




# Examination of Lung Lesions in Parainfluenza-3 Infections in Ruminants with Pathological and Immunohistochemical Methods

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## ABSTRACT

Parainfluenza 3 (PI3) infection is one of the most common viral respiratory diseases in domestic and wild ruminants. The most common finding is characteristic bronchointerstitial pneumonia. Concurrent viral and bacterial infections may exacerbate this condition and lead to fibrinopurulent-necrotic bronchopneumonia. The aim of this study was to investigate the histopathological findings of PI3 infection in ruminants, the release of mannose binding lectin (MBL) and surfactant protein B (SP-B) in lung tissue during inflammation, their role and importance in pathogenesis and their interrelationship. Paraffin-embedded lung tissue blocks were used from 30 ruminants with suspected viral pneumonia and 10 ruminants without lesions. Histopathologically, the acute destructive phase was observed in most cases (78%), whereas the chronic proliferative phase was observed in 4 cases (22%). Immunohistochemistry revealed anti-PI3 positivity in 15 animals (50%). In addition, MBL release was found to be high in acute cases but decreased in subacute or chronic cases. SP-B release was higher in subacute and chronic cases compared to acute cases. In conclusion, it was suggested that MBL release may be insufficient for recovery in cases of immunodeficiency or mixed infections, whereas early and accurate treatment could increase the chances of survival through the effects of SP-B.

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## **INTRODUCTION**

Respiratory infections are a significant health issue for both human and animal health. These infections also result in severe economic losses due to reduced feed efficiency, weight gain, milk yield and working capacity, as well as increased costs for medication and treatment (Dawson et al., 1996; Friton et al., 2005; Gorkem et al., 2020; Jim et al., 1993; Sumen et al. 2023). Respiratory diseases are caused by viral, bacterial, fungal and parasitic agents. Among the viruses commonly encountered in the field, parainfluenza-3 (PI3) virus is prominent, affecting species such as cattle, sheep, goats and horses. PI3 virus belongs to the family Paramyxoviridae, subfamily Paramyxovirinae and genus Respirovirus and is an RNA virus. The virus enters the body via the airborne route and replicates in the upper respiratory tract, alveolar epithelial cells and macrophages. Transmission occurs via nasal mucus, ocular secretions and droplet infection (Yuzbasigil, 2010). When the immune system is suppressed or defence mechanisms are inadequate, bronchointerstitial pneumonia develops with its characteristic inflammation, creating a predisposition to enzootic pneumonia. In mild cases, the disease manifests with clinical symptoms such as fever and nasal discharge leading to weight loss (Fenner et al., 1987; Gunn and Wilson, 1991; Yuzbasigil, 2010). MBL (Mannose-binding lectin) binds to carbohydrate surfaces on pathogens, which facilitates opsonization and phagocytosis (Degn et al., 2007; Neth et al., 2000; Jack et al., 2001; Worthley et al., 2005). By promoting the recognition of pathogens by macrophages, MBL enhances phagocytosis (Jack et al., 2001; Stuart et al., 2005). Surfactant protein B (SP-B) is a hydrophilic surfactant protein secreted by type-II pneumocytes (Pérez, 2008). This phospholipid-structured protein complex coats the alveoli and airways. It is crucial for maintaining airway stability and providing the immunomodulation necessary for host defense (Mulugeta et al., 2006). In addition to preserving alveolar surface tension, it acts as a barrier against foreign pathogens (Whitsett et al., 2002). The aim of this study was to investigate the histopathological findings of PI3 infection in ruminants, the release of mannose binding lectin (MBL) and surfactant protein B (SP-B) in lung tissue during inflammation, their roles and importance in pathogenesis, and their interrelationships.

## **MATERIAL and METHODS**

The material of this study consisted of paraffin-embedded lung tissue blocks from 40 ruminants (cattle, sheep, and goats) diagnosed with intersitital/bronchointerstitial pneumonia between 2017 and 2020, archived in the Department of Pathology, Faculty of Veterinary Medicine, Burdur Mehmet Akif Ersoy University.

The selected paraffin blocks from the study group, comprising 30 animals, included 18 small ruminants (6 males and 12 females) and 12 large ruminants (7 males and 5 females), of which all were adults except for three. The control group, consisting of 10 animals without any inflammatory reaction in the lungs, included 7 small ruminants (2 females and 5 males) and 3 large ruminants (all females).

Tissue sections with a thickness of 5 µm were taken from the blocks and mounted on standard and poly-L-lysine-coated slides. The sections on standard slides were stained with routine Hematoxylin-Eosin for microscopic evaluation of the lesions. The sections on poly-L-lysine-coated slides were subjected to immunoperoxidase techniques using a standard commercial Avidin-Biotin Complex Peroxidase (ABC-P) kit (Abcam, UK, ab236466 UltraVision Polyvalent Rabbit-Mouse HRP, TP-125-HL). The antibodies used were Polyclonal anti-Bovine Parainfluenza 3 (Moab a-BPI3-Biox Med), anti-MBL-2 [Anti-Mannan Binding Lectin antibody (ab203303)], and anti-Surfactant Protein B (SP-B) [Anti-Pro + Mature Surfactant Protein B antibody (ab40876)].

Histopathological evaluation method: Lesioned tissue sections scored the following criterias based on severity: Bronchitis, bronchiolitis, desquamation, bronchopneumonia, interstitial pneumonia, bronchial and bronchiolar hyperplasia, inclusion bodies, syncytial cell formations, and bronchiolitis obliterans. The scoring criteria is shown as Table 1. The scoring criteria and semiquantitative analysis method were derived from the study by Ozyildiz et al. (2018).

**Table 1.** Scoring criteria

Score	Bs/Bsl	Plts	D	ICAL	IASE	BH	İ	SCF	BO	IHC
3	5≥ foci	Diffuse	5≥ foci	5≥ foci	5≥ foci	5≥	5≥	5≥ foci	5≥ foci	Intense
2	3≥ foci	3≥ foci	3≥ foci	3≥ foci	3≥ foci	3≥	3≥	3≥ foci	3≥ foci	Moderate
1	1≥ foci	1≥ foci	1≥ foci	1≥ foci	1≥ foci	1≥	1≥	1≥ foci	1≥ foci	Mild
0	No lesion	No lesion	No lesion	No lesion	No lesion	No lesion	No lesion	No lesion	No lesion	Negative

Bs/Bsl: Bronchus/Bronchiole, Plts: Pleuritis, D: Desquamation, ICAL: Inflammatory cells in alveolar lumens, IASE: Inter-alveolar septal enlargement, BH: Bronchial hyperplasia, İ: Inclusion, SCF: Syncytial cell formation, BO: Bronchiolitis obliterans, IHC: Immunohistochemistry.

### ***Immunohistochemical Evaluation Method***

The lesions were examined for 5 different areas on x200 magnification under microscopy. The immunoreactivities of anti-bovine parainfluenza 3, anti-MBL, and anti-Surfactant Protein B markers in the lung tissue were determined. The scoring criteria is shown as Figure 1.

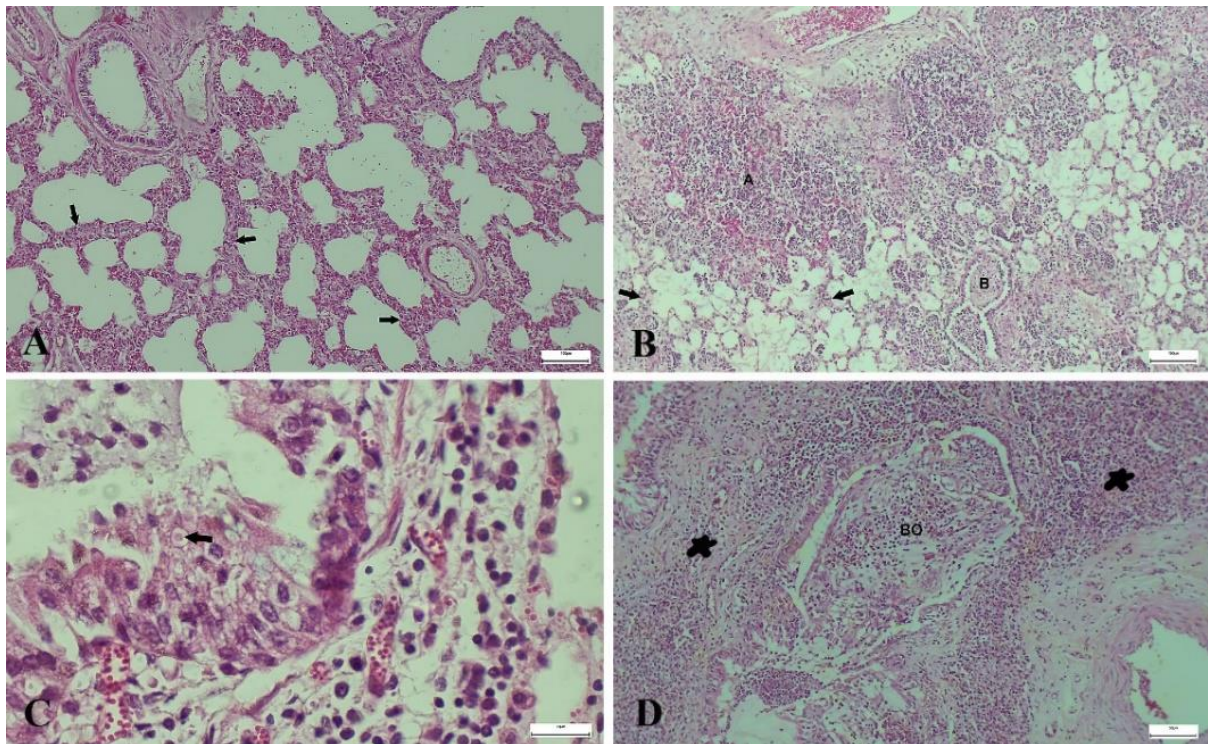
## **RESULTS**

### ***Histopathological Findings and Immunohistochemical Findings***

Histochemical staining revealed lesions characterised as interstitial pneumonia and bronchopneumonia with secondary infections. Based on the composition of inflammatory cells, the lesions were classified as "acute destructive form" and "chronic proliferative form". In the acute form, tissue destruction and a fluid-cellular response were predominant. Interlobar, interlobular and interalveolar vessels showed severe hyperemia. In the acute destructive form, the interalveolar septal tissue is dilated due to oedema and infiltration consisting mainly of lymphocytes, histiocytes and macrophages (Fig. 1A). Alveolar lumens were mostly empty, with some containing pink homogeneous oedema fluid, desquamated type 1 pneumocytes, alveolar macrophages (Fig. 1B), a few neutrophils and syncytial cell formations. In some areas, pink eosinophilic inclusion bodies were seen in the bronchial-bronchiolar epithelium (Fig. 1C). In almost all acute cases there were areas of bronchopneumonia associated with bacterial contamination (enzootic pneumonia).

In the chronic proliferative form, the interalveolar, interlobular, and interlobar septa were markedly widened, and areas of atelectasis and emphysema were observed. The cellular composition of the interstitium included dense fibroblastic cells, lymphocyte infiltration, and histiocytes. Bronchial and bronchiolar epithelia in some areas were desquamated into the lumen. In some areas, there were wide fibrotic areas and some lumens of bronchioles were found to be completely obstructed by organized material (bronchiolitis obliterans) Fig. 1D). At this stage, it was noticed that the vital capacity of the lungs in the animals had significantly decreased due to increased fibroplasia and loss of parenchyma.

**Figure 1.** Histomorphological appearance of lung lesions.



**A:** Enlargements in the interalveolar septal tissue (arrows), H&E, X40, 100  $\mu$ m. **B:** Broncho-interstitial pneumonia, thickening in the interalveolar septal tissue (arrows) with bronchiole (B) and alveolar lumens (A) filled with inflammatory cells, H&E, X40, 100  $\mu$ m. **C:** Eosinophilic intracytoplasmic inclusion body (arrow) in bronchiolar epithelium, H&E, X400, 20  $\mu$ m. **D:** Intense fibrous-histiocytic proliferation in the peribronchial region and atelectasis in the alveoli resulting in parenchymal loss (stars), with bronchiole lumen completely obstructed by inflammatory cells and fibrotic tissue (BO), H&E, X100, 50  $\mu$ m.

To detect infection and its distribution, the localisation and intensity of anti-parainfluenza 3 immunoreactivity in the lesioned lung tissue was determined. The intensity of the immunopositive reactions increased proportionally with the severity of the inflammation (Figure 2A). In addition, areas with strong anti-Parainfluenza 3 positivity also showed intense positive reactions for anti-MBL protein (Fig. 2B). In cases of interstitial pneumonia, the most intense anti-PI3 and MBL immunopositive areas were observed in bronchial and bronchiolar epithelia and lumens, as well as in interalveolar and interlobular regions. Intense anti-PI3 and anti-MBL positivity was also seen in the cytoplasm of macrophages in these areas, in syncytial cell formations and in peribronchial lymph nodes.

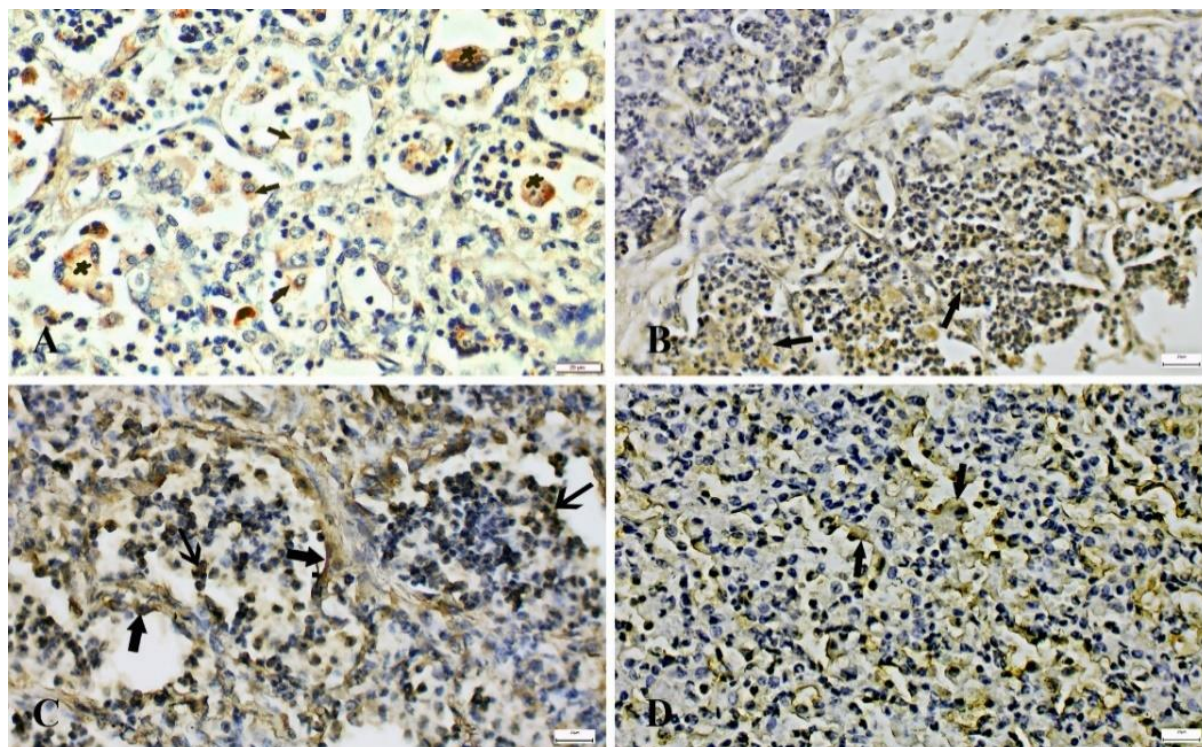
In contrast, anti-SP-B reactions were predominantly observed in the cytoplasm of phagocytic cells and alveolar and bronchiolar epithelia with mild to moderate (Fig. 2C).

In chronic progressive cases, anti-PI3 and anti-MBL immunopositivity was moderate in the cytoplasm of macrophages and interstitial regions, whereas it was mild on the luminal surfaces of bronchial and bronchiolar epithelia and in epithelial cells desquamated into the lumen. Intact alveoli showed strong anti-SP-B positivity, whereas no positivity was observed in atelectatic alveoli (Figure 2D).

In cases of mixed infection, strong anti-PI3 and anti-MBL immunopositivity was seen in the interstitium, bronchiolar and alveolar epithelia and lumens of phagocytic cells, whereas mild to moderate anti-SP-B positivity was observed.

No anti-PI3 or anti-MBL immunopositivity was found in the lung tissue of the control group. However, a very thin layer and mild anti-SP-B positivity were observed in the cytoplasm of type 2 pneumocytes in some alveolar walls.

**Figure 2.** Immunohistochemical characterization of lung lesions.

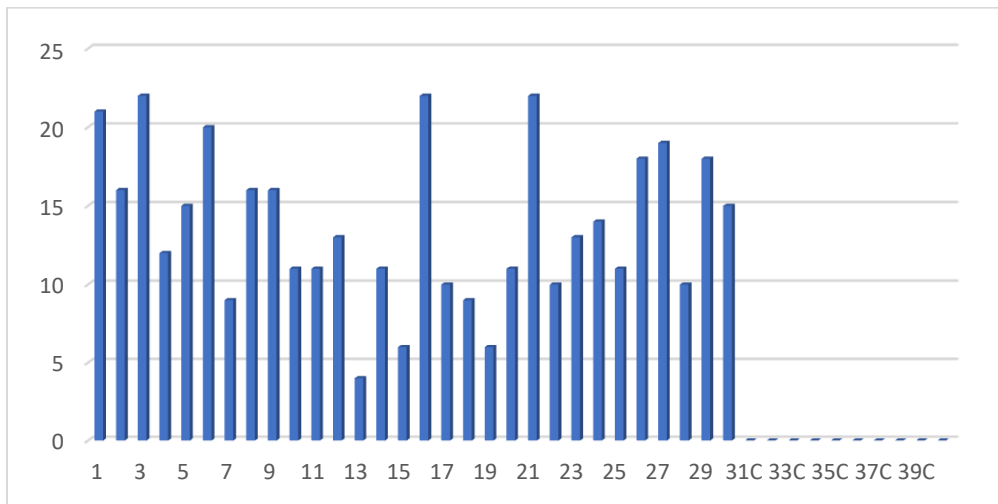


**A:** Anti-PI3 immunopositive reactions within neutrophils (thin arrow), macrophages (thick arrows), and syncytial cell formations (stars) in the alveolar lumens, ABC-P, X400, 20  $\mu$ m. **B:** Anti-MBL positive reactions in the cytoplasm of phagocytic cells within the alveolar lumens (arrows), ABC-P, X400, 20  $\mu$ m. **C:** Inflammatory cell cytoplasm in the alveolar lumens (thin arrows), with anti-SFB immunopositive areas in the alveolar walls and pneumocytes (thick arrows), ABC-P, X400, 20  $\mu$ m. **D:** Chronic proliferative phase; anti-SFB positive immunoreactions in the remaining and partially atelectatic alveolar walls and type 2 pneumocytes (arrows), ABC-P, X400, 20  $\mu$ m

### *Semi-Quantitative Analysis*

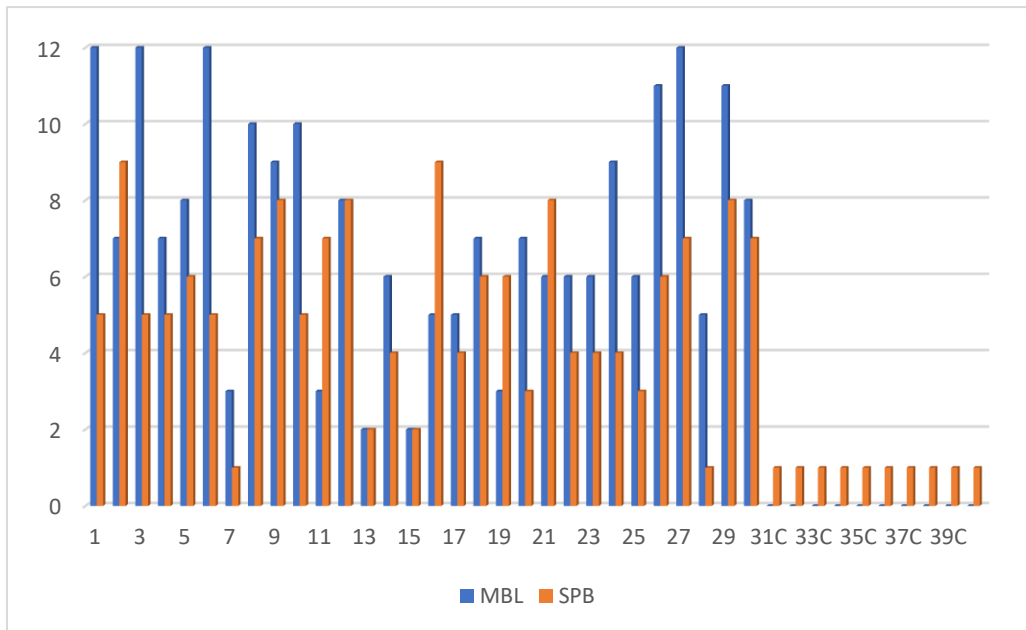
The semi-quantitative analysis results of pathological lesions in the tissues were summed from left to right and top to bottom. The scores were calculated horizontally (TLS) with values above the arithmetic mean marked as high and those below marked as low. Based on this, total lesion scores  $\geq 13,7$  was considered as severe while lower scores were considered as mild. For immunohistochemical data, total lesion scores of MBL were  $\geq 7,26$  and SPB  $\geq 5,3$  were considered as severe while lower scores were considered as mild. Lesions and immunoreactivity values are presented in Figure 3 and 4.

**Figure 3.** Indicate the severity of lesions in lung tissues (TLS).



Horizontal plane: Case number, Vertical plane: Severity of lesions, C: Control group

**Figure 4.** Values of MBL and SPB expressions in lung tissues.



Horizontal plane: Case number, Vertical plane: Severity of lesions, C: Control group

Semi-quantitative analysis shows that the animals with the highest disease severity were typically around three months old and had possible underdeveloped immune systems. Most of these animals were small ruminants, but there was no significant correlation with sex. Another notable finding was that severe infections occurred predominantly in small ruminants.

When the immunohistochemical reactions were analysed using semi-quantitative methods, it was observed that the regions with the most intense positivity for Anti-MBL were, in order, alveolar lumens, interstitium, and bronchial/bronchiolar lumens, whereas Anti-SP-B protein showed the following order: alveolar lumens, bronchial/bronchiolar lumens, syncytial cell formations, and interstitium.

**Statistical Analysis**

In order to determine the relationship between Mannose-Binding Lectin (MBL) and Surfactant Protein B (SP-B) levels in animals diagnosed with pneumonia, a Pearson correlation analysis was performed. Correlation coefficients (r) were interpreted according to Mukaka (2012): 0–0.3 (insignificant), 0.3–0.5 (low), 0.5–0.7 (moderate), 0.7–0.9 (high), and 0.9–1.0 (very high). Prior to the analysis, the Shapiro–Wilk normality test was conducted to confirm that the data were normally distributed. Subsequently, a paired sample t-test was used to compare MBL and SPB levels between the control group and pneumonic animals. The statistical method was determined based on the study of Dr. Selvi (2024). All statistical analyses were performed using Jamovi (Version 2.6; The jamovi project, 2024) and R software (Version 4.4; R Core Team, 2024).

Pearson correlation analysis revealed a significant positive correlation between MBL and SPB ( $r = 0.385$ ,  $p < 0.05$ ), suggesting that higher MBL levels were associated with higher SPB levels in pneumonic animals.

Furthermore, when comparing the control and pneumonic groups, both MBL and SPB levels differed significantly ( $p < 0.001$ ), indicating that pneumonia was associated with elevated levels of these biomarkers. The detailed results of the paired sample t-test are presented in Table 2.

**Table 2.** Paired T test results

		<b>p</b>	<b>Mean</b>	<b>SE</b>
<b>SPB</b>	SPB Control	<.001	4.60	0.686
<b>MBL</b>	MBL Control	<.001	9.00	0.907

SE: Standart error

**DISCUSSION**

Parainfluenza 3 (PI3) infections, which play a significant role in viral pneumonias, have been extensively studied in research on respiratory diseases. Numerous studies conducted in Türkiye have investigated the seroprevalence of the disease and reported a notably high prevalence within respiratory system diseases in farm animals (Alpay et al., 2014; Avcı et al., 2014; Ataseven et al., 2010; Yavru et al., 2005; Yesilbag and Gunlukgor, 2008). While analyses conducted using blood or nasal swabs provide some insights, it is known that not every PI3 virus entering the body causes infection, making it difficult to reach definitive conclusions regarding the accuracy of the results (Alpay et al., 2014; Avcı et al., 2014; Yavru et al., 2005). In this study, 30 lung tissue samples from ruminants diagnosed with pneumonia of suspected viral origin, archived in the Department of Pathology, Faculty of Veterinary Medicine, Burdur Mehmet Akif Ersoy University, between 2017 and 2020, were examined using immunohistochemical methods. PI3 positivity was identified in 15 of these samples (50%), providing limited but valuable insights into the significance of the virus among viral pneumonias in the region.

The pathological changes in tissue sections were classified into acute destructive and chronic proliferative phases. Among the cases examined, 26 were found to be in the acute destructive phase, while 4 were in the chronic proliferative phase. This observation revealed that the majority of deaths caused by respiratory failure associated with PI3 infection occurred during the acute destructive phase, which progressed severely and ultimately resulted in death.

The severity and distribution of immunohistochemical anti-PI3 reactions in tissues have been previously described by Ceribası et al. (2014). In this study, intense immunopositive areas were observed on the luminal surfaces of bronchial, bronchiolar, and alveolar epithelia, as well as in cellular debris and inflammatory cells within the lumen. Moderate immunopositive reactions were also detected in the interstitium, both freely and within the cytoplasm of macrophages. These findings were consistent with those reported by Ceribası et al. (2014).

MBL (Mannose-Binding Lectin) is a polysaccharide-based protein expressed by the liver during inflammation (Eddie et al, 2009; Erken, 2013; Garcia-Laorden et al, 2008; Gunesaçar et al, 2011; Jack et al, 2001). Recent studies have investigated its efficacy against infectious agents, including bacteria, viruses and fungi, via the lectin pathway. The primary function of MBL is to bind to infectious agents, facilitating their recognition by inflammatory cells. This supports the activation of the complement system and enhances cellular and humoral responses via the lectin pathway (Degn et al, 2007; Fujita et al, 2004; Mu et al, 2019; Worthley et al, 2005). In this study, the intensity of MBL in areas of anti-PI3 positivity in ruminant lungs during the acute pneumonia phase highlights the role of MBL in acute inflammation. In contrast, the mild immunopositive areas observed during the chronic proliferative phase suggest that MBL secretion decreases proportionally with the severity of the inflammation.

Surfactant protein B (SP-B), expressed by type II pneumocytes, is a component of surfactant that forms a film layer in the alveolar lumen. This layer acts as a barrier to pathogens and prevents alveolar collapse during respiration (Mulugeta et al, 2006; Whitsett et al, 2002). SP-B exists in two forms: immature and mature. Immature forms are expressed during the foetal period and mature postnatally. Deficiency of immature or proSP-B proteins can lead to a condition known as respiratory distress syndrome (Hazıroglu et al., 1998; Whitsett et al., 2002). Type II pneumocytes are regenerative cells that secrete mature SP-B proteins. Therefore, in the acute destructive phase, anti-SP-B immunopositive responses are mild to moderate, whereas in the chronic regenerative phase, they are enhanced due to repair efforts in remaining tissue (Ozyıldız et al., 2017; Whitsett et al., 2002). In this study, mild to moderate immunopositive reactions were observed in bronchial, bronchiolar and alveolar lumens and epithelia during the acute destructive phase. In the chronic proliferative phase, more intense positivity was observed in intact alveolar epithelia and lumens, consistent with the findings of Ozyıldız et al. (2017).

Previous studies suggest that SP-B is not directly associated with the induction of inflammation, which is why it does not exhibit high expression during acute inflammation (Mulugeta et al., 2006; Ozyıldız et al., 2017; Whitsett et al., 2002). However, in this study, the anti-SP-B reaction was found to be intense in alveolar lumens, while relatively less pronounced in other areas. This may be attributed to the phagocytosis of damaged surfactant by inflammatory cells during acute inflammation. Therefore, it appears to be more related to the removal of damaged tissues than to the induction of inflammation. Additionally, the reduced positivity in interalveolar septa compared to the lumens may be due to the partial expulsion of the damaged film layer through coughing or its absorption via lymphatic vessels.

When comparing the expression levels of MBL and SP-B proteins by semi-quantitative analysis, a positive correlation was identified. However, MBL secretion increased in acute events and decreased in chronic events, whereas SP-B protein secretion was low in acute events but high in chronic events. This finding is in agreement with the study by Ozyıldız et al. (2017), which suggests that SP-B protein secretion reflects the body's ongoing repair efforts during chronic events.

### **Ethical Statement**

This study” Examination of Lung Lesions in Parainfluenza-3 Infections in Ruminants with Pathological and Immunohistochemical Methods” was conducted in compliance with all relevant ethical standards. Since this research did not involve any live animal subjects, an ethics committee approval was not required. The data used in this study were obtained from archived paraffin blocks, ensuring no harm or distress to any live animals during the course of this research.

Any version of this article (whether developed or partially modified) has not been presented orally at any symposium, nor has it been published as a full text or abstract.

### **Ethics Committee Approval**

Ethics Committee Approval is not necessary. The data used in this study were obtained from archived paraffin blocks, ensuring no harm or distress to any live animals during the course of this research.

### **Author Contributions**

Research Design (CRediT 1) Author 1 (%50) – Author 2 (%50)

Data Collection (CRediT 2) Author 1 (%60) – Author 2 (%40)

Research - Data analysis - Validation (CRediT 3-4-6-11) Author 1 (%60) – Author 2 (%40)

Writing the Article (CRediT 12-13) Author 1 (%50) – Author 2 (%20) – Author 3 (%30)

Revision and Improvement of the Text (CRediT 14) Author 1 (%50) – Author 2 (%20) – Author 3 (%30)

### **Finance**

There is not any funding in this study.

### **Conflict of Interest**

Authors declare that there is no conflict of interest.

### **Sustainable Development Goals (SDG)**

3 Good Health and Well-Being

12 Responsible Consumption and Production

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