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Postoperative pulmonary complications in veterinary anaesthesia: Current definitions and presence in veterinary scientific literature – a scoping review

Diplomarbeit

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1. INTRODUCTION

Postoperative pulmonary complications (PPC) are a common problem in human medicine. On average postoperative pulmonary complications occur in < 1 to 23 % of surgical procedures and happen more frequently than cardiac complications (Miskovic and Lumb 2017). In cases in which the respiratory tract is not directly affected by the surgery or the thorax is not opened during the operation, the respiratory system can be stressed by the anaesthesia alone. Anaesthesia has a depressing effect on the central respiratory drive as anaesthetic drugs influence the response to hypercapnia and hypoxia. To compensate this effect and to avoid hypoxaemia, artificial ventilation is commonly used, which in turn can cause ventilator induced lung injury, too. The development of atelectasis and reduced lung volume also contribute to lung pathologies which can lead to PPC (Miskovic and Lumb 2017). Postoperative pulmonary complications can become severe or exacerbate existing symptoms, leading to a life-threatening condition. Systemic inflammation, like systemic inflammatory response syndrome (SIRS) or sepsis, aspiration pneumonia or pulmonary contusions can lead to inflammation of the lungs and thus, to acute respiratory distress syndrome (ARDS). The ARDS is characterized by oedema and infiltration of inflammatory cells in the lungs and is associated with high mortality. In instances of respiratory insufficiency and thus, a permanent lack of oxygen, it can lead to multiple organ dysfunction syndrome (MODS) and shock (Brady and King 2000). Thus, unsurprisingly PPC significantly increases mortality in people with 14-30 % of those with a PPC dying after 30 days of major surgery versus 0.2-3 % without a PPC (Miskovic and Lumb 2017). In veterinary medicine pulmonary complications in the perioperative period are considered of high relevance, with 30-40 % of anaesthesia-related deaths in dogs and 40-50 % in cats considered due to respiratory complications before, during or after anaesthesia (Brodbelt et al. 2015). Aspiration pneumonia as one specific type of PPC has been reported in 0.17 % of dogs undergoing anaesthesia (Wilson and Shih 2015).

Yet, only two studies, which are companion papers, specifically looked at postoperative pulmonary complications (Alwood et al. 2006, Brainard et al. 2006). The incidence of PPC of

22.2 % in dogs after abdominal surgery was comparable to the ones described in human medicine (Alwood et al. 2006).

In human medicine multiple risk factors for developing PPC are known. These include age, pre-existing pulmonary diseases, body mass index, transfusion therapy during surgery, surgical site/type of surgery (thoracic, abdominal, and orthopaedic), perioperative mechanical ventilation, American Society of Anaesthesiologists Physical Score (ASA-PS) status, type of analgesic protocol used and the presence of septic peritonitis. In veterinary medicine Alwood et al. (2006) found only limited risk factors in their study of 162 dogs undergoing laparotomy. Of these, dogs with perioperative vomiting and biliary or septic peritonitis were of increased risk for PPC (Alwood et al. 2006).

Besides a lack of focused literature in veterinary medicine, a universal problem pertains to the definition of PPC in a systematic and transparent manner. An European joint taskforce published in 2015 guidelines for perioperative clinical outcome (EPCO) definitions in human medicine. According to these, PPC includes respiratory infection, respiratory failure, pleural effusion, pulmonary oedema, pulmonary embolism, atelectasis, pneumothorax, bronchospasm, tracheobronchitis, pneumonia, aspiration pneumonitis and acute respiratory distress syndrome (Miskovic and Lumb 2017). There are currently no comparable guidelines to the authors knowledge in veterinary medicine.

While numerous scientific articles elucidate the topic of PPC in human medicine including its risk factors, in veterinary medicine, postoperative pulmonary complications are considered to play an important role, too (Brodbelt et al. 2015). The scientific publications, however, in the field of veterinary medicine regarding PPC are scarce.

The aim of this descriptive literature review was to provide a brief overview of the existing literature related to PPC in veterinary medicine. Specifically, articles were searched for their **definition** of PPC, **domestic species** reported in, and potential **influential context** (e.g. type of surgery or medications).

2. MATERIAL AND METHODS

An initial search with vetmedseeker of the library of the University of Veterinary Medicine in Vienna was performed using “postoperative pulmonary complications” as the main keywords. In the field of veterinary medicine two articles by Alwood et al. (2006) and Brainard et al. (2006) were found that were relevant and reported on the topic of PPC in general in canine undergoing laparotomy. These articles served as a basis for developing further keywords, since PPC as a keyword did not lead to many hits. Thus, synonyms and symptoms that were associated with PPC in these articles were also included as keywords. In addition, the keyword PPC was adapted by adding fewer specific forms such as “postoperative complications” or “postanaesthetic complications” as keywords. A list of all keywords and the number of hits they produced in each database can be found in the appendix (see S1). A search of databases was then carried out using the following search engines (in this order): vetmedseeker of the University Library of the University of Veterinary Medicine in Vienna, PubMed, Scopus, ScienceDirect and Web of Science. The literature search was carried out between April and August 2021, searching for articles in English and German. Species included were dogs, cats and horses. Other species were excluded. Study types included for these articles were primary clinical research studies (prospective and retrospective), case reports, short communications and reviews. Articles were excluded if they reported complications after thoracic surgery, i.e. thoracotomy or lung lobectomy as pulmonary complications are to be expected with these types of operation. Besides thoracic surgery, other exclusion criteria were articles about human medicine and purely laboratory work (ex vivo, in vitro). A time limit regarding the year of publication of the papers was not made.

Considering the sparse nature of dedicated articles in veterinary medicine and thus the broad search strategy, some searches came up with a lot of results. Instead of completely ignoring these searches and only reverting to keywords with lesser hits, the screening of hits was stopped after five result pages (10, 20 or 25 hits/page depending on search engines) did not yield any findings of interest. The sorting mechanism was set to “most relevant”.

In addition, the reference list of articles of interest were studied to identify further articles to be included in this review.

Duplicates were removed. Titles of search results were screened and if a title sounded appropriate, the abstract was accessed for relevant content. If the abstract appeared suitable, the full article was retrieved and checked for information on PPC. Fully screened articles were included when discussing information about PPC or related symptoms within veterinary medicine.

3. RESULTS

A total of 37 articles were included after title and abstract screening. Twenty-seven articles were found through the database search and ten additional articles by screening the reference lists of articles of interest.

Of these 37 articles nine were retrospective studies, nine reviews, ten prospective studies, seven case reports, one was an observational study and one experimental study.

The species most commonly reported were dogs in 24 papers, followed by horses in twelve papers and cats in six papers.

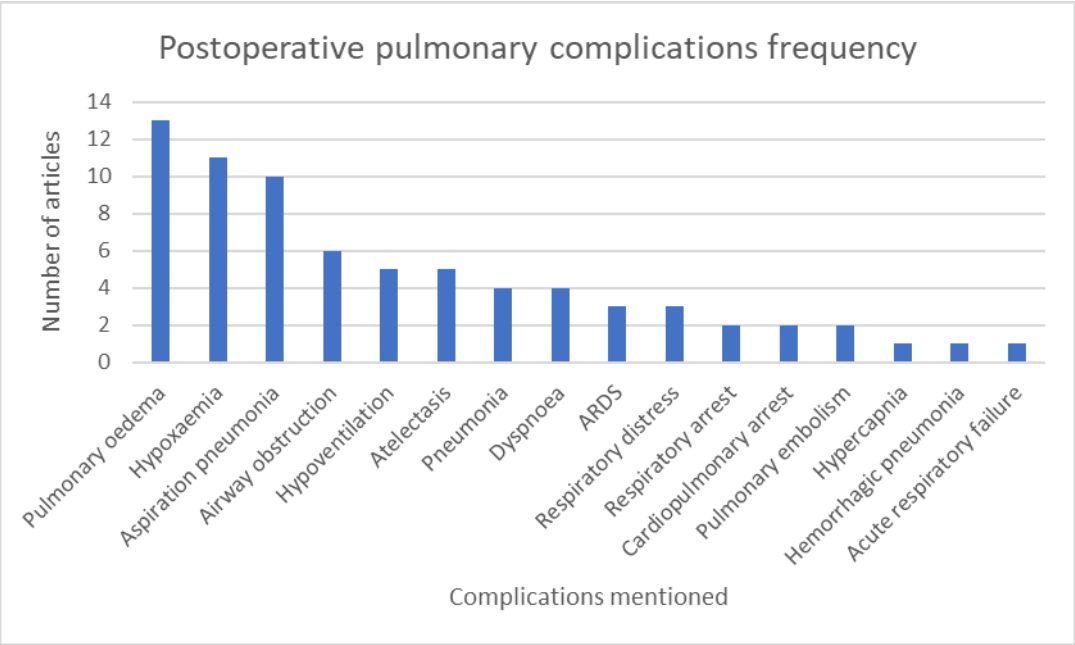
The most frequently mentioned PPCs were pulmonary oedema in horses (nine papers) and dogs (four papers), aspiration pneumonia in dogs (nine papers) and horses (one paper), and hypoxaemia in dogs (ten papers) and horses (one paper).

The surgery methods most commonly examined in the articles were laparotomy (four papers) and intracranial surgery (three papers).

Drugs mentioned in connection with PPC were in most cases opioids (five papers), like (car)fentanyl or morphine, and alpha-2-agonists (four papers), like xylazine or dexmedetomidine.

In only three articles postoperative pulmonary complications were explicitly defined. In the article from Brainard et al. (2006) PPC was defined by evidence of pulmonary disease and/or dyspnoea on physical examination, and development of two or more of the following complications: $SpO_2 < 94$ %, $PaO_2 < 85$ mmHg, radiographic evidence of pulmonary disease or cytologic, microbiologic, or histopathologic evidence of acute infectious or inflammatory pulmonary disease. In the companion article to Brainard et al., i.e. Alwood et al. (2006) symptoms like atelectasis, hypoxaemia, haemorrhage, cardiogenic and non-cardiogenic oedema, acute lung injury, pneumonia, pulmonary thromboembolism and acute respiratory distress syndrome were classified as PPC. Stabile et al. (2021) described in their article the occurrence of hypoxaemia, acute respiratory distress syndrome, pneumonia and acute respiratory failure as PPC.

Table 1: Frequency diagram of PPC mentioned in the articles (dog/cat/horses)



3.1. PPC in connection with mechanical ventilation

Six articles were found that mention PPC in context of mechanical ventilation of anaesthetised patients. Only one of the studies explicitly looked at PPC and also defined the term (Brainard et al. 2006). The other five articles included one review, two prospective studies, one observational study and one case report (see Table 2).

Table 2: Details of articles relating to mechanical ventilation

Authors	Subject of the article	Species	Type of ventilation	Type of PPC mentioned	Definition of PPC? If yes, which?	Type of article
(Rozanski 2015)	Perioperative and postoperative respiratory support	Dog, cat	Intermittent positive pressure ventilation	Hypoxaemia; hypoventilation; upper airway obstruction; (aspiration) pneumonia; pulmonary oedema; atelectasis	No	Review
(Monte et al. 2018)	Comparison of low versus high tidal volume with or without PEEP in healthy dogs	Dog	Positive pressure ventilation with different tidal volumes and PEEP	Hypoventilation; hypoxaemia; atelectasis	No	Prospective study

(Melis et al. 2014)	Pulmonary oedema in a horse and a dog	Horse, dog	Spontaneous ventilation; synchronised intermittent mandatory ventilation	Pulmonary oedema	No	Case report
(Martin-Flores et al. 2020)	Postoperative hypoxaemia in dogs, mechanical ventilation with different fractions of oxygen	Dog	Intermittent positive pressure ventilation	Atelectasis; hypoxaemia	No	Prospective study
(Brainard et al. 2006)	Anaesthetic and perioperative factors for PPC in dogs after laparotomy	Dog	Intermittent positive pressure ventilation	Dyspnoea; $SpO_2 < 94$ %; $PaO_2 < 85$ mmHg; acute infectious or inflammatory pulmonary disease	Physical examination evidence of pulmonary disease and/or dyspnoea; development of two or more of the following complications: $SpO_2 < 94$ %; $PaO_2 < 85$ mmHg; radiographic evidence of pulmonary	Retrospective study

					disease; cytologic, microbiologic, or histopathologic evidence of acute infectious or inflammatory pulmonary disease	
(Farrell et al. 2019)	Pulse oximetry as a surrogate for PaO_2 in awake and anaesthetised dogs	Dog	Mechanical ventilation	Hypoxaemia	No	Observational study

3.2. PPC in connection with surgery methods

Twelve articles were found in which PPCs associated with surgery methods were discussed. In two of them a definition of PPC was given. Six articles were retrospective studies, three articles prospective studies and three reviews (see Table 3).

Table 3: Details of articles relating to surgery methods

Authors	Subject of the article	Type of surgery	Type of PPC mentioned	Definition of PPC? If yes, which?	Type of article
(Brainard et al. 2006)	Anaesthetic and perioperative factors for PPC in dogs after laparotomy	Laparotomy	Dyspnoea; $SpO_2 < 94$ %; $PaO_2 < 85$ mmHg; acute infectious or inflammatory pulmonary disease;	Physical examination evidence of pulmonary disease and/or dyspnoea; development of two or more of the following complications: $SpO_2 < 94$ %; $PaO_2 < 85$ mmHg; radiographic evidence of pulmonary disease; cytologic, microbiologic, or histopathologic evidence of acute infectious or inflammatory pulmonary disease	Retrospective study
(Ovbey et al. 2014)	Procedures, anaesthetic agents and management	Laparotomy, neurosurgery,	Aspiration pneumonia	No	Multicentre, randomised, case-controlled

	factors associated with the development of aspiration pneumonia	thoracotomy, upper airway surgery and endoscopy			retrospective study
(Fransson et al. 2001)	Pneumonia after intracranial surgery in dogs	Craniotomy	Pneumonia (acute dyspnoea, coughing), aspiration pneumonia	No	Retrospective cohort study
(Forward et al. 2018)	Postoperative survival, complications and outcome after intracranial surgery in dogs	Intracranial surgery	Aspiration pneumonia	No	Retrospective case series study
(MacPhail and Monnet 2001)	Postoperative complications and outcomes of surgical treatment of laryngeal paralysis in dogs	Unilateral and bilateral arytenoid lateralization; partial laryngectomy;	Aspiration pneumonia	No	Retrospective study

(Sherman and Karagiannis 2017)	Aspiration pneumonia in the dog	Diagnosis or treatment of intervertebral disk disease (magnetic resonance imaging, computed tomography, hemilaminectomy); unilateral arytenoid lateralization	Aspiration pneumonia	No	Review
(Alwood et al. 2006)	Frequency of PPC in dogs after laparotomy, characterisation of PPC and disease-related risk factors for PPC	Laparotomy	Transient hypoxaemia; hypoventilation; respiratory arrest; pneumonia; acute respiratory distress syndrome;	Atelectasis, hypoxaemia haemorrhage, cardiogenic and non-cardiogenic oedema, acute lung injury, pneumonia, pulmonary thromboembolism, and acute respiratory distress syndrome	Retrospective clinical study
(Liska and Poteet 2003)	Connection between total hip replacement	Total hip replacement surgery	Pulmonary embolism	No	Prospective study

	surgery and pulmonary embolism in dogs				
(Tidwell et al. 2007)	Connection between non-cemented total hip arthroplasty and pulmonary embolism in dogs	Total hip arthroplasty	Pulmonary embolism	No	Prospective study
(Gaynor et al. 1999)	Anaesthesia-associated mortality and complications in dogs and cats	Spinal surgeries; thoracotomies; endoscopies; bronchoscopies;	Hypercapnia, hypoxaemia	No	Prospective study
(Klohnen 2009)	Postoperative complications after abdominal surgery in horses	Exploratory celiotomies	Hemorrhagic pneumonia	No	Review
(Brady and King 2000)	Management of postoperative complications like	Emergency surgery	Acute respiratory distress syndrome, hypoxaemia,	No	Review

	respiratory insufficiency in small animal patients		hypoventilation, aspiration pneumonia		

3.3. PPC in connection with drugs

In eight articles a connection between certain drugs and PPC was mentioned. A definition of PPC was described in only one of these articles. These eight articles included four retrospective studies, two reviews, one prospective study and one case report (see Table 4).

Table 4: Details of articles relating to drugs

Authors	Subject of the article	Species	Type of drugs	Type of PPC mentioned	Definition of PPC? If yes, which?	Type of article
(Boutureira et al. 2007)	Association between ketamine administration and pulmonary oedema	Dog	Ketamine	Pulmonary oedema	No	Case report
(Deutsch and Taylor 2021)	Equine peri-anaesthetic mortality, morbidity and complications; association between pulmonary oedema and carfentanil or xylazine	Horse	Carfentanil, xylazine	Pulmonary oedema	No	Review article
(Senior 2005)	Pathogenesis, diagnosis and	Horse	Xylazine	Pulmonary oedema	No	Review

	treatment of post-anaesthetic pulmonary oedema in horses; relation between xylazine and pulmonary oedema					
(Raekallio et al. 2017)	Adverse reactions of alpha-2-agonists in cats; medetomidine and dexmedetomidine	Cat	Medetomidine; dexmedetomidine;	Pulmonary oedema	No	Retrospective study
(Brainard et al. 2006)	Anaesthetic and perioperative factors for PPC in dogs after laparotomy; PPC in connection with oxymorphone or butorphanol for analgesia postoperatively	Dog	Oxymorphone; butorphanol;	Dyspnoea; SpO_2 < 94 %; PaO_2 < 85 mmHg; acute infectious or inflammatory pulmonary disease;	Physical examination evidence of pulmonary disease and/or dyspnoea; development of two or more of the following complications:	Retrospective study

					SpO_2 < 94 %; PaO_2 < 85 mmHg; radiographic evidence of pulmonary disease; cytologic, microbiologic, or histopathologic evidence of acute infectious or inflammatory pulmonary disease	
(Gozalo-Marcilla et al. 2013)	Comparison of constant-rate infusions with dexmedetomidine versus morphine and their influence on anaesthetic requirements,	Horse	Morphine vs. dexmedetomidine	Pulmonary oedema	No	Prospective, blinded, clinical study

	cardiopulmonary function and recovery quality in anaesthetised horses					
(Ovbey et al. 2014)	Procedures, anaesthetic agents and management factors associated with the development of aspiration pneumonia; connection between aspiration pneumonia and morphine, lidocaine, ketamine, fentanyl and propofol	Dog	Morphine; lidocaine; ketamine; fentanyl; propofol;	Aspiration pneumonia	No	Multicentre, randomised, case-controlled retrospective study
(Ogden et al. 2019)	Cisapride as a possible prevention for postoperative	Dog	Cisapride; butorphanol;	Aspiration pneumonia	No	Retrospective study

	aspiration pneumonia in dogs undergoing unilateral arytenoid lateralization		acepromazine; buprenorphine;			

3.4. PPC in connection with different species

Sixteen articles reported PPC in connection with different species. In one article a definition for PPC was found. Five articles were case reports, four reviews, four prospective studies, two were retrospective studies and one was an experimental study (see Table 5).

Table 5: Details of articles relating to species

Authors	Subject of the article	Type of species	Type of PPC mentioned	Definition of PPC? If yes, which?	Type of article
(Wagner 2008)	Complications in equine anaesthesia, like upper airway obstruction and pulmonary oedema	Horse	Upper airway obstruction; pulmonary oedema	No	Review
(Tute et al. 1996)	Postanaesthetic negative pressure pulmonary oedema in a horse	Horse	Pulmonary oedema	No	Case report
(Veres-Nyéki et al. 2011)	Pulmonary oedema after colic operation, in relation with an in-situ nasogastric tube in a horse	Horse	Pulmonary oedema	No	Case report
(Dugdale and Taylor 2016)	Anaesthesia-associated mortality in horses; post-	Horse	Airway obstruction; pulmonary oedema;	No	Review article

	anaesthesia respiratory obstruction				
(Senior 2005)	Pathogenesis, diagnosis and treatment of post-anaesthetic pulmonary oedema in horses; negative pressure pulmonary oedema	Horse	Pulmonary oedema	No	Review
(François et al. 2014)	Arterial oxygen tension and pulmonary ventilation in horses after anaesthesia, recovery quality	Horse	Hypoxaemia; atelectasis	No	Experimental study
(Borer 2005)	Association between anaesthesia and pulmonary oedema after colic surgery in a horse	Horse	Pulmonary oedema	No	Case report
(Monticelli and Adami 2019)	Aspiration pneumonia as peri-anaesthetic complication in horses	Horse	Aspiration pneumonia	No	Case report
(Ovbey et al. 2014)	Incidence, anaesthetic agents and management	Dog	Aspiration pneumonia	No	Retrospective study

	factors associated with canine postanaesthetic aspiration pneumonia				
(Lindsay et al. 2020)	Postoperative respiratory complications in brachycephalic dogs undergoing surgical correction of one or more components of brachycephalic airway syndrome	Dog	Dyspnoea; aspiration pneumonia; respiratory arrest	No	Retrospective study
(Franklin et al. 2021)	Preoperative and postoperative effect of nebulised epinephrine on brachycephalic obstructive airway syndrome severity in dogs	Dog	Dyspnoea; hypoxaemia; upper airway obstruction	No	Prospective clinical study
(Sumner and Rozanski 2013)	Respiratory distress, upper airway disease, respiratory	Dog; cat	Respiratory distress; upper airway disease; lower airway obstruction	No	Review

	emergencies in small animals				
(Louro et al. 2019)	Postobstructive negative pressure pulmonary oedema in a dog; discussion about pathophysiology, critical care and management	Dog	Respiratory distress; upper airway obstruction; pulmonary oedema	No	Case report
(Hosgood and Scholl 1998)	Peri-anaesthetic morbidity and mortality in the dog	Dog	Cardiopulmonary arrest	No	Prospective cohort study
(Hosgood and Scholl 2002)	Peri-anaesthetic morbidity and mortality in the cat	Cat	Cardiopulmonary arrest; respiratory distress	No	Prospective cohort study
(Stabile et al. 2021)	Comparison of continuous positive airway pressure and oxygen therapy for dogs with hypoxaemia after anaesthesia	Dog	Hypoxaemia; acute respiratory distress syndrome; pneumonia; acute respiratory failure; pulmonary atelectasis; hypoventilation	Hypoxaemia, acute respiratory distress syndrome, pneumonia and acute respiratory failure	Prospective study

4. DISCUSSION

This literature search found only two publications on PPC in veterinary medicine so far. Including PPC-related, yet less specific search terms 37 articles were found that provide some information on the topic of PPC in a variety of species. While the relationship between selected PPC and drugs (eight articles), surgery methods (twelve articles), mode of ventilation (six articles) or animal species (16 articles) were mentioned, only three articles actually defined PPC within the context of their article. The most frequently reported species were dogs (24 articles) and horses (twelve articles) with the most frequently mentioned PPC of pulmonary oedema (13 articles), aspiration pneumonia (ten articles) and hypoxaemia (eleven articles). The surgery methods most commonly examined in the articles were laparotomy (four articles) and intracranial surgery (three articles). Drugs mentioned in connection with PPC were in most cases opioids (five articles), like (car)fentanyl or morphine, and alpha-2-agonists (four articles), like xylazine or dexmedetomidine.

In only three articles postoperative pulmonary complications were explicitly defined. In the article from Brainard et al. (2006) PPC was defined by evidence of pulmonary disease and/or dyspnoea during physical examination, and development of two or more of the following complications: $SpO_2 < 94$ %, $PaO_2 < 85$ mmHg, radiographic evidence of pulmonary disease or cytologic, microbiologic, or histopathologic evidence of acute infectious or inflammatory pulmonary disease. In another article from Alwood et al. (2006) symptoms like atelectasis, hypoxaemia, haemorrhage, cardiogenic and non-cardiogenic oedema, acute lung injury, pneumonia, pulmonary thromboembolism and acute respiratory distress syndrome were classified as PPC. Stabile et al. (2021) described in their article the occurrence of hypoxaemia, acute respiratory distress syndrome, pneumonia and acute respiratory failure as PPC.

Pulmonary oedema, hypoxaemia and aspiration pneumonia were among the most commonly reported complications. This could be due to the fact that they are easier to recognise and diagnose than e.g. hypercapnia or pulmonary embolism. Not many articles were found about postanaesthetic hypoventilation and atelectasis although they are considered common complications during anaesthesia itself (Rozanski 2015, Wilson and Shih 2015). While

hypoventilation should cease in most cases once anaesthetics are wearing off, atelectasis might prevail for longer periods afterwards, particularly during immobility. Diagnosis of atelectasis though needs radiographs or computed tomography, the latter typically performed under anaesthesia in animals. However, it could be the case that not only difficulty in diagnosis of a PPC play a role, but also that insufficient attention is paid to their occurrence.

Mechanical ventilation

The correct settings and type of ventilation during surgery are important to prevent lung damage and to maintain the patient's oxygen supply. Therefore, they also play a role in the prevention of postoperative pulmonary complications. In human medicine, it is reported that intraoperative protective ventilation can reduce PPC. As an example for protective ventilation, it is described that a low tidal volume adapted to ideal body weight of the patient and an adapted positive end-expiratory pressure (PEEP) is beneficial (Kiss et al. 2016). On the other hand, if the PEEP is set too high it can lead to hypotension and thus increased ventilation perfusion mismatch. Thus, PEEP must be high enough to protect the lung against atelectasis while low enough to prevent cardiovascular depression in order to improve oxygenation. Opinions about the ideal PEEP differ depending on the study and are part of ongoing research (Kiss et al. 2016).

In veterinary medicine, though to a lesser degree compared to human medicine, protective lung ventilation is under investigation considering different approaches. In a study by De Monte et al (2018), for example, the authors found that for anaesthetised dogs a tidal volume of 8 mL/kg resulted in an increased degree of atelectasis, alveolar hypoaeration and increased $PaCO_2$, regardless of the application of PEEP or an increased respiration rate. A tidal volume of 15 mL/kg and a PEEP of 5 cm H_2O, on the other hand, turned out to be the most recommendable setting, measured in terms of lung compliance and lung aeration. Regarding oxygenation, however, they could not find any significant difference between the two settings. (Monte et al. 2018). Another study by Martin-Flores et al. (2020) looked at postoperative hypoxaemia in dogs in relation to various settings of the inspired fraction of oxygen (FIO_2) during anaesthesia

(FIO_2 of 0.4 vs. > 0.9). It was found that the incidence of hypoxaemia within four hours postoperatively was higher in dogs ventilated with 0.4 oxygen (Martin-Flores et al. 2020).

Another part of protective ventilation strategies involves the mode of ventilation. Volume-controlled ventilation provides that the ventilator delivers a set volume, regardless of the reached pressure. Using volume-controlled ventilation can cause a reduction of lung compliance and barotrauma unless this mode is additionally pressure limited. In comparison, pressure-controlled ventilation establishes a tidal volume which is determined by a set inspiratory pressure. This mode of ventilation protects against barotrauma, but carries the risk of hypoventilation, i.e. hypercapnia. Hypoventilation can significantly affect postoperative oxygenation and therefore postoperative recovery and mortality (Rozanski 2015).

The peak inspiratory pressure (PIP) is another parameter of the ventilation setting. In patients with obesity this parameter must be chosen carefully because a high PIP in connection with obesity can lead to direct volutrauma of the lungs due to atelectasis, caused by obesity, and overinflation of open alveoli. This can contribute to pulmonary oedema as a postoperative pulmonary complication, as described in two cases in an article by Melis et al. (2014). Obesity also brings other disadvantages such as a decrease in respiratory system compliance. (Melis et al. 2014).

Ventilation-perfusion mismatching, a common problem particularly in equine medicine can lead to severe hypoxaemia. It is known that horses with abdominal distention, e.g. due to colic are at risk to have hypoxaemia during anaesthesia, even if they are breathing 100 % oxygen. The hypoxaemia comes from overventilation of lung lobes with reduced blood flow and decreased ventilation of lung lobes with normal blood flow (V/Q mismatch). This V/Q mismatch appears less in animals with a smaller body mass (Brainard et al. 2006). If hypoxaemia already exists during anaesthesia it will be disadvantageous in the recovery phase and can lead to postoperative hypoxaemia and poor outcome, too.

Farrell et al. (2019) investigated the usefulness of pulse oximetry using SpO_2 as non-invasive measure of oxygenation in dogs in the intensive care unit. Correlation between SpO_2 and arterial oxygen tension (PaO_2) was not acceptable, indicating another problem of PPC recognition: reliability of non-invasive versus invasive monitoring (Farrell et al. 2019).

Based on the selected literature the impact of current ventilation strategies including FIO_2 on PPC is inconclusive.

Surgery methods

Few studies have been published looking at postoperative pulmonary complications in connection with surgery methods. One of the most frequently described pulmonary complication though is aspiration pneumonia. Surgeries in dogs, which carry a higher risk for aspiration pneumonia are thoracotomy, laparotomy, endoscopy, upper airway surgery and neurosurgery (Ovbey et al. 2014).

After intercranial surgery, aspiration pneumonia is the most common non-neurological complication in dogs. One study found that pneumonia usually occurs within one week of the procedure (Fransson et al. 2001). A retrospective case series concluded that non-neurological postoperative complications occurred in 18 % of dogs after intracranial surgery, of which 12 % were aspiration pneumonia. Aspiration pneumonia can result from postoperative neurological deterioration, but at the same time it can also negatively affect the neurological status (Forward et al. 2018).

Aspiration pneumonia is also related to intervertebral disc diseases. Dogs with cervical spinal lesions have a 6-7.6 times higher risk of aspiration pneumonia than those with thoracolumbar or lumbosacral spinal lesions. Likewise, tetraparetic patients have an 18 times higher risk than paraparetic patients for aspiration pneumonia. The reason for this is that cervical lesions lead to a weakening of innervation to the respiratory muscles, resulting in an impaired cough, decrease in tidal volumes, difficulty in clearing secretions, and an increase in atelectasis. With unilateral arytenoid lateralization, studies have shown that aspiration pneumonia occurs in 10-31.8 % of postoperative patients. Reduced laryngeal sensation, anaesthetic-related decreased reflexes, decreased motor responses, and increased gastroesophageal reflux increase the risk further (Sherman and Karagiannis 2017).

After surgery for laryngeal paralysis, aspiration pneumonia is one of the most common complications, especially after arytenoid lateralization. In a retrospective study at a veterinary teaching hospital between 1985-1998, aspiration pneumonia occurred in 33 of 140 dogs (23.6 %), with 19 of the 33 occurring within the first 14 days postoperatively. Seven (5 %) of the 140 dogs also had respiratory distress, which was the second most common complication. Of all dogs that underwent surgery for laryngeal paralysis, 27 (19.3 %) died of respiratory tract diseases (MacPhail and Monnet 2001).

Apart from reports on PPC in connection with intercranial surgery, several reports on abdominal surgery in dogs mention PPCs. For example, a study by Alwood et al. (2006) showed that 22.2 % (36 dogs of 162) of the sample developed PPC after laparotomy. While few of these 36 dogs got severe complications such as respiratory arrest (2.5 %) and ARDS (1.9 %), pneumonia (4.9 %), short-term hypoxaemia (4.9 %) and manageable hypoventilation (8 %) were listed. The occurrence of PPC affects the survival of the patients significantly as the study reveals that 66.7 % of the dogs with PPC survived, compared to 94 % of the dogs without PPC. The authors of the study concluded that the occurrence of PPC was not influenced by physical characteristics, pre-existing diseases, drug therapy, body weight or clinicopathologic results. In contrast, they determined two factors having a significant effect on the development of PPC: 1) Dogs showing vomiting or regurgitation pre-, intra- and/or postoperative, and 2) presenting septic or biliary peritonitis at the time of laparotomy (Alwood et al. 2006). A possible explanation could be that the aspiration of gastrointestinal contents provokes pneumonia and peritonitis, which can lead to a systemic inflammatory response or infection. This in turn can further negatively affect the lungs and their function.

With regard to orthopaedic surgery, total hip replacement (THR) surgery has been associated with pulmonary embolism in dogs. In a study by Liska and Poteet (2003), with the original aim of finding embolic events due to THR, 23 out of 28 dogs showed perfusion defects in lung scans. The reason for this is assumed to be an increased intramedullary pressure during cemented THR surgery. Fortunately, most affected dogs recovered seemingly spontaneously (Liska and Poteet 2003). Another study looked at the occurrence of pulmonary embolism in non-cemented total hip arthroplasty in eleven dogs. No cases of pulmonary embolism were found here. The authors cited as one of the possible reasons that the system they were using

was non-cemented and thus not filling the medullary canal and avoiding pulmonary embolism. (Tidwell et al. 2007).

Frequently mentioned peri- and postanaesthetic complications such as hypercapnia and hypoxaemia are most frequently associated with spinal surgeries (hypercapnia) and hypoxaemia in thoracotomies, endoscopies and bronchoscopies (Gaynor et al. 1999).

Unfortunately, there is too little literature on other species which associate PPC with certain surgical methods. However, it is known that after exploratory celiotomies in colic horses, postoperative haemorrhagic pneumonia can occur, which might be associated with nasogastric reflux (Klohnen 2009).

Drugs

Some evidence exists in the context of drug related PPCs. Pulmonary oedema is mentioned particularly often as a drug induced side effect.

A case report linking pulmonary oedema to ketamine administration in a dog is published. In this case an 8-year-old mixed-breed dog was anaesthetised for colonoscopy with an injection of diazepam and ketamine. After endotracheal intubation a frothy, reddish-coloured fluid emerged from the endotracheal tube for several minutes (Boutureira et al. 2007). The proposed cause mentioned was that ketamine can induce pulmonary hypertension.

An association between pulmonary oedema and the drugs carfentanil and xylazine was observed in horses. The responsible mechanism is said to be the same as that triggered by alpha-2-adrenergic-agonists in sheep, which leads to bronchoconstriction and pulmonary vasospasm (Deutsch and Taylor 2021). Xylazine, due to its catecholaminergic effect of alpha-2-agonists, can not only cause pulmonary oedema in sheep and horses, it is also known for stimulating permeability changes in the lung of rats (Senior 2005).

In sheep it was found that dexmedetomidine can lead to pulmonary oedema because of hydrostatic stress caused by changes in mean pulmonary artery pressure, pulmonary arterial occlusion pressure and estimated capillary pressure (Kästner et al. 2007). Moreover, there are other articles describing an association between alpha-2-agonists and pulmonary complications in sheep. Using explicitly keywords like "sheep + hypoxaemia + alpha-2-agonist" in a scientific database like PubMed, a number of articles can be found. As sheep were not one of the target species for this review, further articles have not been included and won't be discussed here.

In a retrospective study from Finland Raekallio et al. (2017) assessed data collected from the Finish Medicines Agency regarding suspected adverse reactions associated with alpha-2-agonists in cats. In the study period from 2003-2013, reports from 90 cats were considered, with 61 cats showing signs of pulmonary oedema. Of these 61, 14 cats died due to complications. Even if upper airway obstruction and regurgitation cannot be ruled out in all cases as an influencing factor, pulmonary oedema is viewed here as an adverse reaction of this drug class in cats (Raekallio et al. 2017). The absolute incidence of pulmonary oedema with alpha-2-agonists in cats, however, cannot be determined with this data set as only adverse reports were collected and not the total number of administration of these drugs.

Not only alpha2-agonists and carfentanil are associated with PPC, other opioids are known to play a role, too. One study found that dogs which were given postoperatively oxymorphone or butorphanol for analgesia, were at higher risk for PPC than those given hydromorphone. In the same study, however, no significant associations were concluded between PPC and other anaesthetic drugs for premedication, induction or maintenance of anaesthesia (Brainard et al. 2006).

In horses, postoperative pulmonary oedema is mentioned in connection with morphine administration in a few cases. The proposed mechanism seems unclear so far. Fluid overload during anaesthesia and changes in pulmonary permeability induced by morphine have been discussed, but seem not to fit all cases (Gozalo-Marcilla et al. 2013).

In a multicentre study about canine postanaesthetic aspiration pneumonia, the authors found that dogs with a continuous rate infusion of anaesthetic or analgesic agents like morphine, lidocaine, ketamine, fentanyl or propofol, have a 1.8 times higher risk to develop aspiration

pneumonia as a postanaesthetic complication compared to those without (Ovbey et al. 2014). The administration of hydromorphone IV at induction only was associated with a higher incidence of postoperative aspiration pneumonia, but not at any other time point. There is no explanation for this finding. The number of dogs receiving xylazine or medetomidine was very low and no other PPCs besides aspiration pneumonia were assessed. In this study by Ovbey et al. (2014) a high number of anaesthetics and analgesics has been evaluated in a population with a multitude of underlying medical conditions. Thus, it can be expected that some relationships will be obscured besides a total number of 240 dogs with aspiration pneumonia and 488 control dogs without it.

Species

Certain symptoms of PPC were found more frequently in certain animal species.

In horses, PPC is often mentioned in connection with upper airway obstruction (UAO) during or after anaesthesia. Upper airway obstruction leads to pulmonary oedema due to the negative intrathoracic pressure created by inspiratory efforts against the obstruction. The onset of pulmonary oedema is often accompanied by hypoxaemia, hypercapnia and tachypnoea (Wagner 2008). Especially horses undergoing laryngeal surgery, or those having laryngeal functional abnormalities, are affected by pulmonary oedema due to negative intrathoracic pressure caused by airway obstruction (Tute et al. 1996). Furthermore, nasal mucosal congestion and dorsal displacement of the soft palate after tracheal extubation can lead to transient upper airway partial obstruction during recovery from anaesthesia (Dugdale and Taylor 2016).

Elevated catecholamine levels could play a role in the development of pulmonary oedema after UAO as well. Elevated levels after agitation due to the UAO can lead to increased aortic, systemic arterial, pulmonary arterial and pulmonary venous blood pressure. Furthermore, pulmonary oedema has been associated with pulmonary micro embolism following orthopaedic surgery in horses (Senior 2005).

In general, horses are prone to hypoxaemia after anaesthesia. The gas exchange is impaired in the recumbent horse, also by atelectasis in the lower lung regions. In the recovery phase, the oxygen saturation improves when the horse changes to the sternal position and stands up (François et al. 2014). There is evidence that arterial hypoxaemia, causing pulmonary vasoconstriction, and rapid re-expansion of atelectatic lung could lead to pulmonary oedema in horses. Gastric acid aspiration can trigger pulmonary oedema in horses too, similar to the canine aspiration pneumonia (Borer 2005). Although horses are not prone to gastric reflux it does occur in colic horses during exploratory laparotomy. Increased patency of the cardia and intra-abdominal pressure have an effect on gastric reflux. In such cases, gastric reflux can also lead to aspiration pneumonia as a postanaesthetic complication in horses (Monticelli and Adami 2019).

Canine aspiration pneumonia is one of the most common postoperative pulmonary complications in dogs, according to current literature. Aspiration of gastric fluid can occur during or shortly after anaesthesia. If aspiration happens, there are three following phases: an airway response, an inflammatory response, and then a possible secondary bacterial infection. The survival chances for patients with aspiration pneumonia varies from 58 % to 82 % depending on the study (Ovbey et al. 2014). According to the review from Sherman and Karagiannis (2017), after 13-16 % of all anaesthetic events aspiration pneumonia occurs. Undergoing more than one anaesthetic episode increases the risk 7.8 times (Sherman and Karagiannis 2017).

Brachycephalic dogs have an additional risk of postoperative respiratory complications due to stenotic nares, abnormal nasopharyngeal turbinate morphology, elongated soft palate, redundant pharyngeal folds and hypoplastic trachea. Typical complications are for example respiratory distress, regurgitation, pharyngeal oedema, aspiration pneumonia, postoperative haemorrhage and death. In a study with 248 dogs, 58 had complications (23.4 %), of which 7.3 % had dyspnoea and 16.1 % needed an extended endotracheal intubation or a temporary tracheostomy tube, and others had aspiration pneumonia, suffered cardiac or respiratory arrest (Lindsay et al. 2020).

In addition, brachycephalic breeds such as the pug or French bulldog often suffer from brachycephalic obstructive airway syndrome. These dogs can get postoperative respiratory complications like upper airway obstruction due to the mucosal swelling and oedema after surgical interventions (Franklin et al. 2021). In times where upper airway obstruction occurs, it can lead to post obstructive negative pressure pulmonary oedema in dogs, too. An English bulldog was reported to have suffered a tracheal trauma, assumed due to an endotracheal tube that was too large. As a result, there was gross swelling and erythema of the larynx, which led to upper airway obstruction and ultimately to pulmonary oedema (Louro et al. 2019).

A risk factor for PPC in not only brachycephalic dogs, but all dogs, is age. In a study about mortality and morbidity of older aged dogs during and after anaesthesia, respiratory complications are declared as common and cardiopulmonary arrest was mentioned as a severe complication (Hosgood and Scholl 1998). Similar results are documented in a study about peri-anaesthetic mortality and morbidity in cats (Hosgood and Scholl 2002).

Another pulmonary complication in dogs which is often overlooked or not always recognised, is postoperative hypoxaemia. According to a study, postoperative hypoxaemia ($SpO_2 < 95$ %) was observed in 62 % and severe hypoxaemia ($SpO_2 < 90$ %) in 18 % of dogs, recovering from anaesthesia (Stabile et al. 2021).

This shows even more a potential problem of PPC: often patients are not monitored at all or inadequately to recognise PPC or other complications. Only severe complications will be noted and might result in mortality of the patient.

Outlook and conclusion

With regard to postoperative pulmonary complications, many questions remain unanswered or cannot be clearly elucidated by the existing literature. This includes, for example, the extent to which severe pulmonary diseases such as ARDS are considered part of postoperative pulmonary complications and if so, which management changes could reduce the risk of anaesthesia induced ARDS in veterinary medicine. A known risk factor for the development of

ARDS under anaesthesia in dogs is aspiration pneumonia. Other risk factors are pneumonia and mechanical ventilation. In cats, however, SIRS with or without sepsis is mentioned to be the most common cause of ARDS (Boiron et al. 2019).

The lack of clear risk factors and predictability for postoperative pulmonary complications prevents the establishment of monitoring and treatment guidelines in veterinary medicine. In human medicine, e.g. low preoperative SpO_2 is considered a warning sign for the occurrence of PPC. Patients with a preoperative SpO_2 of 91-95 % are twice as likely to develop PPC and with an SpO_2 below 90 % they are 10 times more likely than patients with a SpO_2 over 96 % (Miskovic and Lumb 2017). While Farrell et al. (2019) evaluated the correlation between SpO_2 and PaO_2 in canine ICU patients, their conclusion was that SpO_2 is not a reliable replacement for PaO_2 (Farrell et al. 2019). However, the need for invasive monitoring makes the recognition of hypoxaemia more difficult and costly.

In summary, this review found that although there are some publications that report symptoms that can be classified as postoperative pulmonary complications, there is a scarcity in the literature on the symptom complex of PPC itself.

This could be due to a lack of a precise definition of postoperative pulmonary complications, i.e. it is not clearly defined which symptoms belong to them (Follette et al. 2020). As a result, clinicians may not look for or perceive certain symptoms that occur after anaesthesia as a PPC. Maybe even worse, some symptoms such as mild, temporary hypoxaemia, for example, might be viewed as "normal" after anaesthesia and are therefore not given sufficient attention. While this review attempted to list commonly found symptoms of PPC, the creation of an expert panel seems to be warranted to define and distribute the classification of PPCs in veterinary medicine.

Another key problem to the lack of literature about PPC in veterinary medicine could be its proper identification in the postoperative phase as well as documentation of such complications. Many patients are not monitored as closely after anaesthesia due to lack of personnel and/or patient compliance. This is problematic, considering that of those who die in relation to anaesthesia up to 47 % of canine and 61 % of feline patients do so in the postoperative period (Brodbelt et al. 2008). Particularly in smaller veterinary clinics patients might leave the hospital

soon after the end of anaesthesia. Reasons for an early return include the decrease of patient stress in the hospital, but also lack of resources. Thus, follow-up care also takes place at home under the animal owner's care. If at all, the attending veterinarian only sees the animal for a short time during a follow-up check at least a day later. However, this has the consequence that the patients can no longer be professionally monitored in the postoperative period. In particular, slight complications occurring in the days following the operation cannot be recognised by every owner or are not reported to the veterinarian. As a result, there is often no documentation of a patient's postoperative medical history. This means that e.g. mild, temporary hypoventilation or hypoxaemia can be overlooked and develop into more severe scenarios.

Even when monitoring such as pulse oximetry is used in the recovery phase due to patient compliance alerts might not be considered valid and/or values might not be documented due to additional administrative burden. This in turn could also influence the perception of the occurrence of PPC.

These circumstances can contribute to the lack of literature on postoperative pulmonary complications and actually postoperative complications in general. Since we know that particularly pulmonary complications have a high incidence of being severe, i.e. increasing mortality, it would be desirable to pay more attention to this subject in veterinary medicine/anaesthesia.

To help veterinarians correctly classify, identify and treat PPCs and improve the postoperative outcome more scientific publications on PPC are unquestionably needed.

5. ABSTRACT

Postoperative pulmonary complications play an important role in human medicine, which is why there are numerous scientific publications on this topic. To find out how present this topic in veterinary medicine is, a literature search about postoperative pulmonary complications in veterinary medicine was carried out using the following databases: vetmedseeker of the university library of the University of Veterinary Medicine in Vienna, PubMed, Scopus, ScienceDirect and Web of Science. Most of the articles found reported about specific postoperative symptoms affecting the respiratory system. In these publications, these symptoms were related to ventilation management during anaesthesia (six articles), surgical methods (twelve articles), drugs for anaesthesia or analgesia (eight articles), and certain animal species (16 articles). Most of the information was found about laparotomies (four articles), opioids (five articles) and species like dog (24 articles) and horse (twelve articles). Pulmonary oedema (13 articles), hypoxaemia (eleven articles) and aspiration pneumonia (ten articles) were among the most commonly reported complications. In three articles postoperative pulmonary complications were defined. In addition, two articles were found that provided information on postoperative pulmonary complications as a symptom complex in dogs. The fact that there are only two may be due to the lack of a systematic definition of postoperative pulmonary complications in veterinary medicine. As a result, veterinarians may not perceive these complications as part of this complex and accordingly do not publish about them in the context. In addition, the documentation of postoperative pulmonary complications in veterinary medicine is often insufficient since in many cases the postoperative follow-up care of the patients is taken over by the patient's owners at home and they might not notice slight complications or are not able to interpret them properly. The lack of postoperative monitoring by veterinarians and the lack of a systemic definition for postoperative pulmonary complications in veterinary medicine probably contribute to the fact that so far little information on this topic can be found in the scientific literature.

6. ZUSAMMENFASSUNG

Postoperative pulmonale Komplikationen spielen in der Humanmedizin eine wichtige Rolle, daher gibt es zahlreiche wissenschaftliche Publikationen darüber. Um herauszufinden, wie die Publikationslage in der Veterinärmedizin ist, wurde eine Literatursuche über postoperative pulmonale Komplikationen in der Veterinärmedizin mit Hilfe folgender Datenbanken durchgeführt: vetmedseeker der Universitätsbibliothek der Veterinärmedizinischen Universität Wien, PubMed, Scopus, ScienceDirect und Web of Science. Der Großteil der gefundenen Artikel berichtete über spezifische Symptome, die postoperativ auftraten und das Respirationssystem betrafen. Diese Symptome standen in den Publikationen in Zusammenhang mit Ventilationsmanagement während der Anästhesie (sechs Artikel), Operationsmethoden (zwölf Artikel), Medikamenten für die Anästhesie oder Analgesie (acht Artikel) und bestimmten Tierarten (16 Artikel). Am meisten Information wurde hierbei über Laparotomien (vier Artikel), Opioide (fünf Artikel) und die Tierarten Hund (24 Artikel) und Pferd (zwölf Artikel) gefunden. Lungenödem (13 Artikel), Hypoxämie (elf Artikel) und Aspirationspneumonie (zehn Artikel) waren die am häufigsten erwähnten Komplikationen. Drei Artikel beinhalteten eine Definition, was als postoperative pulmonale Komplikationen gewertet wurde. Außerdem konnten zwei Artikel gefunden werden, die über postoperative pulmonale Komplikationen als Symptomkomplex bei Hunden informieren. Die Tatsache, dass es nur zwei sind, könnte an der fehlenden allgemeinen Definition für postoperative pulmonale Komplikationen in der Veterinärmedizin liegen. Dadurch nehmen TierärztInnen auftretende Komplikationen unter Umständen nicht als Teil dieses Komplexes wahr und publizieren dementsprechend auch nicht darüber in dem Kontext. Darüber hinaus ist die Dokumentation von postoperativen pulmonalen Komplikationen in der Veterinärmedizin erschwert, da in vielen Fällen die postoperative Nachsorge der Patienten von den PatientenbesitzerInnen zu Hause übernommen wird und gerade leichte Komplikationen diesen eventuell nicht auffallen. Somit tragen das fehlende postoperative Monitoring durch TierärztInnen und die fehlende Definition von postoperativen pulmonalen Komplikationen in der Veterinärmedizin wahrscheinlich dazu bei, dass bisher wenig Information über dieses Thema in der wissenschaftlichen Literatur zu finden ist.

7. APPENDIX

S1: Literature search- The following keywords were entered in the search field of the respective database with the following number of results:

	Results vetmedseeker *	Results PubMed **	Results Scopus ***	Results ScienceDirect ****	Results Web of Science *****
Postoperative pulmonary complications veterinary medicine	1,761	95	21	1,125	44
Postoperative pulmonary complications cats AND/OR dogs AND/OR horses	0 Without "AND/OR horses": 1	76,199	115	316	127,711
Postoperative complications cats AND/OR dogs AND/OR horses	0 Without "AND/OR horses": 49	76,199	3,654	664	127,786
Postoperative complications veterinary medicine	8,187	2,623	913	3,253	1,329
Postanaesthetic complications veterinary medicine	83	6	3	35	6
Postanaesthetic complications cats	0	76,199	11	20	127,710

AND/OR dogs AND/OR horses					
Pulmonary complications veterinary medicine	5,818	1,190	141	2,954	260
Pulmonary complications cats AND/OR dogs AND/OR horses	0 Without "AND/OR horses": 5	76,199	457	752	127,720
Respiratory complications veterinary medicine	9,196	838	245	4,461	405
Pulmonary oedema veterinary medicine	1,982	416	25	3,538	497
Pulmonary oedema cats AND/OR dogs AND/OR horses	2	76,199	122	956	127,767
Lung oedema veterinary medicine	2,607	420	23	3,728	295
Respiratory arrest veterinary medicine	2,105	61	53	1,544	84
Acute respiratory distress syndrome veterinary medicine	2,397	200	45	1,621	109
Pneumonia veterinary medicine	18,363	3,576	1,032	7,140	3,328
Pneumonia cats AND/OR dogs AND/OR horses	4	76,199	2,111	1,263	127,865

Aspiration pneumonia veterinary medicine	2,125	180	174	1,651	235
Hypoventilation veterinary medicine	703	71	44	740	100
Hypoxaemia veterinary medicine	1,418	1,178	138	1,285	391
Hypoxaemia cats AND/OR dogs AND/OR horses	0 Without "AND/OR horses": 2	76,199	340	294	127,724
Mortality cats AND/OR dogs AND/OR horses	13	76,199	4,202	1,711	128,066
Morbidity cats AND/OR dogs AND/OR horses	7	76,199	1,543	924	127,839
Mortality AND/OR morbidity veterinary medicine	54	30,896	2,855	5,412	19,961

* If there were more than 50 results, a filter called topic was used, which takes "animals" and "veterinary sciences" into account and a language filter for German and English was used.

** Filters applied - language: English, German; species: Other Animals

*** Filters applied - subject area: veterinary; language: English, German; // "OR" was always used instead of "AND/OR", otherwise an error message would appear.

**** Filters applied - subject areas: veterinary science and veterinary medicine;

***** Filters applied - web of science categories: veterinary sciences; languages: German, English; // "OR" was always used instead of "AND/OR", otherwise an error message would appear.

S2: Articles solely found by the search through databases - Number of articles received for full screening from the respective database:

vetmedseeker	11
PubMed	2
Scopus	12
ScienceDirect	2
Web of Science	0

As shown, no articles were used by Web of Science for this work because no new or relevant articles could be found which were not already found with previous search engines.

8. LIST OF ABBREVIATIONS

ARDS: acute respiratory distress syndrome

ASA-Status: American Society of Anaesthesiologists-Status

FIO_2: fraction of inspired oxygen

MODS: multiple organ dysfunction syndrome

PaO_2: partial pressure of oxygen in arterial blood in mm Hg

PEEP: positive end-expiratory pressure

PIP: peak inspiratory pressure

PPC: postoperative pulmonary complications

SIRS: systemic inflammatory response syndrome

SpO_2: Peripheral oxygen saturation

THR: total hip replacement

UAO: upper airway obstruction

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