RESEARCH PAPER

Complications secondary to endotracheal intubation in dogs and cats: A questionnaire-based survey among veterinary anaesthesiologists

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Abstract

Objective To investigate anaesthesiologists' attitudes towards endotracheal intubation and the perceived incidence of complications secondary to endotracheal intubation in dogs and cats.

Study design A cross-sectional online questionnaire-based study.

Methods Using an online questionnaire distributed via electronic mail, the perceived incidence of complications secondary to endotracheal intubation in dogs and cats was investigated. Attitudes towards endotracheal intubation, average caseload and percentage of animals intubated were examined. The study population consisted of Diplomates, Residents, and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia. Univariate descriptive statistics were calculated. For each complication, a mean incidence score (MIS) was calculated, ranging from 1 (never) to 5 (always). Additionally, a Wilcoxon signed-rank test and binary regression analyses were performed. A p value ≤ 0.05 was considered significant.

Results The overall response rate was 35.1%, with a completion rate of 26.6%. Most dogs and cats undergoing general anaesthesia were intubated. Endotracheal intubation was viewed as an integral part of modern anaesthesia. Significant differences were found in the incidence of 16 of the 24 examined complications between dogs and cats ($p \leq 0.001$). The most frequently perceived complications were reported to be cuff leak (MIS 3.20) and coughing during intubation (MIS 3.10) in dogs, and coughing (MIS 3.01) and laryngeal spasm during intubation (MIS 2.91) in cats. Sociodemographic and practice-specific aspects did not appear to play a significant role in the reported incidence of complications.

Conclusions and clinical relevance Endotracheal intubation was considered a state-of-the-art technique by the respondents. It was associated with a perceived low incidence of major complications and more frequent minor ones. Differences between dogs and cats need to be accounted for. Considering the retrospective and self-reporting nature of this survey, true incidences might differ.

Keywords cat, complications, dog, endotracheal intubation.

Introduction

Veterinary anaesthetists commonly perform endotracheal intubation as part of the airway management of anaesthetized dogs and cats. Benefits of endotracheal intubation include provision of a patent airway, facilitation of mechanical ventilation, protection of lower airways from aspiration of fluids and prevention of contamination of the work environment with waste anaesthetic gases (Mosley 2017). However, endotracheal intubation in dogs and cats has been associated with complications, which may become evident during the procedure itself, shortly after, or even after days or weeks. Described complications range from minor, such as coughing and soft tissue trauma of the oral cavity and larynx, to major (i.e. potentially life-threatening), such as unnoticed oesophageal intubation, laryngeal oedema, tracheal stenosis and tracheal necrosis (Brown 2007; Auckburally & Flaherty 2017; Sager 2018; Dugdale et al. 2020).

Unlike in human medicine, veterinary literature investigating complications secondary to endotracheal intubation is scarce. Endotracheal intubation has been found to increase the risk of complications and the odds of death in cats undergoing general anaesthesia (GA) (Clarke & Hall 1990; Dyson et al. 1998; Brodbelt et al. 2008). Additionally, potentially life-

threatening complications have been described in several veterinary case reports (Knecht et al. 1972; Hardie et al. 1999; Bergadano et al. 2004; Kästner et al. 2004; Alderson et al. 2006; Hofmeister et al. 2007; Bhandal & Kuzma 2008; Thomas & Syring 2013). However, specific studies on the type and incidence of complications associated with endotracheal intubation in dogs and cats have not been yet published.

During the investigation for this study, no veterinary research analysing the factors influencing the risk of complications secondary to endotracheal intubation could be identified. In human medicine, risk factors such as skill level of the physician, urgency of the procedure, physical status of the patient and technique-specific factors have been demonstrated to play a role in the incidence of complications (Divatia & Bhowmick 2005; Griesdale et al. 2008; Pacheco-Lopez et al. 2014). Conversely, in veterinary medicine, this remains to be determined. Likewise, although veterinary anaesthesiologists are trained to perform endotracheal intubation in dogs and cats, research on their knowledge and attitudes towards endotracheal intubation have not yet been published.

Therefore, this study aimed to answer: 1) what are anaesthesiologists' attitudes towards endotracheal intubation in dogs and cats; 2) what is the perceived incidence of complications encountered during endotracheal intubation, while animals are intubated and after extubation in dogs and cats; and 3) whether sociodemographic, practice-specific and technical aspects affect the incidence of these complications.

We hypothesized that veterinary anaesthesiologists perceive endotracheal intubation in dogs and cats as a safe procedure with a low risk of complications, but that minor complications happen frequently. We further hypothesized that there is a significant difference in the perceived incidence of complications secondary to endotracheal intubation between dogs and cats. Finally, we hypothesized that sociodemographic, practice-specific and technical aspects affect the perceived incidence of these complications.

Materials and methods

A closed, web-based survey was designed using the software Alchemer (Louisville, CO, USA). The target population included Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia (ACVAA and ECVAA, respectively). For the purpose of writing the manuscript, the term 'anaesthesiologist' was applied to all participants.

The national ethics committee of the Medical University Vienna (Austria) deemed that no approval was required for this study (Ref: 005_001). Participants' consent for data collection was ensured by a statement in the invitation e-mail and on the first page of the survey. Participation was anonymous, confidential and voluntary. No incentives were offered to participants. Responses were automatically anonymized and neither internet protocol addresses nor other identifying data were available to the authors.

The survey was developed based on relevant literature for endotracheal intubation and guidelines for the development of online surveys, including the 'Checklist for Reporting Results of Internet E-Surveys (CHERRIES; Eysenbach 2004; Bennett 2020). The survey underwent two stages of pre-testing. In the first stage, cognitive interviews (Presser et al. 2004; Campanelli 2008) with five specialists in veterinary anaesthesiology or emergency and critical care were performed to determine whether wording and content could lead to uncertainties or misunderstandings by the respondents. In the second stage, an online pre-test phase was conducted with 21 anaesthesiologists. Relevant comments that were likely to improve the quality of data were incorporated into the final version of the survey.

E-mail invitations containing a link to the online questionnaire were sent by the executive secretaries of the ACVAA and ECVAA to their members. The ECVAA invited 360 members (179 Diplomates and 181 Residents, or residency trained individuals) on 26 May 2021, and the ACVAA invited 358 members (278 Diplomates and 80 Residents, or residency trained individuals) on 16 May 2021. E-mail reminders were sent 2 weeks after the initial invitation. Additionally, the survey was announced on the ECVAA Residents' Facebook group on 9 June 2021 (Klonner 2021). The survey was closed on 24 June 2021. The invitation provided information about the background of the study, the participating university, ethical approval and rights of participants during the reply process.

The survey consisted of four sections focusing on sociodemographic and practice-related factors, general aspects concerning endotracheal intubation, endotracheal tube (ETT) cuff inflation, cuff pressure measurement and complications secondary to endotracheal intubation (Appendix SA). The present study comprises a subset of data obtained from the survey. The data presented here focused on the attitudes of anaesthesiologists towards endotracheal intubation and the perceived complications secondary to endotracheal intubation. The following questions were included in this study.

The first section included 12 close-ended questions (1−12) that provided information on sociodemographic and practice-specific factors.

The second section included six single-choice questions (14−19) that focused on the frequency of intubation in dogs and cats undergoing GA, the number of dogs and cats intubated per week by the participant, and the frequency of difficult intubations. Additionally, three single-choice questions (28−30) on the use of a stylet/bougie, lidocaine spray and lubrication during intubation were included. This section also included eight statements to examine the anaesthesiologists' attitude towards endotracheal intubation in dogs and cats (question 20). Participants were asked to indicate their level of

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agreement from 1 'strongly disagree' to 5 'strongly agree' and 6 'I don't know'. Finally, the perceived occurrence of seven specific complications during endotracheal intubation was queried using the responses from 1 'never' to 5 'always' and 6 'I don't know' (questions 33 and 34).

The third section included two single-choice questions (35 and 38) related to the participants' attitudes towards cuff pressure measurement and reassessment of cuff pressure during anaesthesia.

The final section included four matrix-style questions (41–44). The first two questions queried seven complications seen while animals were intubated, the second two questions queried 10 complications seen after animals were extubated. Participants were requested to indicate the perceived frequency of occurrence from 1 'never' to 5 'very often' and 6 'I don't know'.

Questions could be skipped, enabling participants to finish one or more sections without answering all questions. Respondents were able to review/change their answers until submission of the completed survey.

Data analysis

The statistical software IBM SPSS Statistics version 27.0 (IBM Corporation, Armonk, NY, USA) was used to conduct all analyses. Univariate descriptive statistics are presented in tables or text. Using the results from questions 33, 34 and 41–44, a mean incidence score (MIS) ranging from 1 (never) to 5 (always/very often) was derived by taking the mean value of all answers from the respondents for each specific complication.

For bivariate statistics, Wilcoxon signed-rank tests were conducted to identify differences between dogs and cats for several factors. These factors included general attitudes towards endotracheal intubation, the average number of cases undergoing GA in the facility, the percentage of anaesthetized animals that were intubated, number of animals intubated by the participant per week and the percentage of intubations that were perceived as difficult. In addition, Wilcoxon signed-rank tests were used to identify differences between dogs and cats in relation to the specific complications that may have occurred during endotracheal intubation, while the animals were intubated or after extubation.

Binary logistic regression analyses were conducted separately for dogs and cats to examine the effects of sociodemographic, practice-specific and technical aspects of intubation on the perceived incidence of complications: Tables S1–S3 include information about specific complications (dependent variables), dichotomization of the dependent variables and the predictor variables included in the survey.

Results

A total of 61 partial and 191 complete responses to the survey were collected. Overall response rate was 35.1%, with a completion rate of 26.6%. After review of the data, 59 responses were excluded due to missing answers to questions analysed in this study. Thus, 193 responses were included for statistical analysis, representing 21.8% of all ACVAA and 29.7% of all ECVAA respondents. Detailed information about specific sociodemographic as well as practice-specific data for the whole study population are listed in Table S4.

Attitudes of anaesthesiologists towards endotracheal intubation in dogs and cats

More than 95% of the participants agreed that intubation is a key element of state-of-the-art anaesthesia. Agreement with the statement that 'intubation should be performed in every patient undergoing general anaesthesia' was significantly higher for dogs (90.7%) than for cats (75.6%; $p < 0.001$). Similarly, more respondents agreed with the statement that 'intubation reduces mortality' in dogs (88%) compared with cats (76.6%; $p < 0.001$). The same species difference was found regarding the statement that 'intubation carries a low incidence of complications', which was found to be 94.3% in dogs *versus* 71.0% in cats ($p < 0.001$).

Caseload, frequency of endotracheal intubation and difficulties with endotracheal intubation in dogs and cats

An average caseload of more than 20 cases per week was indicated by 81.4% of the respondents when referring to dogs and 21.0% of the respondents when referring to cats ($p < 0.001$). Subsequently, participants reported that significantly more dogs were intubated per week than cats ($p < 0.001$). Most respondents indicated that endotracheal intubation was performed in 91–100% of their cases undergoing GA, but dogs were significantly more likely to be intubated during GA than cats (95.3% *versus* 88.0% respectively, $p < 0.001$). Difficult intubation was reported in less than 10% of cases by 83.3%, that is most participants, when referring to dogs, whereas 62.0% of participants indicated the same when referring to cats. Similarly, difficult intubation was reported in greater than 10% of cases significantly more often in cats than in dogs (36.2% *versus* 16.1%, $p < 0.001$).

Compared with Diplomates, Residents and residency trained participants intubated on average more dogs ($p < 0.001$) and cats ($p = 0.039$) per week. However, no significant differences between the groups were identified for the perceived incidence of difficult intubations.

Complications secondary to endotracheal intubation in dogs and cats

In the following sections, results are provided to a greater level of detail regarding complications during endotracheal intubation, while animals were intubated and after extubation. All queried complications with their respective MIS were ranked from highest to lowest for dogs and cats (Table 1).

Table 1 Complications secondary to endotracheal intubation in dogs and cats ranked from highest to lowest incidence. Data were obtained via an anonymous online survey distributed to Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia

Rank	Dogs		Cats	
	Complication	MIS ± SD	Complication	MIS ± SD
1	Cuff leak	3.20 ± 0.71*	Coughing during intubation	3.01 ± 0.67*
2	Coughing during intubation	3.10 ± 0.56*	Laryngeal spasm during intubation	2.91 ± 0.87*
3	Coughing after extubation	2.53 ± 0.67	Cuff leak	2.77 ± 0.77*
4	Accidental oesophageal intubation	2.45 ± 0.64*	Endotracheal tube occlusion	2.69 ± 0.63*
5	Difficulties visualizing the larynx	2.43 ± 0.57*	Accidental extubation	2.39 ± 0.67
6	Accidental extubation	2.37 ± 0.60	Coughing after extubation	2.38 ± 0.76
7	Endotracheal tube displacement	2.29 ± 0.64	Accidental oesophageal intubation	2.31 ± 0.71*
8	Endotracheal tube occlusion	2.27 ± 0.57*	Endotracheal tube displacement	2.30 ± 0.66
9	Blood on the tube after extubation	2.21 ± 0.53*	Difficulties visualising larynx during intubation	2.17 ± 0.68*
10	Bronchial intubation or accidental one-lung intubation	2.13 ± 0.54*	Blood on the tube after extubation	2.08 ± 0.57*
11	Difficulties breathing after extubation	1.92 ± 0.68*	Bronchial intubation or accidental one-lung intubation	1.99 ± 0.66*
12	Laryngeal oedema after extubation	1.89 ± 0.56	Laryngeal oedema after extubation	1.93 ± 0.66
13	Bronchitis or pneumonia after extubation	1.88 ± 0.61*	Difficulties breathing after extubation	1.75 ± 0.62*
14	Laryngeal spasm during intubation	1.64 ± 0.59*	Laryngeal laceration or trauma during intubation	1.68 ± 0.69*
15	Ruptured cuff	1.62 ± 0.62*	Bronchitis or pneumonia after extubation	1.67 ± 0.57*
16	Cuff herniation	1.54 ± 0.61*	Ruptured cuff	1.45 ± 0.60*
17	Change of voice after extubation	1.51 ± 0.63*	Tracheal necrosis or rupture after extubation	1.42 ± 0.53*
18	Laryngeal laceration or trauma during intubation	1.48 ± 0.61*	Difficulties swallowing after extubation	1.41 ± 0.53
19	Difficulties swallowing after extubation	1.47 ± 0.55	Cuff herniation	1.36 ± 0.55*
20	Cuff not deflatable	1.42 ± 0.52*	Change of voice after extubation	1.35 ± 0.55*
21	Dental damage during intubation	1.32 ± 0.58	Cuff not deflatable	1.30 ± 0.47*
22	Tracheal stenosis after extubation	1.26 ± 0.44	Dental damage during intubation	1.29 ± 0.58
23	Tracheal necrosis or rupture after extubation	1.22 ± 0.42*	Tracheal stenosis after extubation	1.27 ± 0.48
24	Loss of voice after extubation	1.22 ± 0.42	Loss of voice after extubation	1.20 ± 0.43

MIS, mean incidence score ranging from 1 (never) to 5 (always/very often); SD, standard deviation. *Significant difference between the species.

Complications during endotracheal intubation in dogs and cats

The complication with the highest MIS during endotracheal intubation was reported to be coughing in both species (MIS 3.10 and 3.01 for dogs and cats, respectively). Second-ranked complications were laryngeal spasm in cats (MIS 2.91) and difficulties visualizing the larynx in dogs (MIS 2.43), followed by accidental oesophageal intubation for both species (MIS 2.45 and 2.31 for dogs and cats, respectively). Anaesthesiologists who performed fewer endotracheal intubations in dogs per week indicated a higher perceived incidence of oesophageal intubation ($p = 0.010$) and coughing during endotracheal intubation compared with respondents who intubated dogs more frequently ($p = 0.023$; Table S1). Likewise, younger anaesthesiologists stated a significantly higher perceived incidence of coughing observed during endotracheal intubation compared with older respondents ($p = 0.003$). With MIS of 1.64 *versus* 2.91, laryngeal spasm was significantly less often reported in dogs compared with cats ($p < 0.001$; Table 2). Laryngeal spasm in dogs was positively associated with a greater number of dogs administered GA per week ($p = 0.014$). Additionally, a positive association between the use of a stylet and reported occurrence of laryngeal spasm in cats was identified ($p < 0.001$; Table S2). While less frequently reported than laryngeal spasm, laryngeal laceration or trauma was also perceived to be seen significantly more often in cats (MIS 1.68) than in dogs (MIS 1.48; $p < 0.001$). Difficulty visualizing the larynx ($p < 0.001$), accidental oesophageal intubation ($p = 0.001$), accidental bronchial or one-lung intubation ($p = 0.001$) and coughing ($p = 0.037$) were complications during endotracheal intubation that were reported significantly more often in dogs than in cats (Table 2).

Complications while animals were intubated

Leakage of the ETT cuff was the most commonly reported complication in both species while animals were intubated, with MIS of 3.20 and 2.77 in dogs and cats, respectively. This complication was perceived to be seen significantly more often in dogs than in cats ($p < 0.001$; Table 3). Regression analysis revealed no significant association of sociodemographic or practice-specific factors with leakage of the ETT cuff (Table S2). In cats, the second most commonly reported complication was occlusion of the ETT (MIS 2.69), which was perceived to be seen significantly more frequently than in dogs ($p < 0.001$;

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Table 2 'How often do you see the following complications during intubation of dogs and cats?' Relative frequencies and mean incidence scores of complications during intubation in dogs and cats. Data were obtained via an anonymous online survey distributed to Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia

	Dogs ($n = 191–193$)		**Cats ($n = 190–193$)**		***p****
	n	**%**	***n***	**%**	
Laryngeal spasm					< 0.001
Never	80	41.7	9	4.7	
Rarely	101	52.6	53	27.5	
Sometimes	11	5.7	79	40.9	
Often	–	50	25.9		
Always	–	2	1.0		
I don't know	–	–			
Difficulties visualizing the larynx					< 0.001
Never	5	2.6	25	13.1	
Rarely	103	53.6	113	59.2	
Sometimes	81	42.2	48	25.1	
Often	3	1.6	5	2.6	
Always	–	–			
I don't know	–	–			
Dental damage					0.353
Never	139	72.8	142	74.3	
Rarely	45	23.6	42	22.0	
Sometimes	3	1.6	5	2.6	
Often	3	1.6	1	0.5	
Always	–	–			
I don't know	1	0.5	1	0.5	
Laryngeal laceration or trauma					< 0.001
Never	108	56.3	83	43.5	
Rarely	73	38.0	83	43.5	
Sometimes	8	4.2	21	11.0	
Often	1	0.5	1	0.5	
Always	–	–			
I don't know	2	1.0	3	1.6	
Accidental oesophageal intubation					0.001
Never	11	5.7	23	12.0	
Rarely	88	45.6	91	47.4	
Sometimes	90	46.6	74	38.5	
Often	4	2.1	4	2.1	
Always	–	–			
I don't know	–	–			
Coughing					0.037
Never	1	0.5	1	0.5	
Rarely	18	9.4	38	19.8	
Sometimes	133	69.3	113	58.9	
Often	40	20.8	39	20.3	
Always	–	1	0.5		
I don't know	–	–			
Bronchial intubation or accidental one-lung intubation					0.001
Never	16	8.3	40	21.1	
Rarely	134	69.8	110	57.9	
Sometimes	39	20.3	37	19.5	
Often	1	0.5	1	0.5	
Always	–	–			
I don't know	2	1.0	2	1.1	

Never, 1; Rarely, 2; Sometimes, 3; Often, 4; Always, 5; I don't know, 6. *Related-samples Wilcoxon signed-rank test: 'I don't know' answer option excluded from analyses.

Table 3 'How often do you see the following complications in dogs and cats while they are intubated?' Relative frequencies and mean incidence scores of complications in dogs and cats while intubated. Data were obtained via an anonymous online survey distributed to Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia

	Dogs ($n = 181–183$)		Cats ($n = 182$)		p*
	n	%	*n*	%	
Endotracheal tube displacement					0.647
Never	13	7.1	15	8.2	
Rarely	109	59.9	102	56.0	
Sometimes	55	30.2	60	33.0	
Often	5	2.7	5	2.7	
Very often	–		–		
I don't know	–		–		
Cuff herniation					< 0.001
Never	93	51.4	120	65.9	
Rarely	73	40.3	53	29.1	
Sometimes	11	6.1	6	3.3	
Often	–		–		
Very often	–		–		
I don't know	4	2.2	3	1.6	
Endotracheal tube occlusion (e.g. due to mucus, kinked tube)					< 0.001
Never	9	4.9	2	1.1	
Rarely	116	63.7	67	36.8	
Sometimes	55	30.2	98	53.8	
Often	2	1.1	15	8.2	
Very often	–		–		
I don't know	–		–		
Accidental extubation					0.688
Never	8	4.4	12	6.6	
Rarely	102	55.7	93	51.1	
Sometimes	70	38.3	72	39.6	
Often	3	1.6	4	2.2	
Very often	–		1	0.5	
I don't know	–		–		
Cuff leak					< 0.001
Never	1	0.5	8	4.4	
Rarely	23	12.6	52	28.6	
Sometimes	102	55.7	99	54.4	
Often	52	28.4	20	11.0	
Very often	5	2.7	3	1.6	
I don't know	–		–		
Ruptured cuff					< 0.001
Never	83	45.6	110	60.4	
Rarely	86	47.3	63	34.6	
Sometimes	13	7.1	9	4.9	
Often	–		–		
Very often	–		–		
I don't know	–		–		
Cuff cannot be deflated (i.e. before extubation)					< 0.001
Never	108	59.3	128	70.3	
Rarely	72	39.6	53	29.1	
Sometimes	2	1.1	1	0.5	
Often	–		–		
Very often	–		–		
I don't know	–		–		

Never, 1; Rarely, 2; Sometimes, 3; Often, 4; Always, 5; I don't know, 6. *Related-samples Wilcoxon signed-rank test: 'I don't know' answer option excluded from analyses.

Table 3). Further significant differences between the species were found for cuff herniation ($p < 0.001$) and rupture of the cuff ($p < 0.01$; Table 3). For cuff herniation, no significant association with sociodemographic or practice-specific factors could be found (Table S2).

Complications after extubation

These were reported to be infrequent (Table 4). The complication with the highest MIS after extubation was coughing in both species (MIS 2.52 and 2.38 for dogs and cats, respectively). With MIS of 2.21 for dogs and 2.08 for cats, blood on the tube after extubation was the only other complication with MIS greater than 2, suggesting a relative frequency more often than 'rarely'. Tracheal necrosis or rupture was significantly more often reported in cats than in dogs ($p < 0.001$; Table 4). A positive association between reassessment of cuff pressure after initial inflation and tracheal necrosis and rupture in cats was found ($p = 0.008$; Table S2). Blood on the tube ($p = 0.001$), change of voice ($p = 0.001$), difficulty breathing ($p < 0.001$) and bronchitis or pneumonia ($p < 0.001$) after extubation were reported more often in dogs than in cats (Table 4). Regression analyses indicated that members of the ACVAA reported a significantly higher incidence of bronchitis or pneumonia after extubation in dogs compared with members of the ECVAA ($p = 0.027$; Table S3).

Discussion

This study aimed to examine the attitude of veterinary anaesthesiologists towards endotracheal intubation, the perceived incidence of complications secondary to endotracheal intubation in dogs and cats, and if sociodemographic, practice-specific and technical aspects affect the incidence of these complications.

Respondents stated that the majority of dogs and cats undergoing GA at their facilities were intubated. Anaesthesiologists surveyed in this study considered endotracheal intubation as an integral part of modern anaesthesia and, despite significant differences between dogs and cats, reported a low

Table 4 'How often do you see the following complications in dogs and cats after being extubated?' Relative frequencies and mean incidence scores of complications after extubation in dogs and cats. Data were obtained via an anonymous online survey distributed to Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia

	Dogs (n = 182–184)		Cats (n = 182–183)		p*
	n	%	*n*	%	
Coughing					0.130
Never	5	2.7	20	10.9	
Rarely	87	47.5	83	45.4	
Sometimes	73	39.9	66	36.1	
Often	13	7.1	11	6.0	
Very often	–	–			
I don't know	5	2.7	3	1.6	
Blood on the tube					0.001
Never	10	5.4	22	12.0	
Rarely	124	67.4	125	68.3	
Sometimes	49	26.6	34	18.6	
Often	–	1	0.5		
Very often	–	–			
I don't know	1	0.5	1	0.5	
Laryngeal oedema					0.515
Never	35	19.2	43	23.6	
Rarely	117	63.9	95	52.2	
Sometimes	15	8.2	31	17.0	
Often	1	0.5	–		
Very often	–	–			
I don't know	15	8.2	13	7.1	
Tracheal necrosis or rupture					< 0.001
Never	139	76.0	107	58.5	
Rarely	40	21.9	70	38.3	
Sometimes	–	3	1.6		
Often	–	–			
Very often	–	–			
I don't know	4	2.2	3	1.6	
Change of voice					0.001
Never	79	43.2	96	52.5	
Rarely	55	30.1	38	20.8	
Sometimes	7	3.8	5	2.7	
Often	1	0.5	–		
Very often	–	–			
I don't know	41	22.4	44	24.0	
Loss of voice					0.439
Never	117	63.9	120	65.6	
Rarely	33	18.0	25	13.7	
Sometimes	–	2	1.1		
Often	–	–			
Very often	–	–			
I don't know	33	18.0	36	19.7	
Difficulties with breathing					< 0.001
Never	48	26.2	63	34.4	
Rarely	99	54.1	100	54.6	
Sometimes	31	16.9	18	9.8	
Often	1	0.5	–		
Very often	–	–			
I don't know	4	2.2	2	1.1	
Difficulties with swallowing					0.124
Never	93	51.1	102	56.0	
Rarely	71	39.0	62	43.1	
Sometimes	4	2.2	3	1.6	
Often	–				
Very often	–				
I don't know	14	7.7	15	8.2	
Tracheal stenosis					0.670
Never	125	68.7	126	69.2	
Rarely	43	23.6	39	21.4	
Sometimes	–	3	1.6		
Often	–	–			
Very often	–	–			
I don't know	14	7.7	14	7.7	
Bronchitis or pneumonia					< 0.001
Never	43	23.6	66	36.3	
Rarely	105	57.7	96	52.7	
Sometimes	23	12.6	9	4.9	
Often	–	–			
Very often	–	–			
I don't know	11	6.0	11	6.0	

Never, 1; Rarely, 2; Sometimes, 3; Often, 4; Always, 5; I don't know, 6. *Related-samples Wilcoxon signed-rank test: 'I don't know' answer option excluded from analyses.

perceived rate of complications associated with it. Respondents also reported that severe complications secondary to endotracheal intubation were infrequent, with minor complications, such as cuff leakage, being more common. Sociodemographic and practice-specific aspects were not shown to influence most complications occurring secondary to endotracheal intubation, and they did not appear to play a significant role in their occurrence in the surveyed group of anaesthesiologists.

Although endotracheal intubation was viewed as a key element in state-of-the-art anaesthesia regardless of species, cats were less likely to be intubated compared with dogs. This finding is in agreement with other studies (Wagner & Hellyer 2000; Nicholson & Watson 2001). Endotracheal intubation was found to increase the risk of complications and the odds of death in cats undergoing GA (Clarke & Hall 1990; Dyson et al. 1998; Brodbelt et al. 2008). The reason for this might be a significantly higher percentage of difficult intubations in cats, as reported in this and other studies (Taylor 1994; Wagner & Hellyer 2000; Nicholson & Watson 2001). Besides the fact that the feline airway is small and delicate, a contributing factor to difficult intubation might be the lower number of cats

being intubated by anaesthesiologists resulting in a lack of routine practice compared with dogs. Nonetheless, the reported frequency of difficult intubations in cats was similar between Diplomates and Residents, despite the latter intubating more cats on a weekly basis.

Coughing was found to be the most frequently reported complication during intubation for both dogs and cats. Coughing during endotracheal intubation can be a result of insufficient anaesthetic depth. Younger respondents, as well as those who intubate fewer animals per week, reported coughing during endotracheal intubation in dogs and cats more often compared with older respondents or respondents performing endotracheal intubation more frequently. A possible explanation for this could be less experience and/or routine in endotracheal intubation. This assumption may be supported by the fact that respondents who intubate fewer dogs per week have reported a significantly higher occurrence of coughing than participants with a higher weekly caseload.

Accidental oesophageal intubation was identified as the second and third highest-ranked reported complication during intubation in dogs and cats, respectively. This is in agreement with the results obtained in a study on anaesthesia safety incidents, in which oesophageal intubation was one of the most documented incidents (21.6%; Hofmeister et al. 2014).

Laryngeal spasm was found to be the second most frequently reported complication during endotracheal intubation in cats. It is well known that cats are prone to laryngeal spasm after mechanical stimulation of the soft palate, pharynx or anterior larynx (Rex 1971). Contrary to our expectations, results of the present study showed a positive association between the use of a stylet or bougie to aid endotracheal intubation and the reported incidence of laryngeal spasm in cats. It is possible that due to mechanical stimulation of the larynx, the use of a stylet could present a primary cause for laryngeal spasm. However, it is also possible that respondents experiencing a high incidence of laryngeal spasm might just be more likely to routinely use these tools to aid endotracheal intubation in cats.

While laryngeal spasm was considered a rare event in dogs, there was a substantially higher reported incidence of difficulties visualizing the larynx in dogs compared with cats. Although this might be explained by the increasing prevalence of brachycephalic dog breeds, it is not possible to draw this conclusion as our study did not address the percentage of brachycephalic dog and cats undergoing GA. Therefore, further studies focused on brachycephalic breeds and the associated risk of complications secondary to endotracheal intubation are warranted.

A leak of the ETT cuff was the most frequently reported complication while the trachea was intubated, and the perceived frequency was significantly higher in dogs than in cats. The significant difference in cuff leakage between dogs and cats could be explained by the difference in the size of the cuffs. As the inner diameter of a high-volume, low-pressure cuffed ETT increases, the size of the cuff increases exponentially. Additionally, larger cuffs have a higher surface area, which causes more longitudinal folds and therefore a higher chance for leaks (Hwang et al. 2011).

In cats, occlusion of the ETT was the second most frequently reported complication while the trachea was intubated, and it was reported to occur significantly more often in cats than in dogs. An explanation for this might be that smaller sized ETTs are more prone to occlusion by biological material (e.g. mucus, blood or pus) or by mechanical means (e.g. kinking, compression or cuff herniation).

Blood on the ETT and coughing after extubation are commonly observed complications in human medicine (Pacheco-Lopez et al. 2014). Likewise, these were also the most commonly reported complications in this survey for both dogs and cats. Even when using an appropriate and careful technique, endotracheal intubation consists of the introduction of a foreign body into the trachea and as such, it can lead to irritation of the upper respiratory tract. This damage might result in blood on the ETT and might lead to coughing. In addition, overinflation of the endotracheal cuff or lack of monitoring of ETT cuff pressure might further exacerbate these complications (Liu et al. 2010; Hockey et al. 2016).

Difficulty breathing after extubation was reported in 16% of dogs and 9% of cats. The incidence of respiratory distress in dogs being almost twice that compared with cats after extubation could be explained by a higher prevalence of brachycephalic dog breeds, but it is not possible to draw this conclusion as our survey did not study the association between this complication and brachycephalic animals.

In this study, the perceived incidence of tracheal necrosis or rupture in cats was reported to be very low (MIS 1.42). However, a significant association between reassessment of ETT cuff pressure and the perceived incidence of tracheal necrosis or rupture was observed ($p = 0.008$). The authors believe that this finding does not provide evidence that cuff pressure reassessment increases the risk for tracheal necrosis, but rather that respondents who experienced tracheal necrosis or rupture in their practice are more likely to implement regular cuff pressure reassessment as a means of preventing this complication. Similarly, awareness of the literature could also lead to preventative action by the respondents. Further studies are necessary to determine if a causal relation between reassessment of ETT cuff pressure and incidence of tracheal damage exists.

Although our findings provide the first insights into complications secondary to endotracheal intubation in dogs and cats, this study has limitations. First, the study population was limited to Diplomates, Residents and residency trained members of the ACVAA or ECVAA in order to investigate a more

defined population with a high frequency of endotracheal intubation. However, the assumed high standard of care, knowledge and technical skill may have resulted in a potential bias. Second, most participants reported to work in a university setting. Conclusions regarding the perceived incidence of complications for the general population of veterinarians in other work settings could therefore not be drawn from this study. Future studies surveying general practitioners about their attitudes towards endotracheal intubation in dogs and cats and perceived complications secondary to endotracheal intubation are warranted. Third, survey responses are subjective and rely on self-awareness and recollection of events. A respondent's attitude towards endotracheal intubation might bias how they answer specific questions due to possible (socially) desirable responding (Paulhus 1991), yea-saying (Baumgartner & Steenkamp 2005) or nay-saying (Baumgartner & Steenkamp 2001). While precise quantification can only be reached with a prospective design, the understanding of the survey's questions was assessed using interviews and written feedback. Despite this, interpretation of some answers might not have been the same for every respondent. Third, in relation to the binary regression analyses, dichotomization of the ordinal scaled variables may have led to a certain loss of information. However, based on data obtained and the distribution of responses, conducting ordinal regression analyses would have resulted in questionable findings (Bender & Grouven 1998). Hence, binary regression analyses seemed to be the preferable model, leading to more valid results. Finally, it is important to note that the incidence of complications after extubation might be misrepresented as some are only noticed several hours or even days after GA, for example tracheal necrosis. These variables were not included in the survey, and it is likely that most of the respondents were not involved in the follow-up of the animals. Further studies investigating long-term complications secondary to endotracheal intubation are warranted.

Conclusion

Veterinary anaesthetists who responded to the survey considered endotracheal intubation as a state-of-the-art technique during GA in dogs and cats. Benefits were perceived to be greater in dogs than in cats, while the incidence of complications was perceived to be lower in dogs than in cats. Based on the results presented, major complications were reported infrequently in both dogs and cats. Differences in complications between dogs and cats should be considered to improve anaesthesia safety. Further prospective studies are needed to quantify and qualify the relevance of complications secondary to endotracheal intubation in dogs and cats, including the potential impact of brachycephalic breeds on the incidence of these complications.

Acknowledgements

The authors thank the anaesthesiologists who participated in the study and the veterinarians who participated in the cognitive and online pre-test. Further thanks goes to the American and European College of Veterinary Anaesthesia and Analgesia for their support in distributing the survey among members. No funding was received for this study.

Authors' contributions

MEK: investigation, methodology, statistical analysis, visualization, original draft of the manuscript. SS: investigation, methodology, statistical analysis, data curation, critical revision of the manuscript. CB: supervision and critical revision of the manuscript. All authors contributed substantially to the conceptualization of the study, study design and data interpretation. All authors approved the final version.

Conflict of interest statement

The authors declare no conflict of interest.

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Received 13 May 2022; accepted 9 February 2023.

Available online 21 February 2023

Supporting Information

Additional Supporting Information may be found in the online version of this article: https://doi.org/10.1016/j.vaa.2023.02.007.

Table S1. Binary logistic regression analysis of respondents' sociodemographic, practice-specific and technical aspects on the perceived incidence of complications during endotracheal intubation in dogs and cats.

Table S2. Binary logistic regression analysis of respondents' sociodemographic, practice-specific and technical aspects on the perceived incidence of complications in dogs and cats while intubated.

Table S3. Binary logistic regression analysis of respondents' sociodemographic, practice-specific and technical aspects on the perceived incidence of complications after extubation in dogs and cats.

Table S4. Sociodemographic data obtained via an anonymous online survey distributed to Diplomates, Residents and residency trained members of the American and European Colleges of Veterinary An(a)esthesia and Analgesia.