was 130 beats/min, and eyelid and corneal reflexes were absent. The pony was rushed into theatre and connected to a small animal circle system; flow rate and time controlled intermittent positive pressure ventilation (IPPV) (Mallard Large Animal Ventilation System Model 2800-P, Mallard Medical) was immediately started with 18 breaths/min and gas flow of 100% oxygen. Pulse oximetry and ECG monitoring were started using a multiparameter monitor (Datex Ohmeda S/5, GE Healthcare). Heart rate was 121 beats/min, peripheral oxygen saturation (SpO_2) was 56% and end-tidal carbon dioxide partial pressure ($EtCO_2$) was 5.4 kPa (40.5 mmHg). It was immediately noticed that the anaesthetic machine did not deliver an adequate tidal volume (only 300 ml, measured by movement of the bellow) and that the inspiratory pressure was very high (maximum pressure of 80 cm H_2O). The capnogram showed only a minimal triangular trace. The ETT cuff was rapidly deflated and immediately the anaesthetic machine could deliver an adequate tidal volume (1.2–1.5 L) with an inspiratory pressure of 24 cm H_2O. SpO_2 increased to 84 and 98% in the next few minutes and in this time frame, heart rate decreased to 60 beats/min. The cuff was reinflated to minimal occlusive volume by listening at the mouth during a positive pressure breath and by observation of a normal capnogram waveform. IPPV was continued with a tidal volume of 8–10 ml/kg and 18 breaths/min. Isoflurane (IsoFlo, Zoetis) in 100% oxygen was started at return of slow palpebral reflex and nystagmus. The physiological status of the pony was at this point deemed sufficient in regard to the inclusion criteria of the experiment and the pony was prepared for surgery. Crystalloid infusion was initiated at approximately 6 ml/kg/h IV (Ringer Fresenius, Fresenius Kabi). Thirty minutes after induction, placement of an invasive arterial line for blood gas analysis and blood pressure measurement was unsuccessful. Heart rate was 58 beats/min, SpO_2 99% and variable pulse wave amplitude was visible on the plethysmogram. A fluid bolus of 10 ml/kg (Fresenius Kabi) was administered IV and a continuous rate infusion (CRI) of dobutamine (Dobutamine, 0.25 µg/kg/min, Hameln Pharma) was started. Heart rate decreased to 44 beats/min and an arterial line was successfully placed in the right facial artery. Mean arterial pressure (MAP) was 79 mmHg; the results of arterial blood gas analysis are presented in Table 1 (further arterial blood gas analysis results were in line with the last arterial blood gas results). For the remainder of anaesthesia, the fraction of inspired oxygen was decreased to 0.65–0.77 as dictated by the experimental study protocol (Calero Rodriguez et al., 2021) and SpO_2 remained 99%–100%. Total anaesthesia time was 187 min. Recovery was prolonged, and the pony was hypothermic, but stood well after 30 min. Buprenorphine (Buprecare, 6 µg/kg bwt, AST Farma) and meloxicam (Metacam, 0.6 mg/kg bwt, Boehringer Ingelheim) were administered IV for post-operative analgesia. Inspection of the ETT after extubation did not reveal any obvious abnormalities with overinflation. Fifteen hours after anaesthetic induction, clinical examination

TABLE 1 Arterial and venous blood gas results of Case 1.

	41 min after induction arterial	89 min after induction arterial	Reference (arterial)
pH	7.341	7.346	7.35–7.45
$PaCO_2$	45.6	49.8	35–45 mmHg
PaO_2	415.1	419.5	>90 mmHg
$HCO3^-$	24.1	26.6	20–28 mmol/L
BE	−1.9	0.2	−3 to +3 mmol/L
SBC	22.9	26.6	20–28 mmol/L
Sat	99.8	99.8	>95%
Ht	0.3	0.28	0.3–0.43 L/L
Na^+	136.5	134.9	135–150 mmol/L
K^+	3.0	3.27	3.0–5.9 mmol/L
Ca^{++}	1.24	1.29	1.4–1.7 mmol/L
Cl^-	101	98	96–107 mmol/L
Glucose	7.1	7.0	3.9–5.6 mmol/L
Lactate	4.08	4.04	0.7–1.2 mmol/L
FiO_2	0.93	0.94	

Abbreviations: BE, base excess; Ht, haematocrit; $PaCO_2$, partial pressure of arterial carbon dioxide; PaO_2, partial pressure of arterial oxygen pressure; Sat, saturation; SBC, standard bicarbonate.

revealed paroxysmal tachyarrhythmia (50–70 beats/min); an ECG was recorded and showed sinus arrhythmia with ST elevation. The tachyarrhythmia and ST elevation resolved in the next 24 h. The pony made a full recovery, and a subsequent anaesthesia 4 months later was uneventful.

CASE 2

A 10-day-old 78 kg Dutch Royal Warmblood colt was presented for resection of infected umbilical remnants. The foal was premedicated with detomidine (Domosedan, 13 µg/kg bwt, Orion Pharma) and morphine (Morfine HCL, 0.13 mg/kg bwt, Centrafarm) and then induced with diazepam (Diazepam, 0.06 mg/kg bwt, Centrafarm) and ketamine (Narketan, 2.8 mg/kg bwt, Vetoquinol) IV via a 14G catheter (Mila International). Oxygen was provided via nasal line (5 L/min; FiO_2 ~ 0.25) and the patient was placed on a surgical table in dorsal recumbency. The patient was intubated without apparent difficulty with a pretested 14 mm internal diameter silicone ETT tube (Kruuse) and the LVHP cuff was inflated to a pressure of 140 mmHg at unknown volume using a manometer (DS54 DuraShock Hand Aneroid, Welch Allyn). In theatre, the foal was connected to a small animal circle system and flow rate and time controlled IPPV (Mallard Medical) was started at 18 breaths/min. A maximum tidal volume of 550 ml was obtained at an inspiratory peak pressure of 27 cm H_2O. A pulse oximeter and ECG were attached (Datex Ohmeda S/5, GE Healthcare). No abnormal capnogram waveform was noted with an $EtCO_2$ of 5.8 kPa (43.5 mmHg), but only minimal thoracic excursions were visible. The cuff was deflated and reinflated until audible air leakage just disappeared. Hereafter, the tidal volume immediately increased to 1200 ml at the same inspiratory peak pressure of 27 cm H_2O (ventilator flow rate was unchanged). Arterial saturation (SaO_2) increased from 96.7% to 99.7% (the corresponding increase in arterial partial pressure of oxygen was not recorded; Table 2). Isoflurane (Isoflo, Zoetis) in 100% oxygen was started and the foal was prepared for surgery. Hypotension (MAP 47 mmHg) was treated with dobutamine (Dobutamine, 0.25 µg/kg/min, Hameln Pharma) IV to maintain MAP >60 mmHg. Total anaesthesia time was 169 min. After extubation, the ETT cuff appeared normal, yet haemorrhagic fluid was visible in the ETT lumen and the foal developed a mild stridor, which did not improve after placement of a nasal tube. Oxygen flow at 10 L/min was administered via a nasal line. Recovery was calm and the stridor did not worsen, nor was laboured breathing observed. The day after surgery the stridor had disappeared, and thoracic auscultation did not reveal respiratory abnormalities.

TABLE 2 Arterial blood gas results of Case 2.

	38 min after induction	72 min after induction	Reference (arterial)
pH	7.340	7.354	7.35–7.45
$PaCO_2$	42.4	47.7	35–45 mmHg
PaO_2	93.1		>90 mmHg
$HCO3^-$	21.7	24.4	20–28 mmol/L
BE	−3.3	−0.1	−3 to +3 mmol/L
Sat	96.7	99.7	>95%
Ht		0.27	0.3–0.43 L/L
Na^+	139.1	136.9	135–150 mmol/L
K^+	3.16	3.03	3.0–5.9 mmol/L
Ca^{++}	1.27	1.27	1.4–1.7 mmol/L
Cl^-	116	106	96–107 mmol/L
Glucose	8.3	6.7	3.9–5.6 mmol/L
Lactate	3.89	3.16	0.7–1.2 mmol/L
FiO_2	0.6	0.93	

Abbreviations: BE, base excess; Ht, haematocrit; $PaCO_2$, partial pressure of arterial carbon dioxide; PaO_2, partial pressure of arterial oxygen pressure; Sat, saturation; SBC, standard bicarbonate.

CASE 3

A 1-month-old male Dutch Royal Warmblood foal weighing 85 kg was presented for umbilical resection due to omphalophlebitis. The foal was premedicated with detomidine (Domosedan, 18 µg/kg bwt, Orion Pharma) and morphine (Morfine HCL, 0.12 mg/kg bwt, Centrafarm) and induced with diazepam (Diazepam, 0.06 mg/kg bwt, Centrafarm) and ketamine (Narketan, 2.4 mg/kg bwt, Vetoquinol) IV via a 14G catheter (Mila International). The foal was lifted onto the surgical table and placed in dorsal recumbency with nasal oxygen supplementation (5 L/min; FiO_2 ~ 0.25). Endotracheal intubation with a pretested 14 mm internal diameter silicone ETT tube (Kruuse) was attempted but was unsuccessful. Placement of a pretested 12 mm internal diameter silicone ETT tube (Kruuse) was successful and the LVHP cuff was pressurised to 200 mmHg at unknown volume using a manometer (DS54 DuraShock Hand Aneroid, Welch Allyn). The foal was moved to the theatre and connected to a small animal circle system. Volume controlled IPPV (Sfinx, Veterinary Technics) was started with isoflurane (Isoflo, Zoetis) in 100% oxygen. Continuous pulse oximetry and ECG monitoring was initiated (Datex Ohmeda S/5, GE Healthcare). Anaesthetic gas leakage was detected, and cuff pressure was noted to have dropped well below 200 mmHg; the cuff was reinflated to 220 mmHg at this time. Hereafter, minimal thoracic excursions were seen despite high airway pressures (maximum pressure of 80 cm H_2O), and it was impossible for the anaesthetic machine to deliver more than 250–300 ml tidal volume. Heart rate was 92 beats/min, SpO_2 was 97%, $EtCO_2$ was 5.0 kPa; no obvious abnormalities in the capnogram waveform were noted. The ETT cuff was deflated, and normal thoracic excursions were immediately visible. The cuff was reinflated to minimal occlusive volume as judged by capnogram waveform, audible gas leakage and absence of detectable isoflurane smell. $EtCO_2$ was now 9 kPa and IPPV was started again with a tidal volume of 1.3 L at a rate of 24 breaths/min. $EtCO_2$ decreased within a few minutes and the respiratory rate was decreased to 11 breaths/min. The results of arterial blood gas analysis are presented in Table 3 (further arterial blood gas analysis results were in line with the last arterial blood gas results). The remainder of

TABLE 3 Arterial blood gas analysis results of Case 3.

	15 min after induction	32 min after induction	Reference (arterial)
pH	7.301	7.350	7.35–7.45
$PaCO_2$	56.4	49.5	35–45 mmHg
PaO_2	394.5	421.2	>90 mmHg
$HCO3^-$	27.2	26.9	20–28 mmol/L
BE	−0.4	0.6	−3 to +3 mmol/L
SBC	24.2	25.1	20–28 mmol/L
Sat	99.8	99.8	>95%
Na^+	138.7	138	135–150 mmol/L
K^+	3.17	2.95	3.0–5.9 mmol/L
Ca^{++}	1.47	1.45	1.4–1.7 mmol/L
Cl^-	103	107	96–107 mmol/L
Glucose	11.3	10.1	3.9–5.6 mmol/L
Lactate	2.54	2.27	0.7–1.2 mmol/L
FiO_2	0.85	0.95	

Abbreviations: BE, base excess; $PaCO_2$, partial pressure of arterial carbon dioxide; PaO_2, partial pressure of arterial oxygen pressure; Sat, saturation; SBC, standard bicarbonate.

anaesthesia was uneventful. Total anaesthesia time was 105 min and recovery was smooth. Visual inspection of the ETT after extubation did not reveal any obvious abnormalities.

DISCUSSION

In the equine scientific literature, reports of cuff-related ETT obstruction are rare. Endotracheal tube obstruction due to the ETT cuff can be caused by either cuff overinflation, resulting in excessive pressure effectively obliterating the lumen of the ETT, or cuff herniation, where the cuff extends beyond the opening of the ETT, obstructing gas flow. The two case reports available in veterinary medicine (equine and canine) both describe ETT obstruction due to cuff herniation (Bergadano et al., 2004; Richardson & McMillan, 2017). In the human medical literature, in addition to case reports on ETT obstruction due to cuff herniation, several authors also reported ETT obstruction due to collapse of the ETT lumen secondary to excessive external pressure exerted by an overinflated ETT cuff (Davis et al., 2011; Hofstetter et al., 2010; Zenga et al., 2018). Our case series highlights several clinically relevant aspects of cuff-related ETT obstruction in ponies and foals.

First, it appears that size and ETT material properties matter (Briganti et al., 2012; Davis et al., 2011; Dobrin & Canfield, 1977). In the three cases presented here, cuff overinflation may either have caused inward collapse of the ETT lumen or may have contributed to cuff herniation. Cuff overinflation causing the inner lumen of the ETT to collapse was shown to occur in some brands of polyvinyl chloride (PVC) ETTs used for small animal anaesthesia but not in other brands, and this difference was suggested to be due to PVC quality and therefore compliance of the ETT wall (Davis et al., 2011). Silicone ETTs, such as are commonly used in equine anaesthesia, are even more compliant than PVC ETTs (Briganti et al., 2012; Dobrin & Canfield, 1977). This is particularly true in tubes with a smaller inner diameter, and this affects both the wall strength and the elastic properties of the ETT cuff (Briganti et al., 2012; Dobrin & Canfield, 1977). While cuff herniation in PVC ETTs does not occur even at high intracuff pressures (Hofstetter et al., 2010), no comparable study has been done for silicone ETT cuffs. In the veterinary case reports where cuff herniation occurred (Bergadano et al., 2004; Richardson & McMillan, 2017), ETT cuff pressure was not measured, and it is therefore impossible to determine if cuff overinflation contributed to herniation in those cases as well. Alternatively, cuff herniation can also occur at normal cuff pressures due to manufacturing issues (Barker & Stotz, 2013; Bergadano et al., 2004; Kao et al., 2005). All three cases of ETT obstruction due to cuff overinflation in the current case series involved small size animals (one Shetland pony and two Warmblood foals). It would appear that a small internal diameter silicone ETT (<16 mm) is a possible risk factor for ETT obstruction secondary to cuff overinflation.

Secondly, in all cases, the cuff problem manifested as difficult ventilation, characterised by reduced gas flow and increased respiratory effort, or low delivered tidal volume despite high peak inspiratory pressures during IPPV. This agrees with previous observations reported in human (Barker & Stotz, 2013; Bar-Lavie et al., 1995; Davis et al., 2011; Hofstetter et al., 2010; Justiz & Mayhew, 2007; Kumar et al., 2021) and veterinary (Bergadano et al., 2004; Richardson & McMillan, 2017) literature on ETT obstruction. The sequelae can be severe, as severe hypercapnia and hypoxaemia can develop in minutes if critical hypoventilation is not promptly recognised and the problem resolved. Prompt diagnosis is likely hindered by the fact that shortly after intubation and having verified air flow prior to cuffing, the anaesthetist is unlikely to consider the possibility of luminal obstruction of the ETT thereafter. Also, while kinking or accumulation of secretions may be more common causes of ETT obstruction (Divatia & Bhowmick, 2005), ETT obstruction due to cuff overinflation or herniation is a less likely scenario, making it harder for the anaesthetist to quickly identify and correct the problem. Furthermore, cuff position and shape are dynamic and influenced by, among other things, changes in head-and-neck position (Brimacombe et al., 1999) and ETT displacement. Case 1 illustrates how failure to identify an obstructive breathing pattern can lead to an erroneous assumption of insufficient depth of anaesthesia, with critical time wasted on correcting this presumed problem. Importantly, when induction and intubation are performed outside the operating room under clinical observation only, the lack of monitoring and connection to an anaesthetic machine immediately after intubation may contribute to delay in identifying partial or complete airway obstruction. Continuous patient monitoring like pulse oximetry, capnography, spirometry, changes in peak inspiratory pressure and ECG could help alert the anaesthetist to the issue but is usually only initiated in the operating theatre. In Case 1, critical hypoventilation during the intervening period caused severe tachycardia, tachyarrhythmia and critical desaturation that could have ended with hypoxic organ damage and death; the near-total airway obstruction could also have resulted in negative pressure pulmonary oedema. Difficult ventilation was likewise not identified in the second case until the foal was connected to the anaesthetic machine, IPPV was started, and a low tidal volume was observed despite high peak airway pressures. When the cuff was identified as the cause of ETT obstruction and difficult ventilation, rapid cuff deflation led to immediate return of normal ventilation parameters. In none of the cases post obstruction pulmonary oedema was noticed, which may be due to the short duration of the insult, although in Cases 2 and 3, this may also have been due to a lack of specific post anaesthetic monitoring instituted. The management of difficult ventilation due to ETT obstruction is an emergency situation where early diagnosis and intervention is vital; therefore, rapid cuff deflation should be included in the anaesthetist's algorithm for management of inspiratory dyspnoea in horses (Figure 1).

Thirdly, no recommended cuff pressure range is known for different diameter equine silicone ETTs, meaning achievement of adequate ETT inflation and cuff seal remains a balancing act, and more art than science. While underinflation may lead to leakage and potential aspiration, excessive pressure exerted on the tracheal mucosa as a result of cuff overinflation can lead to mucosal ischaemia and tracheal wall damage. Tracheal capillary perfusion pressure decreases when ETT cuff pressures over 30 cm H_2O were used in rabbits (Nordin et al., 1977) and humans (Seegobin & van Hasselt, 1984), but this was in PVC ETTs fitted with high-volume low-pressure cuffs. In horses, silicone tubes with LVHP cuffs are more commonly used. In these, intracuff pressure does not accurately reflect tracheal wall pressure. In these tubes, intracuff pressure is affected by the cuff's elastic properties and geometry (Dobrin & Canfield, 1977; McGinnis et al., 1971; Sultan et al., 2011). The foal in Case 2 developed a stridor after extubation, which may have been caused by transient laryngeal hemiplegia or tracheal wall damage due to temporarily excessive transmural pressure; however, it is also possible that haemorrhage was secondary to tissue damage incurred during traumatic intubation with a relatively large size ETT. In the foals of Cases 2 and 3, a cuff pressure of 140 to 200 mmHg (190–270 cm H_2O) was used to seal the trachea. In adult horses, an ETT cuff pressure of more than 80 cm H_2O provided a seal sufficient to prevent liquid leakage around the LVHP cuff of a 30 mm internal diameter silicone ETT size (Touzot-Jourde et al., 2005). The 30 mm ETT has a thicker wall and larger diameter, meaning the cuff needs less inflation and deformation to actuate a seal than a 26 mm ETT. In our hospital, we routinely inflate the cuff on a size 26 ETT for adult horses to 200 mmHg (270 cm H_2O) to prevent gas leakage, without apparent difficulties in ventilation. However, in these foals, like in the pony of case one, cuff deflation immediately resulted in restoration of normal ventilation parameters, and there was no

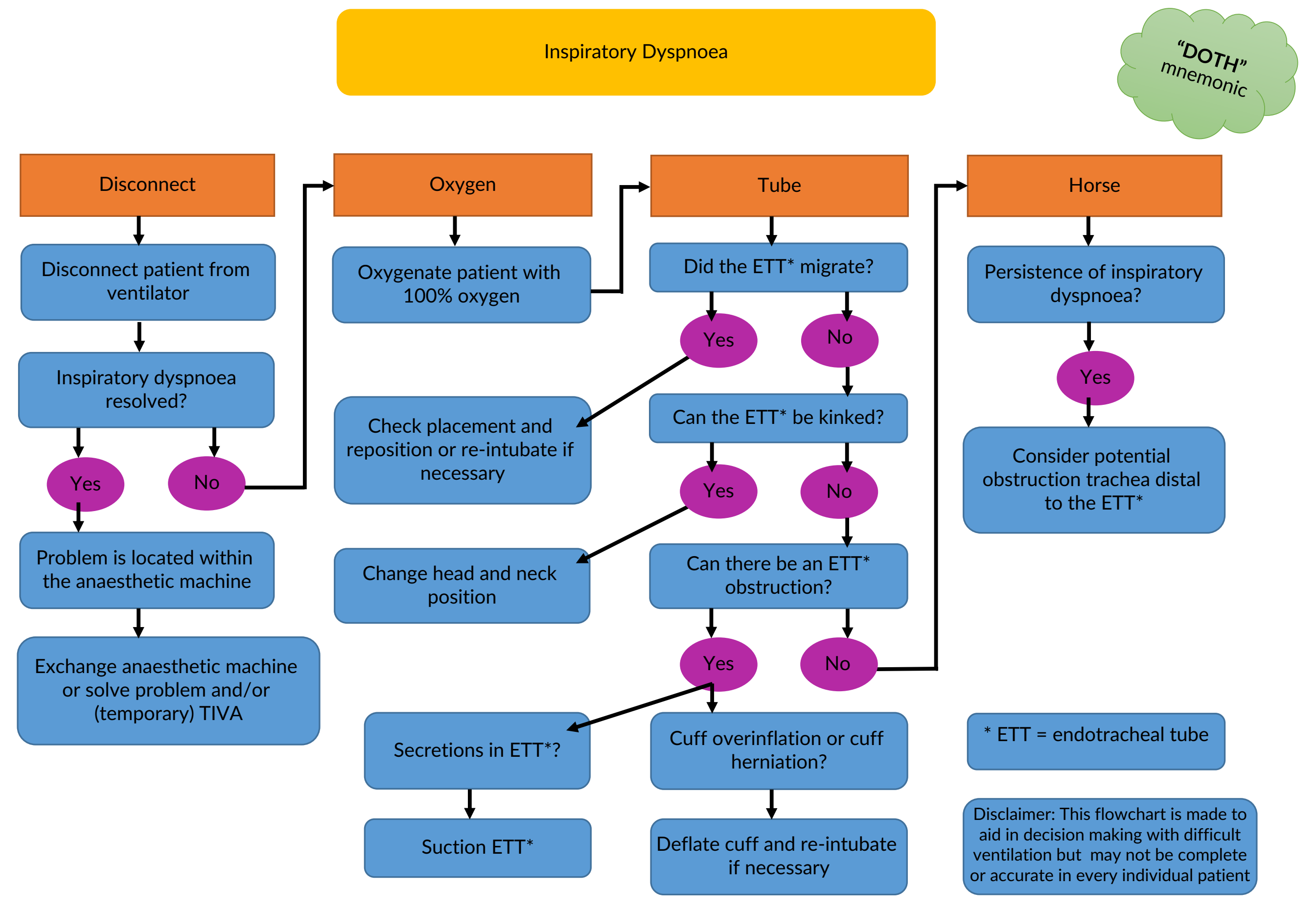

FIGURE 1 Algorithm for management of inspiratory dyspnoea.

recurrence of difficult ventilation after reinflating the same ETT cuff to minimal occlusive volume. We currently lack scientific data for recommended intracuff pressure ranges for different size silicone tubes. Since overinflation is more common than underinflation with most of the routinely used cuff inflation techniques other than pilot balloon palpation (Briganti et al., 2012; Khan et al., 2016; Sathish Kumar & Young, 2002; White et al., 2020), and tracheal mucosal wall damage is also pressure dependent (Touzot-Jourde et al., 2005), ETT cuff pressure measurement is recommended to avoid post-operative complications (Briganti et al., 2012; Hockey et al., 2016; Khan et al., 2016; Sengupta et al., 2004; Sultan et al., 2011; Touzot-Jourde et al., 2005).

In conclusion, ETT obstruction is a potentially life-threatening condition that requires prompt recognition and removal of the underlying cause to prevent morbidity and mortality. When presented with an intubated pony or foal that is difficult to ventilate and high airway pressures are observed, compression of the ETT lumen due to cuff overinflation or obstruction of gas flow due to cuff herniation should be considered as possible causes. Rapid cuff deflation should be included in algorithms for management of difficult ventilation. While cuff pressure measurement may reduce the risk of overinflation and associated tracheal mucosal injury, it may not protect against cuff herniation, and close observation of respiratory pattern and/or airway pressures (if IPPV is supplied) is imperative following ETT cuff inflation. More research is necessary to provide an evidence-based recommendation on a safe range of ETT cuff pressure for different size silicone ETTs used in horses.

AUTHOR CONTRIBUTIONS

Both authors contributed to study design, study execution, data analysis and interpretation and preparation of the manuscript. Furthermore, both authors have approved the final version of the manuscript.

CONFLICT OF INTEREST

No conflicts of interest have been declared.

ETHICS STATEMENT

The procedures described in this case report involved informed client consent. These were clinical cases presented to our hospital for surgery and ethical review was not required.

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