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RESEARCH ARTICLE

Retrospective Pathological Insights into Pneumonia in Farm Animals: Evidence from 158 Necropsies

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ABSTRACT

Pneumonia is the main respiratory disease in farm animals, causing substantial economic losses, due to treatment costs, reduced productivity, and mortality. The objective of this retrospective study was to evaluate cases of pneumonia submitted for necropsy, with an emphasis on morphological patterns of lesions and etiologic agents. A comprehensive analysis was conducted on necropsy reports of farm animals (horses, cattle, sheep, and goats) submitted to the Veterinary Pathology Service from 2017 to 2021. Pneumonia was diagnosed in 158 of these animals. Cattle and horses were the species most frequently affected, representing 41% (65/158) and 28% (45/158), respectively, of the cases. Pneumonia was classified based on morphological patterns of lesions. In this study, cattle were more likely to be affected with broncho or aspiration pneumonia with *Klebsiella*, *Truperella pyogenes* or *Pasteurella multocida* infections, whereas horses had granulomatous or interstitial pneumonia with *Streptococcus equi*, *Klebsiella pneumoniae* and *Escherichia coli*. We concluded that classification of the morphological pattern, based on macroscopic and microscopic descriptions and a microbiological examination, should be done for all necropsies of farm animals with respiratory system pathology, considering the substantial economic losses associated with the disease.

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INTRODUCTION

Respiratory diseases are common in domestic animals, especially farm animals, leading to substantial economic losses for cattle, sheep, and goats (Malafaia *et al.,* 2016; Baptista *et al.,* 2017; Wang *et al.,* 2025), including animal death, treatment expenses, and reductions in productivity and carcass value (Wilson *et al.*, 2017). Furthermore, for horses, losses include the ability to perform or to compete in shows or exhibitions (Carvallo *et al.,* 2017; Hepworth-Warren and Love, 2024; Kabir *et al.,* 2024).

Pneumonia is the main disorder affecting the respiratory system of farm animals. This disease can be caused by bacterial, viral, fungal and parasitic infections, or be primary or secondary to physical or chemical insults (Caswell and Williams, 2016). *Pasteurella multocida*, *Mycoplasma spp.* and *Truperella pyogenes* are reported as important infectious agents involved in the respiratory complex of ruminants (cattle, sheep and goats) in North and South America (Cozens *et al.*, 2019; Franco *et al.*, 2019a; Liang *et al.*, 2025). Furthermore, in horses, *Streptococcus* spp., *Escherichia coli*, *Klebsiella* spp., *Rhodococcus equi,* and *Burkholderia mallei* are important infectious agents involved in respiratory diseases in this species worldwide (Bianchi *et al.*, 2018a; Wen *et al.*, 2025).

In domestic animals, pneumonia can be classified according to etiological agent, secretion type, alteration features, lesion pattern and distribution, or epidemiological characteristics. Based on morphological aspects such as consistency, distribution, type of lesion, and exudate, pneumonia can be divided into five major groups: suppurative or fibrinous bronchopneumonia, interstitial,

granulomatous, and embolic (López and Martinson, 2017; Ribeiro *et al.,* 2024). In animals with pneumonia, necropsy is an important tool for establishing a diagnosis and isolating the agent and providing evidence to support treatment and prevention of infections in other animals. Retrospective studies retrieve stored data to generate information on diseases, including etiology, occurrence, gender, age predisposition, and regional distribution. This kind of research improves diagnostic techniques and identifies and corrects potential flaws (Lucena *et al.,* 2010; Ribeiro *et al.,* 2024).

This was a retrospective study of cases of pneumonia diagnosed in large animals submitted for necropsy from January 2017 to December 2021. The objective was to evaluate cases of pneumonia submitted for necropsy, with an emphasis on morphological patterns of lesions and etiologic agents. In addition, types of pneumonia were correlated with etiological agents isolated by microbiological culture.

MATERIALS AND METHODS

Ethical consideration: This study was approved by the Ethics Committee on the Use of Animals in Research, São Paulo State University (Protocol 0556/2023).

Selection of cases: Necropsy records included in this study (from January 2017 to December 2021) were obtained from the Veterinary Pathology Service at UNESP – Botucatu. All diagnoses were manually curated and categorized as lesions compatible with a pneumonia diagnosis, with only pneumonia cases being considered. Pneumonia records with inadequate-quality slides and/or paraffin blocks were excluded from the study. Samples with good H&E slides and paraffin blocks were retrieved and the final diagnosis was reviewed by G.G.S. and A.H. (pathologists) to confirm it. Other animal species and records with incomplete necroscopic descriptions were excluded from this study.

Sample collection: Pneumonia cases were selected and assigned according to type, as follows: suppurative bronchopneumonia, fibrinous bronchopneumonia, interstitial pneumonia, granulomatous, and embolic pneumonia. Necropsy examinations that did not align with the above-mentioned classification had the macro- and microscopic descriptions reviewed by two veterinary pathologists, and the types of pneumonia were reclassified, considering the following criteria.

When more than one type of pneumonia was present in the same case, they were classified as both. If the condition did not align with the aforementioned criteria, it was designated as "other," encompassing conditions such as parasitic pneumonia, gangrenous pneumonia, aspiration pneumonia, and those deemed ineligible for classification (Lucena *et al.*, 2010; López and Martinson, 2017). For pathogen detection, samples obtained during necropsy included lung lesions and secretions collected using sterile swabs. Samples were kept refrigerated and agents were identified through microbiological cultures (Lucena *et al.,* 2010; Ribeiro *et al.,* 2024).

Type of Pneumonia	Macroscopic Description	Microscopic Description
Suppurative Bronchopneumonia	Cranio-ventral hepatization of the lungs and purulent or mucopurulent exudate in the airways (Brasil *et al.,* 2013)	Neutrophils, macrophages and cell debris in the lumen of the bronchi, bronchioles and alveoli (Brasil *et al.,* 2013)
Fibrinous Bronchopneumonia	Fibrin, which varies from yellowish, brownish or gray, on the dark red lung (Panciera and Confer, 2010).	Bronchial and alveolar lumen with fluid and fibrin, neutrophils, macrophages and cell debris, with possible fibrosis of the interlobular septa and pleura (Panciera and Confer, 2010).
Interstitial Pneumonia	Diffuse lesion or only in the dorsal-caudal areas, absence of collapse of the lungs when the chest cavity is opened, impressions left by the ribs on the surface of the lungs, texture of the parenchyma rubbery, with a meaty appearance when cut, lungs heavier than normal (Panciera and Confer, 2010).	Inflammatory process in the interalveolar septa and bronchiolar interstitium, the alveolar septa are thickened due to cell proliferation and infiltration of inflammatory cells (Panciera and Confer, 2010).
Embolic Pneumonia	Multifocal distribution in all lung lobes, white foci surrounded by red halos (Panciera and Confer, 2010).	Multifocal distribution, usually in the alveolar arterioles and capillaries (Panciera and Confer, 2010).
Granulomatous Pneumonia	Variable numbers of granulomas distributed randomly throughout the lung, firm texture (Coleman *et al.*, 2019).	The center of the granuloma is composed of a center of necrotic tissue surrounded by a ring of epithelioid and giant cells, which, in turn, is surrounded by a layer of connective tissue, with or without infiltration of lymphocytes and plasma cells (Coleman *et al.*, 2019).

Statistical analysis: A descriptive analysis of the results was performed, with clinicopathological data expressed as frequencies or percentages. Information regarding sex, age, breed, macroscopic and microscopic descriptions, and diagnoses was compiled and summarized using Microsoft Excel (Microsoft Office 365). Statistical analyses were conducted with GraphPad Prism v8.1.0 (GraphPad Software Inc., La Jolla, CA, USA). To evaluate correlations among variables, Spearman's correlation was applied, and a matrix of multiple correlations was generated.

RESULTS

The Veterinary Pathology Service recorded 195 cases of pneumonia during post-mortem examinations from 2017 to 2021. Farm animals such as cattle, horses, sheep, and goats were the most represented species, representing 81% (158/195). Of the 503 farm animals that underwent necropsies, 32% (158/503) were affected by pneumonia.

The pneumonia classification was grouped in the first selection listed according to species, sex, and breed (Fig. 1 and 2). All diagnoses were manually curated and categorized according to the morphological description of pneumonia. Records with inadequate-quality slides and/or paraffin blocks were excluded. Samples with good H&E slides and paraffin blocks were retrieved, and the final diagnosis was reviewed. A correct morphological description of pneumonia was presented in 38.0% of the cases (60/158). However, we had to reclassify the type of pneumonia in 62.0% of the cases (98/158) according to the macro and/or microscopic features, being 28 (28/98; 28.6%) and 35 (35/98; 35.7%) (Fig. 3). Both macro- and microscopic descriptions were used to reclassify 12 (12/98; 12.2%) cases. In 23 cases (23/98; 23.5%), classification of the pneumonia was not possible due to an absence of adequate description of the lesion, location, pattern, texture, and the lack of a microscopic description of inflammation (Table 1).

Microbiological culture was done on lung fragments obtained during necropsy in 25 (25/158; 15.62%) of the cases. Etiological agents were isolated from 20 (20/158; 80%) with a negative result in five (5/158; 20%) cases (Table 2).

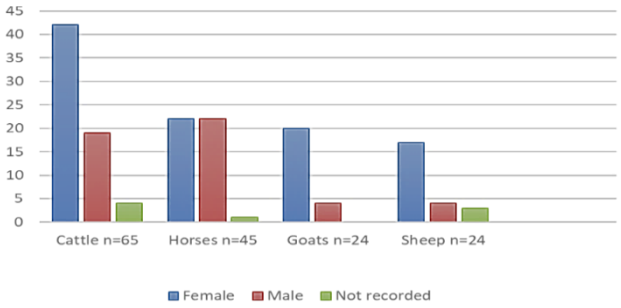

Fig. 1: Species and sex of animals with pneumonia necropsied from 2017-2021 in Botucatu, Brazil.

Table 1: Pneumonia classification according to macro- and microscopic findings by species

	Cattle	Horses	Goats	Sheeps	Total
Bronchopneumonia*	11	3	2	3	19
Fibrinous bronchopneumonia	8	5	1	2	16
Suppurative bronchopneumonia	11	6	5	6	28
Embolic pneumonia	1	0	2	1	4
Granulomatous pneumonia	5	7	2	3	17
Interstitial pneumonia	8	7	6	5	26
Others					
Parasitic pneumonia	2	0	0	0	2
Gangrenous pneumonia	1	0	0	0	1
Aspiration pneumonia	13	3	2	4	22
Not eligible for classification	5	14	4	0	23
Total	65	45	24	24	158

Table 2: Pneumonia classification according to macro- and microscopic findings by species and isolated agent.

Morphology	Cattle	Horses	Goats	Sheep
Bronchopneumonia		*Proteus mirabilis* and *Staphylococcus hemolítico*		
Fibrinous bronchopneumonia	*Mannheimia haemolytica* *E. coli*			*Pasteurella multocida*
Suppurative bronchopneumonia	*Trueperella pyogenes* and *Mannheimia haemolytica*	*Enterobacter aerogenes* and *Salmonella*	*Enterobacter aerogenes* and *Klebisiella oxytoca, Trueperella pyogenes*	*Streptococcus alfa hemolítico, E. coli* and *Aspergillus*
Embolic pneumonia		*E. coli*	*Aspergillus*	*Trueperella pyogenes* and *E. coli*
Granulomatous pneumonia	*Trueperella pyogenes* and *Pasteurella multocida*	*Rhodococcus equi* and *Nocardia sp.* *Staphylococcus beta hemolítico*		*Pseudomonas aeruginosa, Staphylococcus, Streptococcus alpha hemolítico , Pasteurella multocida*
Interstitial pneumonia		*Streptococcus equi, Klebsiella pneumoniae, E. coli*		

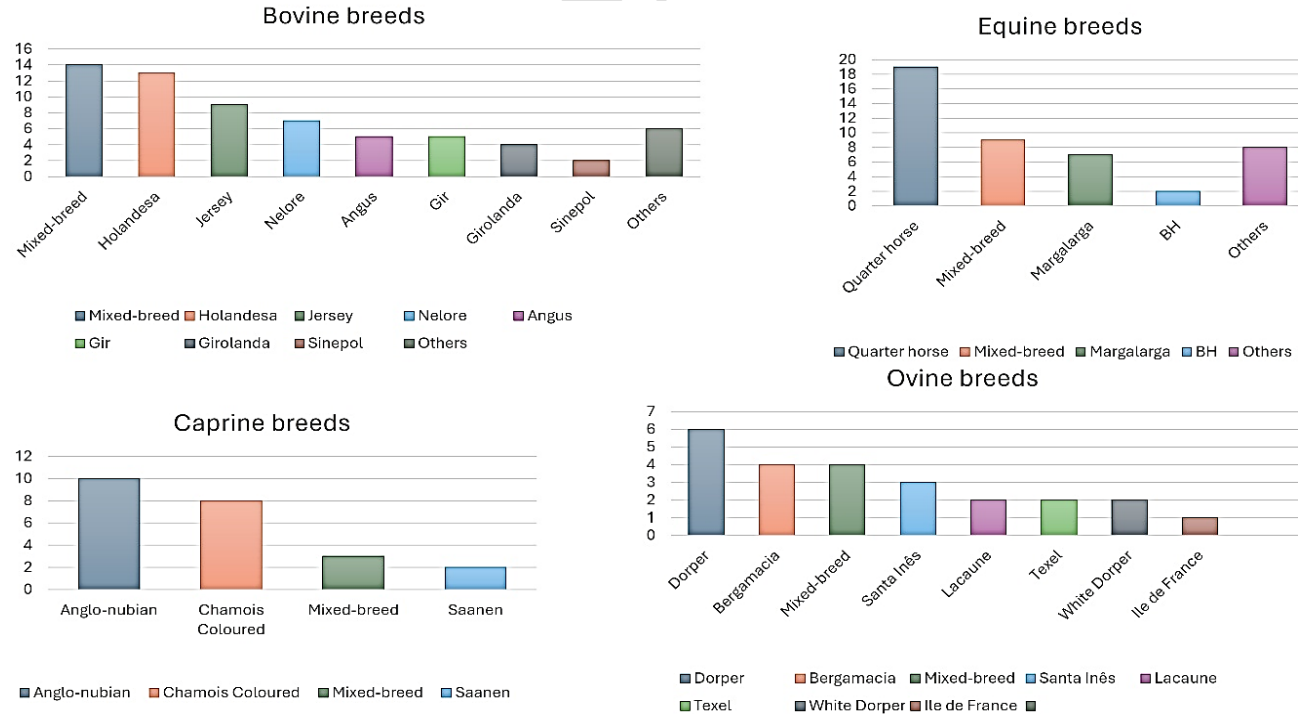

Fig. 2: Breeds of farm animals with pneumonia necropsied from 2017-2021, in Botucatu, Brazil.

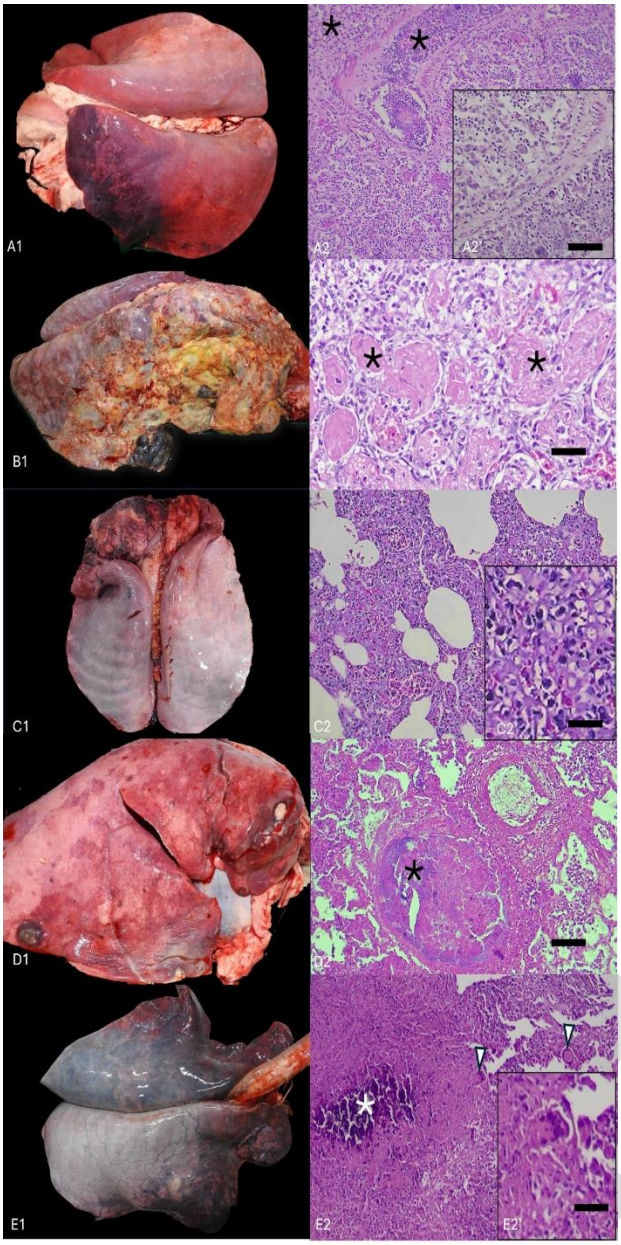

Fig. 3: Macroscopic and microscopic features in various pneumonia types. A1) Cranioventral hepatization of the lungs in suppurative bronchopneumonia. A2) Neutrophils are present in the lumen of the bronchioles and alveoli in suppurative bronchopneumonia (asterisk) (10x) H&E stain, bar = 100 µm. A2') Intrabronchiolar and alveolar inflammatory process shown at higher magnification (asterisk) (20x) H&E stain, bar = 50 µm. B1) Fibrinous bronchopneumonia can be distinguished by its yellowish, brownish, or gray spectrum on macroscopy. B2) Alveolar lumen with fluid and fibrin, and neutrophils in microscopic analysis of fibrinous pneumonia (asterisk) (10x) H&E stain, bar = 100 µm. C1) Rib impression on the surface of the lungs in the interstitial pattern. C2) Inflammatory process in the interalveolar septa and interstitium are observed microscopically in the interstitial pattern (10x) H&E stain, bar = 100 µm. C2') Interalveolar inflammatory process shown at a higher magnification (asterisk) (20x) H&E stain, bar = 50 µm. D1) Macroscopy embolic, white foci surrounded by red halos multifocal distribution in all lung lobes. D2) Center necrotic with bacteria surrounded by neutrophils in microscopy of embolic pattern (asterisk) (10x) H&E stain, bar = 100 µm. E1) Focal granuloma, with firm texture in granulomatous pneumonia. E2) Center of necrotic tissue with calcification (white asterisk), surrounded by a ring of epithelioid and giant cells which, with or without infiltration of lymphocytes are visualized in granulomatous pattern (10x) H&E stain, bar = 100 µm. E2') Multinucleated giant cells are shown in detail at a higher magnification (asterisk) (20x) H&E stain, bar = 50 µm.

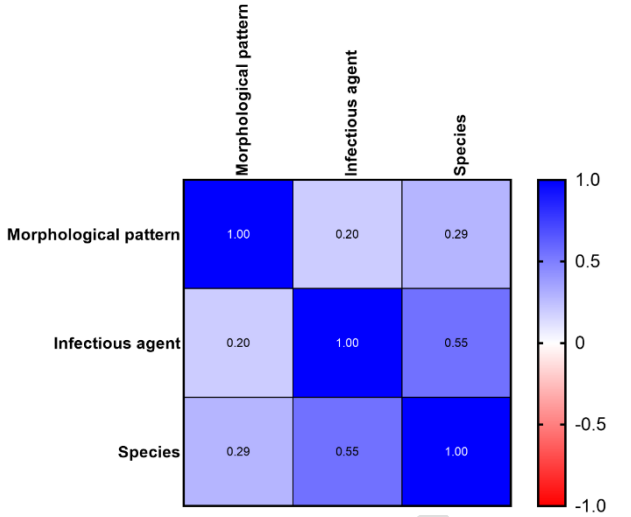

Fig. 4: Multivariate analysis for morphological pattern, infectious agent and species in pneumonia cases.

DISCUSSION

Pneumonia in domestic animals is a common disease. However, the disease is more prevalent and often leads to death, especially in farm animals, resulting in substantial economic losses, as demonstrated in a retrospective study (Smith, 2020). In our investigation, pneumonia was more prevalent in farm animals (81%) compared to small or wild animals.

Pneumonia mortality in cattle was between 1.5 and 5% (Estima-Silva *et al.*, 2020; Molossi *et al.*, 2021). Cattle were the most frequently affected in our study 65 (41.14%), which differs from another study (Molossi *et al.*, 2021). The Pathology Veterinary Service conducted a necropsy on 40 cattle originally brought to the University Veterinary Hospital. Clinical suspicion of pneumonia was recorded in 28% (11/40); however, the remaining 72% (29/40) received other treatments due to other clinical suspicions. In addition, the remaining 25 other patients included in the study were taken directly to the pathology service for post-mortem examination.

In adult horses, the literature contains many cases of clinical pneumonia (Hepworth-Warren and Love, 2024; Kabir *et al*., 2024; Smith 2020), but a low rate of pneumonia as a cause of death (3.88%). In one study, 73% of horses admitted to hospital with concerns for pneumonia responded well to treatment and were discharged. Clinically, tachycardia and higher blood creatinine concentrations increased the risk of death (Hallowell *et al.,* 2024), which was 14% in neonates and foals up to 18 months old (Pierezan *et al.*, 2009; Mouncey *et al.*, 2022). There was a predominance of athletic/performance horses 33/45 (73.33%), which are frequently under acute stress with decreased immunity due to repetitive transportation for competitions, stabling, and/or constant and exhausting training (Po *et al.*, 2013; Nazareno *et al.,* 2015). The Pathology Veterinary Service conducted a necropsy on 28 horses admitted to the University Veterinary Hospital. In 14% (4/28) of cases, the primary diagnosis for hospital admission was pneumonia; the remaining 86% (24/28) received other treatments due to other clinical conditions. The remaining 17 other patients included in the study were taken directly to the pathological service for post-mortem examination.

The number of false route pneumonia in cattle was noteworthy when compared to other species, corresponding to 20% of pneumonia; a similar result was reported by Brasil *et al.* (2013). The main causes of aspiration pneumonia are aspiration of rumen fluid, which can be caused by megaesophagus, reflux, probing, esophageal obstruction, and, in calves, aspiration of meconium, colostrum, or bucket feeding (Panciera and Confer, 2010). Suppurative pneumonia was prevalent in all species, with 11 cases (16.9%) in cattle, 6 (13.3%) in horses, 6 (25%) in sheep, and 5 (20.8%) in goats. The authors reported that suppurative bronchopneumonia was also the most frequent in horses, with the main agent being *Streptococcus equi*, a commensal bacterium of the upper respiratory tract, an opportunist that proliferates when the animal's immunity decreases, and then affects the lower respiratory tract (Bianchi *et al.*, 2018b; Rahman *et al.*, 2022). In sheep, it was also the most frequent, with *Klebsiella oxytoca* and *Klebsiella pneumoniae* as causative agents (Franco *et al.*, 2019b). In cattle, there are reports of a higher frequency of fibrinous pneumonia caused by *Pausterella multocida*, *Mannheimia haemolytica*, *Arcanobacterium pyogenes,* and *Mycoplasma* spp. *Staphylococcus* sp., *Streptococcus* sp., and *Pseudomonas aeruginosa* (Griffin *et al*., 2010; França Dias de Oliveira *et al*., 2016; Nishi *et al*., 2025).

Interstitial pneumonia also had a substantial number of cases in all species, with 8 cases (12.31%) in cattle, 7 (15.55%) in horses, 5 (20.83%) in sheep, and 6 (25%) in goats. The second most common pattern in horses was caused by viral agents followed by suppurative bronchopneumonia. Bacteria, protozoa, and helminth larvae were the main infection agents associated with suppurative bronchopneumonia (Rahman *et al.*, 2022). In calves and foals, septicemic salmonellosis was the most common; in horses influenza and *Pneumocystis carinii*; and in small ruminants lentivirus (CAE, caprine arthritis encephalitis). In horses, there were 7 cases (15.55%) of granulomatous pneumonia, with *Rhodococcus equi* the main cause of this pattern in the species (Coleman *et al.,* 2019); however, in the present study, beta hemolytic *Staphylococcus* and *E. coli* were also isolated, whereas *E. coli* was also isolated in various patterns of pneumonia (Choudhary *et al.*, 2019). In the present study, cattle were more often affected with broncho- or aspiration pneumonia with *Truperella pyogenes* and *Pasteurella multocida* infections, whereas horses had granulomatous and interstitial pneumonia with *Streptococcus equi*, *K. pneumoniae* and *E. coli*.

A limitation was observed in the classification of pneumonias based on their morphological patterns, being restricted to macroscopic assessment. Only 40 cases (38%) were classified accordingly, indicating a substantial discrepancy between macroscopic and microscopic reports. The macroscopic report is typically released before the microscopic examination, and it can assist clinicians in formulating diagnoses. Implementation of standardized descriptions of pneumonia is necessary for the service to reduce this failure and facilitate future research.

In this study, it was not possible to correlate the morphological pattern with the causative agent due to the low number of samples sent for microbiological examination. The cost of microbiological tests may be a common reason for the low number of tests authorized by the owners. However, microbiological examination is of the utmost importance for identifying the agent and determining effective treatments for herd animals, given the increasing level of resistance to antibiotics (Choudhary *et al.,* 2019; Hepworth-Warren and Love, 2024; Ramakrishnan *et al.,* 2024; Ribeiro *et al.,* 2024; Wang *et al.,* 2025), and should be encouraged in future necropsies.

The high rate of pneumonia cases that could not have been classified, 23/98 (23.47%), was due to the lack of standardization in the classification of these cases, as well as the lack of entry of data in the computerized system. The correlation between the macroscopic pattern and the agent was not possible due to the low number of samples sent for microbiological examination, 25/158 (15.82%). Despite this, suppurative and interstitial bronchopneumonia were the most frequent patterns. Among various macroscopic patterns, the most frequently isolated agents were *E. coli*, *T. pyogenes* and *P. multocida*.

Conclusions: In conclusion, suppurative and interstitial bronchopneumonia were the most frequent patterns in production animals. The most frequently isolated agents among various macroscopic patterns were *E. coli, T. pyogenes*, and *P. multocida.* Finally, it is recommended that classification with the morphological pattern in both macroscopic and microscope descriptions, as well as a microbiological exam should be done for all necropsies with pneumonia, to standardize these features in future studies.

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Competing interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics declarations: This study was submitted and approved under the protocol number 0556/2023 by the Ethics Committee on the Use of Animals in Research of São Paulo State University.

Authors´ contributions: Giovanna Gati de Souza, Isabeli Joaquim Contel, performed data curation and formal analysis; Giovanna Gati de Souza, Isabeli Joaquim Contel and Fernanda Barthelson Carvalho de Moura investigation, methodology, and writing original draft; Emanuel Vitor Pereira Apolonio and John Kastelic writing review and editing the manuscript Noeme Sousa Rocha and Alessandre Hataka, supervised, validated, and visualized the entire study. All authors have read and approved the final version of the manuscript.

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