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Evaluation of thoracic radiographs as a screening test for dogs and cats admitted to a tertiary-care veterinary hospital for noncardiopulmonary disease

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Abstract

Thoracic radiographs are used as a screening tool for dogs and cats with a variety of disorders that have no clinical signs associated with thoracic structures. However, this practice has never been supported by an evidence-based study. The objective of this retrospective observational study was to determine if certain canine and feline populations have a higher proportion of radiographic abnormalities, and whether any of these abnormalities are associated with patient hospitalization and outcome. Patients were excluded if current or previous examinations revealed evidence of primary respiratory or cardiac disease, malignant neoplasia, or an abnormal breathing pattern consistent with pulmonary pathology. Any notable thoracic change in the radiology report was considered important and evaluated in this study. One hundred and sixty-six of these included patients were dogs and 65 were cats. Of the 166 dog radiographs evaluated, 120 (72.3%) had normal thoracic radiographs, while 46 (27.7%) had radiographic abnormalities. Of the sixty-five cats included, 36 (55.4%) had normal radiographs, while 29 (44.6%) had abnormal radiographs. Canine patients with abnormal radiographs had a significantly higher lactate level (*P*-value 0.0348) and feline patients with abnormal radiographs had a significantly lower packed cell volume (*P*-value 0.012). A large proportion of patients that had screening thoracic radiographs (32.5%) had documented abnormalities, but a relatively low percentage (6.5%) of our total population had their clinical plan changed as a consequence of detection of these abnormalities. Findings indicated that abnormal screening thoracic radiographs are more likely in dogs with an elevated lactate and cats with anemia, or a low normal hematocrit.

KEYWORDS

noncardiopulmonary, radiography, screening, thoracic

1 | INTRODUCTION

Thoracic radiographs are a noninvasive, rapid, and readily available diagnostic tool frequently used in veterinary medicine. Appropriately taken radiographs can provide a great deal of information to the clinician.[1] The diagnostic utility of thoracic imaging is obvious in animals presenting with clinical signs associated with structures that are included in the standard thoracic imaging field. In such cases, thoracic radiographs are likely to reveal clinically significant and pertinent information. The increasing availability of radiographic imaging has resulted in its frequent use as a screening tool for a variety of disorders in veterinary patients that have no clinical signs associated with the thoracic structures.[2–4] Indications for taking thoracic radiographs in these patients include geriatric wellness, preanesthesia, and general assessment of systemic illness in the hospitalized patient.[5,6] The purpose of thoracic radiographs in such scenarios is to evaluate the patient for any underlying pathology that could alter the diagnostic or therapeutic plan.

Historically, human hospitals have recommended screening thoracic radiographs on all hospital admissions as well as presurgical admissions. This was primarily used to identify patients with pulmonary tuberculosis who lacked clinical signs. Given the decreased prevalence of tuberculosis, such mass screening programs have been mostly abandoned, but the idea and practice of screening thoracic radiography has not.[7] While its utility in certain scenarios cannot be argued, the routine use of radiographic imaging for screening

veterinary patients has never been supported by evidence-based studies. A number of studies in human medicine have concluded that routine screening thoracic radiographs are not indicated preoperatively or upon hospital admission.[7,8] For most disease processes resulting in hospitalization of our veterinary patients, the frequency of significant findings associated with thoracic radiographs has not been described. No evidence exists to indicate a clear benefit to the screening thoracic radiographs in veterinary patients. Given the known negative economic impact, the medical benefits of thoracic radiographs as a screening tool should be identified to justify its commonplace use for screening in veterinary patients.

The purpose of this study was to evaluate the utility of screening thoracic radiographs in canine and feline patients without known thoracic abnormalities. Specific aims were to evaluate the proportion of cats and dogs with screening thoracic radiographs that had radiographic abnormalities documented, as well as to investigate if there are specific signalments, physical examination findings, laboratory parameters, or disease categories that are associated with a higher proportion of radiographic abnormalities, and whether these abnormalities were associated with the duration of hospitalization, cost of hospitalization, or patient outcome. We hypothesized that the overall incidence of radiographic abnormalities in cats and dogs without signs of thoracic disease would be low. Additionally, we speculated that certain disease processes and advancing age would have a significantly higher proportion of identifiable thoracic pathology, substantiating the use of thoracic radiographs as a screening tool more so in those populations.

2 | MATERIALS AND METHODS

2.1 | Animals

This is a retrospective observational study of both outpatient and hospitalized patient populations performed at The Animal Medical Center. Patients were eligible for inclusion if they had a three-view thoracic radiograph study performed between October 1, 2014 and December 31, 2014. The three views had to include right and left lateral views, and either a ventrodorsal or dorsoventral projection. Exclusion criteria consisted of prior definitive diagnosis of primary respiratory or cardiac disease, malignant neoplasia, or clinical findings of dyspnea or an otherwise abnormal breathing pattern consistent with pulmonary pathology. Patients were considered to have pulmonary pathology if they had clinical findings of increased respiratory effort, dyspnea, auscultated crackles, wheezes, or an abnormal breathing pattern. Tachypnea alone did not result in exclusion given the numerous nonrespiratory etiologies of tachypnea, such as fever, pain, or anxiety. For patients that met inclusion criteria and had multiple sets of radiographs taken during the study period, only the first set of radiographs and clinical information from that visit were recorded.

Medical records of all patients who were eligible were reviewed by a licensed veterinarian for exclusion criteria. For those included, when available in the record, data collected included signalment, venous acid-base values, lactate values, electrolytes, packed cell volume and total solids, respiratory rate, heart rate, temperature, and body condition score. All data points documented within 24 h of obtaining thoracic radiographs were included. Each patient's record was evaluated to determine the reason radiographs were taken, as stated in the radiology request submission. Additionally, medical records were reviewed to determine the significant findings associated with thoracic radiographs, if findings on the radiographs altered the clinical plan based on medical note documentation, cost of hospitalization, duration of hospitalization, and outcome (died, euthanized or discharged.) Each patient's primary diagnosis was determined and recorded. When possible, the primary diagnosis was classified into the following subgroups: endocrine, immune, infectious, neoplastic, and trauma.

2.2 | Radiographs

All radiographic abnormalities noted in the radiology report were evaluated. All radiographs were initially evaluated by one of the board-certified veterinary radiologists on duty. Radiograph reports not initially included in a patient's medical record were subsequently reviewed by a single board-certified veterinary radiologist for the purposes of the study. Based on each patient's radiology report, thoracic radiographic abnormalities were classified by a licensed veterinarian as abnormalities associated with pulmonary parenchyma, cardiac silhouette, surrounding soft tissue structures, pleural space, or bone. Feline and canine patients were assigned to the abnormal radiograph group if any of these abnormalities were determined to be present. Patients were assigned to the normal radiograph group if these abnormalities were determined to be absent. Based on reasons listed in each patient's radiology request, dogs were further categorized into the following subgroups: general screening, preanesthesia, heart murmur or gallop ausculted, trauma, suspect esophageal disease, and pyrexia. Cats were further categorized into the following subgroups: general screening, preanesthesia, heart murmur or gallop ausculted, and trauma.

2.3 | Statistical analysis

Statistical tests were selected and performed by one of the authors (KD). The Shapiro-Wilks test was used to assess normality of the continuous variables. Normally distributed variables are expressed as mean (±SD) while median (range) are used to describe not normally distributed variables. The *t*-test (normally distributed) or the Mann-Whitney tests (not normally distributed) were used to compare these variables between groups. Categorical variables are described with proportions and percents. For major categories, 95% confidence intervals are also provided. The chi-square test or Fisher's exact test (if any expected cell count was <5) was used to compare these variables between groups. A P-value < 0.05 was considered significant for all comparisons. A statistical software program (Stata 14.0 for Mac, Stata Corporation, College Station, TX) was used for all analyses.

3 | RESULTS

A total of 913 thoracic radiograph requests were submitted to the hospital during the study period. A total of 231 cases met criteria for

TABLE 1 Overall proportions and 95% confidence intervals of abnormal and normal thoracic radiographs

	Dog	Cat	All patients
NR	120/166 (72.3%, 95% CI: 65–79%)	36/65 (55.4%, 95% CI: 43–68%)	156/231 (67.5%, 95% CI: 61–74%)
AR	46/166 (32.3%, 95% CI: 21–35%)	29/65 (44.6%, 95% CI: 32–57%)	75/231 (32.5%, 95% CI: 27–39%)

Notes. The chi square analysis between the two species was significantly different ($P = 0.014$). CI, confidence interval; NR, normal radiographs; AR, abnormal radiographs.

inclusion in the study and the remaining 682 were excluded. Reasons for exclusion were evidence of pulmonary pathology on physical examination (crackles, wheezes, dyspnea, increased respiratory effort), documented chronic cough, previously identified cardiac disease, and a prior diagnosis of malignant neoplasia, to name a few. The sample population used for analyses in the current study therefore consisted of 166 (71.9%) dogs and 65 (28.1%) cats.

3.1 | Dogs

There were 86 castrated males, 11 intact males, 62 spayed females, and 7 intact females. The median ages between the normal radiograph and abnormal radiograph groups was not statistically significant (normal radiograph group: 123 months, range 6–202 months; abnormal radiograph group: 131.5 months, range 12–220 months, $P = 0.051$). One hundred twenty (72.3%) had normal thoracic radiographs, while 46 (27.7%) had notable radiographic changes (Table 1). Seventeen dogs (37.0%) in the abnormal radiograph group had pulmonary parenchymal abnormalities, eight (17.4%) had cardiac, 16 (34.8%) had bone, 11 (23.9%) had soft tissue, and two (4.3%) had pleural space abnormalities. Eight dogs in the abnormal radiograph group (17.4%) had more than one abnormality (Table 2). Eight dogs in the abnormal radiograph group (17.4%) had an altered clinical plan based on radiographic findings.

One hundred and fifty-seven dogs (94.6%) had documented reasons for obtaining radiographs. Ninety-five dogs (57.2%) had radiographs taken for general screening, thirty-five (21.1%) dogs had radiographs taken for preanesthesia purposes, 11 dogs (6.6%) had radiographs taken due to a heart murmur or gallop ausculted, six dogs (3.6%) had radiographs obtained due to trauma, five dogs (3.0%) had radiographs obtained due to suspect esophageal disease, and five dogs (3.0%) had radiographs taken due to documented pyrexia (Table 3).

Seventy-one dogs (42.8%) had lactate measured within 24 h of the radiographs. Fifty-two (73.2%) had normal thoracic radiographs, while 19 (26.8%) had abnormal thoracic radiographs. Lactate was significantly ($P = 0.0348$) higher in the abnormal radiograph group (median 3.96, range 1.52–5.96 mmol/l) compared to the normal radiograph group (median 2.8, range 0.75–13 mmol/l). There were no significant differences detected in body condition score , packed cell volume, total solids, blood glucose, temperature, blood pH, length of hospitalization, cost of hospitalization, and outcome between dogs in the normal radiograph group and the abnormal radiograph group (Table 5).

TABLE 2 Localization of thoracic radiographic abnormalities in dogs and cats

Dogs[a]	
Pulmonary parenchymal (17/46; 37.0%, 95% CI: 23–52%)	
Bronchointerstitial pattern	4
Focal alveolar pattern	4
Pulmonary nodule(s)	8
Interstitial pattern	1
Cardiac (8/46; 17.4%, 95% CI: 8–31%)	
Cardiomegaly	8
Bone (16/46; 34.8%, 95% CI: 21–50%)	
Rib fracture	2
Osteoarthritis osseous remodeling	8
OCD lesion	1
Osteolysis	3
Vertebral malformation	2
Thoracic limb bone fracture	1
Soft tissue (11/46; 23.9%, 95% CI: 13–39%)	
Tracheal collapse/abnormality	4
Sternal lymphadenopathy	2
Esophageal dilation (gas)	1
Extra pleural tissue swelling/mass	5
Pleural (2/46; 4.3%)	
Pneumothorax	2
Cats[b]	
Pulmonary parenchymal (15/29; 51.7%, 95% CI: 33–71%)	
Bronchial pattern	8
Unstructured interstitial pattern	3
Pulmonary nodule(s)	4
Focal alveolar pattern	3
Cardiac (8/29; 27.6%)	
Cardiomegaly	8
Bone (4/29; 13.8%, 95% CI: 45–32%)	
Spondylosis deformans	1
Rib fracture	1
Osteoarthritis/osseous remodeling	1
Osteolysis	1
Soft tissue (5/29; 17.2%, 95% CI: 6%, 36%)	
Esophageal abnormality (hiatal hernia vs. esophageal mass)	1
Cranial mediastinal mass	1
Extra pleural tissue/mass effect	2
Mass effect cranial to the cardiac silhouette	1
Pleural (4/29; 13.8% 95% CI: 4–32%)	
Pleural effusion	3
Pneumothorax	1

[a]Eight patients had more than one abnormality.
[b]Seven patients had more than one abnormality.

TABLE 3 Listed reasons for obtaining screening thoracic radiographs in dogs and cats

Dogs			
Reason for obtaining radiographs (number of patients)	**Dogs with NR (120)**	**Dogs with AR (46)**	**Changed clinical plan (8)**
General screening (95)	70	25	7
Preanesthesia (35)	26	9	0
Heart murmur or gallop ausculted (11)	7	4	1
Unknown (9)	6	3	0
Trauma (6)	4	2	0
Suspect esophageal disease (5)	4	1	0
Pyrexia (5)	3	2	0
Total (166)	120	46	8
Cats			
Reason for obtaining radiographs (number of patients)	**Cats with NR (36)**	**Cats with AR (29)**	**Changed clinical plan (7)**
General Screening (41)	21	20	4
Unknown (7)	6	1	1
Heart murmur or gallop ausculted (7)	4	3	1
Preanesthesia (6)	3	3	0
Trauma (4)	2	2	1
Total (65)	36	29	7

NR, normal radiographs; AR, abnormal radiographs.

TABLE 4 Disease category subclassification in dogs and cats

Dogs					
	Endocrine	**Immune mediated**	**Infectious**	**Neoplastic**	**Trauma**
Dog NR	9/54 (16.7%)	6/54 (11.1%)	12/54 (22.2%)	21/54 (38.9%)	6/54 (11.1%)
Dog AR	2/20 (10.0%)	2/20 (10.0%)	3/20 (15.0%)	11/20 (55.0%)	2/20 (10.0%)
Dog total	11/74 (14.9%)	8/74 (10.8%)	15/74 (20.3%)	32/74 (43.2%)	8/74 (10.8%)
Cats					
	Endocrine		**Infectious**	**Neoplastic**	**Trauma**
Cat NR	7/11 (63.6%)		1/11 (9.0%)	2/11 (18.1%)	1/11 (9.0%)
Cat AR	5/21 (23.8%)		7/21 (33.3%)	7/21 (33.3%)	2/21 (9.5%)
Cat total	12/32 (37.5%)		8/32 (25.0%)	9/32 (28.1%)	3/32 (9.4%)

Notes. Each dog and cat total is the total number of patients whose primary diagnosis fell into the listed categories. NR, normal radiographs; AR, abnormal radiographs.

Eighty-eight dogs were hospitalized (69 from the normal radiograph group, 78.4%; 19 from the abnormal radiograph group, 21.6%). The duration of hospitalization was not significantly different (P = 0.12) between the groups (normal radiograph group: median 2 days, range 1–15 days, abnormal radiograph group: 1 days, range 1–5 days). The other 78 dogs were either treated as an outpatient, or reached their outcome prior to 12 h of hospitalization. One hundred forty-eight (89.2%) dogs survived. One hundred and nine (73.6%) survivors had normal radiographs and 39 (26.4%) had abnormal radiographs. Fifteen dogs (9.0%) were euthanized. Nine (60%) euthanized dogs had normal radiographs and six (40%) had abnormal radiographs. Finally, three (1.8%) dogs died. Two of these dogs (66.7%) had normal radiographs and one (33.3%) had abnormal radiographs. There was no statistically significant (P = 0.482) difference between the groups.

We were able to place 74 dogs (44.6%) into a specific disease category based on their primary diagnosis. No one disease process had a significantly different percentage of abnormal radiographs (Table 4).

3.2 | Cats

There were 27 castrated males, 1 intact male, 33 spayed females, and four intact females. The median ages between the normal radiograph and abnormal radiograph groups was not statistically significant (normal radiograph group: 131 months, range 4–238 months; abnormal radiograph group: 156 months, range 2–210 months; P = 0.658). Thirty-six cats (55.4%) had normal thoracic radiographs, while 29 (44.6%) had notable radiographic changes (Table 1). Fifteen cats (51.7%) in the abnormal radiograph group had pulmonary parenchymal abnormalities, eight (27.6%) had cardiac, four (13.8%) had bone,

TABLE 5 Presenting physical examination and laboratory parameter comparison between groups with and without radiographic abnormalities in dogs and cats

Dogs			
	Dog NR	**Dog AR**	***P*-value**
Age (months)	123 (6–202)	131.5 (12–220)	0.051
BCS (out of 9)	5 (1–9)	5 (2–8)	0.626
Temperature (Fahrenheit)	101.3 (96.6–106.5)	101.2 (96.6–103.6)	0.239
PCV (%)	44.0 (19–65)	44.0 (18–64)	0.734
TS (g/dl)	6.8 (4.6–10.6)	7.0 (5.1–9.2)	0.449
Glucose (mg/dl)	99 (56–562)	100 (43–175)	0.423
pH	7.33 (6.98–7.50)	7.34 (7.11–7.49)	0.937
Lactate (mmol/l) †	2.8 (0.75–13)	3.96 (1.52–5.96)	0.035
Cost of hospitalization ($)	2161.78 (308.93–24909.80)	2012.13 (444.17–10468.96)	
Discharged/survived (patients)	109	39	0.482
Euthanized (patients)	9	6	0.482
Died (patients)	2	1	0.482
Cats			
	Cat NR	**Cat AR**	***P*-value**
Age (months)	131 (4–238)	156 (2–210)	0.658
BCS (out of 9)	4.5 (1–8)	4 (2–9)	0.888
Temperature (Fahrenheit)	99.6 (88.2–103.6)	100.2 (93.6–102.9)	0.466
PCV (%)*†	38.5 (± 10.5)	30.3 (±10.5)	0.012
TS (g/dl)	8.0 (6–11.2)	7.7 (5.2–11)	0.281
Glucose (mg/dl)	167.5 (82–518)	135 (77–433)	0.228
pH	7.29 (6.98–7.45)	7.27 (6.90–7.41)	0.531
Lactate (mmol/l) †	3.12 (1.25–8.78)	1.56 (0.83–6.13)	0.017
Cost of hospitalization ($)	3858.95 (1026.40–20352.42)	4084.04 (1001.96–5913.31)	
Discharged/survived (patients)	30	23	0.869
Euthanized (patients)	5	5	0.869
Died (patients)	1	1	0.869

*All values listed are the median (range), unless otherwise noted with an asterisk indicating use of the mean (±standard deviation).
†Statistical significance.
NR, normal radiographs; AR, abnormal radiographs; BCS, body condition score; PCV, packed cell volume.; TS, total solids.

five (17.2%) had soft tissue changes, and four (13.8%) had pleural space abnormalities. Specific abnormalities for each of these categories are further summarized in Table 2. Seven abnormal radiograph group cats (24.1%) had more than one abnormality noted on radiographs. Seven abnormal radiograph group cats (24.1%) were documented to have an altered clinical plan based on these findings.

Fifty-eight cats (89.2%) had documented reasons for obtaining radiographs. Forty-one cats (63.1%) had radiographs taken for general screening, six cats (9.2%) had radiographs taken for preanesthesia purposes, seven cats (10.8%) had radiographs taken due to a heart murmur or gallop ausculted, and four cats (6.2%) had radiographs obtained due to trauma. No cats had radiographs obtained due to documented pyrexia (Table 3).

There were no significant differences detected in age, body condition score, temperature, blood pH, length of hospitalization, cost of hospitalization, and outcome between cats in the normal radiograph group and those in the abnormal radiograph group (Table 5).

Forty-five cats (69.2%) had a packed cell volume measured within 24 h of the radiographs. Twenty-five of these cats (55.6%) had normal radiographs and 20 (44.4%) had abnormal radiographs. Cats with normal radiographs had a significantly ($P = 0.012$) higher packed cell volume compared to those with abnormal radiographs (normal radiograph group: mean 38.5% (SD ± 10.5); abnormal radiograph group: 30.33% (SD ± 10.5)).

Thirty-four cats (52.3%) had a lactate measured within 24 h of the radiographs. Twenty of these cats (58.8%) had normal radiographs and 14 (41.2%) had abnormal radiographs. Cats with normal radiographs had a significantly ($P = 0.017$) higher lactate compared to those with abnormal radiographs (normal radiograph group: median 3.12 mmol/l, range 1.25–8.78 mmol/l; abnormal radiograph group: 1.56 mmol/l, 0.83–6.13 mmol/l).

Forty-two cats were hospitalized (27 from the normal radiograph group, 64.3%; 15 from the abnormal radiograph group, 35.7%). The duration of hospitalization was not significantly different ($P = 0.30$)

between the groups (normal radiograph group: median 3 days, range 1–14, abnormal radiograph group: 2 days, range 1–6 days). The other 23 cat patients were treated on an outpatient basis, or reached their outcome prior to 12 h of hospitalization.

Fifty-three cats (81.5%) survived. Thirty of these survivors (56.6%) had normal radiographs and 23 (43.4%) had abnormal radiographs. Ten cats (15.4%) were euthanized. Five euthanized cats had normal radiographs (5/10; 50%), while the other five had abnormal radiographs (50%). Finally, two cats died (3.1%). One cat that died had normal radiographs (50%) and the other had abnormal radiographs (50%). There was no statistically significant difference between the groups ($P = 0.869$).

We were able to place 32 cats (49.2%) into a specific disease category based on their primary diagnosis (Table 4). No one disease process had a significantly difference percentage of abnormal radiographs (Table 4).

4 | DISCUSSION

The purpose of this study was to determine the diagnostic utility of routine screening thoracic radiographs based on evaluation of dogs and cats at our hospital that were presented for three-view thoracic radiographs; did not have respiratory signs; and had no known history of cardiac disease, pulmonary parenchymal disease, or neoplasia. Our evaluation revealed thoracic radiographic abnormalities in a total of 32% of the patient population. More specifically, 28% of the dogs included and 45% of the cats included were documented to have abnormal thoracic radiographs. This is a relatively large percentage of our patient population, which may be in part due to our broad inclusion criteria. We chose to include all abnormalities listed by the radiology report, as only choosing abnormalities that we considered clinically relevant would introduce bias into the collected data. The use of thoracic radiography as a screening tool has been scrutinized in human patient populations for several decades. For example, humans presenting through the emergency department, are a patient population frequently investigated. One such study evaluated the utility of chest radiographs on all patients admitted from the emergency department, including those with and without signs of chest disease. Of a total of 294 routine films obtained, only four patients (1.4%) were identified with thoracic radiograph abnormalities referable to occult chest disease.[9] Most human patients presenting to a hospital can verbalize and thereby localize the particular area of their body where they are experiencing an issue. However, given our veterinary patients' inability to verbally communicate, our initial recommendations rely upon our physical examination findings, but also the patient's history and the owner's perceived general concern. This inherent difference in human and veterinary medicine may result in a higher proportion of veterinary patients who truly do have underlying signs referable to the thorax, that are simply not perceived by the owners nor verbalized by the patient, being included in our screening population.

The percentage of canine and feline patients whose clinical plan was altered out of the total number of included cases in our study, was considerably lower (4.8% and 10.8%, respectively). Even though the clinical plan was adjusted based on radiographic abnormalities in several cases, it is difficult to judge whether there was a clear benefit to the patient. The degree of further investigation into the nature of the radiographic abnormalities was not uniform among the patients in the study and was challenging to glean retrospectively. Alternatively, inadequate documentation of the clinician's plan and decision-making process could have resulted in undervaluing of the information provided by thoracic radiographs.

The large percentage of feline patients in our sample that had radiographic abnormalities may be clinically significant. Previous studies have found that feline patients in particular may lack clinical signs referable to diseases of the respiratory tract, when advanced diagnostics have definitively identified underlying disease.[10] For example, a retrospective study evaluating feline patients with histologically confirmed infectious pneumonia, found that only 36% of these cats had signs referable to the respiratory tract.[11] Similarly, a study evaluating cats with histologically identified bronchiectasis found that of all the feline patients confirmed to have bronchiectasis, only 42% had clinical signs localizable to the lower respiratory tract. Taking into consideration the less reliable clinical signs in feline patients associated with respiratory tract disease, as well as our findings of a greater yield in thoracic radiographic abnormalities for cats in our sample, the continued use of screening thoracic radiography is justified in cats regardless of presenting clinical signs.

The utility of preoperative chest radiographs in both human and veterinary medicine has been investigated in more detail.[7,12,13] Preoperative surgical patients, emergent and elective, comprise a large portion of the population in which screening radiographs are recommended.[5] Numerous human studies have focused on identifying preoperative patient populations with certain risk factors resulting in a higher incidence of abnormalities identified on screening thoracic radiographs.[8] Such risk factors include being over the age of 60, a history of cardiac or pulmonary disease, malignancy or stroke, signs and symptoms of chest disease, and a recent thoracic surgery.[8] To our knowledge comparable studies identifying veterinary patients' risk factors have not been performed. A single study evaluating preoperative thoracic radiograph findings in dogs presenting with a GDV, found a negative association between survival and the presence of cardiomegaly potentially supporting thoracic radiography in this population of patients.[13] Our results showed 25% of canine patients and 50% of feline patients who had thoracic radiographs obtained as a preanesthesia screening had documented abnormalities. However, the clinical plan was not documented to be changed in a single patient that had radiographs taken for preanesthetic purposes. Certainly, the clinical plan may have been adjusted without clear documentation in the record in which case, this number would be artificially low; however, this brings into question routine use of thoracic radiographs in animals prior to an anesthetic event, particularly in the emergent setting.

Geriatric patients often have thoracic radiographs obtained prior to an invasive procedure due to increased risk of age-related diseases, such as neoplasia. In these situations, thoracic radiographs are used to evaluate the pulmonary parenchyma for evidence of metastatic

disease, as this discovery may alter the clinician's and owners' desire to move forward with the procedure. Advanced age alone has also been evaluated as a potential risk factor for thoracic radiograph abnormalities.[6] Several human studies have identified an increasing prevalence of radiographic thoracic abnormalities with increasing age; however, many of these studies did not exclude patients with clinical evidence of chest disease.[6,8,14,15] While not statistically significant, our results would indicate a trend that implies older dogs may be more likely to have abnormalities on the thoracic radiographs. Therefore, our findings potentially justify performing radiographs in this patient population. This finding supports the recommendation of the Senior Advisory Board, a group of experienced veterinarians in the American Animal Hospital Association that established guidelines and recommendations for annual health screening. Thoracic radiographs were listed under diagnostics that should be considered annually.[16] However, given the variability in life expectancy amongst dogs and cats, defining when they are considered geriatric and would require such screening, is another challenge. The previously discussed Senior Advisory Board suggests a patient be considered geriatric when they are in the last 25% of their life expectancy.[16] Additionally, this recommendation is often times based on clinician preference, owner's wishes, and clinically relevant information or changes associated with the patient. While this recommendation intuitively makes sense, to our knowledge no study has previously provided evidence justifying this practice.

Body condition scoring, while subjective in nature, is a semiquantitative measure of percent body fat and muscle mass.[17] The 9-point body condition scoring system has been shown to be reliable and repeatable amongst assessors when specific guidelines and protocols are provided.[18] Weight loss and cachexia associated with underlying disease processes, specifically cancer, is a well-recognized syndrome in human patients. The diagnosis of cachexia has been associated with a variety of diseases in our veterinary patients, including chronic inflammation or infection, as well as neoplasia.[19,20] Thus, we hypothesized that patients with a lower body condition score would have more radiographic abnormalities compared to patients with a normal or obese body condition score. However, our findings did not indicate a significant difference in body condition scores between the normal radiograph and abnormal radiograph group for both cats and dogs.

Lactate level at the time of obtaining radiographs was one of the parameters evaluated in both dogs and cats. Lactate has been studied extensively in human literature as a marker of severity of critical illness as well as a measurement frequently monitored for prognostic significance in a variety of disease processes.[21] Several studies in veterinary patients evaluated the usefulness of lactate both as single measure of critical illness severity, and as a measure of response to therapy and prognosis.[22] In dogs, prognoses of various disease processes have been evaluated looking at different measures of lactate including admission lactate and lactate clearance.[22,23] However, to our knowledge, no study has ever evaluated the relationship between lactate level and radiographic findings in veterinary patient populations. Dogs with documented radiographic abnormalities had significantly higher lactate concentrations in the current study. There was no single type of radiographic abnormality that was overrepresented in our population of hyperlactatemic dogs. It is possible that the dogs with radiographic abnormalities represent a sicker population of patients with higher incidence of hypoperfusion. However, given the uncertain usability of a single lactate measurement determining severity of illness and/or prognosis in canine patients, the clinical significance of this finding is unclear at this time.

Anemia is a common finding in both human and veterinary patients. It is associated with numerous disease processes, is a marker of illness severity and may be associated with decreased survival in multiple diseases.[24] In our study, feline patients with radiographic abnormalities were found to have a significantly lower packed cell volume. It is possible that the animals that trend toward anemia are more systemically ill, and thus, may have more abnormalities associated with the thoracic structures. The most common radiographic abnormality identified in our anemic feline patient population was cardiomegaly. This finding may be attributed to the high cardiac output state that chronically anemia patients develop. Regardless of the cause, identification of such radiographic abnormalities may provide valuable information for the clinician about fluid balance and how to proceed with resuscitation. Therefore, it is reasonable to suggest performing radiographs on cats that present with anemia, as there may be a higher likelihood of positive yield on thoracic radiographs.

When sufficient data were available, each patient was further classified based on their primary underlying disease process at the time radiographs were obtained. There was no significant difference in the proportion of radiographic abnormalities between any of the categories (endocrine, immune, infectious, neoplastic, and trauma), in either canine or feline patients. This suggests that out of the five categories evaluated, there is not one disease category, in which thoracic radiographs should be prioritized more as part of a diagnostic work up if no respiratory signs are present.

Performing radiographs as a part of a diagnostic workup in animals without signs referable to the respiratory system may be justified by presenting to the owner the most complete clinical picture.[15] However, cost is a concern for many clients and often influences decisions regarding hospitalization or continuation of care. The current study identified no association between duration or cost of hospitalization and radiographic abnormalities. It is possible that this was in part due to the fact that a substantial portion of abnormalities in our sample of cats and dogs were not clinically significant.

The main limitations of this study include frequently incomplete medical records, as well as the study's retrospective nature. The retrospective evaluation of medical records resulted in missing data points for physical examination findings and clinicopathologic parameters. In addition, it only allowed for subjective interpretation of whether the clinical plan was altered due to abnormalities on the thoracic radiographs, and it is possible that such information was missing from the records, which could have affected inclusion and exclusion of certain patients. Only a percentage of patients could be placed in major disease categories, decreasing the power of these results. Finally, given that obtaining radiographs was at the discretion of the primary clinician, bias is inherently introduced, as we presume the primary clinician

performed this diagnostic due to their belief of its clinical utility in each patient.

Overall, a significant proportion of patients that had screening thoracic radiographs performed at our institution had documented abnormalities, but a lower percentage of the patient population had their clinical plan changed as a result of the findings. No patients that had thoracic radiographs performed prior to anesthesia had an altered clinical plan based on the results of the thoracic radiographs, putting into question the routine use of thoracic radiographs as a screening tool prior to an anesthetic event. The use of screening thoracic radiographs could be considered in canine patients with an elevated lactate, as well as feline patients with anemia, or a low normal hematocrit. Additionally, given the trend toward increased abnormalities on thoracic radiographs in geriatric dogs, we also recommend considering thoracic radiographs in this patient population. Further prospective evaluation of specific physical examination, clinicopathologic abnormalities, and disease processes is necessary to determine the utility of screening thoracic radiography.

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Category 1

(a) Conception and Design: Keyserling C, Buriko Y, Fischetti A, Drobatz K

(b) Acquisition of Data: Keyserling C and Lyons B

(c) Analysis and Interpretation of Data: Drobatz K

Category 2

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(b) Revising the Article for Intellectual Content: Buriko Y, Lyons B, Fischetti A, Drobatz K

Category 3

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REFERENCES

1. Barthez PY, Hornof WJ, Theon AP, Craychee TJ, Morgan JP. Receiver operating characteristic curve analysis of the performance of various radiographic protocols when screening dogs for pulmonary metastases. *J Am Vet Med Assoc*. 1994;204:237–240.
2. Melian C, Stefanacci J, Peterson ME, Kintzer PP. Radiographic findings in dogs with naturally occurring primary hypoadrenocorticism. *J Am Anim Hosp Assoc*. 1999;35:208–212.
3. Fluckiger M, Baumann D. Radiographic findings in the thorax of dogs with leptospiral infection. *Vet Radiol Ultrasound*. 2001;42:305–307.
4. Venco L, Genchi C, Genchi M, Grandi G, Kramer LH. Clinical evolution and radiographic findings of feline heartworm infection in asymptomatic cats. *Vet Parasitol*. 2008;158:232—237.
5. Joo HS, Wong J, Naik VN, Savoldelli GL. The value of screening preoperative chest X-rays: a systematic review. *Can J Anaesth*. 2005; 52:568–574.
6. Sagel SS, Evens RG, Forrest JV, et al. Efficacy of routine screening and lateral chest radiographs in a hospital-based population. *N Engl J Med*. 1974;291:1001–1004.
7. Tape TG, Mushlin AI. Diagnostic decision: the utility of routine chest radiographs. *Ann Intern Med*. 1986;104:663–670.
8. Rucker L, Frye EB, Staten MA. Usefulness of screening chest roentgenograms in preoperative patients. *JAMA*. 1983;250:3209–3211.
9. Hubbell AF, Greenfield S, Tyler JL, Chetty K, Wyle FA. The impact of routine admission chest X-ray films on patient care. *N Engl J Med*. 1985;312:209–213.
10. Norris CR, Griffey SM, Samii VF, et al. Thoracic radiography, bronchoalveolar lavage, cytopathology, and pulmonary parenchymal histopathology: a comparison of diagnostic results in 11 cats. *J Am Anim Hosp Assoc*. 2002;38:337–345.
11. Norris CR, Samii VF. Clinical, radiographic, and pathologic features of bronchiectasis in cats: 12 cases (1987–1999). *J Am Vet Med Assoc*. 2000;216:530–534.
12. Törnebrandt K, Fletcher R. Pre-operative chest X-rays in elderly patients. *Anaesth*. 1982;37:901–902.
13. Green JL, Cimino Brown D, Agnello KA. Preoperative thoracic radiographic findings in dogs presenting for gastric dilatation-volvulus (2000–2010): 101 cases. *J Vet Emerg Crit Care*. 2012;22:595–600.
14. Fink DJ, Fang M, Wyle FA. Routine chest X-ray films in a veterans hospital. *JAMA*. 1981;245:1056–1057.
15. Rees AM, Roberts CJ, Bligh AS, Evans KT. Routine preoperative chest radiography in non-cardiopulmonary surgery. *Br Med J*. 1976;1:1333–1335.
16. Epstein M, Kuehn NF, Landsberg G, et al. AAHA senior care guidelines for dogs and cats. *J Am Anim Hosp Assoc*. 2005;41:81–91.
17. German AJ, Holden SL, Moxham GL, Holmes KL, Hackett RM, Rawlings JM. A simple, reliable tool for owners to assess the body condition of their dog or cat. *J Nutr*. 2006; 136:2031S–2033S.
18. Bjornvad CR, Nielsen DH, Armstrong PJ, et al. Evaluation of a nine-point body condition scoring system in physically inactive pet cats. *Am J Vet Res*. 2011;72:433–437.
19. Schermerhorn, T. Cachexia. In: Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine*. 6th ed. St. Louis: Elsevier Saunders; 2006:78–80.
20. Michel KE, Sorenmo K, Shofer FS. Evaluation of body condition and weight loss in dogs presented to a veterinary oncology service. *J Vet Intern Med*. 2004;18:692–695.
21. Marty P, Roquilly A, Vallee F, et al. Lactate clearance for death prediction in severe sepsis or septic shock patients during the first 24 hours in intensive care unit: an observational study. *Ann Intensive Care*. 2013;3:3.
22. Allen SE, Holm JL. Lactate: physiology and clinical utility. *J Vet Emerg Crit Care*. 2008;18:123–132.

23. de Papp E, Drobatz KJ, Hughes D. Plasma lactate concentration as a predictor of gastric necrosis and survival among dogs with gastric dilatation-volvulus: 102 cases (1995–1998). *J Am Vet Med Assoc*. 1999;215:49–52.
24. Hayden SJ, Albert TJ, Watkins TR, Swenson ER. Anemia in critical illness: insights into etiology, consequences, and management. *Am J Respir Crit Care Med*. 2012;185:1049–1057.

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