UNIVERSITI PUTRA MALAYSIA

RETROSPECTIVE STUDY ON POSTOPERATIVE PULMONARY COMPLICATIONS (PPCS) IN CATS AND DOGS UNDERGOING LAPAROTOMY AT UNIVERSITY VETERINARY HOSPITAL (UVH), UNIVERSITI PUTRA MALAYSIA (UPM), FROM 2019 TO 2021

LEHKHA A/P GOPALA KRISHNAN

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CERTIFICATION

It is hereby certified that we have read this project paper entitled "Retrospective study on postoperative pulmonary complications (PPCs) in cats and dogs undergoing laparotomy in Universiti Veterinary Hospital (UVH), Universiti Putra Malaysia (UPM), from 2019 to 2021"

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DEDICATION

To My Late Grandmother with Love

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And finally to my beloved dogs Fatty, Brownie, Tracy, Simba and late Maya for being
close to my heart during the challenging times of completing this thesis.

LIST OF ABBREVIATIONS

AAHA	American Animal Hospital Association
ARDS	Acute respiratory distress syndrome
ARISKAT	assess respiratory risk in surgical patients of Catalonia
ASA PS	American Society of Anesthesiologists Physical Scoring
BAL	Bronchoalveolar lavage
BCS	Body Condition Score
ETT	Endotracheal tube
FiO2	Fraction of inspired oxygen
FRC	Functional Residual Capacity
FURD	Feline upper respiratory disease
HAP	Hospital-associated pneumonia
ICU	Intensive care unit
NSAIDs	Non-steroidal anti-inflammatory drugs
OHE	Ovariohysterectomy
OHS	Obesity Hypoventilation Syndrome
PCV	Packed cell volume
PEEP	Positive end expiratory pressure
PP	Plasma Protein
PPCs	Postoperative pulmonary complications
PERISCOPE	prospective evaluation of a risk score for postoperative pulmonary complications in Europe
SPO2	Partial pressure of oxygen
VAP	Ventilator-associated pneumonia

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ABSTRAK

Abstrak daripada kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999 –Projek Tahun Akhir.

Kajian Retrospektif Tentang Komplikasi Pulmonari Pasca Pembedahan Dalam Kucing dan Anjing Yang Menjalani Laparotomi Di Hospital Veterinar Universiti (UVH), Universiti Putra Malaysia (UPM), dari Tahun 2019 hingga 2021

oleh

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2022

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Komplikasi Pulmonari Pasca Pembedahan merujuk kepada suatu kumpulan komplikasi respiratori yang kuat mempengaruhi kadar pemulian pesakit setelah menjalani pembedahan. Banyak kajian telah dibuat untuk menyiasat kelaziman dan presentasi klinikopathologik dan radiografik komplikasi ini sekaligus berusaha mengenalpasti faktor-faktor penyebab terjadinya komplikasi respiratori ini dalam kalangan pesakit manusia. Model ramalan risiko secara efektifnya telah membantu mengurangkan kadar berlakunya komplikasi pulmonari pasca pembedahan ini, turut mengurangkan morbiditi dan mortaliti pesakit manusia. Walaubagaimanapun, pemahaman kita terhadap faktor penyebab komplikasi pulmonari pasca pembedahan ini dalam bidang perubatan veterinar terutamanya dalam pesakit haiwan kesayangan seperti kucing dan anjing tidak mencukupi. Oleh itu, kajian ini bertujuan mengenalpasti presentasi, kekerapan dan faktor penyebab berkaitan anesthesiologi yang mencetuskan komplikasi pulmonari pasca pembedahan ini dalam kalangan pesakit kucing dan anjing yang menjalani laparotomi di UVH dari tahun 2019 hingga 2021. Sejumlah 117 kucing dan anjing tanpa sebarang masalah pulmonari sebelum pembedahan telah dianalisis untuk faktor - faktor seperti, signalmen, ‘American Society of Anesthesiologists (ASA) physical status (PS)’, tempoh berpuasa, muntahan perioperatif, hipoalbuminemia sebelum pembedahan, protokol anestesiologi dan analgesia, tempoh anestesiologi, jumlah keseluruhan isipadu cecair (fluids) yang diberi semasa pembedahan, pembetulan tekanan darah rendah dengan terapi cecair, posisi badan dan bahagian pembedahan menggunakan ujian Khi Kuasa Dua. Jumlah pesakit yang menerima terapi cecair untuk membetulkan tekanan darah rendah semasa pembedahan lebih tinggi dalam kalangan pesakit yang menghadapi komplikasi pulmonari pasca pembedahan. Haiwan yang skor kondisi badannya kurang daripada 3 dan yang menjalani pembedahan di bahagian bawah kawasan abdominal telah dikenalpasti memperoleh komplikasi pulmonari selepas pembedahan. Haiwan yang menjalani ovariohisterektomi (OHE) rutin kebanyakannya memperoleh komplikasi pulmonari pasca pembedahan (n=6), diikuti dengan kes piometra (n=2) dan surgeri hepatobiliari (n=2). Komplikasi pulmonari pasca pembedahan termasuklah atelektasis, edema pulmonari, pneumonia disebabkan ventilator atau aspirasi, pneumonitis kemikal, bronkitis, trakeitis, bronchospasme, pneumotoraks and hipoksemia pasca pembedahan jangka pendek. Haiwan yang berisiko tinggi seharusnya perlu dipantau rapi sebelum, semasa dan selepas pembedahan untuk mengelakkan terjadinya komplikasi pulmonari pasca pembedahan.

Kata kunci : Komplikasi Pulmonari Pasca Pembedahan; laparotomi; cecair; hipoksemia, pneumonia

ABSTRACT

Retrospective Study on Postoperative Pulmonary Complications (PPCs) in Cats and Dogs Undergoing Laparotomy in University Veterinary Hospital (UVH), Universiti Putra Malaysia (UPM) from 2019 to 2021.

by

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2022

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Postoperative pulmonary complications (PPCs) are a heterogeneous group of respiratory complications that significantly alter the postsurgical outcome of patients. Numerous studies have been conducted to investigate the prevalence, clinicopathologic and radiographic presentation of PPCs, and especially the risk factors for their development in humans. Risk prediction models have reduced PPC-associated postoperative patient morbidity and mortality in humans. However, a knowledge gap exists in understanding the risk factors for PPCs in veterinary small animal surgical patients. This study aims to determine the frequency, nature of PPCs and investigate the perianesthetic risk factors of PPCs among cats and dogs that underwent laparotomy in UVH from 2019 to 2021. A total of 117 animals without preoperative pulmonary pathology were analyzed for factors of patient signalment, American Society of Anesthesiologists (ASA) physical status (PS), fasting duration, perioperative vomiting, preoperative hypoalbuminemia, anesthetic and analgesic protocol, anesthesia duration, intraoperative fluids total volume, correction of intraoperative hypotension with fluids, body positioning and surgical site using Chi-square test. Correction of hypotension with fluids was statistically higher in animals that developed PPCs than those that did not (nPPC). Animals with a body condition score (BCS) of 3 or below, and those with lower abdominal surgery, were more likely to acquire PPCs from this study. Routine ovariohysterectomy cases recorded the highest PPC count (n=6), followed by pyometra (n=2) and hepatobiliary surgeries (n=2). PPCs included suspected atelectasis, pulmonary edema, ventilator-associated or aspiration pneumonia, chemical pneumonitis, bronchitis, tracheitis, bronchospasms, pneumothorax and short-term postoperative hypoxemia. Animals presented with risk factors should be closely monitored in their postoperative stage to prevent the development of PPCs.

Keywords: postoperative pulmonary complications (PPCs); laparotomy; fluids; hypoxemia; pneumonia

1.0 INTRODUCTION

The Confederate General "Stonewall" Jackson, who died of pneumonia 10 days after otherwise successful ether anesthesia in 1863, was one of the earliest known deaths of a pulmonary complication following surgery. Even with recent advancements in anesthesiology and patient care, PPCs remain difficult to treat or prevent in the human medical field (Warner & Weiskopf, 2000). A thorough understanding of how modifiable risk factors should be managed is still inadequate, especially in the veterinary field as evidenced by a lack of studies investigating PPCs in small animal surgical patients. PPCs are more common than cardiac complications in surgical patients postoperatively (Brooks-Brunn, 1997).

PPCs are a heterogenous group of respiratory problems which include, atelectasis, pulmonary edema, pneumonia, pleural effusion, respiratory infection, respiratory failure, pneumothorax, bronchospasms, tracheitis, bronchitis, tracheobronchitis, acute respiratory distress syndrome (ARDS), etc. and it differs based on the definition adopted by different studies. PPCs delay the postoperative recovery of patients, prolong hospitalization periods, increase treatment cost and increase postoperative suffering and even cause death in patients postoperatively.

Therefore, risk factors contributing to the development of PPCs are crucial to be identified and categorized into patient-related or surgery-related risk factors. Patient-related risk factors such as species, age, sex, body condition scores (BCS), ASA class, preoperative upper respiratory status, in most cases are considered non-modifiable. Modifiable surgery-related risk factors on the other hand are surgical site, body position during surgery, duration of anesthesia, anesthetic and analgesic protocol, postoperative pain control and intraoperative correction of hypotension with fluids. These modifiable risk factors must be investigated further to allow us to better understand how to alter the perioperative patient care to prevent the occurrence of PPCs among surgical patients.

1.1 Objective

To determine the frequency, characterize the presentation and identify the perianesthetic risk factors for the development of postoperative pulmonary complications (PPCs) in cats and dogs undergoing laparotomy in University Veterinary Hospital (UVH), University Putra Malaysia (UPM) from 2019 to 2021.

1.2 Justification

A retrospective study on postoperative pulmonary complications (PPCs) in cats and dogs undergoing laparotomy will help elucidate perianesthetic risk factors for the development of PPCs and help us better understand the nature of presentation of PPCs in these affected patients. This will allow us to not only identify patients at higher risk of developing PPCs but will also help us modify their anesthetic regime based on their individual predisposition for developing PPCs. As a result, we will be able to optimize their care as an effort to increase their chances of survival after laparotomy especially in the future.

This study hypothesizes that there is a relationship between perianesthetic risk factors and the development of postoperative pulmonary complications (PPCs) in cats and dogs undergoing laparotomy at Universiti Veterinary Hospital (UVH), Universiti Putra Malaysia (UPM).

This paper will begin with an in-depth literature review, followed by materials and methods, including the criterias for the selection of samples, data collection procedures, and the statistical test used to analyze the data collected, results, discussion and interpretation of the results obtained and finally, the conclusion.

2.0 LITERATURE REVIEW

2.1 Postoperative Pulmonary Complications

Any abnormalities or changes to the lower respiratory system, particularly the lungs, are referred to as postoperative pulmonary complications (PPCs). They significantly impact the clinical outcome and recovery of human surgical patients (Miskovic & Lumb, 2017). PPCs are as frequent as cardiac complications and raise patient morbidity and mortality, length of stay, and treatment costs for surgical patients in the human medical field (Qaseem et al., 2006). PPCs can occur in one of two ways: as a brief, self-limiting, clinically insignificant pulmonary issue, or as a serious, clinically significant disturbance that causes the gradual deterioration of the patient's condition, which may or may not respond to therapeutic intervention provided during the postsurgical recovery period (Thanavaro & Foner, 2016).

2.2 Definition of Postoperative Pulmonary Complications

There is currently no consensus on the definition of PPCs, demonstrating a lack of uniformity among studies conducted in human medicine as to which of the many respiratory conditions would be included in the definition of PPCs (Miskovic & Lumb, 2017). The vast discrepancy in the documented frequency of PPCs among researchers is due to the different definitions and criteria utilized in various PPC investigations. Miskovic and Lumb (2017) did an excellent job compiling the many definitional variations found in the literature for PPCs, particularly those found in the 2015. European joint task force published guidelines for the definition of perioperative clinical outcome (EPCO) and other published definitions of PPCs to demonstrate such variances. Most studies investigated PPCs included: atelectasis, pneumonia, pleural effusion, pulmonary edema, respiratory infection, respiratory failure, pneumothorax, bronchospasms, acute respiratory distress syndrome (ARDS), and tracheobronchitis in combination or as independent outcomes (Miskovic & Lumb, 2017). In studies where these respiratory conditions are grouped, identifying risk factors for individual conditions becomes difficult (Smetana, 2009), thereby hampering precise frequency determination and a better comprehension of PPCs in human surgical patients.

2.3 Pathophysiology of Postoperative Pulmonary Complications

PPCs are largely attributed to anesthesia since alterations to the respiratory system occur immediately upon the induction of general anesthesia in a surgical patient (Miskovic &

Lumb, 2017). Anesthesia and other perioperative drugs affect the brain's respiratory center, which regulates breathing and alters the normal function of respiratory muscles, particularly the diaphragm. In some instances, respiratory muscle dysfunction due to anesthesia is not solely due to the lack of overall activity of respiratory muscles, but more a matter of lack of coordination among different muscle groups leading to their inefficiency and eventual hypoventilation in surgical patients intraoperatively. As a result, functional residual capacity decreases and atelectasis develops in dependent lung regions, which impairs pulmonary gas exchange. At times, the intraoperative change in breathing pattern continues into the postoperative phase due to pain caused by surgical trauma and residual anesthetic effect. There are three mechanisms by which surgical trauma affects breathing postoperatively. First, functional disruption of respiratory muscles by incision. Second, voluntary limitation of respiratory motion due to pain. Finally, inhibition of phrenic motor neuron output and function of respiratory muscles due to mechanical traction and manipulation of viscera which affects the diaphragmatic descent (Warner & Weiskopf, 2000).

2.4 Risk factors for the Development of Postoperative Pulmonary Complications

Preoperative, intraoperative, and postoperative risk factors all play a role in the development of PPCs. Risk factors can be categorized into surgery-related or patient-related risk factors (Thanavaro & Foner, 2016). Surgery-related risk factors include surgical site, duration of surgery, an anesthetic technique used and emergency surgery

(Qaseem et al., 2006). Thoracic and abdominal surgeries are considered high risk due to the close proximity of the incision to the respiratory muscles and diaphragm, thereby affecting their functionality (Thanavaro & Foner, 2016). Additionally, anesthesia and surgery that last more than two hours are linked to developing PPC (Miskovic & Lumb, 2017). Nandan et al., 2017 mentioned that patients undergoing emergent surgeries were more at risk for postoperative complications than elective surgeries. On the other hand, patient-related risk factors are age, weight, BCS, ASA class, respiratory status, comorbidities, etc. Whether the risk factor is modifiable or not, it can be manipulated to reduce the incidence of PPCs among surgical patients. Many of the identified risk factors for PPCs are interrelated, but this has been difficult to define because the small sample size precludes multivariate logistic regression from identifying independent factors (Miskovic & Lumb, 2017). Additionally, perianesthetic risk factors which are part of the surgery-related risk factors for the development of PPCs, are the most modifiable yet least studied in the veterinary field.

2.5 Risk Index for Prediction of Postoperative Pulmonary Complications

In the human medical field, risk prediction models for PPCs are available for use by clinicians, reducing the postoperative morbidity and mortality of surgical patients. Many prediction models have been published in the past 5 years. However, the limitations of these models are that they are being developed from retrospective studies and focus on single adverse outcomes such as pneumonia, respiratory failure, acute lung injury, ARDS, etc. Some models even lack the inclusion of specific categories of risk factors, such as intraoperative risk factors per say, which makes them inaccurate or difficult for actual field application. ARISCAT (assess respiratory risk in surgical patients of Catalonia), PERISCOPE (prospective evaluation of a risk score for postoperative pulmonary complications in Europe) and multiple other prospective cohort studies are good examples of such risk prediction models available in the medical field (Miskovic & Lumb, 2017). However, models like these are unavailable for use in veterinary patients due to the scarcity of studies on PPCs in small animals, indicating the lack of awareness of PPCs among the veterinary pupils.

3.0 MATERIALS AND METHODS

3.1 Criteria for selection of cases

All cats and dogs that underwent laparotomy within three years from 2019 to 2021 were identified from the surgical case log of the University Veterinary Hospital (UVH). Case files were excluded from the study based on a set of exclusion criterias. The exclusion criterias were animals with incomplete or missing medical records, animals euthanized within 12 hours of anesthetic induction either intraoperatively or postoperatively, animals with preoperative evidence of cardiac or renal disease, animals with pre-existing pulmonary, pleural space or diaphragmatic diseases whereby 2 or more criterias stated as follows must be fulfilled to be declared as having pre-existing pulmonary issues: physical examination findings (abnormal lung sound, abnormal breathing pattern or rate, clinically apparent respiratory difficulty or distress, cyanotic mucous membrane, etc.), radiological evidence or results of other diagnostic imaging modalities of pulmonary, pleural space or diaphragmatic disease, pulse oximetry reading of less than 95% for oxygen saturation (SpO2) and evidence of therapeutic intervention addressing the pulmonary issue.

3.2 Procedures

Data collected from the medical records of selected patient case files were organized into three categories: preoperative, intraoperative, or postoperative data. Preoperative data included patient history, signalment, primary complaint, diagnosis, pre-existing upper respiratory problems (e.g. feline upper respiratory disease (FURD) for cats), preoperative blood test or other laboratory test results when available, preoperative sepsis, duration of fast, vomiting, administration of preoperative medications (antibiotics, gastrointestinal, anti-inflammatory drugs, etc), preanesthetic evaluation and ASA Class of patient. Intraoperative data included the patient body position during surgery, surgical site (upper or lower abdominal surgery), type of drug used for premedication, induction and maintenance of surgical patient, duration of surgery, duration of anesthesia, fluid type, fluid rate, duration of hypotension, percentage blood loss if available, the total volume of intraoperative fluids administered and intraoperative complications if any. Postoperative data included, postoperative admission either into the ward or intensive care unit (ICU), postoperative pain medication given, postoperative vitals including oxygen saturation (SpO2) measured by pulse oximetry reading, postoperative evaluation of lung sound, breathing pattern and any abnormal physical examination findings relevant to the development of PPCs. Additionally, radiological findings and diagnosis for PPCs, therapeutic intervention attempted to resolve the PPCs, patient response to treatment, length of hospitalization and patient outcome were also recorded for evaluation/ analysis.

Animals were declared to have developed PPCs if they fulfill 2 of the 4 selection criterias listed down below:

i) Physical examination findings of abnormal lung sound, increased respiratory rate, changes in breathing pattern, clinically observable respiratory distress or difficulty and cyanosis of the mucous membrane.

ii) Radiological evidence of pulmonary, pleural space and diaphragmatic diseases, including evidence by other imaging modalities as well.

iii) Oxygen saturation (SpO_2) by pulse oximetry reading of less than 95%

iv) Evidence of response to therapeutic intervention given to treat PPCs such as oxygen therapy, furosemide, bronchodilators, etc.

3.3 Statistical analysis

Data were checked for normality by visual inspection of data and using the Shapiro-Wilks test. Continuous variables with non-normal distribution were described by median and range. Proportions or percentages described categorical variables and the chi-square test was used to compare the groups. A p-value of 0.05 was considered significant as the confidence level was set to 95%. Due to the sample size is less than 500, multivariate logistic regression analysis was not employed to investigate the relationship between the independent and dependent variables in this study.

4.0 RESULTS

Two hundred and twenty-three laparotomy case files were retrieved from the surgical case log for the selection of samples and analysis for this study. Out of the 223 cases, 106 case files were excluded as follows: 51 cases which had pre-existing pulmonary, cardiac or renal disease, 37 missing case files and another 18 irrelevant non-laparotomy case files. The remaining 117 case files were available for further analysis as they fit the inclusion criteria. Among the 117 case files, 73 (62.4 %) were feline and 44 (37.6%) were canine case files showing us that feline patients represented the majority of the laparotomy population.

Among the 73 feline patients, the median age was 1.5 years and the median weight was 2.9 kg. Among the 44 canine patients, the median age was 7 years and the median weight was 13.6 kg. Animals were categorized into stages such as kittens or puppies, young adults, mature adults or seniors based on the guidelines provided by the American Animal Hospital Association (AAHA) for data analysis. However, results indicated that age and body weight were not statistically different among animals that developed PPC and those that did not (nPPC).

Body condition score (BCS) was statistically different between the PPC and nPPC group animals. Animals with below ideal body conditions (BCS scores 1, 2 and 2.5) made up 63% of the PPC group indicating that very thin and underweight animals were much more predisposed to developing PPCs than animals with an ideal body weight or were overweight and obese. The BCS of animals and the incidence of PPCs are shown in Table1.

Body Condition Score (BCS)	**Animals with PPCs**	**Animals without PPCs**	**Total**
2 - Underweight*	5	14	19
2.5 - Very thin	2	26	28
3 - Ideal	3	59	62
3.5	0	1	1
4 - Overweight	0	5	5
5 - Obese	1	1	2
Total	11	106	117

Significant with P<0.05

Table 1: Animal body condition scores and the incidence of pulmonary problems following surgery (PPCs)

The preoperative diagnoses included mammary gland tumor (N=11), cystolithiasis (n=7), stump pyometra (n=4), unilateral or bilateral abdominal cryptorchidism (n=4), foreign body obstruction (n=3), abdominal hernia (n=3), Feline lower urinary tract disease (FLUTD) (n=2), rectal prolapse (n=2), umbilical hernia (n=2), rectal stenosis (n=2), ovarian remnant syndrome (n=2), urolithiasis (n=1), extrahepatic biliary duct obstruction

(EHBDO) (n=1), portosystemic shunt (n=1), paracostal hernia (n=1), small intestinal intussusceptions (n=1), suspected gossypiboma (n=1), splenic mass (n=1) and mass in uterine body (n=1).

The two highest ASA PS observed among the laparotomy cases were ASA PS 1 and 2, with respective frequencies of 64 and 42, followed by ASA PS 3 and 4 with a frequency of 9 and 2, indicating that more than half of the laparotomy population (55%) were normally healthy patients with no systemic illnesses. This might be influenced by the fact that a large fraction of the laparotomy population, about 60%, consists of routine OHE cases, the majority of which are presented with no systemic illness hence resulting in a high percentage of ASA PS 1 among the PPCs group as well (n=6). Nonetheless, there was no statistically significant difference in the ASA PS of the PPCs group and nPPCs group.

Classes	**Animals with PPCs**	**Animals without PPCs**	**Total**
Class 1	6	58	64
Class 2	3	39	42
Class 3	2	7	9
Class 4	0	2	2
Total	11	106	117

Table 2: ASA PS of patients and the incidence of pulmonary problems following surgery (PPCs)

There was a statistically significant difference in the type of surgery performed between animals in the PPC group and nPPC group whereby the high frequency of OHE cases (n=6) was presented among the PPCs group. The reasons for laparotomy were numerous and are listed in Table 3.

Surgical procedure	**Animals with PPCs**	**Animals without PPCs**	**Total**
Routine OHE *	6	65	71
Mastectomy and OHE	-	11	11
Cystotomy / bladder rupture repair	-	7	7
Gastrointestinal surgeries	1	6	7
Abdominal cryptorchidectomy	-	6	6
Pyometra (OHE or stump removal)	2	2	4
Abdominal or umbilical herniorrhaphy	-	3	3
Hepatobiliary surgeries	2	1	3
Exploratory laparotomy	-	4	4
Splenectomy	-	1	1
Total	11	106	117

*Statistically significant $p<0.05$

Table 3: Reasons for laparotomy and incidence of postoperative pulmonary complications (PPCs) in 117 that underwent laparotomy in Universiti Veterinary Hospital (UVH).

Emergency surgeries were only 7.7% of total laparotomy cases whereas 92.3% were elective surgeries due to the large proportion of laparotomies being routine OHE. The handful of emergency surgeries observed throughout these 3 years was of stump pyometra removal (n = 2), bladder rupture repair (n=1), cystotomy (n = 2), abdominal herniorrhaphy (n=1), umbilical herniorrhaphy (n=1) and small intestinal resection and anastomosis (n=2). There was no statistical significance between emergency status of surgeries and the development of PPCs among animals in this study.

Surgical sites were categorized into either upper or lower abdominal surgeries for the purpose of data analysis. Animals that underwent lower abdominal surgeries had statistically higher PPCs occurrence (n=9) than animals that underwent upper abdominal surgeries (n=2). Therefore, the pre-existing understanding that the close proximity of the upper abdominal incision to the diaphragm and respiratory muscles will increase the chances of the animal developing PPCs is in contradiction with the results of this study. However, most cases in the PPCs group underwent lower abdominal surgeries, statistical difference in the surgical site does exist between the PPCs and nPPCs group.

Among the total 117 laparotomy cases, 56% did not have any blood test done or available in their medical records, 38% did not have preoperative hypoalbuminemia and only 6% had preoperative hypoalbuminemia. Among the 11 animals that developed PPCs, 5 had no hypoalbuminemia, another 5 did not have any blood test done and only 1 had hypoalbuminemia. Therefore, no statistical difference in hypoalbuminemia was observed between the PPCs and nPPCs groups.

Animals presented with suspected peritonitis were only 7 out of the total 117 laparotomies making up only 6% of the laparotomy population. Out of those 7 animals only 2 developed PPCs while the remaining 5 did not develop PPCs. No statistical difference was seen between the PPCs and nPPCs groups. Peritonitis was suspected in cases of stump pyometra (n=2), closed pyometra (n=2), ruptured bladder with uroperitoneum (n=1) and foreign body obstruction (FBO) with suspected perforated small intestine (n=1) and suspected colonic perforation in a rectal prolapse case (n=1).

Duration of preoperative fast before induction of anesthesia was categorized as either less than 8 hours or more than 8 hours. A majority of 113 of the 117 laparotomy patients fasted for more than 8 hours, typically to about 12 hours which is the standard protocol practiced in UVH. Only 4 animals were fasted for less than 8 hours of which, one animal developed PPCs. No statistical difference in the duration of preoperative fasting exists between the PPCs and nPPCs.

The preoperative medications administered to laparotomy patients included antibiotics (n=47), gastrointestinal medications (n=10) and anti-inflammatories or non-steroidal anti-inflammatory drugs (NSAID) (n=30). Preoperative antibiotics were given to 47 (40 %) laparotomy cases while the remaining majority 70 (60%) cases did not receive any preoperative antibiotics. Antibiotics administered preoperatively: amoxicillin and clavulanic acid (n=28), metronidazole (n=2), enrofloxacin or marbofloxacin (n=6), cephalexin (n=1), combinations of metronidazole with either enrofloxacin or marbofloxacin (n=6), combinations of metronidazole and augmentin (n=2), combinations of enrofloxacin and augmentin (n=2). The reasons for the administration of preoperative antibiotics were pyometra, concurrent upper respiratory tract infections, concurrent bacterial infection of the skin, as prophylaxis in the case of mastectomy and OHE, trauma cases with neutrophilia requiring surgical treatment, emergency cases of herniorrhaphy, urolithiasis, cases of gallbladder decompression, etc. Preoperative antibiotic administration to the animals was not statistically significantly associated with PPCs development in this study.

Gastrointestinal medications were given to only 10 (8.5%) animals among the 117 laparotomy patients. They were ranitidine (n=4), cimetidine (n=2) and a combination of ranitidine and metoclopramide (n=4). Only 1 of the 11 animals that developed PPCs had received preoperative gastrointestinal medications, namely ranitidine and metoclopramide. In comparison, the remaining 10 animals of the PPCs group did not receive any preoperative gastrointestinal medications. No statistical significance was observed between preoperative gastrointestinal medications and the development of PPCs. Anti-inflammatory drugs such as meloxicam, danzen (serratiopeptidase) and papase were administered to 30 patients preoperatively and 3 that received them developed PPCs with no statistical significance observed.

Perioperative vomiting or regurgitation had no statistical significance in the development of PPCs among laparotomy cases in this study. Perioperative vomiting was observed in 12 surgical small animal patients, 2 out of the 12 patients acquired PPCs while the remaining 10 did not. Vomiting or regurgitation was observed in animals that were presented for hepatobiliary surgeries with a diagnosis of either portosystemic shunt (PSS) (n=1) or extrahepatic biliary duct obstruction (EHBDO) (n=1), as well as surgeries of small intestinal resection and anastomosis or exploratory laparotomy for suspected foreign body obstructions (FBO) (n=3) or small intestinal intussusception (n=1), stump pyometra or open or closed pyometra (n=2) and routine OHE (n=4).

Laparotomy patients were premedicated with either tramadol (n=109), morphine (n=3), a combination of morphine and meloxicam (n=4) or a combination of tramadol and midazolam (n=1). The route of premedication remained the same among the large majority of laparotomy patients (n=105) which is via the subcutaneous route followed by a small minority of cases (n=8) which received premedication by intravenous route and 4 patients who received them intramuscularly.

The induction drug most commonly used was propofol, either alone or in combination with other drugs. Propofol alone was administered for the induction of 109 (93%) patients, followed by a combination of propofol and midazolam for 4 (3.4%) patients, propofol and ketamine for 3 (2.5%) patients and Zoletil for only 1 (0.85%) patient. Nonetheless, no induction drug used alone or in combination was over-represented in the PPCs group compared to the nPPCs group. Additionally, body position during surgery for all cases was dorsal recumbency due to all the surgeries being laparotomies which involve an abdominal incision.

Duration of anesthesia was taken as the time from induction to extubation or when the vaporizer was off. Duration of anesthesia was variable based on the type of surgical procedures the animals underwent. For data analysis, the duration of anesthesia was categorized into durations of less than an hour, 1 to 2 hours, 2 to 3 hours, 3 to 4 hours, 4 to 5 hours and more than 5 hours. The majority of routine OHE cases fell into the 1-to-2-hour duration with a frequency of 41 (57.7%) cases. Another 17 (23.9%) routine OHE cases were of 2-to-3-hour duration, followed by 2 (2.8%) routine OHE cases 3 to 4 hours under anesthesia and only 11 (15.5%) routine OHE cases were of less than an hour duration. The duration of anesthesia with the highest frequency of surgeries (n=49) 41.8% was 1 to 2 hours with surgeries such as routine OHE (n=41), gastrointestinal surgeries (n=2), abdominal or umbilical herniorrhaphy (n=2), hepatobiliary surgery (n=1), abdominal cryptorchidectomy (n=1), mastectomy and OHE (n=1) and finally OHE or stump removal for pyometra (n=1). Nevertheless, no statistical significance was observed between the duration of anesthesia and the development of PPCs.

Information on the personnel performing the anesthesia on the laparotomy patients was not obtained due to the unavailability of data during the data collection process. Therefore, it was difficult to know whether the anesthetic procedure was performed by the surgical team staff, the senior veterinary student, or the supervising veterinary anesthesiologist.

For animals that developed intraoperative hypotension, corrective fluid therapy was provided whereby fluids, either Lactated Ringers or 0.9% Sodium Chloride (NaCl) were given at a specific rate for a specified duration. Corrective fluid therapy for intraoperative hypotension was statistically significant for developing PPCs in the laparotomy population in this study. 7 of the 11 (63.6%) cases within the PPCs group had correction of hypotension with fluids. In contrast, only 2 animals within the PPCs group did not receive any intraoperative fluids to correct hypotension. Due to limitations such as insufficient data during data collection for this study, the exact rate of fluids administered during the period of hypotension in cases that developed PPCs was not available. In two cases of PPCs however, the fluid rate administered was recorded as 3 drops per second for 15 to 20 minutes for the correction of intraoperative hypotension, which gives a total volume of 180 ml per hour which is 3 times higher than the recommended rate which is 60 ml per hour which might have lead to the development of PPCs.

4.1 Pulmonary complications

Among the 117 laparotomy cases, 11 developed PPCs whereas the remaining 106 did not, representing 9.4% of the laparotomy population in Universiti Veterinary Hospital (UVH) from 2019 to 2021. Among the 11 PPC cases, 2 were canine cases (representing 4.5% of the canine laparotomies) while the remaining 9 were feline cases (representing 12.3% of the feline laparotomies). The representation of a higher frequency of cats in the PPCs group is likely due to a large percentage of the laparotomy population being feline patients (62.4% of the laparotomy population).

The cases were evaluated based on an overall consideration for patient signalment, clinical signs, radiographic evidence of pulmonary infiltrates, oxygen saturation (SpO2) measured by pulse oximetry reading of less than 95% and the patient's response to therapeutic intervention provided for the PPCs. Clinical signs such as harsh, crackles or dull lung sounds were heard in 7 of the 11 patients (63.6%) that acquired PPCs whereas the remaining 4 cases did not have any records of abnormal lung sound heard postoperatively. Only 4 out of 11 laparotomies cases had radiographic evidence of pulmonary pathology. Four cases with radiographic evidence of pulmonary infiltrates, diagnosis of suspected atelectasis, pulmonary edema or pneumonia, and hyperinflation of the lungs, along with concurrent pneumothorax or pleural effusions in 2 cases were identified.

Since only four cases had radiographic findings, detailed elaboration on the interpretation of the patients pulmonary condition is given below. Among the four radiographs, 3 belonged to relatively healthy cats without any pre-existing upper or lower respiratory problems with ASA PS of Class 1 that underwent routine OHE while the remaining 1 case was of a cat with a history of feline upper respiratory disease (FURD) with ASA PS of Class 2 that underwent cholecystectomy and liver lobectomy. Eventually, all 4 of these animals developed PPCs postoperatively with radiographic evidence to support their diagnosis of pulmonary complications.

In the first case, the alveolar pattern was observed at the right middle and caudal lung lobes with reduced visibility of the cardiac silhouette. Such an alveolar pattern could be due to either atelectasis or consolidation whereby consolidation can be caused by fluid or mass. Additionally, the fluid can be either transudate, exudate or modified transudate while the suspicion of a mass could be further investigated with the acronym "CHANGE" which stands for cysts, hematoma, abscess, neoplasia, granuloma, etc. Therefore, to differentiate if these radiological findings are due to atelectasis, pulmonary edema or pneumonia, radiological findings alone are not definitive. Clinical signs, the history of the animal, the duration taken to develop the clinical signs and the response to treatment provided were analyzed cumulatively.

Next, in the second case, flattening of the diaphragm, large appearance and increased radiolucency of the lungs as well as the increased size of the area ventral to the caudal vena cava indicated hyperinflation of the lungs. In the third case, lobar signs at the cranial lung lobes suggestive of an alveolar pattern, mixed bronchial and interstitial pattern at the caudal lung lobes and mild pneumothorax were identified giving a suspected diagnosis of moderate to severe pneumonia. In the fourth and final case, mixed alveolar and interstitial patterns with air bronchogram suggest exacerbation of pre-existing asthma since this cat had a history of preoperative FURD. However, it is important to note that this cat did not exhibit any clinical signs of respiratory distress before undergoing surgery thereby not satisfying the selection criteria to be considered as having preoperative pulmonary problems; hence justifying its inclusion into the sample selected for this study.

4.2 Management and outcome of patients

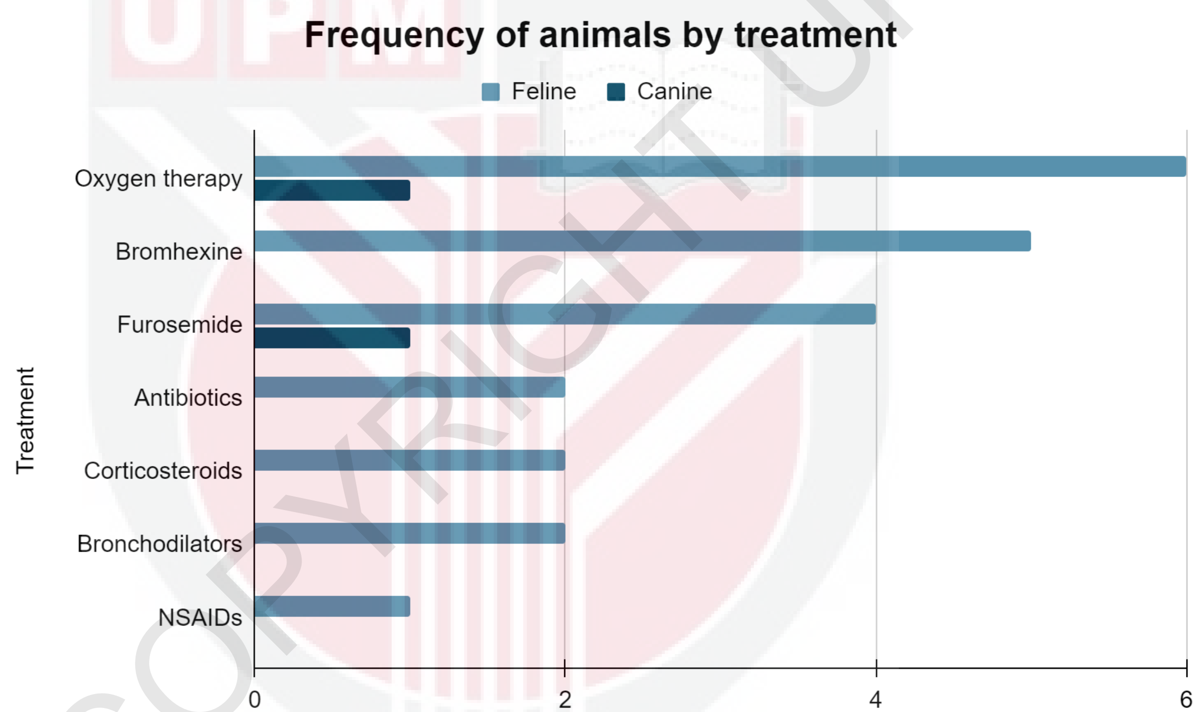

Figure 1: A bar chart representing the therapeutic interventions provided for PPCs in this study.

Treatments provided for the PPCs in this laparotomy population of UVH are shown in the bar chart above. With the highest frequency (n=7), oxygen therapy was the first-line therapeutic intervention provided in cases of PPCs, followed by bromhexine a mucolytic agent (n=5), furosemide (n=5), antibiotics (n=2), corticosteroids (n=2), bronchodilators (n=2) and NSAIDs (n=1). All cases of PPCs except for one received therapeutic interventions in this study (n=10).

5.0 DISCUSSION

In this study conducted to identify the perianesthetic risk factors associated with the development of postoperative pulmonary complications (PPCs) in the laparotomy population of UVH, an incidence rate of 9.4% among the laparotomy cases were observed for PPCs. This result is consistent with Thanavaro & Foner (2016) who found that the incidence rate was 7 % which can vary between 5% to 70% depending on the different definitions of PPCs adopted by the large variety of studies investigating PPCs in surgical patients.

This study also identified four significant risk factors for the development of PPCs. Firstly, surgical patients with a lower body condition scoring (BCS) such as BCS of 2 and 2.5 were associated with increased risk for the development of PPCs in this study. However, this result was in contradiction with the majority of the medical literature as explained by Cline & Murphy (2019) that obese and overweight animals with a BCS of above 3 were at a higher risk to experience obesity hypoventilation syndrome (OHS) in which increased fat deposition in the abdominal and thoracic region in these animals led to reduced pulmonary compliance or in other words caused stiffening of the respiratory system subsequently reducing the lung volumes, tidal volumes and functional residual capacity (FRC) of the lungs. Reduction in tidal volume and FRC of lungs can lead to ventilation-perfusion mismatch and cause alveolar hypoventilation, which results in hypoxemia. Other than that, airway closure can also occur causing alveolar collapse and eventually atelectasis. This is important to note because atelectasis may act as a precursor for the development of many other conditions such as pneumonia and pulmonary edema which are all PPCs.

Several factors could account for this study's paradoxical findings, which showed that animals with BCS scores below 3 were overrepresented in the PPCs group. Firstly, this could be due to the majority of the PPCs cases were feline patients (82%) and a high percentage of the feline patients among the laparotomy populations were of low BCS (66.7%) which might have skewed the data to a high number of low BCS laparotomy patients developing PPCs, inaccurately suggesting that there is an association between low BCS and development of PPCs. However, a few research studies like Sabaté et al. (2014) and Phung et al. (2013) identified that low body condition scores or recent weight loss could be an indicator of a patient's low nutritional status and hence a weakened immune system putting them at higher risk to acquire respiratory infections after surgery supporting the findings of this study.

As for the second significant risk factor, the surgical site whether it was an upper or lower abdominal surgery was also investigated for the development of PPCs in these laparotomy patients. Animals that underwent lower abdominal surgeries were peculiarly overrepresented in the PPCs group in this study as compared to animals that underwent upper abdominal surgeries challenging the generally accepted understanding in the medical field that upper abdominal surgeries have a higher risk of disrupting the normal respiratory mechanics of surgical patients due to the close proximity to the thoracic region in upper abdominal surgeries as compared to lower abdominal surgeries.

Warner & Weiskopf (2000) elaborated in support of the general understanding that in upper abdominal surgeries, intraoperative changes to the breathing pattern occurred and even persisted in the postoperative period of patients due to surgical trauma and that there were three main mechanisms by which this occurs. First, the incision placed close to the thoracic region leads to disrupted functioning of the respiratory muscles especially the intercostal muscles even after surgical repair. Next, voluntary limitation of respiratory motion due to postoperative pain and finally, the visceral manipulation was done during upper abdominal surgeries to inhibit the phrenic motor neuron output affecting the normal diaphragmatic descent both intra and postoperatively. Either one of these mechanisms independently or in combination can initiate the development of PPCs in surgical patients as they lead to alveolar hypoventilation.

To explain the contradictory results (lower abdominal surgeries over upper abdominal surgeries) obtained for this risk factor, it might be possible that since a large portion of the PPCs cases were routine OHE (66.67%), this could have misrepresented a high number of lower abdominal surgeries among the laparotomies thereby suggesting a possible association between lower abdominal surgeries and the development of PPCs. However, no link between lower abdominal surgeries and the development of PPCs was established by far in any literature, but a possible association could be made between routine OHE and PPCs specifically in this study as would be elaborated in the next risk factor.

As for the third risk factor associated with the development of PPCs, the type of surgery had a significant association with the development of PPCs in this laparotomy population. A higher number of routine ovariohysterectomy (OHE) was observed among the PPCs group, followed by stump pyometra removal or OHE for pyometra, at third place hepatobiliary surgeries and finally gastrointestinal surgeries. A possible explanation as to why a high number of animals that underwent routine OHE experienced PPCs after laparotomy is that there is a lack of screening tests done on patients presented for routine OHE to UVH unless indicated. For instance, patients presented for routine OHE do not have preliminary diagnostic imaging (radiography, ultrasound, etc) or blood screening done preoperatively due to cost constraint and due to the owners preference.

The basic screening done in most routine OHE patients in UVH is screening for packed cell volume (PCV) and plasma protein (PP), which is not adequate enough to identify pre-existing pulmonary or upper respiratory problems which might be exacerbated or certain conditions that may predispose patients after anesthesia and surgery to the development of PPCs postoperatively in these patients. When an admission chest radiograph was performed preoperatively as baseline data for comparison postoperatively, Mendelson et al. (1987) discovered that surgical patients' postoperative management was improved and their treatment costs substantially decreased. Another study by Strobel et al. (2016) found that preoperative leukocytosis identified by blood test was a significant predictor of postoperative pneumonia hence supporting the importance of doing a preliminary blood test preoperatively.

Preoperative screening tests are important in identifying underlying pulmonary problems in patients before undergoing surgery. It is compulsory in the human surgical field for patients to undergo radiological examination and blood screening before any surgical procedure is carried out on them unlike veterinary patients. Therefore, the importance of preoperative screening must be highlighted to owners as they might not be aware of the risk for PPCs in their pets. At least the option of screening their pets with either a blood test or a simple chest radiograph before surgery should be recommended or offered by the clinician to the pet owners to increase vigilance against possible underlying pulmonary problems.

Additionally, the second most represented case in the PPCs group was those cases that underwent laparotomy for surgical treatment of pyometra. The development of PPCs in these cases could be due to a few reasons. Firstly, some of the pyometra cases were presented at later stages of pyometra, with suspected septicemia or a systemic infection which could on rare occasions spread to the lungs establishing an infection and contributing to pneumonia (Pneumonia, n.d., nidirect). Besides that, a condition known as uremic pneumonia which is also a rare complication of pyometra could be the cause. It is a member of the "non-cardiogenic edema" or "acute respiratory distress syndrome" group and is related to acute renal failure (Canine-thorax, n.d, Vetpixel). Moreover, development of PPCs could also be due to vomiting which is a common clinical sign observed in not only pyometra patients but also in patients presented with hepatobiliary diseases, small intestinal foreign body obstruction or small intestinal intussusception.

Vomiting could occur as a result of gastric ulceration due to uremia due to the inability of kidneys to remove the urea and creatinine effectively from blood caused by the ascending bacterial infection which spreads from the pus-filled uterus to the kidneys as the kidneys are in close proximity to the infected uterus. Vomiting in pyometra cases could also be due to pain caused by the pus-filled uterus. Ultimately, vomiting or regurgitation leads to the development of aspiration pneumonia postoperatively which will be discussed in the following paragraphs (Kelkar, 2015).

The most important perianesthetic risk factor for the development of PPCs is the correction of hypotension with fluids, and it refers to the fluid overload brought on by the high fluid rate used intraoperatively to treat hypotension, which results in pulmonary edema, or a buildup of fluid in the lungs. Unfortunately, because there was a paucity of information on fluid rate administered intraoperatively, this study could not identify the precise fluid rate that could have potentially caused the development of PPCs among the PPCs group. A fluid rate of 3 drops per second was however identified in two of the eleven PPCs suggesting an indeterminate association. The recommended dosage for correction of hypotension as per BSAVA is 20 ml per kg for over 20 minutes which equates to 60 ml per hour. Comparatively, 3 drops per second would equate to 180 ml per hour when microdrip set is used which is 3 times higher than the recommended dosage which according to Liu et al., 2020 can cause fluid overload and pulmonary edema.

As for the types of pulmonary complications suspected in laparotomy patients of UVH, atelectasis, pulmonary edema, pneumonia, tracheitis, bronchitis, tracheobronchitis, bronchopneumonia and short-term postoperative hypoxemia were all diagnosed based on clinical signs and signalment of the patients with or without radiological evidence.

Atelectasis is highly relevant and common among surgical patients due to several predisposing factors. Firstly, prolonged periods of the recumbent position of animals during surgery cause the dependent lung regions, more specifically the ventral lung lobes (in dorsal recumbency) to collapse just due to the weight of the lungs alone, which is more commonly known as positional or compression atelectasis. Positional atelectasis has been documented to take more than 24 hours to resolve in human surgical patients. Secondly, a high fraction of inspired oxygen (FiO2) of about 100% to surgical patients throughout anesthesia washes out the nitrogen skeleton required to maintain the structure and patency of alveoli thereby causing the spontaneous collapse of the alveoli and this type of collapse is termed as absorption atelectasis (Brainard et al., 2006).

Nonetheless, the effects of atelectasis are self limiting and reversible in normal lungs of patients encouraged with early mobilization and physiotherapy, complete correction of the atelectasis is possible (Brainard et al., 2006). It could be said that suspected atelectasis cases in this study were all self-limiting as they successfully recovered within 24 hours of the presentation of respiratory distress with or without therapeutic intervention. The efficacy of positive end expiratory pressure (PEEP) which is said to be effective in preventing atelectasis in anesthetized patients was not investigated in this study as no mechanical ventilation is used in surgical patients of UVH.

Pulmonary edema in this study was suspected based on pulmonary infiltrates observed in radiographs along with clinical signs of crackles or harsh lung sound, labored, abdominal or open mouth breathing with successful patient recovery upon diuretics such as furosemide. The cause of the non-cardiogenic pulmonary edema in this study was suspected to be due to the high fluid rate used for the correction of hypotension intraoperatively.

Pneumonia was suspected in 6 of the 11 PPCs in this study. The suspicion of pneumonia as one of the PPCs diagnosed in this study was based on radiological findings of pulmonary infiltrates specifically in the dependent lung lobe which is the right middle lung lobe as well as evidence of crackles or harsh lung sound, productive cough and fever in some cases and open mouth breathing observed in most cases, accompanied by recovery after administration of drugs such as oxygen therapy, bromhexine, corticosteroids and antibiotics such as marbofloxacin.

The aetiopathogenesis of pneumonia in post surgical patients varies largely. Pneumonia can be either hospital-acquired or can be secondary to altered pulmonary defenses, aspiration or even established via the hematogenous route. In this study population, hospital acquired pneumonia (HAP) also known as nosocomial pneumonia, defined as a pulmonary infection that develops at 48 hours or more of hospitalization and not incubating at the time of admission, was highly suspected to be the cause of pneumonia. HAP in human surgical patients has an incidence rate of 0.5% to 2% and a high mortality rate of about 30% to 70% (Tarsia et al., 2005).

Ventilator-associated pneumonia (VAP), a significant subset of HAP, is common among intensive care unit (ICU) patients in the human medical field. VAP is defined as pneumonia that develops at 48 to 72 hours after tracheal intubation and mechanical ventilation. However, VAP by definition does not completely fit the pneumonia characterized in this study population because VAP specifically applies to tracheal intubated and mechanically ventilated patients while small animals surgical patients of UVH did not receive any mechanical ventilation perioperatively.

Essentially, endotracheal intubation regardless of the duration of intubation of patients and whether patients had received mechanical ventilation can be suspected as a source of infection among many others in this study due to the fact that the disposable endotracheal tubes (ETTs) are reused among patients in UVH but with sterilization done between each use in different patients. Bauer et al. (2002) found in his study that ETTs act as a reservoir for bacterial biofilms substantially contributed to the pathogenesis of pneumonia in intubated patients. Bacterial biofilms are bacterial populations adhered to the inner lumen of the ETTs which have reduced susceptibility towards antibiotics. In the context of nosocomial pneumonia, common pathogens found in the lumen of ETTs were gram negative bacilli such as *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter spp*, *Acinetobacter spp*. and gram positive cocci such as Staphylococcus aureus which includes methicillin resistant S. aureus and Streptococcus spp.(Shebl & Gulick, 2022).

Endotracheal intubation has a direct effect on the airways which disrupts the normal host defense mechanisms which includes mucosal injury which impairs mucociliary clearance of debris and bacteria laden secretions, followed by the bypassing of upper airway defenses and reduced effectiveness of coughing. Secondly, intubation also increases the capacity of gram negative bacteria to bind to tracheobronchial cells. Third mechanism is when basement membranes of the bronchial tree become binding sites for bacteria upon injury caused by the intubation.

Other factors that might contribute to the development of pneumonia in postoperative period is patients' immune systems that might be weakened due to the stress of surgery or underlying diseases. Additionally, anesthesia associated-depression of normal laryngeal function and normal breathing pattern weakens host defenses against pathogens causing easy establishment of an infection contributing to pneumonia. It is possible that patients' pre-existing respiratory infection was overlooked in those cases that did not have any preliminary radiological examination or blood test performed preoperatively. For instance, preoperative leukocytosis can act as a predictor for postoperative pneumonia (Strobel et al., 2016).

Another type of pneumonia could also be suspected which is aspiration pneumonia. Aspiration pneumonia occurs when a patient aspirates either feed material, gastric acids or bile which causes injury to the lung parenchyma allowing the establishment of a secondary bacterial infection and subsequent inflammation in the lungs. In this type of pneumonia, expected radiological findings would be alveolar infiltrates mainly in the left and right cranial lung lobes as well as the dependent right middle lung lobe (Kelkar, 2015). In this study, a minimum of 2 cases were observed to have pulmonary infiltrates in cranial lung lobes. The volume and content of aspirate is also an important factor to determine severity of the infection. In cases where acidic or bilious substances were aspirated, chemical pneumonitis could have occurred (Nakajima et al., 2018).

However, it is important to keep in mind that a definitive diagnosis of pneumonia can only be made from a positive culture of pathogenic microbes from fluid obtained from bronchoalveolar lavage. Unfortunately though, no such data was available in this study as owners preference for empirical treatment was higher than preference for further diagnostic tests such as BAL when an animal was suspected of having pneumonia.

Besides that, a condition known as post intubation tracheitis was also suspected in this study. Harada et al., (1977) found in their review of case reports that human surgical patients intubated for a minimum of 3 to 4 hours intraoperatively, developed dyspnea, irritant cough, laryngeal edema, laryngeal stridor and in most cases produced expectorant approximately 12 to 24 hours after extubation. All of these cases developed membranous tracheitis. It was suggested that cuffed endotracheal intubation, due to the high pressure produced by the inflated cuff tube on the wall of trachea lead to local ischemia, which if persisted long enough, caused ulceration and the shedding of the inner epithelium of the trachea. Additionally, intubation of unsterilized tubes and tubes of larger size caused irritation and inflammation of the trachea. Moreover, long term intubation which caused persistent pressure by the cuff and the drying effect of atropine had caused retention of secretions in the lower respiratory tract contributing to intubation-associated pneumonia (Harada et al., 1977).

Tracheal tears due to intubation also known as, iatrogenic tracheal rupture, were also a possible cause of PPCs in feline surgical patients in this laparotomy population. Adshead, 2011 in his study found that tracheal tears characterized by a linear tear about 2 to 5 cm on the dorsal longitudinal trachealis muscles or the dorsolateral aspect of trachea at the junction of tracheal rings, leads to coughing, tachypnea, expiratory dyspnea, gagging, cyanosis and muffled heart sounds. As air escapes the torn trachea, it travels to the mediastinum causing pneumomediastinum. If the pressure is high enough, air then ruptures the mediastinum, leading to pneumothorax and in cases where the tracheal tear acts as a one-way valve, tension pneumothorax develops. He also claimed that tracheal tears occur due to improper placement of ETT, use of improper ETT sizes, over inflation of the ETT cuff, improper use of intubation stylet and failure to deflate the cuff before repositioning or extubation of the tube.

It was found that, due to the smaller size and more delicate nature of the feline trachea, cats are more predisposed to tracheal tears than dogs. A little more than 6 ml of air in the cuff can increase the risk for tracheal rupture. Finally, tracheal tears are radiologically diagnosed whereby 100% of the cases will have subcutaneous emphysema due to escape of air from the mediastinum into the subcutaneous regions (Quandt, 2017). In this study however, tracheal tears could only be suspected and not definitively diagnosed due to the lack of radiological evidence in 7 cases of PPCs. The four other cases with radiographic evidence of PPCs did not have any findings consistent with tracheal tears.

Tracheitis could also progress to become tracheobronchitis and eventually pneumonia. Craven et al. in, 2014 found that the pathophysiology of ventilator associated tracheobronchitis (VAT) to ventilator associated pneumonia (VAP) has been attributed to leakage of oropharyngeal secretions surrounding the ETT or embolization of bacterial biofilm from the inner surface of the ETT to lower tracheobronchial and alveoli after airway instrumentation. They also found that appropriate antibiotic therapy successfully halted the progression of VAT to VAP in the patient population studied.

Moreover, short term postoperative hypoxemia was also suspected in this case study and the diagnosis was achieved based on the clinical presentation of surgical patients postoperatively. Patients suspected of having short term postoperative hypoxemia developed cyanosis of the mucous membrane, shortness of breath or labored breathing and tachypnea, immediately after surgery which improved instantaneously after oxygen therapy within a matter of minutes. This type of postoperative hypoxemia is associated with ventilation perfusion mismatch as part of a postanesthetic effect. The detailed description of its pathogenesis is as described under the pathogenesis of atelectasis in the earlier paragraphs.

As for the treatment given to the PPC cases in this study, clinicians preferred oxygen therapy as their frontline treatment for PPCs. Followed by bromhexine at second place, furosemide at third and antibiotics at fourth place. This practice is consistent with Waddell, 2016 who said that oxygen therapy should be provided to any small animal patient presented with respiratory distress. Patients with pulse oximetry reading (SpO2) of below 95% or with an arterial partial pressure (PaO2) of below than 80 mmHg should be administered oxygen. The author also mentioned that the risk involved in short-term oxygen supplementation was minimal which in most cases rapidly benefits hypoxic patients.

Bromhexine, as a mucolytic agent, was administered to both categories, patients who had productive cough or phlegm, and patients who did not have productive cough but showed signs of respiratory distress such as labored, open mouth or abdominal breathing. This might be due to the clinicians suspecting a possibly overlooked FURD in feline patients. Hence, administering a mucolytic agent such as bromhexine will reduce the elasticity and viscosity of mucus, making expectoration much easier in these patients.

Besides that, furosemide was administered to 5 of the 11 PPCs, nearly half of the PPCs group and considered as inconsistent. This inconsistency is due to some patients who did not have evidence of abnormal lung sound but were only having clinical evidence of respiratory distress. It is important to note here that postoperative pain control was well managed in UVH as all the surgical patients of this study population were administered tramadol postoperatively and patients were dispensed tramadol tablets for good pain management after discharge. Pain management after abdominal surgeries is of utmost importance because pain causes voluntary restriction in respiration which will compromise the ventilation leading to hypoventilation postoperatively (Warner & Weiskopf, 2000).

This study as a retrospective study was fast and inexpensive to be conducted as compared to prospective or experimental studies but drawbacks such as lack of data due to loss of patient medical record or poor documentation and the need for further clarification on the data obtained were limitations faced. A lack of data especially for the predictor variable eliminated the case involved immediately, as without the predictor variable no analysis could be done regarding that variable thereby reducing the sample size and the power of this study. Therefore, proper documentation of data and regular checking of medical records to prevent missing documentation should be emphasized among staff and students for future studies to be conducted with ease. Students should be informed of the important information deemed compulsory to be recorded in the case files. Next limitation faced was smaller sample size than anticipated. A high number of laparotomies were anticipated initially during the process of case file retrieval but only a total of 117 out of the 223 cases were available for analysis. This affected the power of this study because, if a larger sample size was available logistic regression could have been employed to statistically analyze the data obtained.

Logistic regression which requires at least a sample size of 500 would enable us to study the relationship between the independent variables in association with the dependent variable as compared to other non-parametric tests which only test the relationship between the independent and dependent variables. Therefore, to obtain a larger sample size the duration or timeline of the study must be increased from a 3 year period to a minimum of 6 year period. The duration to conduct the study must therefore also be increased as this will provide more time for a deeper and thorough analysis to be done on all the data obtained. Furthermore, reliable literature sources for reference on this topic of postoperative pulmonary complications is highly scarce in veterinary medicine as compared to human medicine. Only a considerable amount of cross reference can be made with human studies as large differences exist due to the species difference.

Regarding the study design, future studies should focus on postoperative ICU admission cases because not all surgery cases undergo necessary diagnostic tests postoperatively in UVH and in terms of obtaining sufficient data for better analysis, a study focused on ICU cases of postoperative pulmonary complications, would provide lot more necessary information such as oximeter readings, blood pressure readings, duration of oxygen therapy, hourly documentation of data on patient vitals as these information are crucial for a more accurate diagnosis of the type of pulmonary condition the patient has developed. Moreover, future studies should look into the independent risk factors individually so that a deeper understanding could be achieved on that individual risk factor equipping us with better knowledge to alter or modify the risk factor appropriately to prevent development of PPCs in veterinary patients.

6.0 CONCLUSION

In conclusion, some of the risk factors such as body condition score (BCS), site of surgery (upper or lower abdominal), type of surgery and correction of hypotension with fluids, do contribute to the development of PPCs in the laparotomy patients of UVH. It can be concluded that there is an association between the perianesthetic risk factors and development of PPCs in laparotomy patients of UVH. Hence, animals presented with the said risk factors must be very closely monitored for clinical signs of pulmonary complications after surgery. Pulmonary complications such as atelectasis, pulmonary edema, pneumonia, tracheitis, bronchitis, tracheobronchitis and short term postoperative hypoxemia should be further investigated for their aetiopathogenesis and proper preventative measures must be taken to halt their occurrence. Patients undergoing abdominal surgeries, patients who are at either extremes of BCS and patients with pre-existing pulmonary problems should undergo proper screening before entering the operation theater. Owners of those pets scheduled for routine OHE must be informed of the possibility of PPCs and screening tests should be recommended to them to prevent patient suffering postoperatively. More stringent management of fluids and fluid rates intraoperatively by the anesthesiologists, staff and students must be practiced to prevent fluid overload and subsequent PPCs.

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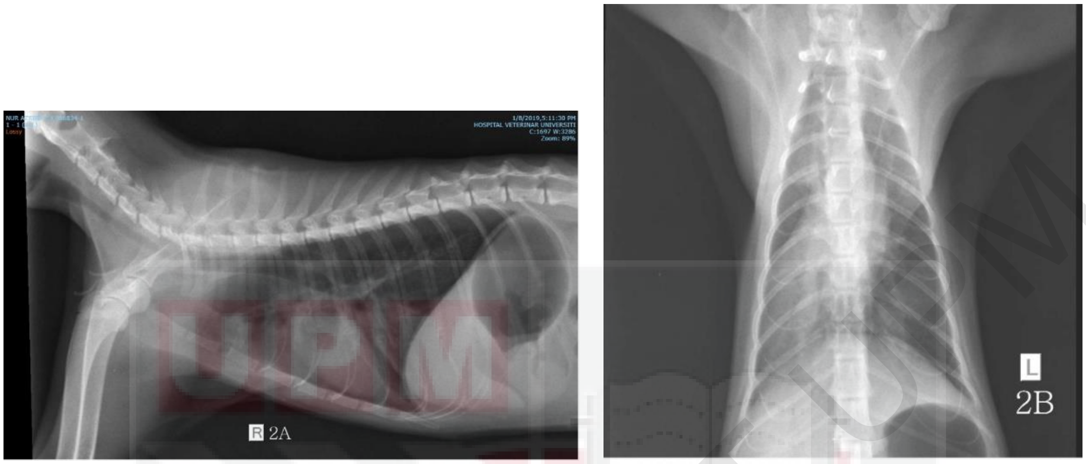
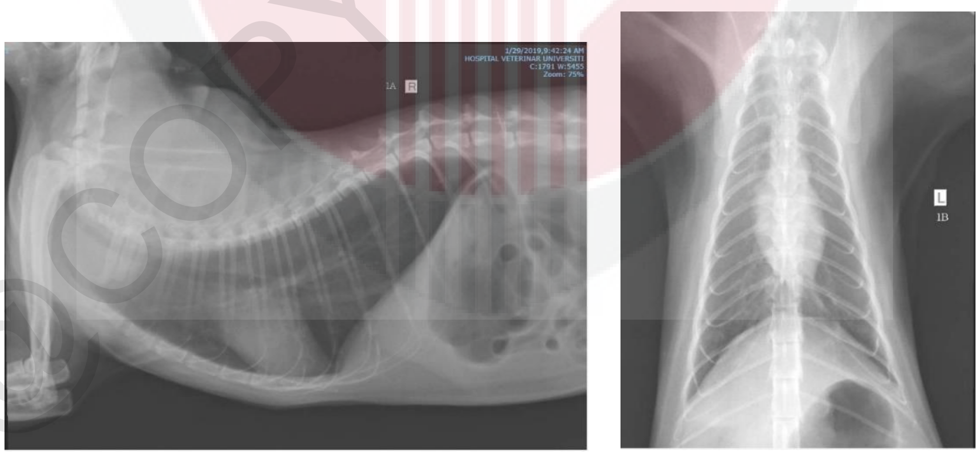
8.0 APPENDIX

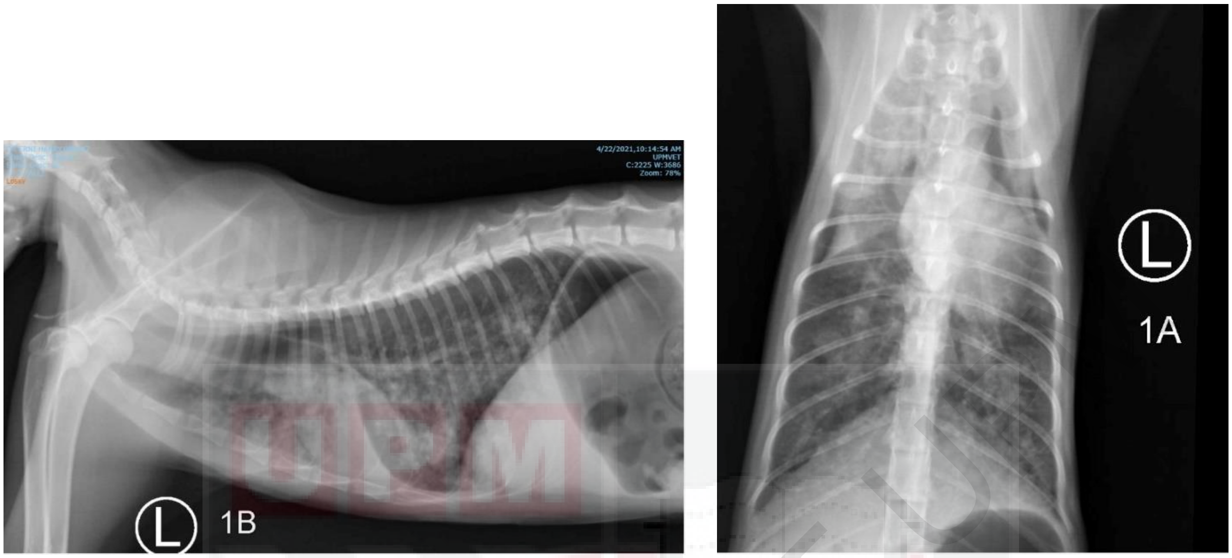


Case 1 : Lobar sign and consolidation of lungs indicating alveolar pattern in the right middle and caudal lung lobes

(Suspected atelectasis, pulmonary edema or pneumonia)

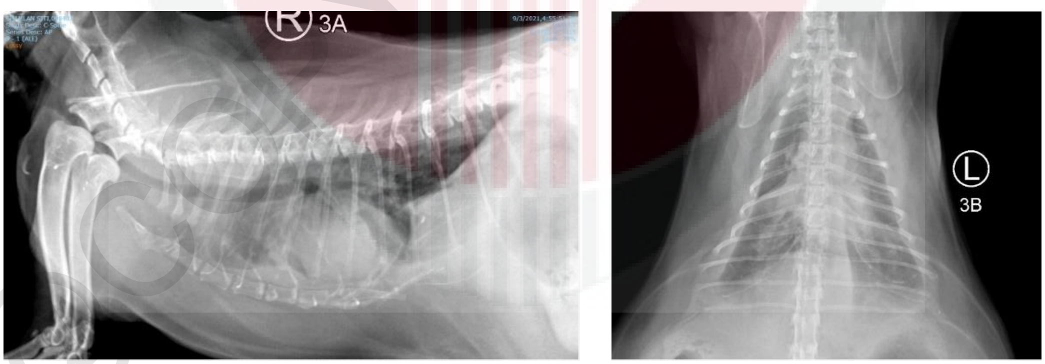


Case 2 : Flattened diaphragm and large and more radiolucent appearance of lungs (Hyperinflation of the lungs)



Case 3 : Lobar sign at cranial lung lobe and mixed bronchioalveolar pattern at caudal lung lobes with pneumothorax

(Suspected severe pneumonia with mild pneumothorax)



Case 4 : Mixed alveolar and intersititial pattern with presence of air bronchogram visible; retraction of lungs from the rib cage indicates pleural effusion

(Exacerbation of asthma postoperatively in a cat)