RETROSPECTIVE STUDY

Retrospective investigation of the neutrophil-to-lymphocyte ratio in dogs with pneumonia: 49 cases (2011–2016)

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Abstract

Objective: To assess the utility of the neutrophil-to-lymphocyte ratio (NLR) in predicting outcome in canine pneumonia compared with routine hematological parameters and systemic inflammatory response syndrome (SIRS) scores.

Design: Retrospective study.

Setting: University teaching hospital.

Animals: Forty-nine client-owned dogs.

Interventions: None

Measurements and Main Results: Medical records were reviewed to identify dogs with a diagnosis of pneumonia from July 2011 to December 2016. Signalment, clinical findings, laboratory characteristics, and outcome were recorded. Inclusion criteria were a clinical and radiographic diagnosis of pneumonia, plus reference laboratory hematology at diagnosis. Cases that received steroids were excluded. Euthanized dogs were only included in statistical analysis if euthanized solely due to pneumonia severity. The NLR, total WBC count, neutrophil count, lymphocyte count, band neutrophil percent of total WBC count (%-bands), and percentage of cases diagnosed with SIRS were compared between survivors and nonsurvivors. Receiver operating characteristic curves were generated to identify optimal sensitivity and specificity cutoffs for nonsurvival to discharge.

Two hundred records were retrieved; 49 cases fulfilled the inclusion criteria. Of these, 33 (67%) survived to discharge. The NLR did not differ significantly between the survivors and nonsurvivors, nor did total WBC count or neutrophil count. Survivors had a significantly lower %-bands than nonsurvivors ($P < 0.001$) and higher lymphocyte count ($P = 0.004$). The mortality rate did not differ significantly between dogs with and

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without SIRS. Receiver operating characteristic analysis identified a %-bands cutoff of 2.5% or higher had an 83% sensitivity and 79% specificity for nonsurvival.

Conclusions: Unlike in human medicine, neither NLR nor SIRS scores predicted outcome in this cohort of dogs with pneumonia. However, survivors had a lower %-bands and higher lymphocyte count than nonsurvivors, which may be helpful prognostically in clinical cases.

KEYWORDS
aspiration pneumonia, NLR, prognostic factors, SIRS

1 | INTRODUCTION

Pneumonia is a common cause of respiratory disease in dogs and has a variety of etiologies, including infectious pneumonia and aspiration pneumonia. In both human and canine medicine, pneumonia can vary in severity but is a common cause of sepsis and the systemic inflammatory response syndrome (SIRS). Reported mortality rates for pneumonia in veterinary medicine are approximately 20%,[1,2] whereas in people the mortality rate varies widely, from as low as 1% to as high as 59% depending on the patient population studied.[3,4]

In human medicine, there are a number of clinical scoring systems to stratify patients with pneumonia by mortality risk, including the British Thoracic Society Score, North American Pneumonia Severity Index, and the CURB-65 score.[3,5,6] Biomarkers such as C-reactive protein (CRP) also have some prognostic use in various subsets of pneumonia patients. Although there are a number of veterinary scoring systems for predicting prognosis in acute ICU admissions such as the acute patient physiologic and laboratory evaluation (APPLE) score and SIRS score, these are diagnosis independent scores.[7,8] There are few studies looking at prognostic indicators in canine pneumonia and no pneumonia-specific scores. In one study, the number of lung lobes affected radiographically was significantly higher in nonsurvivors than survivors, but no other clinicopathological differences were reported.[1] Although CRP at presentation has some use in differentiating bronchopneumonia from other respiratory diseases,[9] in a subsequent study it had no correlation with duration of hospitalization or other markers of disease severity; however, its association with survival was not evaluated.[10] In populations of dogs with SIRS resulting from mixed underlying conditions, CRP was not prognostic for survival.[11,12]

In human medicine, there has been recent interest in developing less expensive and more easily accessible biomarkers to help predict prognosis in individuals with pneumonia. Studies have shown the neutrophil-to-lymphocyte ratio (NLR), calculated from the standard hematological peripheral blood total neutrophil and lymphocyte counts, is as good a predictor of severity and outcome as the Pneumonia Severity Index and CURB-65 scores and a better predictor than some classical biomarkers such as CRP.[13,14] In veterinary medicine, the NLR has diagnostic and prognostic relevance in various canine tumors.[15,16] And although the NLR is not associated with duration of hospitalization, APPLE scores, or mortality in dogs with septic peritonitis,[17] no studies have evaluated its utility in canine pneumonia.

The aims of this study were to assess whether the NLR is a useful prognostic marker in canine pneumonia and to compare the prognostic value of the NLR with other routine hematological parameters, CRP and SIRS scores.

2 | MATERIALS AND METHODS

A retrospective study of canine pneumonia cases between July 2011 and December 2016 was performed by searching the hospital imaging records for the keyword "pneumonia" as a differential diagnosis. Full case records were then reviewed for suitability. Inclusion criteria were a final clinical diagnosis of pneumonia made by a combination of lower respiratory tract signs and radiographic or computed tomography changes compatible with pneumonia, plus a CBC and blood smear examination performed at a reference laboratory, either within 24 hours of admission for newly presenting cases or within 24 hours of onset of respiratory signs for cases developing pneumonia while hospitalized. All radiographs and computed tomography images were evaluated by a board-certified radiologist or a resident in an approved training program under the supervision of a board-certified radiologist. All total WBC counts were performed on an automated hematology analyzer[a] with a WBC differential performed by a board-certified clinical pathologist. Cases with concurrent conditions such as lymphoma or leukemia, and any treated with drugs such as steroids or chemotherapeutic agents that could independently affect differential WBC, were excluded. Cases with only a CBC performed on the in-house analyzer without manual smear examination were excluded for consistency in measurement methods.

Routine clinical, hematological, and biochemical data, number and type of concurrent conditions predisposing to aspiration, final diagnosis, plus the outcome measures hospitalization time and survival to discharge were collected for all cases. Dogs not admitted to the hospital and treated as outpatients were allocated a hospitalization time of 0 days. Where dogs were euthanized, records were reviewed to try to determine the reason for euthanasia. These were divided into the categories of "severity of pneumonia," "cost," "long-term prognosis," "not recorded," or a combination of those categories. Cases were classified as being euthanized due to severity of pneumonia alone if the notes recorded worsening of tachypnea, dyspnea, respiratory effort, pulse oximetry readings <90%, or cyanosis, plus recorded recommendation

of euthanasia by the case clinician, with no other records of concerns over cost or long-term prognosis. Otherwise, cases were classified as having a combination of reasons for euthanasia.

SIRS scores at admission were calculated for all cases for which there were sufficient data available. Dogs were classified as having SIRS if they fulfilled 2 or more of the following criteria: body temperature <38.1°C or >39.2°C; heart rate >120/min; respiratory rate >20/min; total WBC count <6.0 × 10^9/L (<6 × 10^3/μL) or >16 × 10^9/L (>16 × 10^3/μL); and percentage of bands >3% of the total WBC count, as per the previously reported criteria.[8] Descriptive statistics for total WBC count, total neutrophil count (segmented and band neutrophils), lymphocyte count, band neutrophil count, total neutrophil percent of total WBC count, band neutrophil percent of total WBC count (%-bands), lymphocyte percent of total WBC count, NLR, and SIRS score were generated and compared between dogs that did and did not survive to discharge. Only dogs that either died naturally or were euthanized solely due to the severity of pneumonia were included in the nonsurvivors group.

2.1 | Statistical methods

All data were tested for normality using a Shapiro–Wilk test. Nonparametric data were then compared between groups using a Mann–Whitney *U*-test. Receiver operating characteristic (ROC) curve analysis was used to identify cutoff levels for sensitivity and specificity for nonsurvival to discharge for those parameters showing a statistically significant difference between survivors and nonsurvivors. The proportion of dogs with SIRS was compared between survivors and nonsurvivors using a chi-squared test. The data were also evaluated for correlations with hospitalization time in the survivors using Spearman's rank correlation. A *P*-value < 0.05 was considered statistically significant. All statistical analyses were performed using commercially available statistical software.[b]

3 | RESULTS

Two hundred records were retrieved, of which 49 cases fulfilled the inclusion criteria. The median age was 5 years (range, 2 wk to 13 y). Six dogs were mixed breeds, and 43 were pure breeds, with 28 different breeds represented. Weimaraners (*n* = 4) were the most common pure breed, followed by Pugs and Great Danes (*n* = 3), then Border Collies, Boston Terriers, Boxers, Bulldogs, Scottish Terriers, Shih Tzus, Staffordshire Bull Terriers, and Yorkshire Terriers (all *n* = 2). The median hospitalization time for all dogs was 3.5 days, ranging from 0 to 25 days. Of the final diagnoses, 36 of the 49 patients had a diagnosis of "aspiration pneumonia," whereas the remainder were diagnosed with "pneumonia" or "bronchopneumonia." Dogs with a final diagnosis of aspiration pneumonia had a mortality rate of 36%, compared to 23% for other pneumonia subtypes; this was not significantly different (*P* = 0.39).

Thirty-four of the dogs had 1 or more concurrent conditions reported to predispose to aspiration pneumonia.[18] These conditions included vomiting/regurgitation/esophageal or gastrointestinal disease (*n* = 20), laryngeal or pharyngeal disease (*n* = 5), neurological disease (*n* = 7), and brachycephalic obstructive airway syndrome (*n* = 5). Thirty-nine dogs had pneumonia present at the time of referral to the hospital, whereas 10 developed pneumonia while either hospitalized or under our outpatient treatment. Of these 10, the underlying predispositions for pneumonia were recent general anesthetic (*n* = 6), esophageal dysmotility (*n* = 2), and neurological disease (*n* = 2). Of the 6 dogs recently anesthetized, 2 were for brachycephalic obstructive airway syndrome surgery, 1 for investigation of hyperglobulinemia, 1 for intestinal leiomyoma resection, 1 for insulinoma excision, and 1 for cervical disk extrusion. One of the dogs with neurological disease had hypernatremia, and the other had a cerebellar infarction. Of all dogs, 13 had antibiotic treatment prior to referral, whereas 26 had not. The survival rate did not differ, however, between newly presenting dogs pretreated with antibiotics and those that were not (69% vs. 73%, respectively). Thirty-nine of the dogs had sufficient data recorded for SIRS scoring. Only 10 dogs had CRP measurements at admission, ranging from 0 to 498 mg/L (0–498 μg/mL), so further statistical analysis of CRP values was not performed.

Of the entire group of 49 dogs, 33 (67%) survived to discharge. Of all the nonsurvivors, 7 died, whereas 9 were euthanized. Of those 9 euthanized, 5 could be retrospectively categorized as being euthanized due to the severity of pneumonia alone, 2 due to the poor long-term prognosis, and 2 due to a combination of the severity of pneumonia and the long-term prognosis. The 4 dogs euthanized for reasons other than pneumonia severity alone were excluded from the statistical analysis. As such, 45 dogs were included in the NLR analysis, including 12 nonsurvivors. There was no significant difference between the median age of the survivors (84 months, range, 0.5–144) and the nonsurvivors (54 months, range, 12–156) (*P* = 0.71).

The median hematological parameters for the 45 dogs are shown in Table 1. The NLR (median ± SD) did not differ significantly between the survivors (12.6 ± 14.5, range, 2.4–47.9) and nonsurvivors (23.4 ± 15.0, range, 2.4–48) (*P* = 0.065; Table 1 & Figure 1). There was also no significant difference between the groups for total WBC count, neutrophil count, total neutrophil percent of total WBC count, or lymphocyte percent of total WBC count. Nonsurvivors had a significantly higher median %-bands (6.0 ± 9.0) than survivors (1.0 ± 1.9) (*P* = 0.0001; Figure 2) and lower lymphocyte count (nonsurvivors 0.37 ± 0.65 [× 10^9/L]; survivors 0.93 ± 1.3 [× 10^3/μL]) (*P* = 0.004; Table 1 & Figure 3).

ROC curves were generated for the 2 parameters that showed a statistically significant association with the risk of death: the lymphocyte count and the %-bands (Figure 4). The area under the curve (AUC) was higher for the %-bands (0.871; upper bound 1.0, lower bound 0.74) than for the lymphocyte count (0.785; upper bound 0.94, lower bound 0.63); however, pairwise comparison showed this difference was not statistically significant (*P* = 0.16). A cutoff of %-bands greater than 1 gave a sensitivity and specificity of 91% and 67%, respectively, for death before discharge, whereas a cutoff of 2.5 and greater gave a sensitivity of 83% with a specificity of 79%. An optimal specificity for death

TABLE 1 Median hematological parameters for the 45 client-owned canine pneumonia cases included in the statistical analysis and comparison between survivors and nonsurvivors

	All dogs		Subgroups		
	Median	Range	Survivors	Nonsurvivors	P-value
n	45		33	12	–
Total WBC ($\times 10^9$/L) ($\times 10^3$/μL)	14.3	1.0–38.6	14.3 ($\pm$ 9.2)	12.1 ($\pm$ 9.8)	0.19
Total neutrophil count ($\times 10^9$/L) ($\times 10^3$/μL)	12.0	0.5–35.7	12.0 ($\pm$ 8.4)	11.3 ($\pm$ 8.4)	0.24
Mature neutrophil count ($\times 10^9$/L) ($\times 10^3$/μL)	11.7	0.3–35.7	12.0 ($\pm$ 8.1)	10.5 ($\pm$ 7.5)	0.20
Band neutrophil count ($\times 10^9$/L) ($\times 10^3$/μL)	0.21	0.00–5.55	0.11 ($\pm$ 0.46)	0.5 ($\pm$ 1.50)*	0.007
Lymphocyte count ($\times 10^9$/L) ($\times 10^3$/μL)	0.81	0.05–5.73	0.93 ($\pm$ 1.3)	0.37 ($\pm$ 0.65)*	0.004
Total neutrophil % of total WBC (%)	88.5	48–96	87 ($\pm$ 9.9)	89 ($\pm$ 13.0)	0.42
Band % of total WBC (%)	2	0–30	1.0 ($\pm$ 1.9)	6.0 ($\pm$ 9.0)*	0.0001
Lymphocyte % of total WBC (%)	5.5	2–26	7.0 ($\pm$ 6.6)	4.0 ($\pm$ 5.0)	0.06
NLR	16.7	2.4–47.9	12.6 ($\pm$ 14.5)	23.4 ($\pm$ 15.0)	0.065
SIRS score points	3	0–5	3.0 ($\pm$ 1.4)	4.0 ($\pm$ 1.0)	0.21
SIRS positive (% of cases)	86% (31/36)		80%	100%	0.125

Note: Subgroup results median ($\pm$ SD).

Abbreviation: NLR, neutrophil-to-lymphocyte ratio; SIRS, systemic inflammatory response syndrome.

*Statistically significant difference between survivors and nonsurvivors.

FIGURE 1 Box and whisker plot comparing the neutrophil-to-lymphocyte ratio (NLR) for survivor versus nonsurvivor dogs treated for pneumonia. The central horizontal lines indicate the median value; the upper and lower lines of the box plot represent the upper and lower quartiles of the values, respectively. The vertical lines indicate the 95% and 5% data range. Circles represent outliers
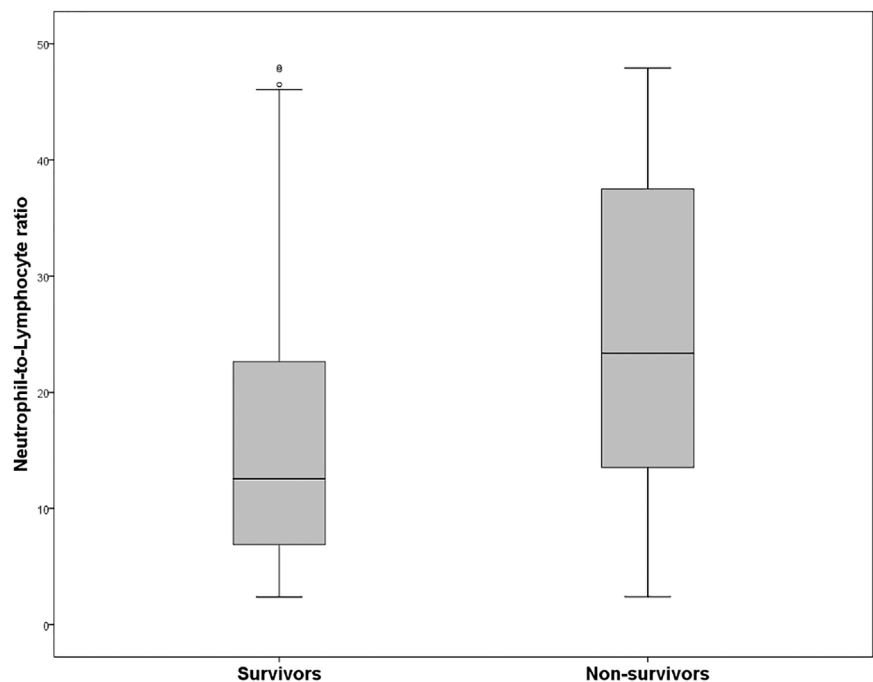
of 97% was obtained for a cutoff of 6.0 and greater, with a sensitivity of 50% (Table 2).

For the 36 dogs with SIRS scores, the proportion surviving to discharge did not statistically differ between those with (n = 31) and without (n = 5) SIRS (68% and 100%, respectively, P = 0.125). Although there was a higher percentage diagnosed with SIRS among the nonsurvivors, this did not reach statistical significance (100% vs. 80%; P = 0.125) (Table 1). The median number of SIRS criteria points scored (of a total of 5, those with 2 or more classified as having SIRS) did not differ between the survivors (3.0 $\pm$ 1.4) and the nonsurvivors (4.0 $\pm$ 1.0) (P = 0.21). The NLR was also not significantly different between dogs with and without SIRS (17.8 $\pm$ 15.6 vs. 8.9 $\pm$ 8.4; P = 0.06).

For the 33 surviving dogs, the hematological and SIRS data were evaluated for correlation with duration of hospitalization. The NLR, neutrophil count, lymphocyte count, and number of SIRS criteria points
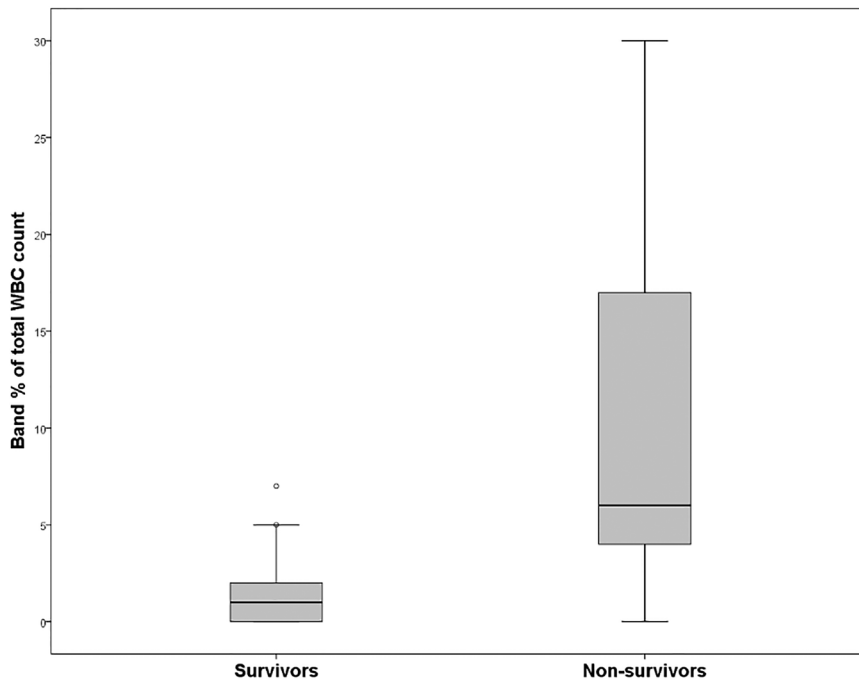
FIGURE 2 Box and whisker plot comparing the number of bands as a percentage of the total WBC count (%-bands) for survivor versus nonsurvivor dogs treated for pneumonia. The central horizontal lines indicate the median value; the upper and lower lines of the box plot represent the upper and lower quartiles of the values, respectively. The vertical lines indicate the 95% and 5% data range. Circles represent outliers

FIGURE 3 Box and whisker plot comparing total lymphocyte count for survivor versus nonsurvivor dogs treated for pneumonia. The central horizontal lines indicate the median value; the upper and lower lines of the box plot represent the upper and lower quartiles of the values, respectively. The vertical lines indicate the 95% and 5% data range. Circles represent outliers. Asterisks represent extreme outliers
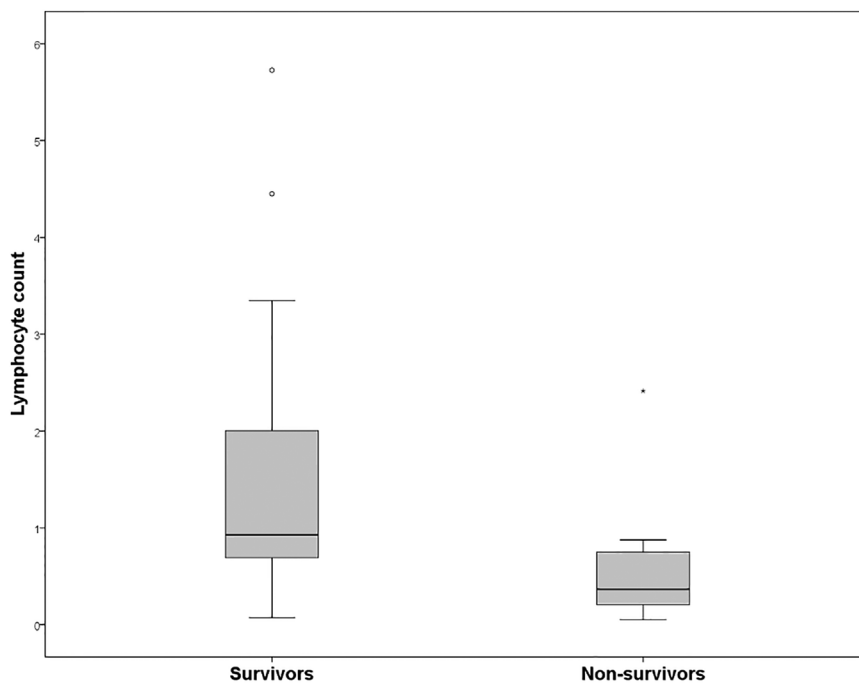
showed no significant correlation with hospitalization time. The %-bands showed a weak but statistically significant positive correlation with hospitalization time ($r = 0.38$, $P = 0.03$).

4 | DISCUSSION

Unlike in human medicine,[13] the NLR was not prognostic for survival in this cohort of canine pneumonia patients. Neutrophilia and lymphope-

nia are part of the innate immune response to systemic inflammation, regardless of initiating cause. Lymphopenia is caused by increased apoptosis and margination of lymphocytes within organs of the reticuloendothelial system. Neutrophilia results from release of mature neutrophils from the bone marrow storage pool alongside increased neutrophil production due to cytokine stimulation of the marrow. More marked inflammation can lead to a left shift, where neutrophil precursors including bands are released from the marrow due to extreme demand. In severe infections, this can progress to a neutropenia due

TABLE 2 ROC curve data

Parameter	Cutoff	Sensitivity	Specificity
Band neutrophil percent of total WBC count	>1.0	91%	67%
Band neutrophil percent of total WBC count	>2.5	83%	79%
Band neutrophil percent of total WBC count	>6.0	50%	97%
Lymphocyte count ($\times 10^9$/L) ($\times 10^3$/μL)	<0.89	92%	54%
Lymphocyte count ($\times 10^9$/L) ($\times 10^3$/μL)	<0.74	75%	70%
Lymphocyte count ($\times 10^9$/L) ($\times 10^3$/μL)	<0.28	50%	94%

Note: Sensitivity and specificity for nonsurvival for client-owned dogs with pneumonia for the band neutrophil percent of total WBC count at levels above 3 selected cutoffs, and for nonsurvival at levels below 3 selected cutoffs for total lymphocyte count based on ROC curve analysis.
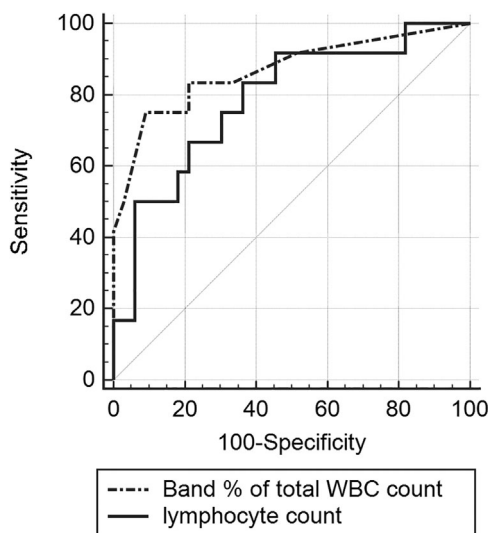

FIGURE 4 ROC curves for band neutrophil percent of total WBC count (%-bands) and total lymphocyte count as predictors of nonsurvival for dogs treated for pneumonia. The area under the curve (AUC) for the %-bands is 0.871 and for the lymphocyte count is 0.785. These AUC values indicate good diagnostic accuracy in discriminating for survival status

to a combination of neutrophil sequestration in infected tissues and exhaustion of the marrow neutrophil reserve.

Some patients can also show a degenerative left shift (DLS), defined as when the number of immature band neutrophils present in the circulation exceeds the number of mature neutrophils. The presence of a DLS is associated with an increased risk of mortality in canine patients with a variety of disease processes. In a retrospective study of dogs with a DLS at presentation to a veterinary teaching hospital, pneumonia was the most common underlying disease, diagnosed in 19% of cases. Notably, however, when the significance of a DLS was analyzed in individual diseases, there was no difference in survival between pneumonia patients with and without a DLS.[19] In the current study, no dogs showed a DLS; however, there was a significantly higher %-bands in the nonsurvivors than in the survivors. Based on ROC curve analysis, the %-bands also showed a good prognostic value for survival (AUC = 0.87). A %-bands cutoff of 2.5% or greater had 83% sensitivity and 79% specificity for nonsurvival to discharge. Although in the DLS study, the

severity of the left shift was assessed using the ratio of mature to immature neutrophils,[19] unlike in the current study, this ratio does not take into account the total number of WBC, so whether a similar association existed between increasing proportion of bands and survival to that found here is unknown. Equally, given involvement of a greater number of lung lobes is associated with worse prognosis in canine pneumonia,[1] it is possible that respiratory compromise from impaired gas exchange leads to death in some dogs with pneumonia before marrow neutrophil exhaustion is reached.

A recent prospective study compared various WBC parameters with some of the newer acute phase biomarkers in human community-acquired pneumonia (CAP) patients. They found both a higher NLR in patients dying within 30 days compared to survivors, and a higher neutrophil count percentage and lower lymphocyte count percentage, but no statistical difference in the absolute neutrophil or absolute lymphocyte counts between the groups.[20] Similar to the current study's finding of the %-bands having the higher ROC AUC, however, the human CAP study found the neutrophil count percentage had a higher ROC AUC than the NLR (0.87 vs. 0.79), and in multivariate analysis only the admission neutrophil count percentage retained statistical significance for mortality.[20] They did not report the percentage of bands, however, so whether this parameter may be similarly significant in people, as in the canine population in the current study, is unknown.[20] Overall, it is possible that differences in WBC kinetics between people and dogs contributed to this differing significance of absolute cell counts compared to count percentages.

Reasons for the difference in the NLR's significance between people and dogs with pneumonia are likely multifactorial but may in part be due to the option of euthanasia in veterinary patients. As with all veterinary studies investigating predictors of survival, euthanasia of patients due to costs, perceived poor prognosis, or other owner- or case-specific factors is likely to have a significant confounding effect. In the current study, attempts were made to address this by only including cases where euthanasia was recommended due to the severity of the pneumonia and an actively deteriorating clinical picture such that death was considered inevitable. However, it is important to note that this retrospective classification of reasons for euthanasia has significant limitations, in that only information recorded in the case records can be evaluated, and subtle impacts of factors such as cost may have played a role in either the veterinarian's or owners' decision to

euthanize a patient, even if they were not verbalized or formally recorded in the records. Although the difference in the median NLR between survivors and nonsurvivors was not statistically significant, it was similar in magnitude to that seen in larger human studies evaluating the NLR.[13,20] As such, it is possible that inclusion of a larger number of dogs may have detected a significant difference, and the present study has not because of a type II error. Future prospective studies that are larger in size and that exclude all euthanized patients may be warranted to further assess the utility of the NLR.

Differences in pneumonia type may also play a role in the different significance of the NLR between human and canine patients. Although in human studies the reported proportion of patients with CAP with the subtype of aspiration pneumonia varies between 7% and 24%,[4,21] in the current study, 73% of dogs had a final recorded diagnosis of aspiration pneumonia. Despite many instances of aspiration involving true bacterial colonization of the lower respiratory tract, either from aspiration of large particulate gastric contents or secondary opportunistic infection, a proportion of cases are better described as a pneumonitis due to chemical injury and sterile inflammation within the airways.[22] As many pneumonia patients are insufficiently stable for anesthesia and sampling of the lower airways for bacterial isolation, combined with the low positive culture rates seen in true bacterial pneumonia, it is difficult to achieve a definitive differentiation between pneumonitis and bacterial pneumonia in clinical cases, both in human and veterinary medicine.[1,4,23,24] In human medicine, although the NLR has a good positive predictive value for bacteremia in patients with a variety of conditions presenting for emergency care,[25] routine WBC counts have not been shown to differ between ventilated patients with confirmed pneumonitis and those with bacterial pneumonia.[26] Whether the NLR may differ between canine patients with bacteremia or sepsis compared to those with nonseptic inflammation is unknown. A recent meta-analysis of mortality risk in human aspiration patients compared to other CAP patients found that those with a risk factor for aspiration and, therefore, presumed aspiration pneumonia, had a more than 3-fold increased risk of in-hospital and 30-day mortality.[4] In the current study, dogs with a final diagnosis of aspiration pneumonia had a slightly higher mortality rate than those with other pneumonia subtypes, although this did not reach statistical significance. Thus, it is possible that relatively high mortality rates in the current study due to overrepresentation of aspiration cases affected the prognostic use of the NLR. Future investigation into whether there is a survival difference between canine pneumonia patients with known aspiration compared to those with bacterial pneumonia secondary to other etiologies, and whether the NLR has any prognostic use in the latter population, would be useful.

There are several limitations to the current study. The study population included dogs referred for known respiratory disease, including dogs with acute untreated pneumonia, treated but worsening pneumonia, and stable or improving pneumonia requiring ongoing care, plus dogs that newly developed pneumonia while hospitalized for other conditions. Although 33% of dogs received antibiotics prior to referral, due to the retrospective nature of the study, the specifics of treatment duration prior to referral were not available in the majority of cases. As a result, there is likely variability in the timing of the CBC from which the NLR was calculated in relation to onset of clinical signs and, therefore, our findings may not be directly applicable to acute untreated pneumonia patients presenting to primary care practice. Future prospective studies in which the NLR is calculated at serial time points or only in untreated patients would help clarify its prognostic utility.

A further limitation of the current study being performed in a referral practice is that this may have introduced a selection bias for sicker patients, because a major reason for referral of patients with pneumonia to specialty hospitals is the need for 24-hour ICU care. Thus, further investigation of the predictive value of the NLR and other hematological variables in a general practice population of dogs with pneumonia may be warranted. An inclusion criterion was a hematology and smear exam performed at the reference laboratory, partly for consistency in measurement methods, and partly because the in-house laboratory point-of-care analyzer cannot count band neutrophils. The advantage to the NLR is that it is easy to calculate based on results from automated hematology cell counters that are available to most veterinarians in general and emergency out-of-hours practice. Although the %-bands had prognostic value for canine pneumonia patients, calculating this measure requires a manual blood smear exam, making it more time-consuming to determine than the NLR. Finally, although it was hoped to additionally evaluate the utility of baseline CRP as a prognostic indicator in this population, only 10 dogs fulfilling the inclusion criteria had CRP measured at presentation. As this small number of eligible dogs would be underpowered to detect a significant difference, CRP was excluded from the statistical analyses.

Failure to find a significant difference in survival between dogs with and without SIRS at presentation may have been due to a type II error from the low number of dogs not fulfilling the SIRS criteria. This limitation is also likely a reflection of the current study being performed at a referral hospital and arguably representing a sicker population of dogs affected by pneumonia. Future studies including more dogs overall and less severely affected dogs from a primary care population to reflect a wider spectrum of disease severity might better evaluate the prognostic implications of SIRS at diagnosis. Additionally, SIRS is a very nonspecific marker of illness severity, merely reflecting the presence or absence of systemic inflammation. As such, it is not designed to differentiate between moderate and high severities of systemic illness. It was not possible to evaluate alternative disease severity scoring systems, such as APPLE scores, as additional data such as lactate measurements were not available for most cases in the current study.

To the authors' knowledge, there are no previous studies evaluating the prognostic value of WBC percentages in canine pneumonia. The current study found that although the NLR was not useful prognostically, the number of band neutrophils as a percentage of the total WBC count (%-bands) was significantly higher in nonsurvivors than survivors and showed a weak correlation with longer duration of hospitalization in survivors. Although a %-bands of greater than 2.5% had a specificity of 79% for death in hospital, further studies evaluating this in a larger population of dogs presenting to both referral and primary care practices would be of interest. Additionally, larger studies

including additional clinicopathological variables such as biochemical data and CRP may allow development of a better performing multiparameter disease-specific scoring system for canine pneumonia, similar to those used in human medicine.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ENDNOTES

[a] ADVIA 120, Siemens, Frimley, UK.
[b] IBM SPSS Statistics for Windows, version 24.0, Armonk, NY.

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