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Evaluation of Radiographic Positioning Techniques Used in Local Hospitals after Teleradiology Consultation

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Abstract The purpose of this study was to evaluate the radiographic positioning techniques used in local animal hospitals, identify the most common positioning problem, and determine whether there were changes after teleradiology consultations. From September 2016 to April 2021, 15 local animal hospitals that requested radiographic interpretation more than 10 times and for more than six cases of thoracic radiographs were selected. Six sets of two-views of (lateral and ventrodorsal [VD] or dorsoventral [DV] views) digital thoracic radiographs from six dogs per hospital were evaluated in four categories. For the lateral view, radiographic technique scores used in ten local animal hospitals improved, one remained the same, and four became worse. For the VD/DV view, the score for eleven hospitals improved and worsened for four. The most common problem was rotation (57/90) for the lateral view, followed by an inappropriate field of view (59/90), and incorrect beam center (71/90). For the VD/DV view, an inappropriate field of view (54/90) was the most common problem, followed by asymmetry (63/90), and incorrect beam center (73/90). Every factor, except rotation in the lateral view, improved after obtaining technical consultation; however, the degrees of improvement were not remarkable. There was no significant correlation between the number of requests and the degree of improvement. According to the results, the radiographic technique used in local animal hospitals was improved by technical advice on teleradiology. These changes make it possible to provide accurate diagnoses of the requested images. There are some limitations regarding the indicators of evaluation and the number of cases; therefore, further studies that use detailed indicators in large cohort group are needed. In addition, an effective method of teaching should be developed to improve radiographic techniques in local animal hospitals.

Key words technical advice, radiography, teleradiology, optimal view, local animal hospital.

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Introduction

Radiograph is the image showing the internal organs of the patient in two-dimensional image based on the spatial distribution of x-rays passes through the patient (5). Compared to other imaging examinations, the radiography is relatively inexpensive, is minimally invasive, and can be taken in a short time, it is used as the most basic diagnostic imaging tool in veterinary medicine (2). Radiographic images were recorded on analog film in original, but with the development of technology for decades, they are now recorded in a digital format, called Digital Imaging and Communications in Medicine (DICOM), and this makes it possible to evaluate radiographic images anywhere with a DICOM viewer (1,5). Also, digital radiography reduced problems with radiographic exposure and darkroom errors (5).

Recently, digital radiography has been commonly used in local animal hospitals, and general practitioners routinely interpret radiographs (3). Nevertheless, to avoid misdiagnosis and gain professional interpretation, local animal hospitals are looking for exclusive radiologists, but the number of radiologists is currently not meeting the demand. As the alternative plan, they are using teleradiology to get the second opinions from specialists (4,6).

Since 2016, the department of Veterinary Medical Imaging, Chungbuk National University, Republic of Korea has been interpreting radiographs requested by local animal hospitals through the service of teleradiology company. Despite the digitalization of radiography resolved many problems occurred by radiation exposure and darkroom errors, there are still many problems that made interpreting difficult, and we find out that the main problem was inadequate radiographic positioning techniques of local animal hospitals. Because of these insufficient techniques could cause misdiagnosis, we thought that consulting on the wrong radiographic positioning technique is absolutely necessary, and we provided proper consultation depends on the situations. However, it has not been clearly evaluated whether the consultation provided through these teleradiology referral actually improves radiography positioning techniques in local animal hospitals.

The purpose of this study is to evaluate the radiographic positioning techniques used in local animal hospitals in quantitative method and to determine whether the technical consultation through teleradiology improved the techniques of local animal hospitals. We hypothesized that the radiographic positioning techniques of the local animal hospitals would have improved by technical consultations and that the number of consultations is correlated to the improvement of techniques.

Materials and Methods

Case selection criteria

We performed a retrospective study from September 2016 to April 2021. Forty-four local animal hospitals requested radiographic interpretation for a total of 989 cases. They submitted their requests to the department of Veterinary Medical Imaging, Chungbuk National University Veterinary Teaching Hospital (CBNU-VTH) through WooriCare, a teleradiology company in South Korea. We obtained consent for the use of images from WooriCare and each local animal hospitals by telephone.

Among the local animal hospitals that requested interpretation through WooriCare, hospitals that received more than 10 interpretation paper in total from CBNU-VTH, of which more than 6 were for thoracic radiographs that include two or more orthogonal views, were included.

After identifying the local animal hospitals that satisfy the inclusion criteria, thoracic radiographic images for evaluation were randomly selected. However, the images that were unfeasible to evaluated by the following reasons were excluded; 1) Due to the severe increase in the opacity of the lung field, surrounding structures for evaluation were invisible, 2) massive mass in the thoracic or abdominal cavity affected the regions for evaluation, and 3) other technical problems except positional factors, such as motion artifact, affected evaluation.

Image analysis

All digital images were assessed using the Digital Imaging and Communications in Medicine (DICOM) viewer (RadiAnt DICOM Viewer software; MEdixant Co., Poznan, Poland). Since the labeling was not accurate in most of the images, it was impossible to distinguish between the left and right lateral view or ventrodorsal [VD] and dorsoventral [DV] view; therefore, the radiograph images were labeled as "lateral view" and "VD/DV view." Two graduate students (S. J. K and M. J. O) of veterinary medicine at CBNU-VTH performed the scoring. Disagreements were resolved through consensus.

Scoring

Positional factors were divided into four categories and assessed using a scoring system of 0, 1, and 2 points.

Positional factors for the lateral view included 1) rotation of rib head (rotation), 2) non-peak inspiration (inspiration), 3) inappropriate field of view (FOV), and 4) incorrect beam center (beam center) (Fig. 1). For rotation, 2 points were awarded for the head of the ribs superimposed on each other, 1 point for one of the rib heads that rotated dorsally but did not

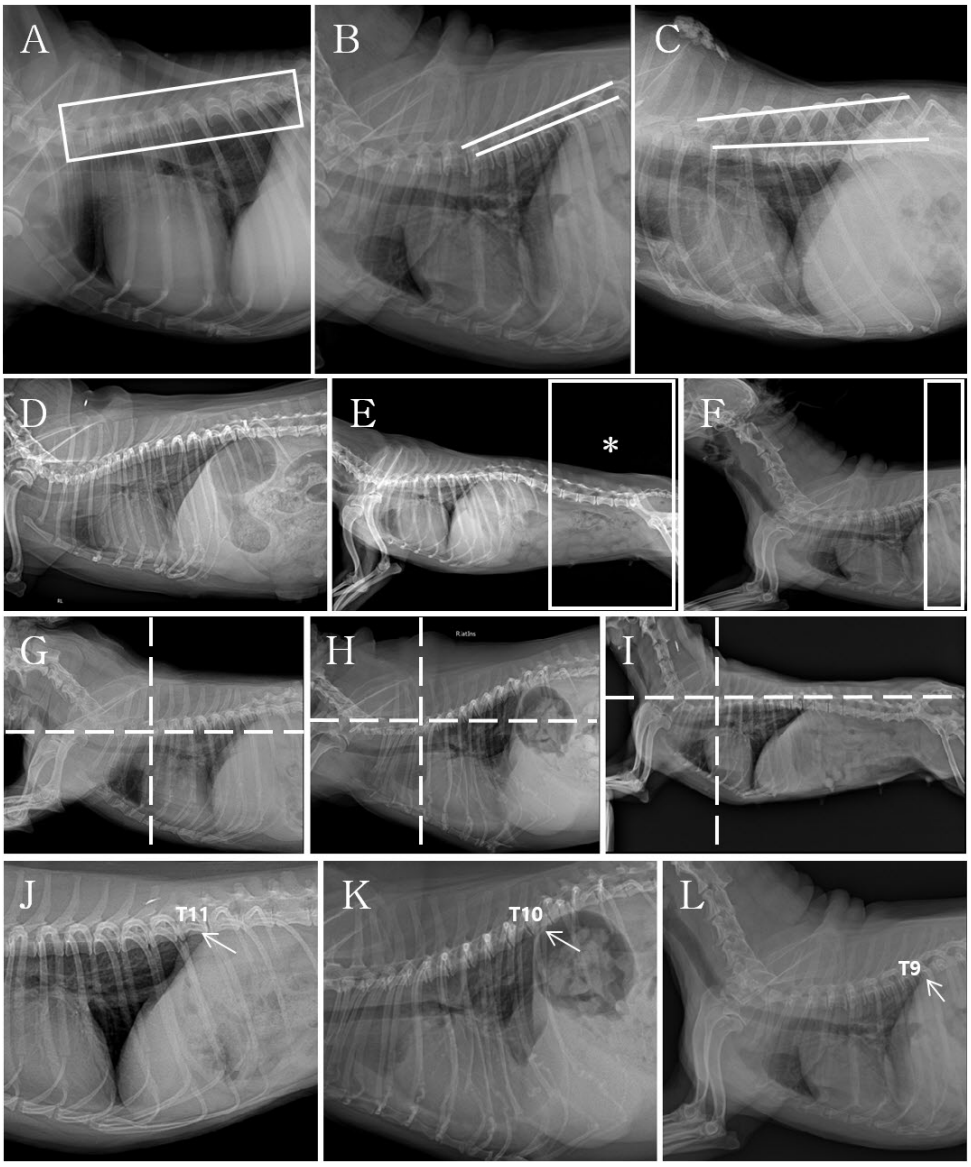

Fig. 1. Scoring criteria for the lateral view. For rotation, (A) the rib heads superimposed on each other perfectly (score 2), (B) one rib head rotated dorsally but did not extend the dorsal lamina of the vertebra (score 1), (C) one rib head rotated and extended the dorsal lamina (score 0). For the field of view (FOV), (D) the image obtained optimally shows 1-2 vertebra from manubrium cranially and from the 13th rib caudally (score 2), (E) the FOV set too large to record thoracic and abdominal images in one cut (asterisk) (score 1), (F) a part of the thorax could not be imaged (score 0). For the beam center, (G) the image center is located at the caudal margin of the scapula optimally (score 2), (H) the center is located mildly out of the optimal center but not too much (score 1), (I) the center is located totally out of the optimal location to record the thoracic and abdominal image in one cut (score 0). For the inspiration, the crus of the diaphragm (arrow) (J) located caudal to T11 (score 2), (K) located between T10 and T11 (score 1), (L) located cranial to T10 (score 0).

extend from the dorsal lamina of the vertebra, and 0 points for one of the rib heads that rotated dorsally and extended from the dorsal lamina of the vertebra. For inspiration, 2 points were awarded for the crus of the diaphragm located caudal to T11, 1 point for the crus of the diaphragm located between T10 and T11, and 0 points for the crus of the diaphragm located cranial to T10. For the FOV, 2 points were awarded for imaging with 1-2 vertebra from the manubrium cranially and from the 13th rib caudally, 1 point for setting the FOV too large to obtain thoracic and abdominal images in one cut, and 0 points for the part of the thorax that was out of boundaries and could not be imaged. For the beam center, 2 points were awarded for the center of the image located at the caudal margin of the scapula, 1 point for mild-

ly out of optimal center but not too much, and 0 points for totally out of the optimal center as observed while recording thoracic and abdominal image in one cut.

Positional factors for the VD/DV view included 1) asymmetry (symmetry), 2) non-peak inspiration (inspiration), 3) inappropriate FOV (FOV), and 4) incorrect beam center (beam center) (Fig. 2). For symmetry, 2 points were awarded for the spine and sternum superimposed completely, with the spinous process located at the center of vertebral bodies, 1 point for the spine not superimposed on the sternum, but

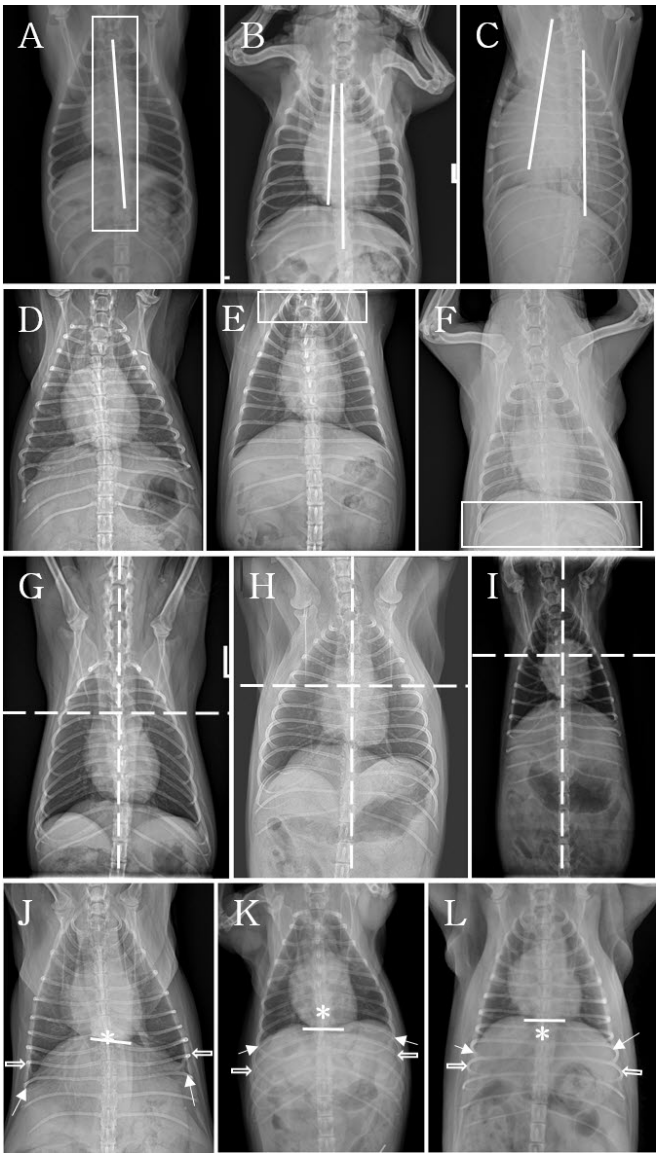

Fig. 2. Scoring criteria of the VD/DV view. For symmetry, (A) the spine and sternum superimposed to each other perfectly (score 2), (B) the spine and sternum did not superimpose but the end of the spinous process was located in the range of vertebra bodies (score 1), (C) the spine and sternum did not superimpose each other at all (score 0). For the field of view, (D) the image obtained optimally shows at least C6 imaged cranially and L2 caudally (score 2), (E) some parts of the thorax, especially the cranial and caudal margins of the thoracic cavity, were out of the boundary but sufficient for interpreting (score 1), (F) a part of the thorax, especially the caudal margins of the caudal lobes, could not be imaged (score 0). For the beam center, (G) the image center is located at the caudal margin of the scapula optimally (score 2), (H) the center is located mildly out of the optimal center but not too much (score 1), (I) the center located totally out of the optimal location to record the thoracic and abdominal image in one cut (score 0). For inspiration, the location of the crus of the diaphragm (white line) and the costophrenic angle (arrow) (J) were both caudal to T8 (asterisk) and the 10th rib (hollow arrow), respectively (score 2); (K) one of them is located cranial to T8 or the 10th rib (score 1), (L) both are located cranial to T8 and the 10th rib (score 0).

the end of the spinous process not extending the lateral margin of the vertebral bodies, and 0 points for the spine not superimposing on the sternum. For inspiration, 2 points were awarded for the highest part of the cupula of the diaphragm located caudal to T8 and the costophrenic angle opening caudal to the 10th rib, 1 point for one of the two criteria not being met, and 0 points if both the criteria were not met. The scoring for the FOV and beam center was same as that of the lateral view.

To evaluate whether the radiographic techniques used in local animal hospitals had improved with the consultation, the scores of all four categories for all the three cases were calculated according to the formula; Total score = (FOV + beam center) x 10 + (symmetry + inspiration) x 15. This calculation method weighted factors that can cause misdiagnosis in essential parts of interpretation, such as size and shape or heart, opacity of lung field, change in diameter of trachea and bronchus. It was set to have a maximum score of 100, and the score for a hospital was calculated as the average of the scores of the three cases. The average scores of the before three cases were compared with those of the after three cases. In addition, to evaluate the degree of improvement for each category, the summation of the scores before and after each category were compared.

Other factors, such as limb extension and motion artifact, were excluded because the specific evaluation criteria for scoring could not be set. Also, evaluation of inappropriate radiation exposure was excluded because the DICOM viewer could adjust the opacity of images and the performance of X-ray machine used in each hospital affected the quality of the images, that could not be corrected through advice. Also other body parts, such as the abdomen and musculoskeletal system, were not evaluated because their positioning factors were different.

For comparison with an upper control group, three random cases of the CBNU-VTH were selected and scored using the same criteria.

Statistical analysis

All statistical analyses and statistical figures were acquired by using the statistical software Prism 9.0 (GraphPad Software, San Diego, CA, USA). Wilcoxson matched pairs signed ranks test was used to evaluate the improvement of positioning techniques of local animal hospitals. Statistical significance was set at $p < .05$.

Results

Fifteen local animal hospitals met the inclusion criteria for our study. First, the positioning factors were scored according to the criteria for each category (Table 1). The summation of the scores were compared before and after the consultation. For the lateral view, rotation had the lowest score (57/90), followed by the FOV (59/90), beam center (71/90), and inspiration (84/90) before the consultation. The order of the scores was the same for the lateral view after the consultation, that is, rotation had the lowest score (55/90), followed by the FOV (68/90), beam center (83/90), and inspiration (88/90). Except for rotation (57 before consultation to 55 after consultation), the scores for the other three categories increased after the consultation for the lateral view. For the VD/DV view, the FOV had the lowest score (54/90), followed by symmetry (63/90), beam center (73/90), and inspiration (85/90) before the consultation. The order of the

Table 1. The scores before and after consultations for each positional factor

Positional factors	Before				After				Improvement
	Score 2	Score 1	Score 0	Total	Score 2	Score 1	Score 0	Total	
VD/DV (n = 45)									
FOV	14	26	5	54	20	23	2	63	9
Beam center	28	17	0	73	33	12	0	78	5
Symmetry	19	25	1	63	27	18	0	72	9
Inspiration	40	5	0	85	42	3	0	87	2
Lateral (n = 45)									
FOV	18	23	4	59	25	18	2	68	9
Beam center	27	17	1	71	38	7	0	83	12
Rotation	16	25	4	57	13	29	3	55	-2
Inspiration	40	4	1	84	43	2	0	88	4

FOV, field of view; VD/DV, ventrodorsal/dorsoventral.
For the VD/ DV view, FOV and symmetry improved the most, and for the lateral view, beam center improved the most.

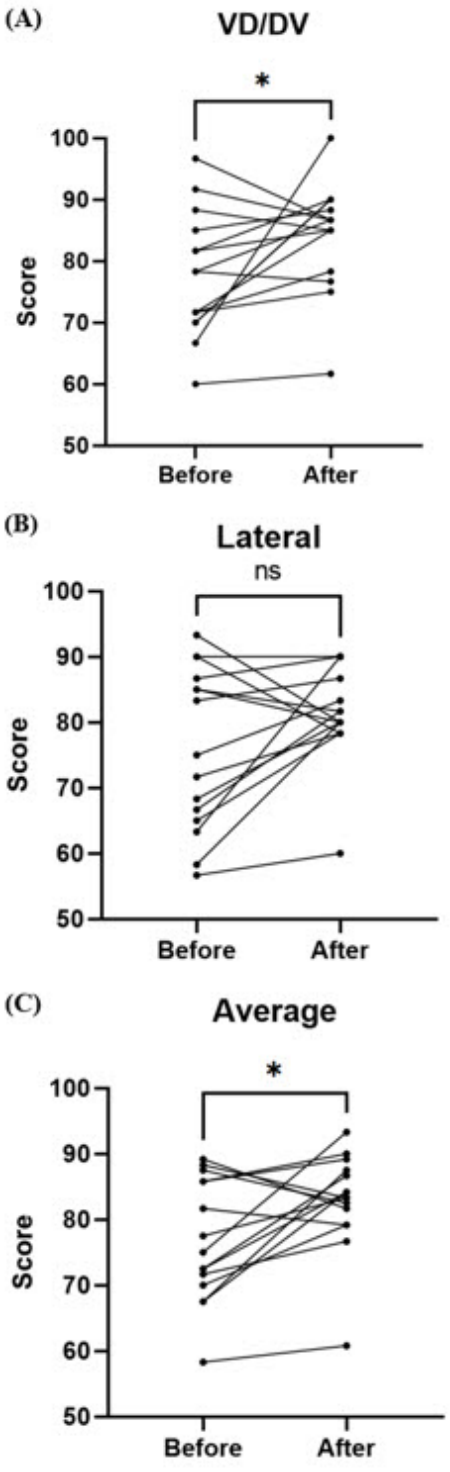

Fig. 3. The scores before and after consultation for local animal hospitals. The average score increased (A) by 6.8 from 77.6 to 84.3 in the VD/DV view and (B) by 5.3 from 75.9 to 81.2 in lateral view. (C) The overall average increased by 6.1 from 76.7 to 82.8. The statistical significance was confirmed in VD/DV view and in average, but not in lateral view. *$p < 0.05$: Wilcoxon matched-pair test comparing data between before and after consultations. VD/DV, ventrodorsal/dorsoventral.

scores was the same for the VD/DV view after the consultation, that is, the FOV had the lowest score (63/90), followed by symmetry (72/90), beam center (78/90), and inspiration (87/90). It was confirmed that the score increased for all the factors of the VD/DV view after the consultation. The most significant improvement was for FOV, symmetry in the VD/DV view and beam center in the lateral view, which increased by 9 points and 12 points, respectively. Rotation in the lateral view, which decreased by 2 points was the only factor that did not improved after consultation.

Next, the pre- and post-scores were compared for each local animal hospital out of 100 (Fig. 3). In VD/DV view and average score, significant improvement was confirmed with consultations ($p < .05$, Fig. 3A, C), but in lateral view, there was no statistical significance ($p = 0.1000$, Fig. 3B). For the VD/DV view, improvement was confirmed in 11 out of 15 hospitals (73.3%), with the average score increasing from 77.6 to 84.3. The largest improvement of a hospital was by 33.3 points (from 66.7 to 100). For the lateral view, improvement was confirmed for 10 out of 15 hospitals (66.6%), and the average score increased from 75.9 to 81.2. Among the hospitals, the largest improvement was 26.7 points (from 63.3 to 90). In average, the improvement was confirmed in 11 out of 15 hospitals (73.3%), with the total average score increasing from 76.7 to 82.8. The largest improvement of a hospital was by 20.0 points (from 67.5 to 87.5).

Finally, the degree of improvement in accordance with the number of consultations was assessed (Table 2). It was divided into four sections based on the number of consultations. Hospitals that received 30 to 49 consultations had the highest degree of improvement for the both views (100%), and in those who received more than 100 consultations, only one hospital was improved after consultation in both views.

The scores of three random cases in the CBNU-VTH for comparison, the scores were 88 for the lateral view and 96 for the VD/DV view, which were much higher than the average of the local animal hospitals included in the study.

Discussion

The objective of this study was to evaluate the radiographic positioning techniques used in local animal hospitals using quantitative methods, compare them to determine the most common problem, and evaluate if there was improvement in the techniques used in the hospitals after consultation for technical advice. Rotation was the most common problem for the lateral view, while the FOV was the most common problem for the VD/DV view. In addition, except for rotation in the lateral view, all other factors improved after consulta-

Table 2. The degree of improvement in accordance with the number of consultations

Total (n=16)	Lateral			VD/DV		
	Improved	Equal	Non-improved	Improved	Equal	Non-improved
>100 (n = 3)	1 (33%)	1 (33%)	1 (33%)	1 (33%)	0 (0%)	2 (66%)
50-99 (n = 4)	3 (75%)	0 (0%)	1 (25%)	3 (75%)	0 (0%)	1 (25%)
30-49 (n = 3)	3 (100%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)
10-29 (n = 5)	3 (60%)	0 (0%)	2 (40%)	4 (80%)	0 (0%)	1 (20%)

VD/DV, ventrodorsal/dorsoventral.

tions. Considering the convex chest shape of dogs, it is hard to match the left and right symmetry, and this might be the cause of least improvement of rotation factor in lateral view. Comparing the pre- and post-scores of each hospital, 66.6% scores improved for the lateral view, 73.3% for the VD/DV view and in average, and statistical significance was confirmed in VD/DV view and in average, but not in lateral view. Therefore, it can be inferred that while the positioning techniques used in the local animal hospitals improved with consultations, but the improvement has not been made in all aspects. Finally, it was confirmed that the amount of advice was not correlated with the degree of improvement.

Hospitals with good previous scores showed high scores despite slight decrease in the scores, and the import part was "interpretable of radiography"; therefore, the cut-off value was set to 80 points. As a result, for the VD/DV view, 6 hospitals exceeded the cut-off value before consultation and then 11 hospitals exceeded the cut-off after the consultation, and for the lateral view, it showed 7 hospitals exceeded the cut-off value before consultation and 11 hospitals exceeded the cut-off after the consultation. When comparing the mean values before and after the consultations, it was found that the hospitals that exceeded the cut-off value increased from 6 hospitals before consultation to 11 hospitals after consultation.

Considering that the degree of improvement for local hospitals is not significant in lateral view and did not reach the scores of institute, the CBNU-VTH, effective training methods should be considered to improve radiographic techniques in local animal hospitals. Examples include organizing online seminars, such as webinars that can be provided without time and space limitations, providing well-organized data about positions, emphasizing on optimal positioning being important in interpreting radiographs, and training of using positioners that help positioning easier.

In this study, FOV, beam center, symmetry, and inspiration were designated as evaluation categories related to the technical consideration of teleradiology. Among them, in the case of symmery and inspiration, a higher point was designated for the two categories considering that they were highly likely to affect the thoracic radiograph reading. Considering that radiographic imaging is an imaging technique that shows a three-dimensional object as a two-dimensional image, there is a possibility that the radiographic image incorrectly expresses the actual shape or location of the object. For this reason, if the symmetry of the patient's radiographic image does not match, it may affect the evaluation of the size of the heart, the diameter of trachea and bronchus. In addition, when thoracic radiography is performed during maximum inspiration, the lungs are observed more radiolucent, so the contrast with the structures in the thoracic cavity is increased to facilitate reading. In the case of thoracic radiographs taken during exhalation, there is a possibility that the lungs may be misinterpreted as problems with the lung parenchyma because the lungs are observed radiopaque.

However, this study has some limitations. In order to evaluate as many hospitals as possible, the inclusion criteria were set to request radiograph more than 10 times, at least 6 of them were thoracic radiograph, therefore hospitals with relatively few requests were excluded. Further research will be needed using this scoring system for hospitals that have not been evaluated in this study based on additional requested cases after the study period.

In addition, only six cases per hospital were randomly selected and evaluated, this is insufficient number to represent the overall positioning techniques of each hospital, therefore, these limitations may have made there no correlation between the number of consultations and improvements. Also, with its retrospective nature, comparing same patients was impossible, so the differences between individuals that can affect evaluation, such as body condition scores (BCS), shape of thoracic cavity, and compliance of patient, were not reflected. Therefore, in order to definitely evaluate the development of techniques of each hospital, in further studies, scoring should be conducted on images obtained from the same patient through cooperation with the local animal hospitals.

In this study, we focused on factors that can be specifically scored through the location of the surrounding structures, many other factors affecting interpretation of thoracic radiograph were not included in this study. For accurate evaluation, it is necessary to develop of scoring system that include additional criteria. Furthermore, a scoring system that can evaluate other body parts should be studied.

Also, the same indicators for DV and VD chest radiographs were applied in this study. In the case of DV and VD radiographic images, it is known that there is an imaging difference such as a difference in the position of the diaphragm. Therefore, we continuously recommend that DV and VD be marked on radiographic images, and it is judged that additional research on indicators that can be evaluated separately for DV and VD images are needed.

In conclusion, we found that the radiographic techniques used in the local animal hospitals were improved through technical advice on teleradiology. These changes make it possible to provide an accurate diagnosis. However, the degree of improvement in lateral view was not meet the statistical significance, and an effective way of teaching should be considered to improve the radiographic techniques used in local animal hospitals. There are some limitations regarding the details of the evaluation criteria and the number of cases and hospitals that included; therefore, further studies that use detailed scoring criteria on large cohort groups and score other parts, such as abdominal and musculoskeletal images are needed.

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Conflicts of Interest

The authors have no conflicting interests.

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