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Research Article

Coherence of Clinical Symptoms at Antemortem Inspection and Pathological Lesions at Postmortem Inspection in Slaughter Pigs

Nikola ČOBANOVIĆ [1,a] Urška JAMNIKAR-CIGLENEČKI [2,b] Andrej KIRBIŠ [2,c] Manja KRIŽMAN [2,d] Marina ŠTUKELJ [3,e] Ivan VIĆIĆ [1,f] Nedjeljko KARABASIL [1,g]

[1] University of Belgrade, Faculty of Veterinary Medicine, Department of Food Hygiene and Technology, Bulevar Oslobodjenja 18, 11000 Belgrade, SERBIA
[2] University of Ljubljana, Veterinary Faculty, Institute of Food safety, Feed and Environment, Gerbičeva 60, 1000 Ljubljana, SLOVENIA
[3] University of Ljubljana, Veterinary Faculty, Clinic for Ruminants and Pigs, Clinic for Reproduction and Farm Animals, Cesta v Mestni log 47, 1000 Ljubljana, SLOVENIA

ORCIDS: [a] 0000-0003-2650-6272; [b] 0000-0002-3522-0551; [c] 0000-0003-2734-2222; [d] 0000-0002-5578-8486; [e] 0000-0003-2295-3788 [f] 0000-0001-8762-2811; [g] 0000-0001-6097-3216

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Abstract

The aim of this study was to examine the relationship between clinical symptoms recorded during the antemortem inspection in the lairage and pathological lesions at postmortem inspection of slaughter pigs. If clinical symptoms were an accurate indicator of pathological lesions at postmortem inspection it could be possible to incorporate only those parameters in the health and welfare monitoring system. The study was conducted on 1033 pigs originated from 39 small-scale farms. During the antemortem inspection, pigs were clinically inspected for the presence of coughing, sneezing and laboured breathing. The plucks of slaughtered pigs from each farm were examined for pneumonia, pleurisy and liver milk spots. No relationship was found between clinical symptoms and pathological lesions using Spearman correlation analysis. According to receiver operating characteristic curves and the area under the curves, 'positive farms' for pathological lesions at the postmortem inspection could not be accurately detected by the clinical symptoms recorded during antemortem inspection. These results suggest that the recording of pathological lesions at postmortem inspection is more reliable and feasible method for pig health and welfare monitoring than the recording of clinical symptoms during the antemortem inspection. Therefore, incorporating of pathological lesions scoring as part of the routine postmortem veterinary inspection process could function as iceberg indicators of underlying problems affecting pig health and welfare at farm level.

Keywords: *Coughing, Liver milk spots, Lung lesions, Receiver operating characteristic analysis, Sneezing*

Domuzlarda Antemortem Muayenedeki Klinik Bulgular İle Postmortem Muayenede Belirlenen Patolojik Lezyonların Tutarlılığı

Öz

Bu çalışmanın amacı, kesim domuzlarının barınakta antemortem muayenesi sırasında kaydedilen klinik semptomlar ile post-mortem muayenesinde belirlenen patolojik lezyonlar arasındaki ilişkiyi incelemektir. Böylece, klinik semptomlar postmortem muayenede belirlenen patolojik lezyonların doğru bir göstergesi ise, sadece bu parametreleri hayvan sağlığı ve refahı takip sistemine dahil etmek mümkün olabilir. Çalışma 39 küçük ölçekli çiftlikten temin edilen 1033 domuz üzerinde gerçekleştirildi. Antemortem muayene sırasında domuzlar öksürük, aksırma ve solunum güçlüğü yönünden klinik olarak incelendi. Kesilen domuzlar pnömoni, plörezi ve karaciğer süt lekeleri açısından incelendi. Spearman korelasyon analizi kullanılarak yapılan değerlendirmede klinik semptomlar ile patolojik lezyonlar arasında ilişki bulunmadı. Oluşturulan karakteristik eğrilere ve eğrilerin altında kalan alana göre, ölüm sonrası incelemede patolojik lezyonlar bakımından "pozitif çiftlikler", ön inceleme sırasında kaydedilen klinik semptomlarla doğru bir şekilde tespit edilemedi. Bu sonuçlar, domuz sağlığı ve refahının izlenmesinde postmortem muayenede patolojik lezyonların kaydedilmesinin, antemortem muayene sırasında klinik semptomların kaydedilmesinden daha güvenilir ve uygulanabilir bir yöntem olduğunu göstermektedir. Bu nedenle, rutin postmortem veteriner hekim muayene sürecinin bir parçası olarak patolojik lezyon skorlamasının kullanılması, çiftlik düzeyinde domuz sağlığını ve refahını etkileyen altta yatan sorunların göstergesi olarak işlev görebilir.

Anahtar sözcükler: *Öksürük, Karaciğer süt lekeleri, Akciğer lezyonları, Alıcı işletme karakteristik analizi, Aksırma*

Correspondence
+381 11 2685653
cobanovic.nikola@vet.bg.ac.rs

INTRODUCTION

Respiratory diseases and ascariasis are one of the major contributors to reduce health and welfare in pig production. Respiratory disorders in pigs may be accompanied by the clinical symptoms such as coughing, sneezing, laboured breathing, nasal discharge, lethargy, and fever [1,2], while *Ascaris suum*-induced respiratory distress in pigs can be followed by coughing and laboured breathing [3]. As a consequence of respiratory diseases and ascariasis in fattening pigs, pathological lesions at the postmortem inspection are frequently found, as an incidence between 12% and 45% for lung lesions and between 14.5% and 40% for liver milk spots [4-6]. These lesions are associated with significant economic losses for the pig producers, primarily due to a reduction in average daily weight gain, growth rate and feed conversion efficiency and increased morbidity, mortality, medication and veterinary expenses [7,8]. They also cause financial losses to the slaughterhouse as a consequence of reduced carcass and pork quality, increased carcass and viscera trimming procedures and disposal of organs unfit for human consumption [9-11].

A certain degree of contradiction exists between the studies whether the clinical examination is actually needed for a reliable health and welfare assessment at farm level or assessment of pathologic lesions at postmortem inspection would be a more sufficient way to assess pig health and welfare. Several studies [2,12-14] have reported that animal health and welfare at farm level can be estimated by calculating the frequency of clinical symptoms recorded during the antemortem inspection at the slaughterhouse and/or on the farm of origin. However, some authors [15-18] did not detect the relationship between clinical symptoms of respiratory diseases and *Ascaris suum* invasion and pathological lesions at postmortem inspection, indicating that the clinical observation during antemortem inspection was not a sensitive indicator of pig health and welfare. Therefore, the aim of this study was to examine the relationship between clinical symptoms (coughing, sneezing and laboured breathing) recorded during antemortem inspection in the lairage and pathological lesions obtained for the same batches of slaughter pigs during postmortem inspection. The hypothesis was that the level of clinical symptoms recorded in a given batch of pigs would be a good measure to detect 'positive farms' for pathological lesions at the postmortem inspection.

MATERIAL and METHODS

The study was conducted between 1 January 2016 and 1 January 2019 on 1033 slaughter pigs (539 barrows and 494 gilts), about six months old, with an average live weight of approximately 115 kg. All pigs were of the same genetics ([Yorkshire × Landrace] sows sired with Pietrain boars) and originated from 39 small-scale commercial farms. The study farms showed a large variability in housing conditions, microclimate control, feeding plan and management. On the day of slaughter, all pigs were subjected to similar pre-slaughter handling, transportation and lairaging in compliance with the standard marketing conditions for Southeastern Europe [19]. Slaughter procedure and carcass processing were identical for all pigs and were performed in accordance with the standard industry-accepted practices in the same low-input slaughter facility, with a weekly slaughter rate of 175 pigs.

Antemortem Inspection

One group of pigs for each of the 39 small-scale farms was selected during lairaging, whereby the animals were inspected for clinical symptoms by three trained assessors. At each sampling day, two pens which best represent the farm of origin, holding a minimum of 10 pigs were selected. Hospital pens were not included in the sampling plan. During clinical examination, assessors were stationed in the corridor with a clear view into all pigs in the selected pens. The pigs in the pens under surveillance are firstly roused and then have five minutes to calm down until their activity had gone back to normal.

Three symptoms were taken into account to evaluate the presence of clinical symptoms of respiratory diseases and *Ascaris suum* invasion: coughing, sneezing and laboured breathing. Coughing was recorded when pigs displayed an audible expulsion of air through the mouth. Sneezing was defined as a sudden involuntary expulsion of air from the nose and mouth due to irritation of one's nostrils. A pig exhibited laboured breathing when at least one of the following signs was observed: tachypnea (breathing frequency higher than 20 breaths/min), enforced abdominal breathing, breathing in a pumping way and excessive nostril movements. Coughing and sneezing were counted in each pen under surveillance for five minutes using the Welfare Quality® protocol [20]. In addition, the percentage of pigs showing coughing, sneezing and laboured breathing was also calculated. The farm level score was calculated based on the Welfare Quality® protocol [20].

Postmortem Inspection

The pluck from each slaughtered pig consisted of heart, lung and liver that are removed from the carcass by abattoir personnel and first visually and then by palpation assessed for macroscopically visible lesions of pneumonia, pleurisy and liver milk spots by the three trained investigators using the Welfare Quality® protocol [20]. Pigs that were inspected in the slaughterhouse were those which were clinically observed during an antemortem inspection in lairage. The assessment was performed directly at the slaughter line before the routine postmortem veterinary inspection, to include organs that would have been discarded during inspection. Pneumonia, pleurisy and liver milk spots were recorded as binary variables with the lesion being scored

as either present (score 2) or absent (score 0) in each organ. The farm level score was calculated based on the Welfare Quality® protocol [20].

Statistical Analysis

Statistical analysis of the results was conducted using SPSS software (Version 23.0, IBM Corporation, Armonk, NY, USA) [21]. The incidence of clinical symptoms and pathological lesions in slaughter pigs was calculated at the batch level. A batch was defined as a group of pigs belonging to the same farm that were killed on the same day at the same slaughterhouse. Batch size ranged from 20 to 35 pigs, with an average of 26.5 pigs per batch. The batch was used as an experimental unit for all statistical analyses. Data were described by descriptive statistical parameters as the mean value, standard deviation, standard error of means, and minimum and maximum range. A probability level of $P<0.05$ was chosen as the limit for statistical significance in all tests.

Spearman rank correlation analysis (r_{sp}) was run between the clinical symptoms and pathological lesions in slaughter pigs to numerically summarise the degree of association between any two variables. A further set of analysis compared the incidence of pathological lesions observed for the 39 batches (one per farm) with a benchmark value above which the health and welfare situation of the batch should be regarded as seriously compromised. Those farms with the incidence of pathological lesions that exceeded the alarm threshold set by the Welfare Quality® protocol [20] were considered as 'positive' farms (55% for lung lesions and 23% for liver milk spots). Threshold for lung lesions percentage was established based on alarm threshold for pleurisy [20], since it corresponded to the mean percentage of lung affected by lesions in the 39 screened farms. For each clinical symptom were created the receiver operating characteristic (ROC) curves, and the areas under the ROC curve (AUC) were calculated to acquire the accuracy of the prediction. The optimal cut-off points on the ROC curves (percentage of pigs expressing the clinical symptom) were determined by selecting the optimal sensitivity (SE) and specificity (SP) using the following formula: minimal value of $[(1 - SE)^2 + (1 - SP)^2]$ [22]. Sensitivity, specificity and positive predictive values were calculated for the selected cut-off point for each clinical symptom. Values of AUC were interpreted as follows: i) area greater than 0.9 indicates high accuracy; ii) area between 0.7 and 0.9 indicates moderate accuracy; iii) area between 0.5 and 0.7 indicates low accuracy; iv) area lower than 0.5 is interpreted as non-informative [22]. To determine if the detection of 'positive farms' for pathological lesions based on clinical examinations would improve when multiple clinical symptoms were considered, a logistical regression analysis was carried out with pathological lesion scores as a binary response variable (2 for an incidence above 55% for lung lesions; 23% for liver milk spots; and 0 for an incidence below aforementioned thresholds).

RESULTS

Incidence of Clinical Symptoms at Antemortem Inspection and Pathological Lesions at Postmortem Inspection

Incidence of clinical symptoms at antemortem inspection and pathological lesions at postmortem inspection calculated at farm level is shown in *Table 1*. Coughing was the most prevalent clinical symptom at antemortem inspection, with a mean value of 4.55% (0.06 coughs/pig) of the pigs affected, followed by sneezing (3.11%, 0.06 sneezes/pig) and laboured breathing (0.43%). The frequencies of coughing (ranged from 0.00 to 0.14 coughs/pig), sneezing (ranged from 0.00 to 0.24 sneezes/pig) and laboured breathing (ranged from 0.00% to 3.85%) at the farm level (n=39) were maintained under alarm threshold values set by the Welfare Quality® protocol [20].

The most prevalent pathological lesion at postmortem inspection was pneumonia (43.04%), followed by liver milk spots (31.83%) and pleurisy (21.68%) *(Table 1)*. According to Welfare Quality® protocol [20], each farm had the incidence of pneumonia above the alarm threshold set for this health criterion. In addition, of the 39 farms assessed, 30.77% exceeded the warning threshold and 5.13% exceeded the alarm threshold set for pleurisy. Of the 39 farms assessed, 33.33% exceeded the warning threshold and 48.72% exceeded the alarm threshold for liver milk spots.

Spearman Correlations Between Clinical Symptoms at Antemortem Inspection and Pathological Lesions at Postmortem Inspection

Spearman rank correlations between clinical symptoms at antemortem inspection and pathological lesions at the postmortem inspection are depicted in *Table 2*. No significant correlation was found between clinical symptoms during antemortem inspection and pathological lesions at the postmortem inspection ($P>0.05$).

ROC Curve Analysis for the Detection of 'Positive Farms' for Pathological Lesions at Postmortem Inspection based on Clinical Symptoms during Antemortem Inspection

When considering the alarm thresholds for pigs with pathological lesions at postmortem inspection set by the Welfare Quality® protocol [20], the incidence of 'positive farms' was 35.90% for lung lesions and 48.72% for liver milk spots.

The ROC curves for the detection of 'positive farms' for lung lesions using the clinical symptoms are shown in *Fig. 1*. The AUC were 0.63 for coughing (95% CI of 42.50-82.50), 0.66 for sneezing (95% CI of 47.60-84.20) and 0.67 for laboured breathing (95% CI of 50.00-84.70). For coughing the optimal cut-off value was 3.39% with a sensitivity of 68.20%, a specificity of 50.00%, and a positive predictive

Table 1. *Incidence of clinical symptoms at antemortem inspection and pathological lesions at postmortem inspection calculated at farm level (n = 39)*

Parameter		Mean	SD	SE	Minimum	Maximum	Warning Threshold [20]	Alarm Threshold [20]
Clinical symptoms	Coughing (%)	4.55	3.78	0.61	0.00	10.00	-	-
	Coughs/pig[1]	0.06	0.05	0.01	0.00	0.14	>0.15	>0.46
	Sneezing (%)	3.11	3.31	0.53	0.00	10.00	-	-
	Sneezes/pig[2]	0.06	0.07	0.01	0.00	0.24	>0.27	>0.55
	Laboured breathing (%)	0.43	1.15	0.18	0.00	3.85	>1.8	>5.0
Pathological lesions	Pneumonia %)	43.04	25.98	4.16	8.00	89.29	>2.7	>6.0
	Pleurisy (%)	21.68	18.99	3.04	0.00	71.43	>28.0	>55.0
	Liver milk spots %)	31.83	24.81	3.97	0.00	93.33	>10.0	>23.0

[1] number of coughs per pig during 5 min; [2] number of sneezes per pig during 5 min; ***SD:*** *standard deviation;* ***SE:*** *standard error of means*

Table 2. *Spearman rank correlations (r_{sp}) between clinical symptoms at antemortem inspection and pathological lesions at postmortem inspection*

Variables	Coughing	Sneezing	Laboured Breathing
Pneumonia	0.202	0.267	0.137
Pleurisy	0.034	0.248	0.120
Milk spots	0.017	-	0.108

** Statistical significance at (P<0.05)*

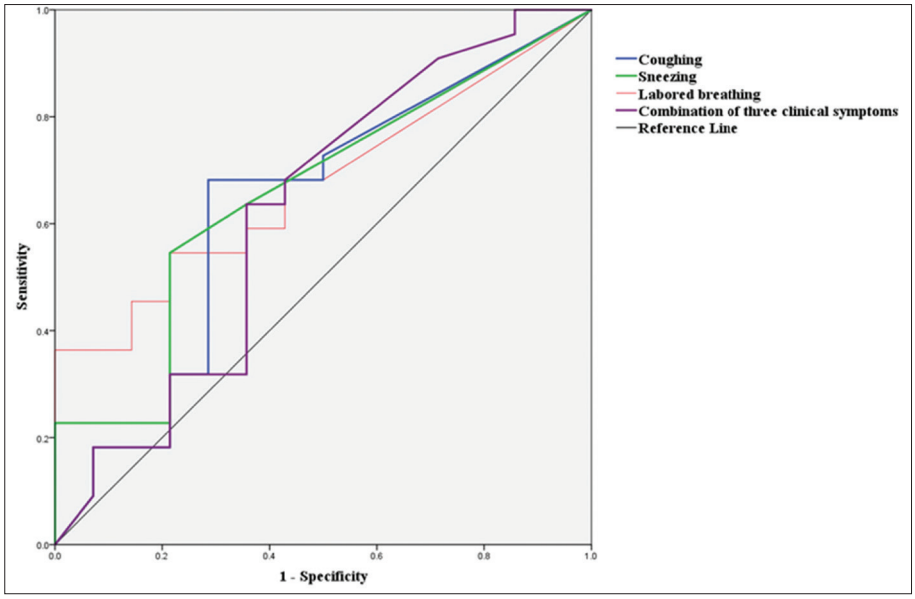

Fig 1. ROC curves for the detection of 'positive farms' for lung lesions using the clinical symptoms

value of 52.16%. For sneezing the optimal cut-off value was 1.67% with a sensitivity of 63.60%, a specificity of 35.70% and a positive predictive value of 44.00%. For laboured breathing, the optimal cut-off value was 1.47%, with a sensitivity of 68.20%, a specificity of 52.16% and a positive predictive value of 52.68%.

The logistic regression model that predicted high incidence of lung lesions best, comprised the following three clinical symptoms: coughing, sneezing and laboured breathing. As can be seen in *Fig. 1*, using this multivariable model for the detection of 'positive farms' for lung lesions did not significantly improve the quality of the ROC curve. The AUC using a multivariable model was slightly lower compared to the AUC for ROC curves obtained for single clinical symptoms: 0.62.

The ROC curves for the detection of 'positive farms' for liver milk spots using the clinical symptoms are shown in *Fig. 2*. The AUC were 0.63 for coughing (95% CI of 43.90-81.20) and 0.60 for laboured breathing (95% CI of 40.90-79.10). For coughing the optimal cut-off value was 1.67% with a sensitivity of 84.60%, a specificity of 52.20% and a positive predictive value of 47.71%. For laboured breathing the

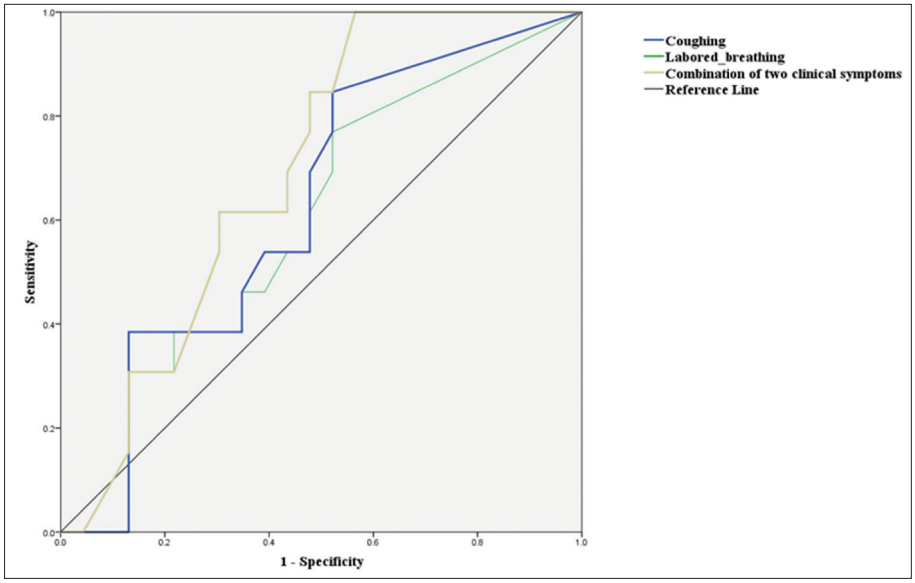

Fig 2. ROC curves for the detection of 'positive farms' for liver milk spots using the clinical symptoms

optimal cut-off value was 1.47% with a sensitivity of 76.90%, a specificity of 52.20%, and a positive predictive value of 45.25%.

The logistic regression model that predicted high incidence of liver milk spots best, comprised the following two clinical symptoms: coughing and laboured breathing. As depicted in *Fig. 2*, using this multivariable model for the detection of 'positive farms' for liver milk spots did not significantly improve the quality of the ROC curve. The AUC using a multivariable model was marginally improved compared to the AUC for ROC curves obtained for single clinical symptoms: 0.69.

DISCUSSION

The incidence of clinical symptoms recorded at antemortem inspection remained low throughout the entire study period. In addition, the frequencies of coughing, sneezing and laboured breathing were below both warning and alarm threshold values set by the Welfare Quality® protocol [20]. Therefore, according to the results of clinical examination, it can be argued that there was no indication of a health and welfare problem on the farm of origin. The incidence of pathological lesions detected at the postmortem inspection was much higher than the incidence of clinical symptoms recorded during the antemortem inspection. Furthermore, each pig farm had the incidence of at least one of the pathological lesions detected at the postmortem inspection above the alarm threshold set by the Welfare Quality® protocol [20]. Hence, according to the incidence of pathological conditions in slaughtered pigs, there was a strong indication of a serious health and welfare problem on the farm of origin.

The possibility to detect 'positive farms' for pathological lesions at postmortem inspection by recording the incidence of clinical symptoms during antemortem inspection was tested by ROC curve analyses. This statistical approach should not be interpreted as an assessment of the potential capability of clinical symptoms to be used in the diagnosis of pig diseases. ROC analysis was conducted to assess the potential use of clinical symptoms recorded at antemortem inspection as parameters able to discriminate between 'positive' and 'negative' farms for pathological lesions recorded at the postmortem inspection as indicators of health and welfare on the farm of origin. The positive predictive values found can be considered as low given the fact that only 44.00%-52.68% of the farms regarded as positive based on one of the clinical symptoms exceeded the positive threshold for pathological lesions at postmortem inspection. During this investigation, the incidence of 'positive farms' for lung lesions and liver milk spots was relatively high and, thus, it could be expected high positive predictive values [23]. Furthermore, AUC values between 0.63 and 0.67 for individual clinical symptoms and 0.62 for a multivariable model, indicating that 'positive farms' for lung lesions could not be accurately predicted by clinical observation. Likewise, AUC values between 0.60 and 0.69 for individual clinical symptoms and 0.62 for a multivariable model, indicating that the ability of the coughing and laboured breathing to detect 'positive farms' for liver milk spots was very low. Sensitivity between 63.60%-84.60% and specificity between 35.70%-52.20% were achieved for clinical symptoms in discriminating 'positive farms' for pathological lesions at the slaughter line. However, obtained specificity means that between two thirds and half of 'negative farms' would be incorrectly identified as 'positive farms' for pathological lesions at postmortem inspection. This indicates that this measure would not be of practical use in informing pig producers of potential health and welfare issues within the herd as feedback would be inaccurate in many cases. The results obtained by the ROC curve analyses were strengthened because in the present research, no relationship was found

between clinical symptoms and pathological lesions using Spearman correlations (r_{sp} ranged from 0.017 to 0.267; P>0.05) *(Table 2)*. Therefore, it can be considered that clinical symptoms recorded during antemortem inspection did not allow an accurate detection of 'positive farms' for pathological lesions at the postmortem inspection.

The results obtained in this study are comparable to several studies [15-18], who found a high prevalence of lung lesions in the herds without clinical symptoms. These results can be explained by the fact that respiratory diseases and ascariasis in fattening pigs are characterised by vague and nonspecific clinical symptoms [1,24]. These diseases occur in a subclinical form or as uncomplicated infections, and produce pathological lesions that can be only identified during postmortem inspection [1,15,17]. There is a possibility that sporadic clinical symptoms recorded in this study were not only provoked by lung inflammation, but also by inadequate environmental conditions in the lairage and/or on the farm of origin, such as high ambient temperature and relative humidity, presence of aerial dust and manure gases. In these situations, gross irritation of the nostrils and airways, together with suppression of the microscopic lung defense mechanisms resulted in sporadic coughing, sneezing and laboured breathing in finishing pigs. Thus, clinical examination cannot be regarded as an efficient and reliable method for the health and welfare assessment [16,25,26]. Accordingly, the evaluation of pathological lesions during postmortem inspection is of paramount importance to identify subclinical diseases, which are not possible to detect by clinical examination during an antemortem inspection at the slaughterhouse and/or on the farm of origin [26]. In addition, there are several advantages of pathological lesion assessment at the slaughter line compared with clinical examination at antemortem inspection at the slaughterhouse and/or on farm of origin. Although clinical examination is an inexpensive method for pig health and welfare assessment, it may be labour intensive, time-consuming and usually require pig handling or the pig needs to be forced to move [26]. The advantage of pathological lesion examination at the postmortem inspection is that the pigs from different farms can be examined on the same day, reducing travelling costs and minimising the risks of disease transmission within and between farms during assessments [26]. Also, postmortem health and welfare assessment avoid potential problems associated with having to assess pigs in crowded, dirty or poorly-lit conditions such as in the lairage pens and/or on the farm of origin [26].

Contrary to the findings of this study, some authors [2,12-14] found a positive association between the occurrence of pathological lesions at the postmortem inspection and clinical symptoms on farm during fattening. Several possible factors can be raised to explain this discrepancy. Data on clinical symptoms on farm during fattening and pathological lesions at the postmortem inspection are based on a slightly different sample of animals in the batches [13]. In addition, animals delivered to a slaughterhouse are clinically healthy, while those individuals who exhibit clinical symptoms during production cycle usually stay on farm and receive medical treatment until full recovery. Furthermore, some of the severely diseased pigs will not complete the production cycle because they will die or be culled during fattening prior to cohort slaughter. It is also possible that respiratory infections and ascariasis at the early stage of the fattening period will not necessarily result in pathological lesions as these might heal or become less evident at the postmortem inspection [13].

In conclusion, the results of this study showed that, in the context of pig health and welfare monitoring, the recording of pathological lesions at postmortem inspection is more reliable and feasible method than the recording of clinical symptoms during antemortem inspection. Therefore, incorporating of pathological lesions scoring as part of the routine postmortem veterinary inspection process could function as iceberg indicators of underlying problems affecting pig health and welfare on the farm of origin. However, before any firm conclusions can be drawn, further investigation is required to clarify the potential use of clinical symptoms in pigs during fattening on the farm of origin, concentration of acute phase proteins and serological testing for the most common respiratory pathogens and *Ascaris suum* to forecast the 'positive farms' for pathological lesions in slaughtered pigs.

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Conflicts of Interest

The author declares no conflict of interest.

Authors Contributions

NK and NČ defined the research theme, gave the conception of the research. NČ, IV and NK carried out experimental part of the study. UJC and MK have made supervised the analysis of the results, and contributed to the writing of the manuscript. AK and MŠ were involved in drafting the manuscript and revising it critically for important intellectual content and have made a substantial contribution to conception and design, analysis and interpretation of data. All authors discussed the results and contributed to the final manuscript.

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