Prevalence of Mycoplasma-like Lung Lesions in Pigs From Commercial Farms From Spain and Portugal

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Abstract

Background: *Mycoplasma hyopneumoniae* causes a chronic respiratory disease that produces important economic losses due to poor productive performance, increased mortality and increased costs due to treatment and control. The prevalence of mycoplasma-like lesions (MLL) at abattoir has been widely studied in different countries and different scoring systems have been used. However, most of them are difficult to apply in case of abattoirs with high number of pigs sacrificed per hour. For that reason, it is necessary to adapt the scoring system to the reality of the modern abattoir even if there is a loss of accuracy. Our purpose was to validate a mycoplasma-like scoring system at abattoirs with a high number of pigs per hour in Spain and Portugal using the histopathological diagnosis as confirmatory method to identify pattern of pneumonia correlated to gross lesion.

Results: Cranioventral pulmonary consolidation (MLL) was the most frequent lung lesion (30.97 %) detected at the abattoir, followed by dorsocaudal infarcts with pleurisy (12.51 %) and pleurisy alone (6.26 %). The average score calculated for all lungs examined at abattoir was 1.99 out of 5 points. The histopathological study revealed that the 78.17 % of the lungs with MLL randomly selected presented microscopic lesions compatible with *M. hyopneumoniae* infection. Most bronchointerstitial and interstitial pneumonia lesions had a chronic course while most suppurative and fibrinous bronchopneumonia lesions had an acute course and a higher degree of severity. The combination of microscopic lesions more frequently observed was bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia. The average loss of ADWG calculated for all pigs included in the study according the extension of the lung lesions was 22.33 g/day.

Conclusions: The prevalence of MLL at abattoir was 30.97% but the microscopic examination of a sample of randomly selected lungs indicated that the real prevalence of lungs with lesions compatible with *M. hyopneumoniae* infection would be reduced to 24.21 %. The average score of MLL using a 0 to 5 points was 1.99 and the average loss of ADWG associated to those lesions was 22.33 g/day. The result of our study supports the importance of *M. hyopneumoniae* as primary pathogen in cases of PRDC.

Background

Mycoplasma hyopneumoniae is the principal etiological agent of enzootic pneumonia (EP), a chronic respiratory disease considered to be as one of the most widespread and economically damaging diseases on pig farms [1, 2, 3]. In addition, *M. hyopneumoniae* plays a pivotal role as primary agent involved in the development of porcine respiratory disease complex (PRDC), a multifactorial disease resulting from the interaction of different infectious agents (viruses, mycoplasmas and bacteria), management and environmental conditions and host factors [4, 5]. Typical EP gross lung lesions are characterized by well defined, greyish to reddish depressed cranioventral areas of consolidation. Microscopically, these areas are correlated to a pattern of bronchointerstitial pneumonia with lymphoid cells infiltrating the lamina propria of bronchioles to a differing extent and, finally, evolving an hyperplasia

of the bronchus-associated lymphoid tissue (BALT) at peribronchial, peribronchiolar and perivascular levels [6, 7].

At abattoir, the post-mortem inspection is a truly common and useful practice in many countries to gather information about the herd health status and to monitor those changes in management or treatment which have been implemented in the farms. There are many studies carried out to evaluate the presence and severity of lung lesions and to identify the possible etiology and herd risk factors associated with these lesions, as well as the impact of the lesions on the carcass and meat quality [8, 9, 10, 11, 12, 13]. Thus, it is reported that the prevalence of mycoplasma-like lesions (MLL) at abattoir raging from 23.85% in Belgium to 72.60% in Germany, with a high variation among countries [9, 10, 13, 14, 15, 16, 17].

There are several and different methods for evaluating the severity of lung lesions at abattoir [18, 19, 20, 21, 22]. Most of them are based on the quantification of the affected lung surface, nevertheless, nowadays, due to the speed of the slaughterline at industrial abattoirs with more than 500 pigs per hour, some of these methods are impractical and difficult to follow. For that reason, the scoring systems need to be modified and adapted to the new reality, being easy to perform and repeatable, even if there is a loss of accuracy.

Economic losses associated to *M. hyopneumoniae* are mainly due to poor productive performance, increased susceptibility to other respiratory diseases, high mortality and elevated costs due to treatment and control of the disease [2]. A significant negative correlation has been found between prevalence of pneumonic lesions at abattoir and growth rate with a weight loss of about 0.7% for each point of pneumonia increase [23]. Similarly, in a study carried out by Bringas et al. [24], with a scoring system from 0 to 5 points, a difference of 38 g in the average daily weight gain (ADWG) was found between batches of pigs with a percentage of MLL with a score of 3 or more above 25% and batches with a percentage lower than 5%.

The aim of this study was to corroborate the usefulness of a mycoplasma-like scoring system (0 to 5 points) to be adapted to abattoirs with a high number of slaughtered pigs per hour by investigating the prevalence and severity of MLL at abattoirs in Spain and Portugal and making use of histopathological diagnosis to identify patterns of pneumonia involved in the examined lungs.

Results

Lung examination at abattoir and scoring

The type and percentage of lung lesions observed at abattoir are shown in Fig. 1. Approximately half of all examined lungs at abattoir did not exhibit any gross lung lesion (100,371 lungs; 50.26%). Cranioventral pulmonary consolidation (MLL) was the most frequent lung lesion detected (61,832 lungs; 30.97%) (Fig. 2A, C and E), followed by dorsocaudal infarcts with pleurisy (*Actinobacillus pleuropneumoniae* infection) (24,970 lungs; 12.51%) and pleurisy alone, that was recorded in 12,505 lungs (6.26%). Similar percentages of MLL were found in Spain (31.14%) and in Portugal (29.95%).

Figure 3 depicts the number of lungs according to the score from 0 to 5 for MLL. Most examined lung were classified as score 0 (137,846 lungs; 69.03%), being scores 1 and 2 the more frequent found with 13.04% (26,046 lungs) and 9.02% (18,008 lungs), respectively. The average score of all lungs showing cranioventral consolidation was 1.99, no finding differences across countries, 2.00 for Spain and 1.93 in the case of Portugal.

Histopathology of the lungs

Table 1 summarizes the microscopic patterns of pneumonia, severity and course of the lesions observed in the examined lungs. Bronchointerstitial pneumonia, compatible with *M. hyopneumoniae* infection, was the most frequent lesion pattern (78.17%) (Fig. 2B) followed by suppurative bronchopneumonia (73.47%) (Fig. 2D), interstitial pneumonia (68.65%) and fibrinous bronchopneumonia (14.21%). The highest degree of severity was observed in the fibrinous bronchopneumonia (2.89) followed by suppurative bronchopneumonia (2.52), bronchointerstitial (2.17) and interstitial pneumonia (1.74), the latter with the lowest score. With respect to the course, most of the cases of bronchointerstitial and interstitial pneumonia had a chronic course, whereas most of the cases of suppurative and fibrinous bronchopneumonia had an acute course. Moreover, roughly 41% of studied lungs showed pleurisy, chronic in most of the cases (89.17%).

Table 1
Patterns of pneumonia, severity and course of the lesions found in the histopathological study.

Type of microscopic lesion	Number (%)	Severity (1–3)	Course (acute/chronic)
Bronchointerstitial pneumonia	616 (78.17%)	2.17	(3.09% / 96.91%)
Suppurative bronchopneumonia	579 (73.47%)	2.52	(72.36% / 27.64%)
Fibrinous bronchopneumonia	112 (14.21%)	2.89	(66.07% / 33.93%)
Interstitial pneumonia	541 (68.65%)	1.74	(3.51% / 96.49%)
Pleurisy	323 (40.99%)	-	(10.83% / 89.17%)

Of note, more than one lesion pattern coexisted in most sampled lungs (Table 2). Thus, from the 788 microscopically examined lungs, 720 (91.37%) presented more than one microscopic pattern, 59 lungs (7.49%) only showed one microscopic pattern and, only 9 lungs (1.14%) did not present any microscopic lesion. The most frequent combination of microscopic patterns was bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia in 171 lungs (21.70%) and the same combination accompanied by pleurisy in other 108 lungs (13.71%), followed by the combination of bronchointerstitial pneumonia + suppurative bronchopneumonia (Fig. 3F) found in 77 lungs (9.77%) and in 62 additional lungs together with pleurisy (7.87%). Only six combinations out of 32 (highlighted in bold and with grey background in Table 2) included two thirds (66.13%) of the lungs microscopically examined, and in all of them microscopic lesions characteristic of *M. hyopneumoniae* infection were

found. Combinations with an equal number of lesion patterns presented a higher degree of severity when any type of bronchopneumonia appeared.

Table 2

Combination of microscopic patterns of pneumonia including the number and percentage of lungs and lesion severity. Highlighted in bold and with grey background appear the six more prevalent combinations of microscopic lesions.

Patterns of microscopic lesion	Number (%)	Severity
Bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopenumonia + pleurisy	7 (0.89%)	9.57
Bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopenumonia	15 (1.90%)	9.40
Bronchointerstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopenumonia + pleurisy	11 (1.40%)	9.18
Interstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopenumonia + pleurisy	8 (1.02%)	8.50
Bronchointerstitial pneumonia + interstitial pneumonia + fibrinous bronchopenumonia + pleurisy	8 (1.02%)	7.50
Bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia + pleurisy	**108 (13.71%)**	**7.45**
Bronchointerstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopneumonia	12 (1.52%)	7.25
Interstitial pneumonia + suppurative bronchopneumonia + fibrinous bronchopneumonia	12 (1.52%)	7.25
Suppurative bronchopneumonia + fibrinous bronchopneumonia + pleurisy	1 (0.13%)	7.00
Bronchointerstitial pneumonia + interstitial pneumonia + suppurative bronchopneumonia	**171 (21.70%)**	**6.44**
Bronchointerstitial pneumonia + interstitial pneumonia + fibrinous bronchopneumonia	2 (0.25%)	6.25
Suppurative bronchopneumonia + fibrinous bronchopneumonia	10 (1.27%)	6.00
Bronchointerstitial pneumonia + fibrinous bronchopneumonia + pleurisy	7 (0.89%)	5.86
Bronchointerstitial pneumonia + suppurative bronchopneumonia + pleurisy	**62 (7.87%)**	**5.55**
Interstitial pneumonia + fibrinous bronchopneumonia + pleurisy	6 (0.76%)	5.50
Bronchointerstitial pneumonia + interstitial pneumonia + pleurisy	**50 (6.35%)**	**5.12**
Suppurative bronchopneumonia + interstitial pneumonia + pleurisy	22 (2.79%)	5.05

Patterns of microscopic lesion	Number (%)	Severity
Bronchointerstitial pneumonia + fibrinous bronchopneumonia	6 (0.76%)	4.67
Bronchointerstitial pneumonia + suppurative bronchopneumonia	**77 (9.77%)**	**4.64**
Suppurative bronchopneumonia + interstitial pneumonia	40 (5.08%)	4.18
Bronchointerstitial pneumonia + interstitial pneumonia	**53 (6.73%)**	**4.11**
Interstitial pneumonia + fibrinous bronchopneumonia	3 (0.38%)	4.00
Fibrinous bronchopenumonia + pleurisy	1 (0.13%)	4.00
Suppurative bronchopneumonia + pleurisy	10 (1.27%)	3.50
Fibrinous bronchopenumonia	3 (0.38%)	3.00
Suppurative bronchopneumonia	12 (1.52%)	2.69
Bronchointerstitial pneumonia + pleurisy	9 (1.14%)	2.56
Interstitial pneumonia + pleurisy	11 (1.39%)	2.50
Bronchointerstitial pneumonia	18 (2.28%)	2.22
Interstitial pneumonia	23 (2.92%)	1.83
Pleurisy	1 (0.13%)	1.00
No lesion	9 (1.14%)	0.00

Decrease of ADWG due to mycoplasma-like lung lesions

The average of percentage of lung affected for each score level was estimated using as reference the scoring system proposed by Christensen et al. [21] as follows: 0% for score 0, 3% for score 1, 6% for score 2, 12% for score 3, 24% for score 4 and 48% for score 5. Accordingly, the average percentage of affected lung was 5.97%, with an average percentage of 6.00% for Spain and 5.91% for Portugal. The loss of

ADWG calculated, using as reference the data provided by Straw et al. [25], was 22.33 g/day for the whole study, with a loss of 22.44 g/day for Spain and 22.10 g/day for Portugal.

Discussion

Despite the efficacy of *M. hyopneumoniae* vaccines in reducing lung lesions [26] and bacterial load from the respiratory tract [27], they are not capable to fully eliminate the bacteria from the animal giving rise to typical MLL in a variable percentage of pigs at abattoir in different countries [10, 14, 16, 17]. To corroborate the usefulness of a mycoplasma-like scoring system to be adapted to abattoirs with a high number of slaughtered pigs per hour we investigated the prevalence of mycoplasma lung lesions in Spain and Portugal in a study with an elevated number of pigs (199,678) involving a high number of farms (221). Additionally, a valuable sample of 788 lungs was considered to corroborate microscopically the presence of lesions characteristics of the infection by *M. hyopneumoniae.*

In our study, 50.26% from all lungs examined at abattoir did not exhibit any gross lesion and roughly 31% showed cranioventral consolidations compatible with mycoplasma lesions, with similar values for Spain (31.14%) and Portugal (29.95%). These prevalence rates of MLL were higher than those observed in Belgium (23.85%) [14] but lower than those previously found in Spain (44.61 to 55.69%) [9, 16], Italy (46.38%) [10], France (69.30%) [15] or Germany (72.60%) [17]. The main difference between studies was the number of examined lungs, with nearly 200,000 lungs evaluated in this study in comparison with numbers ranging from 600 [16] to 10,404 [9]. However, other factors such as the epidemiological scenario in each country play also a role in these differences. Consequently, taking into account the high number of farms and the different pig production areas, we consider that our data provide a precise percentage of prevalence of MLL in Spain and Portugal. Moreover, if we consider the results obtained in the histopathological study and quantify the percentage of selected lungs with MLL that really presented microscopic lesions compatible with *M. hyopneumoniae* infection (78.17%), the real prevalence of gross lesions caused by the bacteria would be reduced from 30.97% to 24.21%. Other lesions, such as suppurative bronchopneumonia, as shown in Fig. 2, have a similar gross appearance [28, 29] and, hence, could be mixed up with the lesions caused by *M. hyopneumoniae*. In this sense, those studies in which a microscopic confirmation has not been performed, could bias the results overestimating the percentages of prevalence. In the study carried out by Luhers et al. [17], 78.30% out of 400 lungs with MLL collected at the abattoir were positive to *M. hyopneumoniae* by PCR, a percentage very similar to the one found with compatible microscopic lesions in our study (78.17%). These results highlight the interest of performing additional studies on lungs with MLL to confirm the diagnosis of EP or infection by *M. hyopneumoniae*.

Pleurisy, associated to dorsocaudal infarcts or alone, was the second most prevalent gross lesion found in our study affecting 18.77% of the examined lungs, a percentage very similar to that found in France (15.00%) [15] but lower than those previously reported in Italy (25.10%) [10] and in Spain (26.80%) [9]. In our case, most of the pleurisy (66.65%) was associated with dorsocaudal infarcts, a hallmark of *A. pleuropneumoniae* infection, therefore, the measures to control this pathogen (management, therapeutic or vaccination) should be revised and/or implemented in the farms included in the study.

According to our findings, most of the lesions of bronchointerstitial and interstitial pneumonia (characteristics of mycoplasma and viral infections, respectively) had a chronic course, by contrast, the majority of the lesions of suppurative and fibrinous bronchopneumonia (characteristics of bacterial infection) had an acute course and a higher degree of severity. These results suggest that viruses and mycoplasmas could have acted in an earlier stage of the life of piglets, probably during nursery, and later on, during the fattening period, bacteria would have taken action. Ruggeri et al. [30] reported that the most prevalent microscopic lesions in fattening pigs were pleurisy, followed by pleuropneumonia, catarrhal bronchopneumonia and bronchointerstitial pneumonia, but animals included in that study died because of respiratory diseases, that is, samples were not collected from healthy animals at abattoir as in the present study. However, to a certain extent, it agrees with our observations since most of the deaths were consequence of an acute process of fibrinous and suppurative bronchopneumonia. The recent study carried out in Brazil by Galdeano et al. [13], also found the characteristic lesions of *M. hyopneumoniae* infection as the most prevalent ones, which were detected in 63.75% of the lungs examined microscopically, but different to our study, the following observed lesion was chronic bronchopneumonia (57.14%) and other lung lesions common in our study such as suppurative bronchopneumonia, interstitial pneumonia or fibrinous bronchopneumonia, were observed in a lesser extent (15.63%, 3.61% and 0.15%, respectively). Nevertheless, it must be taken into account that in Brazil porcine reproductive and respiratory syndrome virus (PRRSV) has never been detected [31], then the effect of one of the main primary agents involved in the PRDC [5], alone or in combination with other pathogens, is not taken place in those farms. Therefore, the clinical and lesional picture at abattoir in Brazil would be totally different when compared with those countries where PRRSV is endemic such as Spain or Portugal.

Besides to allow us having a more accurate idea of the real prevalence of lesions caused by *M. hyopneumoniae*, the histopathological study provided information about the action of other pathogens involved in the PRDC that sometimes go clinically unnoticed. By contrast, some lesions are unspecific and could be caused by different pathogens, but in association with other techniques, such as serology, bacteriology or PCR, histopathology could provide a more accurate information about which agent is causing the lesion, since a positive result in those diagnostic techniques against some pathogens (i.e. *M. hyopneumoniae* or porcine circovirus type 2 (PCV2)) does not necessarily always mean that they are causing any lesion.

Lesions of bronchointerstitial pneumonia compatible with *M. hyopneumoniae* infection were found in the six more frequent combinations of lesion patterns in our study, representing 66.13% of the lungs examined, what support the fact that this agent plays a relevant role in the PRDC as primary agent as well as enhancing the action of other pathogens involved in as PRRSV [32], PCV2 [33] or swine influenza virus [34].

The scoring system from 0 to 5 points used in this study for MLL, adapted from a previous one [35], has been shown as a simple and repeatable method that can be easily applied in cases of abattoirs with fast slaughterline (sometimes more than 500 pigs per hour). By contrast, it is not as precise as other methods which express the proportion of affected lung area in percentages [19, 20, 21, 22]. Therefore, in the case

of a disease with an evident economic importance as EP, to complete a study of prevalence and severity of lung lesions with their relationship with productive parameters as ADWG, it is necessary to translate the score 0 to 5 to percentage of affected area, as was done in our study.

The average loss of ADWG calculated in our study was 22.33 g/day (22.44 g/day for Spain and 22.10 g/day for Portugal). In a study carried out in Spain by Bringas et al. [24] involving almost 50,000 pigs, they used a similar scoring system that the herein proposed (0 to 5 points) and divided the batches according the percentage of maximum lung lesions (lungs with score 3 or higher) in four quartiles. Comparing with our results, we would have an 8.90% of lungs with a score 3 or higher and would be included in their second quartile (5-12.50% of lungs with maximum lesions), and the difference with batches included in the first quartile (0–5% of lungs with maximum lesions) would be of 23 g in the ADWG, almost the same loss found in our study but calculated according the surface of lung affected. In the light of the above mentioned, both methods have been revealed as a valuable approach to calculate the loss in growth rate associated to MLL using a 0 to 5 scoring system.

Conclusions

The 0 to 5 points scoring system proposed in the present study was shown to be a simple, useful and repeatable method that can be easily applied in cases of abattoirs with a fast slaughterline. An average score of MLL of 1.99 was obtained by using this scoring system and a real prevalence of 24.21% was determined after confirmation by histopathology of lungs with cranioventral consolidations compatible with mycoplasma lesions. The average loss of ADWG associated to lungs lesions found in our study was 22.33 g/day. Our results highlight the significance of *M. hyopneumoniae* in PRDC acting as primary agent in combination with other pathogens which lead to different patterns of lung lesions and emphasize the necessity of implementing holistic control measures against this agent.

Methods

Study population

A total of 199,678 pigs from 221 different herds from Spain (170,174 pigs; 85.22%) and Portugal (29,504 pigs; 14.78%) were randomly selected and examined at abattoir from 2013 to 2017. Most of the origin farms (142/221; 64.25%) were located in southern Spain (regions of Andalusia, Extremadura and Murcia), 25.79% (57/221) in the north of Spain (regions of Cataluña, Aragón and Castilla y León) and 9.96% (22/221) in Portugal. All farms included in the study have been historically vaccinated against *M. hyopneumoniae* with commercial vaccines.

Lung examination at abattoir and scoring

Lung examinations were performed in 46 different abattoirs located in Spain (36) and Portugal (10) by seven veterinarians thoroughly trained to follow the same scoring criteria in order to avoid individual discrepancies. Lungs were visually appraised and palpated to detect lesions compatible with pneumonia.

The system used for scoring lung cranioventral consolidations was based on the previously score proposed by Bollo et al. [35] with some modifications. Briefly, score 0: no lesion observed; score 1: consolidation affecting unilaterally the apex of one or two different lung lobes; score 2: consolidation affecting bilaterally the apex of one or two different lung lobes; score 3: consolidation affecting bilaterally the apex and medial part of one or two different lung lobes; score 4: consolidation affecting bilaterally the apex and medial part of one or two different lung lobes and partial involvement of the cranial area of one caudal lung lobe; score 5: consolidation affecting all lobes, including the cranial area of both caudal lobes. The average score was calculated for each batch (data not shown) and each country. The presence of other lesions, such as infarcts, abscesses and pleurisy, was also recorded.

Histopathology of the lung

Three to four lungs per batch with MLL were randomly selected at the abattoir for histopathological examination. Therefore, a total of 788 lungs, 737 from Spain and 51 from Portugal, were pictured and four samples per lung were collected: one belonging to the cranial lung lobe, other from the middle lung lobe and two from the ventral and dorsal areas of the caudal lung lobe of the right lung. In case of the left lung, the two portions of the cranial lung lobe together with the two samples coming from the caudal lung lobe were collected. Samples were fixed in 10% neutral buffered formalin for 24 hours, embedded in paraffin wax, sectioned at 4 microns and stained with hematoxylin and eosin.

Microscopic lung lesions of pneumonia were classified as bronchopneumonia (suppurative or fibrinous), bronchointerstitial and interstitial pneumonia according to the morphological pattern. Briefly, bronchopneumonia was characterized by the presence of inflammatory exudate into bronchi, bronchioles and alveoli that in the case of suppurative bronchopneumonia was predominantly composed of degenerated neutrophils while in fibrinous bronchopneumonia the predominant component of the exudate was fibrin, associated with the presence of necrosis and hemorrhages. Interstitial pneumonia was characterized by the thickening of alveolar walls by the presence of mononuclear cells and hyperplasia and hypertrophy of type II pneumocytes. In the case of bronchointerstitial pneumonia, mononuclear cells encircling airways and infiltrating alveolar septa and BALT hyperplasia were present [28, 29]. Pleurisy, characterized by the presence of fibrin or connective tissue in the pleura, was also recorded. Each microscopic lesion was scored according to its severity in mild (score 1), moderate (score 2) or severe (score 3), except for pleurisy that was scored as 0 (absence) or 1 (presence). The criteria for the scoring of microscopic lung lesions are summarized in Table 3. The microscopic score was calculated for each pattern of pneumonia and the final score was calculated by adding the individual scores for each type of pneumonia. As four samples were microscopically examined per lung, the score selected for each lesion pattern was the most severe one observed in any of the examined samples.

Table 3
Scoring system used to determine the severity of microscopic lung lesions.

Type of pneumonia	Mild (Score 1)	Moderate (Score 2)	Severe (Score 3)
Bronchointerstitial pneumonia	BALT in > 5 bronchi or bronchioles (1–2 BALT per structure)	**1.-** BALT in > 5 bronchi or bronchioles (50% of the structure is surrounded by BALT) or **2.-** BALT in > 5 bronchi or bronchioles (1–2 BALT per structure) and one bronchus or bronchiole completely surrounded by hyperplasia of BALT	**1.-** At least two structures are almost completely surrounded (80%) by hyperplasia of BALT or **2.-** All structures of the section are affected
Interstitial pneumonia	1–2 lobule/s affected*	50% affected*	All lobuli are affected*
Suppurative pneumonia	1–2 lobule/s affected*	50% affected*	All lobuli are affected*
Fibrinous pleuropneumonia	1–2 lobule/s affected*	50% affected*	All lobuli are affected*
Pleurisy	Presence	—	—

The term “structure” describes a bronchus or bronchiole, equally. *Every evaluated section included at least 6 lobuli. BALT: bronchus-associated lymphoid tissue.

Lesions were also differentiated according to their course as acute or chronic lesions. Acute lesions were defined as those with neutrophils as the dominant inflammatory cell type, extensive edema and fibrin exudation. Chronic lesions were characterized by mononuclear cell infiltrate primarily consisting of lymphocytes and plasma cells, proliferation of connective tissue, epithelial or BALT hyperplasia, and hypertrophy of the smooth muscle layer around bronchioles and alveolar ducts.

All the slides were blindly evaluated by two pathologists to determine the pattern and score of pneumonia.

Decrease of ADWG due to mycoplasma-like lung lesions

The average decrease of ADWG was calculated for each country. For this purpose, the average percentage of lung affected equivalent to each score was calculated according to the value given to each pulmonary lobe by Christensen et al. [21]. The relation between ADWG and the percentage of affected lung was based on the data published by Straw et al. [25], who estimated a decrease of 37.4 g in the growth rate for every 10% of lung affected by pneumonia.

Abbreviations

ADWG
average daily weight gain; BALT:bronchus-associated lymphoid tissue; EP:enzootic pneumonia; MLL:mycoplasma-like lesions; PCV2:porcine circovirus type 2; PRDC:porcine respiratory disease complex; PRRSV:porcine reproductive and respiratory syndrome virus.

Declarations

Ethics approval and consent to participate

The present article does not include experimental data. Therefore, animal ethics committee approval was not necessary.

Consent for publication

All authors gave their consent for publication.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors contribution

JAA, LC and FJP designed the study; IMRG, JGL, JMSC and IRT photographed and sampled the lungs. FJP and IMRG performed the histopathological study; RF, JGL and FJP analyzed the data; FJP and JAA wrote the manuscript; LC supervised the study. All authors read and approved the final version of the manuscript.

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Figures

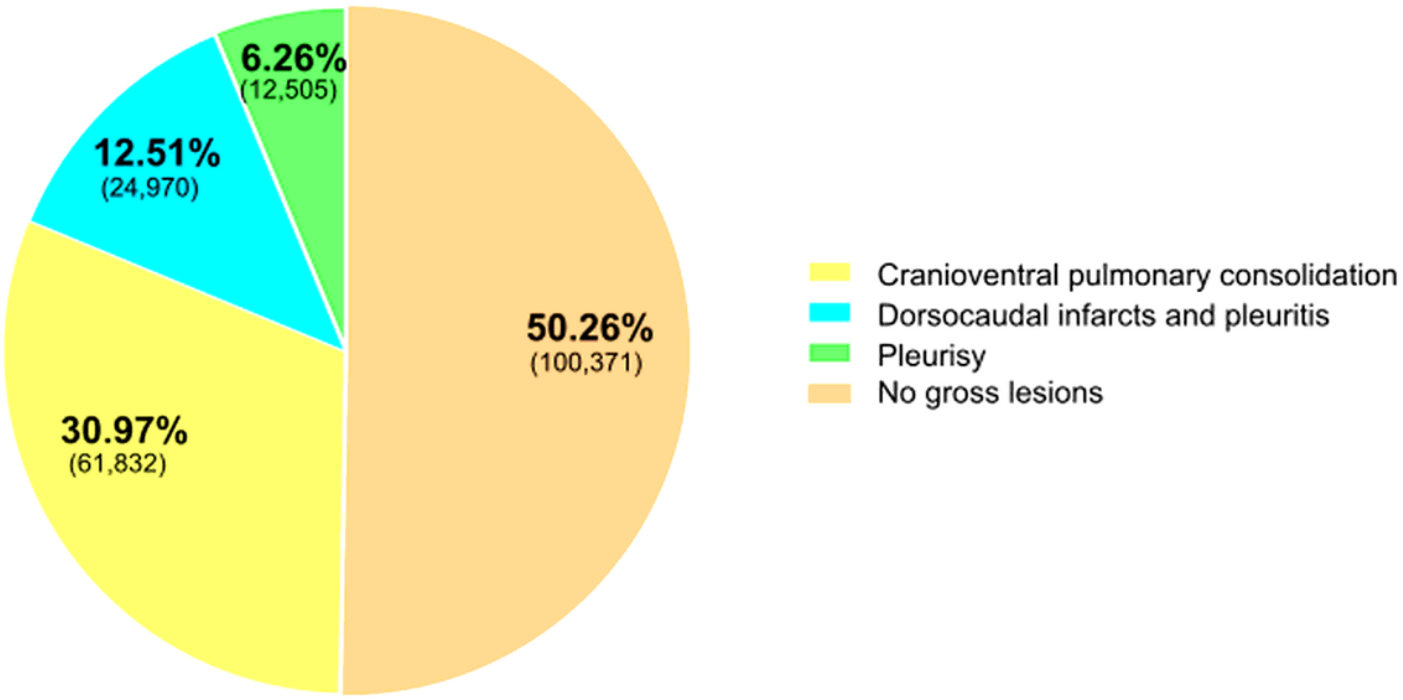

Figure 1

Types and percentage of gross lung lesions observed at abattoir.

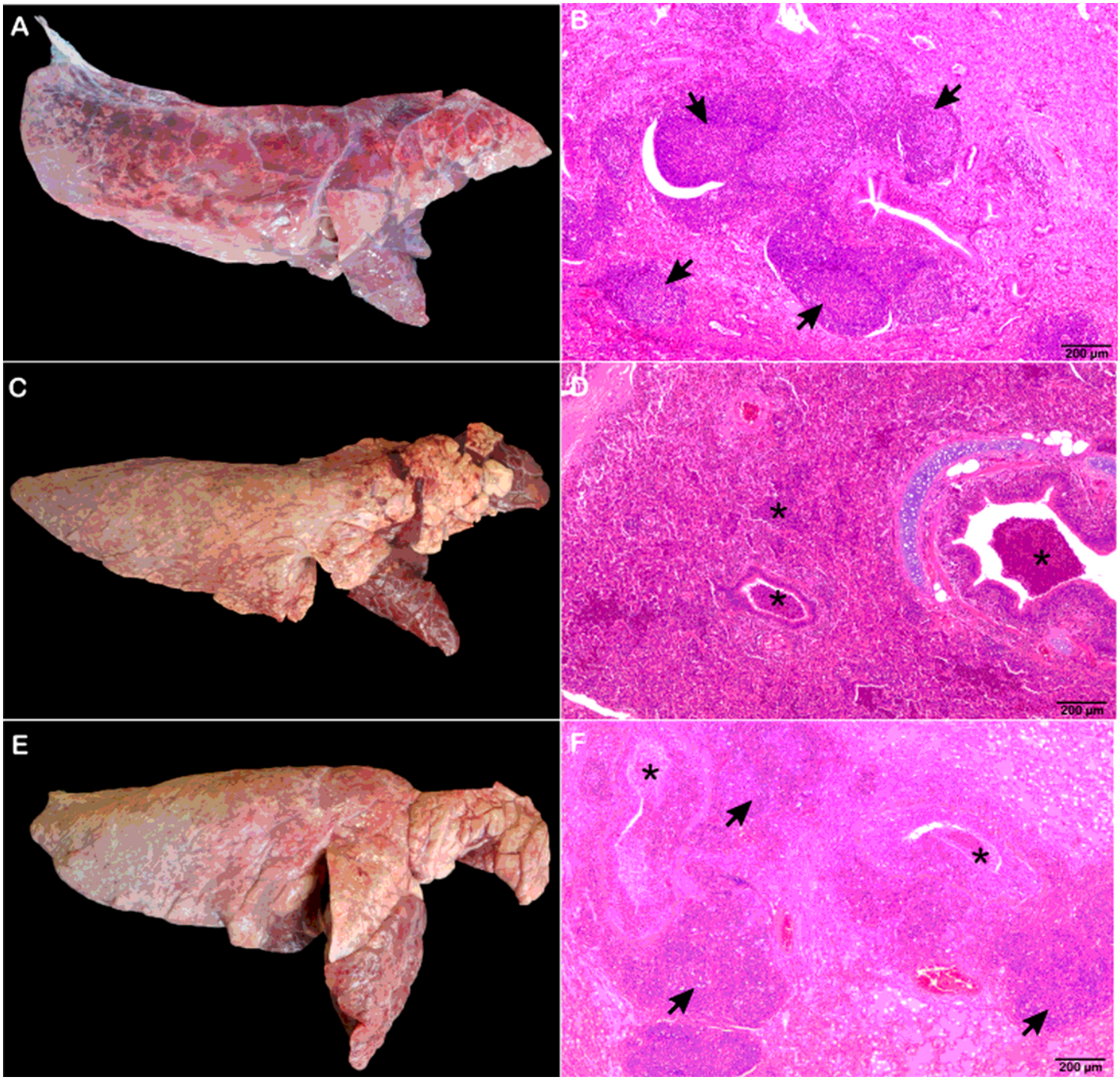

Figure 2

Lungs showing MLL at abattoir (A, C and E) and their corresponding microscopic lesions (B, D and F, respectively). B: Peribronchiolar lymphoid clumps of cells of varying degrees of development infiltrating the lamina propria of the bronchioles to a differing extent (BALT hyperplasia) (arrows). Bronchointerstitial pneumonia. D: Exudate into bronchi, bronchioles and alveoli predominantly composed of degenerated neutrophils (asterisks). Suppurative bronchopneumonia. F: Mixed pattern of lesions showing both types of pneumonia described in pictures B and D (arrows and asterisks). Bronchointerstitial pneumonia + suppurative bronchopneumonia.

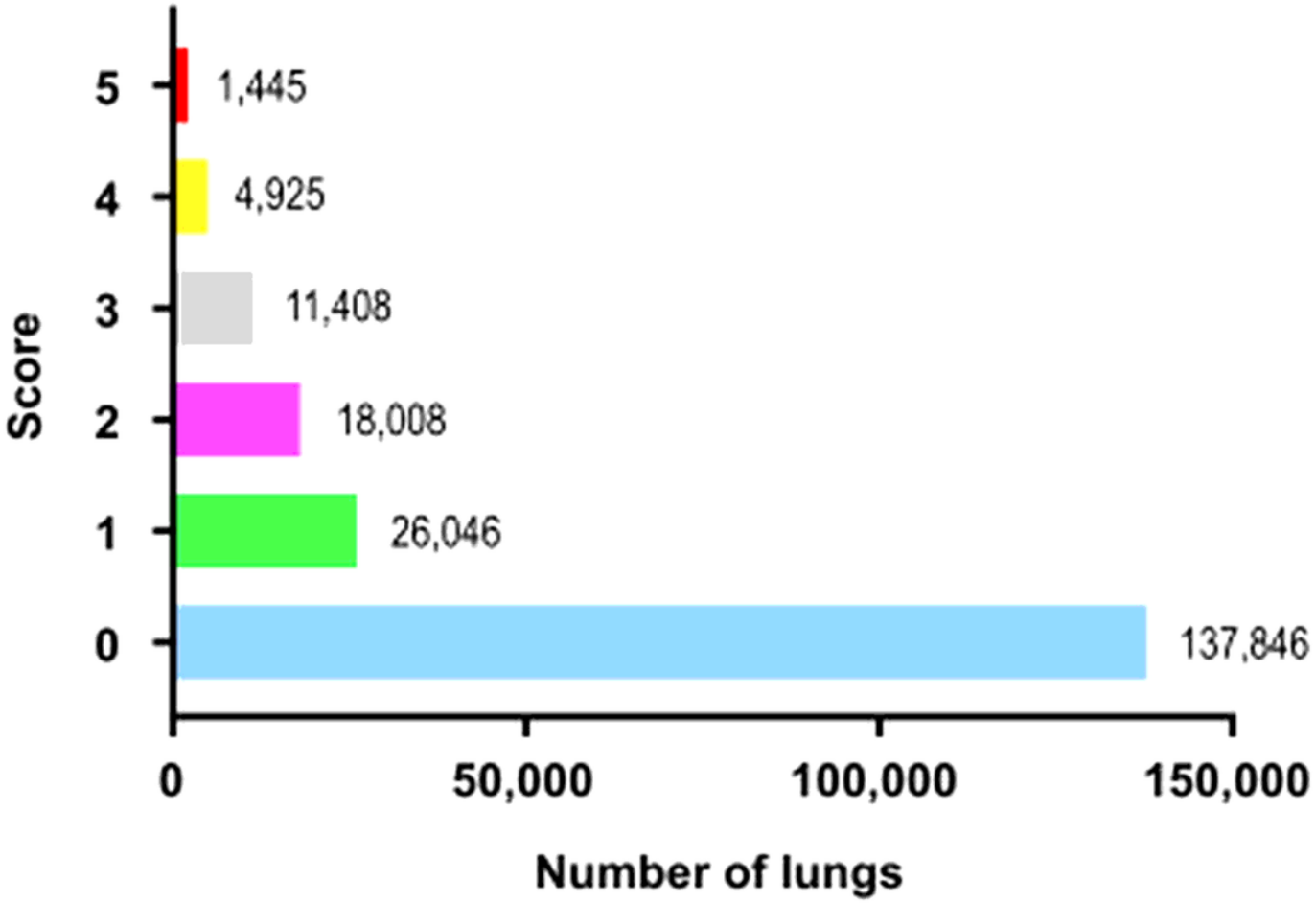

Figure 3

Number of lungs examined belonging to each score (0-5).