Rovedar

Small Animal Advances. 2026; 5(3): 22-29.
DOI: 10.58803/saa.v5i3.59
http://saa.rovedar.com/

Research Article

Evaluation of Serum Lactate and Neutrophil-to-Lymphocyte Ratio as Early Predictors of Disease Severity in Dogs with Acute Gastroenteritis

Ramtin Ghorban Pour[1], Ali Heydari[2*], Ghazaleh Kompani[3], Sara Sadat Tavakoli[4], Hossein Zaree[5], Ali Jebeli Eshrat Abadi[5], Parsa Jahani[7], and Narges Anari[8]

[1] Faculty of Veterinary Medicine, Islamic Azad University, Shabestar Branch, East Azerbaijan, Iran
[2] Department of Clinical Science, Faculty of Veterinary Medicine, Karaj Branch, Islamic Azad University, Karaj, Iran
[3] Faculty of Veterinary Medicine, Baft Branch, Islamic Azad University, Kerman, Iran
[4] Small Animal Internal Medicine Clinician, Tehran, Iran
[5] Faculty of Veterinary Medicine, Islamic Azad University, Garmsar Branch, Iran
[6] Department of Veterinary Medicine, Faculty of Veterinary Medicine, Science and Research Branch, Islamic Azad University, Tehran, Iran
[7] Department of Clinical Science, Science and Research Branch, Islamic Azad University, Tehran, Iran
[8] Doctor of Veterinary Medicine, Haqdin Clinic, Arak, Iran

*** *Corresponding author:*** Ali Heydari, Department of Clinical Science, Faculty of Veterinary Medicine, Karaj Branch, Islamic Azad University, Karaj, Iran. Email: aliheydari345@gmail.com

ARTICLE INFO

Article History:
Received: 28/06/2026
Revised: 25/07/2026
Accepted: 05/09/2026
Published: 30/09/2026

Keywords:
Acute gastroenteritis
Biomarker
Disease severity
Dog
Neutrophil-to-lymphocyte ratio
Serum lactate

ABSTRACT

Introduction: Acute gastroenteritis (AGE) in dogs ranges from mild to severe, requiring supportive care. Serum lactate reflects tissue perfusion and metabolic status, while the neutrophil-to-lymphocyte ratio (NLR) marks systemic inflammation. The present study aimed to assess the value of serum lactate and NLR as early predictors of disease severity in dogs with AGE.

Materials and methods: In this prospective clinical study, 72 dogs (39 males and 33 females) with AGE and a mean age of 4.5 years were included. Clinical severity was assessed based on predefined clinical criteria, including degree of dehydration, frequency of vomiting and diarrhea, body temperature, heart rate, mental status, and need for hospitalization or intensive supportive treatment using intravenous fluid therapy and antiemetic administration. Blood samples were collected to determine serum lactate concentration and complete blood count before any treatment, including intravenous fluid therapy and antiemetic administration. The NLR was calculated from absolute neutrophil and lymphocyte counts. Correlation and regression analyses were performed to assess how these biomarkers were associated with clinical severity. Receiver operating characteristic (ROC) analysis assessed the ability of NLR to distinguish severe disease from mild-to-moderate disease.

Results: Serum lactate concentrations and NLR were higher in dogs with severe AGE compared with dogs with mild-to-moderate gastroenteritis. Serum lactate concentrations and NLR revealed significant positive correlations with clinical severity scores. Higher lactate concentrations and NLR were associated with prolonged hospitalization and the need for intensive supportive treatment. In multivariate analysis, serum lactate and NLR remained independently associated with gastroenteritis. Based on ROC analysis, combining lactate and NLR provided superior discrimination compared to using each biomarker individually; thus, the combination offered enhanced discriminative ability.

Conclusion: Serum lactate and NLR were associated with disease severity in dogs with AGE and served as markers for early clinical risk stratification.

1. Introduction

Acute gastroenteritis (AGE) is one of the most common causes of veterinary consultation in small animal medicine[1].

Cite this paper as: Ghorban Pour R, Heydari A, Kompani G, Sadat Tavakoli S, Zaree H, Jebeli Eshrat Abadi A, Jahani P, and Anari N. Evaluation of Serum Lactate and Neutrophil-to-Lymphocyte Ratio as Early Predictors of Disease Severity in Dogs with Acute Gastroenteritis. Small Animal Advances. 2026; 5(3): 22-29. DOI: 10.58803/saa.v5i3.59

The Author(s). Published by Rovedar. This is an open-access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The clinical signs are broad, ranging from transient, self-limiting diarrhea to life-threatening conditions characterized by severe dehydration, systemic inflammatory response syndrome (SIRS), and sepsis[1,2]. Many dogs with uncomplicated AGE recover with symptomatic and supportive treatment. However, some dogs progress to critical disease requiring intensive intravenous fluid therapy, antiemetic therapy, nutritional support, and, in some cases, multimodal organ function monitoring[3]. Acute gastroenteritis accounts for a high proportion of emergency canine diseases; rapidly and accurately identifying dogs at risk of severe disease is a clinical priority[3]. Identifying these dogs would enable timely clinical assessment and early therapeutic intervention, which may ultimately improve patient outcomes[3].

In routine veterinary emergency practice, initial evaluation of disease severity often relies on clinical parameters, including physical examination findings, hydration status, and owner-reported history[3]. However, these variables are subject to inter-observer variability and often do not reflect the underlying pathophysiology, especially early in presentation[4]. Hence, interest has grown in rapidly measurable biomarkers that provide complementary information on systemic perfusion, metabolic disturbance, and the magnitude of the host inflammatory response[4]. Among the candidate markers, those markers most extensively studied in both human and veterinary critical care medicine include serum lactate and neutrophil-to-lymphocyte ratio (NLR)[5].

Serum lactate is a sensitive marker of tissue hypoperfusion, cellular hypoxia, and impending shock, a long-recognized metabolite of the dynamic balance between anaerobic glycolysis and hepatic clearance[6,7]. Lactate measurement is readily available, cost-effective, and easily incorporated into initial emergency assessments in dogs[8]. Meanwhile, the NLR, easily calculated from absolute neutrophil and lymphocyte counts obtained by routine complete blood count (CBC), has emerged as a robust surrogate marker of systemic inflammatory stress and immunological status[7]. An increased NLR indicates both enhanced innate immune activity (neutrophilia) and relative suppression of adaptive immunity (lymphopenia), a combination frequently observed in severe inflammatory or septic conditions[9]. Several veterinary studies have demonstrated the prognostic relevance of NLR in different pathological conditions, such as sepsis and parvoviral enteritis[10,11], but its specific role in unselected canine AGE has been less rigorously studied. The integrated evaluation of serum lactate and NLR may offer a more precise prediction of outcomes compared to each marker individually, as these two indicators represent complementary aspects of perfusion-related metabolic dysfunction and inflammatory-immune activation, although each marker has its own utility[9]. However, prospective data assessing the simultaneous measurement of these two biomarkers at admission for early risk stratification in dogs with AGE are limited. The present study aimed to evaluate the utility of serum lactate concentration and NLR as independent early indicators of disease severity in dogs with AGE.

2. Materials and Methods

2.1. Ethical approval

The present study was conducted at Islamic University of Karaj, Faculty of Veterinary Medicine, Karaj, Iran, between March and June 2025, following approval by the Institutional Animal Care and Use Committee of the Faculty of Veterinary Medicine (IAUK.AC.1402.0215). Written informed owner consent was obtained prior to enrollment for all dogs, and all procedures were performed in accordance with the relevant guidelines and regulations for the ethical use of animals in research.

2.2. Study population and inclusion criteria

A total of 118 dogs presenting with vomiting, diarrhea, or both of acute onset (<72 hours' duration) were consecutively screened for eligibility during the study period. Of these 118 dogs, 46 dogs were excluded for different reasons, including chronic gastrointestinal disorders (n = 12), concurrent systemic diseases potentially confounding lactate or NLR interpretation (n = 9), corticosteroid or immunosuppressive therapy within the preceding 14 days (n = 8), prior fluid therapy or antiemetic administration before presentation (n = 7), history of surgery or trauma within 30 days (n = 4), and a definitive non-gastrointestinal diagnosis established during hospitalization (n = 6). Consequently, 72 dogs met the inclusion criteria and were enrolled in the study.

2.3. Assessment of clinical severity and grouping

All dogs underwent a common physical exam by a board-certified veterinary internist or senior emergency clinician at presentation. A comprehensive clinical severity scoring system was used based on six parameters, including degree of dehydration (0-3), frequency of vomiting (0-3), frequency of diarrhea (0-3), body temperature (0-3), heart rate (0-3), and mental status (0-3), which yields a total composite score ranging from 0 to 18[12]. Dogs were classified as having mild-to-moderate disease with a total score of ≤ 8, or severe disease with a total score of ≥ 9. The severe disease category was defined as any dog that required immediate intensive care, continuous intravenous fluid therapy, or vasopressor support, regardless of numerical score. The need for hospitalization, need for intensive supportive treatment defined as administration of intravenous crystalloids, colloids, antiemetics, gastrointestinal protectants, antibiotics, or plasma transfusions, and total duration of hospitalization in days were recorded for each dog. In addition, dogs did not receive only one medication. Each dog was on a wide range of medications.

2.4. Blood sampling and laboratory analysis

The amount of 3-5 mL of peripheral blood was collected from each dog by cephalic or jugular venipuncture before initiation of any therapeutic intervention. Plasma lactate was measured in samples collected in lithium-heparin tubes and analyzed within 15 minutes of collection using a commercially available handheld lactate analyzer (Lactate Scout Vet, EKF

Diagnostics, Penarth, UK) validated for canine whole blood. All measurements were done in duplicate, and the mean value was recorded in mmol/L. Samples were collected in K2-EDTA tubes and processed within 2 hours for a CBC using an automated veterinary hematology analyzer (Sysmex XN-1000V, Sysmex Corporation, Kobe, Japan), from which absolute neutrophil and lymphocyte counts were obtained. The NLR was subsequently calculated by dividing the absolute neutrophil count by the absolute lymphocyte count. All laboratory personnel involved in the biomarker measurements were unaware of the clinical severity status of the dogs to minimize detection bias.

2.5. Follow-up and evaluation of results

All enrolled dogs were prospectively followed from the presentation until hospital discharge, death, or euthanasia, and attending clinicians recorded clinical data daily. For dogs discharged in less than 24 hours, follow-up was performed at 48-72 hours post-discharge to confirm clinical resolution and no relapse. The primary outcome variable was disease severity classification (severe versus mild-to-moderate). Secondary outcomes were need for hospitalization, total duration of hospitalization in days, need for intensive supportive treatment, and in-hospital mortality or euthanasia directly related to complications of gastroenteritis.

2.6. Statistical analysis

Normality was assessed using the Shapiro-Wilk test. Serum lactate and NLR were compared among all dogs in the present study using a Mann–Whitney U test, and categorical variables were compared using a chi-square test with p-value set at 0.05. Spearman's rank correlation was used to assess the association between each biomarker and the continuous severity score, avoiding information loss from dichotomization. Binary logistic regression identified independent predictors of severe disease, including lactate and NLR by design, while controlling for age, sex, and body weight. Receiver operating characteristic (ROC) curve analysis evaluated discrimination ability, with area under the curve (AUC) calculation, Youden index for cut-offs, and DeLong's test for AUC comparisons. Sample size was based on a pilot study (80% power, two-sided alpha = 0.05); a minimum of 26 dogs per group was required, but at least 70 dogs were enrolled to allow for exclusions. Analyses were performed in SPSS 27.

3. Results

3.1. Study population and baseline characteristics

The study included 72 dogs, 44 (61.1%) with mild-to-moderate gastroenteritis and 28 (38.9%) with severe gastroenteritis (Table 1). The median age of the study population was 4.5 years (range 0.5-14 years), and it consisted of 39 male (54.2%) and 33 female dogs (45.8%). The median body weight was 22.5 kg. In the mild-to-moderate group, mean body weight was 23 kg, and in the severe group, it was 21.5 kg; this difference was not significant between groups ($p > 0.05$). The most common breeds were mixed-breed dogs (n = 18, 25.0%), German Shepherds (n = 9, 12.5%), and Golden Retrievers (n = 7, 9.7%). The two severity groups did not differ significantly in age, sex, body weight, or breed distribution ($p > 0.05$), suggesting these variables were well balanced at baseline and unlikely to confound the primary analyses. The median total duration of signs was 18 hours (IQR = 8.0-36.0); in dogs with mild-to-moderate gastroenteritis, it was 16 hours (IQR = 6.0-32.0), and in dogs with severe gastroenteritis, it was 22 hours (IQR = 10.0-48.0).

Table 1. Baseline demographic and clinical characteristics of dogs with acute gastroenteritis, stratified by disease severity, in Karaj, Iran, March-June 2025

Characteristics	Total (n = 72)	Mild-to-moderate gastroenteritis (n = 44)	Severe gastroenteritis (n = 28)	p-value
Age (median range)	4.5 years (0.5-14)	4.8 years (0.5-14)	4.0 years (0.8-12)	0.34
Body weight (median IQR)	22.5 kg (14.0-32.0)	23.0 kg (14.5-33.0)	21.5 kg (13.0-31.0)	0.41
Sex (%)				0.52
Male	n = 39 (54.2%)	n = 23 (52.3%)	n = 16 (57.1%)	
Female	n = 33 (45.8%)	n = 21 (47.7%)	n = 12 (42.9%)	
Breed (%)				0.63
Mixed-breed	n = 18 (25.0%)	n = 11 (25.0%)	n = 7 (25.0%)	
German Shepherd	n = 9 (12.5%)	n = 5 (11.4%)	n = 4 (14.3%)	
Golden Retriever	n = 7 (9.7%)	n = 5 (11.4%)	n = 2 (7.1%)	
Other breeds	n = 38 (52.8%)	n = 23 (52.3%)	n = 15 (53.6%)	
Duration of signs (median IQR)	18 hours (8.0-36.0)	16 hours (6.0-32.0)	22 hours (10.0-48.0)	0.08

n: number of dogs, IQR: Interquartile range, kg: Kilograms. A p-value less than 0.05 was considered statistically significant.

3.2. Biomarkers

Serum lactate concentrations were significantly higher in dogs with severe gastroenteritis (3.8 mmol/L) compared to dogs with mild-to-moderate gastroenteritis (1.6 mmol/L; Table 2; $p < 0.05$). The NLR was significantly higher in the dogs with severe gastroenteritis (median: 12.4) compared to the dogs with mild-to-moderate gastroenteritis (median: 4.2; $p < 0.05$). The percentage of dogs with hyperlactatemia (serum lactate > 2.0 mmol/L) was significantly higher in dogs with severe gastroenteritis (82.1%) compared to dogs with mild-to-moderate gastroenteritis (20.5%; $p < 0.05$). An elevated NLR (> 7.0) was observed in 78.6% of dogs with severe gastroenteritis, a proportion significantly higher than the 15.9% observed in dogs with mild-to-moderate gastroenteritis ($p < 0.05$).

Table 2. Serum lactate and neutrophil-to-lymphocyte ratio between dogs having mild-to-moderate and severe gastroenteritis in Karaj, Iran, March-June 2025

Biomarkers	Mild-to-moderate gastroenteritis (n = 44)	Severe gastroenteritis (n = 28)	p-value
Serum lactate (mmol/L; median IQR)	1.6 mmol/L (1.2-2.1)[b]	3.8 mmol/L (2.6-5.4)[a]	< 0.001
NLR (median IQR)	4.2 (2.8-6.1)[b]	12.4 (8.7-18.2)[a]	< 0.001
Hyperlactatemia (> 2.0 mmol/L)	20.5% (n = 9)[b]	82.1% (n = 23)[a]	< 0.001
Elevated (NLR > 7.0)	15.9% (n = 7)[b]	78.6% (n = 22)[a]	< 0.001

NLR: Neutrophil-to-Lymphocyte ratio, IQR: Interquartile range, n: number of dogs. Data are presented as median (interquartile range) for continuous variables and number (percentage) for categorical variables. [a,b] Mean different superscript letters in a row indicate significant differences at p < 0.05.

3.3. Association of biomarker with clinical severity scores

Serum lactate concentrations correlated significantly and positively with composite clinical severity scores (p < 0.05); thus, higher lactate levels were consistently associated with increased clinical disease severity (Table 3). Similarly, NLR was significantly and positively correlated with severity scores (ρ = 0.68), indicating that higher inflammatory stress, as assessed by NLR, was linked to worsening clinical condition. Serum lactate concentrations (ρ = 0.65) and NLR (ρ = 0.59) were strongly correlated with the degree of dehydration and severity score (p < 0.05). Mental status changes were strongly correlated with dehydration and severity score for lactate (ρ = 0.58, p < 0.001) and NLR (ρ = 0.62, p < 0.001). Serum lactate was correlated with body temperature (ρ = 0.29, p = 0.04) and heart rate (ρ = 0.22, p = 0.08), while NLR correlated with body temperature (ρ = 0.26, p = 0.06) and heart rate (ρ = 0.24, p = 0.07). Significant yet weaker correlations were observed between both biomarkers and vomiting frequency (lactate: ρ = 0.41, p = 0.003; NLR: ρ = 0.38, p = 0.008), as well as diarrhea (lactate: ρ = 0.35, p = 0.02; NLR: ρ = 0.33, p = 0.03).

Table 3. Spearman's correlation coefficients between biomarkers and clinical severity score components in dogs with acute gastroenteritis in Karaj, Iran, March-June 2025

Severity score / Biomarkers	Serum lactate severity score (ρ)	p-value	NLR severity score (ρ)	p-value
Total severity score (0-18)	0.71	< 0.001	0.68	< 0.001
Components (each scored 0-3)				
Degree of dehydration	0.65	< 0.001	0.59	< 0.001
Mental status	0.58	< 0.001	0.62	< 0.001
Frequency of vomiting	0.41	0.003	0.38	0.008
Frequency of diarrhea	0.35	0.02	0.33	0.03
Body temperature	0.29	0.04	0.26	0.06
Heart rate	0.22	0.08	0.24	0.07

NLR: Neutrophil-to-lymphocyte ratio, ρ: Spearman's rank correlation coefficient. A p-value less than 0.05 was considered statistically significant.

3.4. Clinical outcomes and biomarker associations

Dogs presenting with elevated lactate concentrations (> 2.0 mmol/L) at the time of presentation to the hospital were significantly more likely to require hospitalization compared to those with normal lactate levels (84.4% versus 35.0%; p < 0.001; Table 4). Among hospitalized dogs, the median duration of hospitalization was significantly higher in the hyperlactatemia group (4.0 days, IQR = 2.0-6.0 days) compared to dogs with normal lactate (1.5 days, IQR = 1.0-3.0 days; p = 0.003). Similarly, dogs with high NLR (> 7.0) had a significantly higher hospitalization rate (86.2% versus 37.2%; p < 0.001) and longer hospitalization time (median: 3.5 versus 2.0 days; p = 0.01) compared to dogs with normal NLR. Dogs with elevated lactate (81.3% versus 32.5%) and dogs with elevated NLR (86.2% versus 32.6%) were both significantly more likely to require intensive supportive care (p < 0.001), including intravenous crystalloid fluids, antiemetics, and systemic antibiotics. Mortality was observed in 4 dogs (12.5%) in the elevated lactate group and 4 dogs (13.8%) in the elevated NLR group, with no deaths in either normal biomarker group.

Table 4. Clinical outcomes in dogs with acute gastroenteritis according to serum lactate and neutrophil-to-lymphocyte ratio status

Biomarkers / Outcomes	Normal lactate level (n = 40)	Elevated lactate level (n = 32)	p-value	Normal NLR (n = 43)	Elevated NLR (n = 29)	p-value
Hospitalization (%)	n = 14 (35.0%)[a]	n = 27 (84.4%)[b]	< 0.001	n = 16 (37.2%)[a]	n = 25 (86.2%)[b]	< 0.001
Hospital stays (median IQR)	1.5 days (1.0-3.0)[a]	4 days (2.0-6.0)[b]	0.003	2 days (1.0-3.0)[a]	3.5 days (2.0-5.0)[b]	0.01
Intensive supportive treatment (%)	n = 13 (32.5%)[a]	n = 26 (81.3%)[b]	< 0.001	n = 14 (32.6%)[a]	n = 25 (86.2%)[b]	< 0.001
Mortality (%)	n = 0 (0.0%)[a]	n = 4 (12.5%)[b]	0.04	n = 0 (0.0%)[a]	n = 4 (13.8%)[b]	0.03

n: number of dogs, IQR: Interquartile range, NLR: Neutrophil-to-Lymphocyte ratio. Normal lactate: ≤ 2.0, Elevated lactate: > 2.0, Normal NLR: ≤ 7.0, Elevated NLR: > 7.0. Normal lactate level and NLR reference: Pierini et al.[12]. [a,b] Mean different superscript letters in a row indicate significant differences at p values < 0.05 for lactate and NLR separately.

3.5. Multivariable regression analysis

A binary logistic regression analysis was performed to determine independent predictors of severe gastroenteritis (Table 5). Serum lactate (OR: 2.84, 95% CI: 1.92-4.21) and

NLR (OR: 1.35, 95% CI: 1.18-1.54) were significantly associated with severe disease (p < 0.001), whereas age (OR: 0.97, p = 0.34), sex (OR: 1.22, p = 0.52), and body weight (OR: 0.98, p = 0.41) were not. Both biomarkers remained independently associated after adjustment, with adjusted odds ratios of 2.96 (95% CI: 1.98-4.42, p < 0.001) for serum lactate and 1.38 (95% CI: 1.20-1.59, p < 0.001) for NLR, while age (adjusted OR: 0.96, p = 0.28), sex (adjusted OR: 1.18, p = 0.62), and body weight (adjusted OR: 0.98, p = 0.35) remained non-significant.

Table 5. Univariate and multivariable logistic regression analyses of predictors for severe gastroenteritis in dogs with acute gastroenteritis

Variables	Univariate OR (95% CI)	Univariate p-value	Multivariable adjusted OR (95% CI)	Multivariable p-value
Serum lactate (per 1 mmol/L increase)	2.84 (1.92-4.21)	< 0.001	2.96 (1.98-4.42)	< 0.001
NLR (per 1 unit increase)	1.35 (1.18-1.54)	< 0.001	1.38 (1.20–1.59)	< 0.001
Age (per year increase)	0.97 (0.91-1.04)	0.34	0.96 (0.89-1.03)	0.28
Sex (male versus female)	1.22	0.52	1.18	0.62
Body weight (per kg increase)	0.98 (0.95-1.02)	0.41	0.98 (0.94-1.02)	0.35

OR: Odds ratio. The 95% CI represents the range of odds ratios compatible with the observed data at the 5% significance level, with intervals excluding 1.0 indicating statistically significant independent predictors of severe gastroenteritis. A p-value less than 0.05 was considered statistically significant.

3.6. Receiver operating characteristic analysis

The ROC curve analysis assessed the discriminative ability of serum lactate, NLR, and their combination in differentiating severe from mild-to-moderate gastroenteritis in dogs (Table 6). The AUC for serum lactate alone was 0.84 (95% CI: 0.75-0.93), suggesting high discriminatory ability. The AUC for NLR alone was 0.82 (95% CI: 0.72-0.91), indicating comparable predictive ability. The combined model with both biomarkers had a significantly higher AUC of 0.92 (95% CI: 0.86-0.98) than lactate alone (p = 0.03) or NLR alone (p = 0.02). Using the Youden index, the optimal cut-off for serum lactate was 2.3 mmol/L (sensitivity of 82.1%, specificity of 79.5%) for predicting severe gastroenteritis, while the optimal NLR cut-off was 7.2 (sensitivity of 78.6%, specificity of 84.1%). The combined model achieved the highest overall diagnostic accuracy, with a sensitivity of 89.3%, specificity of 88.6%, positive predictive value of 84.2%, and negative predictive value of 93.2%. These findings indicated that the combined determination of serum lactate and NLR offers higher discrimination than either biomarker alone, supporting the complementary utility of these markers in early clinical risk stratification.

Table 6. Receiver operating characteristic analysis for predicting severe gastroenteritis in dogs during March-June 2025, Karaj, Iran

Biomarkers	AUC (95% CI)	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	P-value
Serum lactate	0.84 (0.75-0.93)	2.3 mmol/L	82.1	79.5	71.9	87.5	0.03
NLR	0.82 (0.72-0.91)	7.2	78.6	84.1	75.9	86.0	0.02
Combined model	0.92 (0.86-0.98)	-	89.3	88.6	84.2	93.2	-

AUC: Area under the curve, CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value, NLR: Neutrophil-to-lymphocyte ratio. Cut-off values were determined using the Youden index. Comparisons between AUCs were performed using DeLong's test. The p-values in the table (0.03 for lactate, 0.02 for NLR) refer to comparisons against the combined model, not to whether each biomarker alone is significant.

4. Discussion

This prospective clinical study demonstrated that serum lactate concentration at presentation and NLR were associated with gastroenteritis severity in dogs presenting with AGE. The combined assessment of the biomarkers provided superior discriminatory performance compared to each biomarker alone. The current results indicated that serum lactate concentration and NLR, two readily available, cost-effective biomarkers, can serve as useful early clinical risk indicators for canines with AGE, potentially influencing clinical decision-making regarding clinical assessment, hospitalization, and the intensity of supportive care. The increased serum lactate concentration in dogs with severe gastroenteritis was consistent with lactate's known role as a sensitive marker of tissue hypoperfusion and anaerobic metabolism[13,14]. In AGE, severe vomiting and diarrhea can cause substantial fluid losses resulting in decreased intravascular volume and decreased cardiac output with subsequent impairment of systemic oxygen delivery[13]. Inadequate oxygen delivery to meet the metabolic requirements of tissues causes cells to switch from aerobic to anaerobic glycolysis, which results in accumulation of lactate in circulation[13]. The median lactate concentration in the current study in dogs with severe gastroenteritis (3.8 mmol/L) was similar to previous studies that described lactate concentrations of 3.0-5.0 mmol/L in dogs with severe conditions[13,15]. Hyperlactatemia was present in 82.1% of dogs with severe gastroenteritis, further underscoring the clinical importance of the NLR biomarker for identifying dogs with compromised perfusion who may need immediate resuscitation. Lactate is an indirect measure of systemic hypoperfusion and tissue hypoxia and has established prognostic value in critically ill dogs. Timely point-of-care measurement, which has been shown to agree with laboratory analyzers, supports its use in this setting[16]. Importantly, the strong correlation between lactate and degree of dehydration, as well as mental status alterations, supported the construct validity of the present severity scoring system and reinforced the physiological link between lactate accumulation and clinical signs of impaired tissue perfusion[15]. Similarly, the elevated NLR in dogs with severe gastroenteritis and its strong positive correlation with clinical severity scores were consistent with previous findings of Zahorec[17], who established NLR as a simple and rapid parameter of systemic inflammation and stress.

Pierini et al.[12] reported an elevated NLR (median of 11.69) in dogs with SIRS, supporting its use as a readily available marker of systemic inflammation, consistent with the present findings in dogs with AGE, in which elevated NLR was associated with greater disease severity. The current finding that NLR was higher in dogs with severe disease was consistent with previous reports in puppies with sepsis secondary to canine parvoviral enteritis, in which NLR values were elevated at admission. Higher NLR was associated with deterioration in clinical condition and poorer prognosis, whereas lower NLR values reflected greater clinical status and outcome[18]. The association between NLR and mental status alterations in the present study was consistent with previous findings linking systemic inflammation to neurological dysfunction. However, Hodgson et al.[19] found that NLR neither distinguished septic from nonseptic systemic inflammatory disease nor correlated with hospitalization length, morbidity, or mortality in dogs, suggesting limited diagnostic and prognostic utility. In the current study, the correlation between NLR and mental status alterations suggested that systemic inflammation, as reflected by NLR, may also be associated with neurological compromise in dogs with AGE, possibly through SIRS-mediated effects on cerebral perfusion and function.

The current finding indicated that both biomarkers were independently associated with severe disease in the multivariable regression model. After adjusting for potential confounders such as age, sex, and body weight, serum lactate was a strong independent predictor (adjusted odds ratio 2.96 per 1 mmol/L increase), while NLR had an adjusted odds ratio of 1.38 per unit increase. These results indicated that each biomarker provided unique and complementary information about the pathophysiological state of the dogs. Acute-phase and inflammatory markers such as C-reactive protein are elevated in dogs with acute hemorrhagic diarrhea syndrome and correlate with clinical severity scores and other laboratory indices of systemic inflammation[20]. Plasma lactate reflects tissue oxygen delivery and overt or occult hypoperfusion. Admission levels of plasma lactate and clearance predict mortality and morbidity in dogs with sepsis peritonitis[21]. This complementary nature likely explains the combined model's superior performance in the ROC analysis compared with lactate and NLR alone. The combined model had high sensitivity (89.3%) and specificity (88.6%), indicating that measuring both biomarkers simultaneously could improve clinical decision-making by identifying most dogs at risk for severe disease while maintaining an acceptable false-positive rate. The negative predictive value of 93.2% was especially reassuring, as it indicated that dogs with normal lactate and NLR were very unlikely to develop severe disease, and this might enable safe outpatient management in a substantial proportion of cases[22]. A recent study indicated that lactate combined with NLR provided a more accurate prognostic ability than classical scoring systems such as SIRS criteria in critically ill dogs and cats[11].

The observed correlations between increased biomarkers and poor clinical outcomes further supported their prognostic utility. In dogs with septic peritonitis, admission hyperlactatemia (>2.5 mmol/L) was associated with mortality. Lactate >4 mmol/L predicted about 7-fold higher odds of nonsurvival (OR 7.1, 95% CI 2-25). Failure to normalize lactate within 6 hours and persistent postoperative hyperlactatemia were also strongly associated with nonsurvival[21]. Similarly, elevated NLR can predict more severe disease and greater healthcare use in dogs with systemic inflammation[21]. The current findings align with studies linking higher presentation biomarker levels to greater healthcare resource use. In dogs with septic peritonitis, admission hyperlactatemia was associated with blood product and vasopressor requirements, while persistent hyperlactatemia strongly predicted nonsurvival[21]. The higher lactate and NLR values in dogs requiring intensive supportive treatment further support the clinical relevance of these biomarkers for identifying dogs that need early care. The mortality rate of 12.5% and 13.8% observed in the present study (all deaths occurring in the severe group) was higher than previously published mortality rates for canine gastroenteritis ranging from 3% to 10%[22]. The notably high serum lactate and NLR levels at presentation in non-survivors indicated that these markers could help identify dogs at greatest risk of death.

Serum lactate and NLR are easily available in most veterinary clinical settings. The reliability and feasibility of lactate measurement in canine patients have been well established, with studies demonstrating predictable lactate kinetics and the clinical utility of serial lactate monitoring in dogs[15]. Similarly, NLR is derived from routine CBC parameters and has been validated as a practical and valuable prognostic marker in dogs with systemic inflammatory conditions, requiring no additional cost or sample processing beyond standard hematological analysis[18]. These characteristics make both biomarkers particularly suitable for emergency triage, where rapid, cost-effective risk stratification is essential. This accessibility makes NLR particularly suitable to be used in emergency triage, where decisions should be made on hospitalization and intensity of treatment with limited information and under time pressure[24]. The current study proposed a pragmatic algorithm for clinical decision-making. In this algorithm, serum lactate and CBC were measured at presentation, and NLR was calculated. Dogs with both biomarkers below the specified cut-offs could be considered for outpatient management with close monitoring. Dogs with elevation in either or both biomarkers could be considered for hospitalization and more aggressive supportive care. The degree of elevation served as a surrogate for the urgency and intensity of intervention[23,24]. Recent advances in veterinary critical care have emphasized the importance of early recognition and intervention for improved outcomes in critically ill canines, including those with acute gastrointestinal emergencies[24]. The acute hemorrhagic diarrhea syndrome index was introduced to standardize clinical severity assessment in dogs with acute hemorrhagic diarrhea syndrome, underscoring the value of structured severity scoring in this population[25]. The current findings indicated that serum

lactate and NLR, two readily available biomarkers, provided complementary prognostic information for early risk stratification in dogs with AGE, further extending the conceptual framework from previous studies.

5. Conclusion

In the current study, serum lactate and NLR were independently associated with disease severity in dogs with AGE, and their combined evaluation yielded more accurate predictive performance than either biomarker alone. Both biomarkers were significantly elevated in severe cases, with a median serum lactate of 3.8 mmol/L versus 1.6 mmol/L in mild-to-moderate cases and a median NLR of 12.4 versus 4.2, respectively. Elevated lactate was associated with an 84.4% hospitalization rate compared to 35.0% in dogs with normal lactate, and elevated NLR was associated with an 86.2% hospitalization rate compared to 37.2% in dogs with normal NLR. The high negative predictive value indicated that dogs with normal values of both biomarkers were unlikely to develop severe gastroenteritis and could be safely managed as outpatients, while elevation of either marker should prompt hospitalization. Thus, serum lactate and NLR are promising early predictors for risk stratification in dogs with AGE, and their combined use may help veterinarians to identify dogs that require closer monitoring and more intensive care. Limitations of the current study included a single-center design, a small sample size, and biomarker measurement at a single time point, which may limit generalizability. Multicenter studies are needed to confirm the prognostic value of NLR and serum lactate.

Declarations

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgments

The authors conducted the study independently and received no external contributions.

Authors' contributions

Ramtin Ghorban Pour conceptualized the study, designed the research protocol, and supervised the entire project from inception to completion. Ali Heydari served as the corresponding author, was responsible for clinical case enrollment, performed the physical examinations and severity scoring, and drafted the original manuscript. Ghazaleh Kompani contributed to clinical case enrollment and assisted in the assessment of clinical severity parameters. Sara Sadat Tavakoli was responsible for blood sample collection, laboratory analysis, and data curation. Ali Jebeli Eshrat Abadi performed statistical analyses and contributed to data interpretation. Parsa Jahani conducted the literature review and critically revised the manuscript for important intellectual content. All authors read and approved the final edition of the manuscript before submission. All authors have read and approved the final edition of the manuscript prior to publication in the present journal.

Competing interests

The authors declare no competing financial interests or personal relationships that could have appeared to influence the study reported in this manuscript.

Ethical considerations

The authors confirm that they carefully considered and addressed all ethical issues, including plagiarism, publication consent, research integrity, data fabrication and/or falsification, duplicate publication and/or submission, and redundancy, in accordance with accepted publication ethics standards. No generative artificial intelligence tools were used to generate data, results, or conclusions. Only Grammarly was used to remove grammatical errors. The authors further affirm that they are solely responsible for the accuracy, originality, and integrity of the final content both before initial submission, during the revision process, and upon final publication. The authors have checked and verified all scientific data, interpretations, and conclusions without reliance on AI for intellectual content.

Funding

The present study received no external funding.

References

1. Trotman TK. Gastroenteritis. In: Silverstein DC, Hopper K, editors. Small animal critical care medicine. 2nd ed. St. Louis: Elsevier; 2014. p. 622-626. DOI: 10.1016/B978-1-4557-0306-7.00117-3
2. Lawrence Y, and Lidbury J. Symptomatic management of primary acute gastroenteritis. Today's Vet Pract. 2015; 5(6): 46-52. Available at: https://todaysveterinarypractice.com/gastroenterology/symptomatic-management-of-primary-acute-gastroenteritis/
3. Pardo M, Spencer E, Odunayo A, Ramirez ML, Rudloff E, Shafford H, et al. 2024 AAHA fluid therapy guidelines for dogs and cats. J Am Anim Hosp Assoc. 2024; 60(4): 131-163. DOI: 10.5326/JAAHA-MS-7444 -2
4. Goggs R. The use of biomarkers to track and treat critical illness. Vet Clin North Am Small Anim Pract. 2025; 55(3): 459-482. DOI: 10.1016/j.cvsm.2025.01.010 -3
5. Hwang SY, Shin TG, Jo IJ, Jeon K, Suh GY, Lee TR, et al. Neutrophil-to-lymphocyte ratio as a prognostic marker in critically-ill septic patients. Am J Emerg Med. 2017; 35(2): 234-239. DOI: 10.1016/j.ajem.2016.10.055
6. Pino RM, and Singh J. Appropriate clinical use of lactate measurements. Anesthesiology. 2021; 134(4): 637-644. DOI: 10.1097/ALN.0000000000003655
7. Zahorec R. Neutrophil-to-lymphocyte ratio, past, present and future perspectives. Bratisl Med J. 2021; 122(7): 474-488. DOI: 10.4149/BLL_2021_078
8. Gillespie Í, Rosenstein PG, and Hughes D. Update: Clinical use of plasma lactate. Vet Clin Small Anim Pract. 2017; 47(2): 325-342. DOI: 10.1016/j.cvsm.2016.10.011
9. Buonacera A, Stancanelli B, Colaci M, and Malatino L. Neutrophil to lymphocyte ratio: An emerging marker of the relationships between the immune system and diseases. Int J Mol Sci. 2022; 23(7): 3636. DOI: 10.3390/ijms23073636
10. Sevim K, Çolakoğlu EÇ, and Kaya U. Evaluation of hematologic indices in parvovirus infected dogs with systemic inflammatory response syndrome (SIRS). Top Companion Anim Med. 2025; 66: 100977. DOI: 10.1016/j.tcam.2025.100977
11. Dinler Ay C. Neutrophil to lymphocyte ratio as a prognostic biomarker

in puppies with acute diarrhea. J Vet Emerg Crit Care. 2022; 32(1): 83-89. DOI: 10.1111/vec.13159 -4
12. Pierini A, Gori E, Lippi I, Ceccherini G, Lubas G, and Marchetti V. Neutrophil-to-lymphocyte ratio, nucleated red blood cells and erythrocyte abnormalities in canine systemic inflammatory response syndrome. Res Vet Sci. 2019; 126: 150-154. DOI: 10.1016/j.rvsc.2019.08.028
13. Pang DS, and Boysen S. Lactate in veterinary critical care: Pathophysiology and management. J Am Anim Hosp Assoc. 2007; 43(5): 270-279. DOI: 10.5326/0430270
14. Allen SE, and Holm JL. Lactate: Physiology and clinical utility. J Vet Emerg Crit Care. 2008; 18(2): 123-132. DOI: 10.1111/j.1476-4431.2008.00286.x
15. Boysen SR, and Dorval P. Effects of rapid intravenous 100% L-isomer lactated Ringer's administration on plasma lactate concentrations in healthy dogs. J Vet Emerg Crit Care. 2014; 24(5): 571-577. DOI: 10.1111/vec.12213
16. Acierno MJ, and Mitchell MA. Evaluation of four point-of-care meters for rapid determination of blood lactate concentrations in dogs. J Am Vet Med Assoc. 2007; 230(9): 1315-1318. DOI: 10.2460/javma.230.9.1315
17. Zahorec R. Ratio of neutrophil to lymphocyte counts-rapid and simple parameter of systemic inflammation and stress in critically ill. Bratisl Med J. 2001; 102(1): 5-14. DOI: 10.1007/BF03656390
18. Muñoz AI, Maldonado-García JL, Fragozo A, Vallejo-Castillo L, Lucas-Gonzalez A, Trejo-Martínez I, et al. Altered neutrophil-to-lymphocyte ratio in sepsis secondary to canine parvoviral enteritis treated with and without an immunomodulator in puppies. Front Vet Sci. 2022; 9: 995443. DOI: 10.3389/fvets.2022.995443
19. Hodgson N, Llewellyn EA, and Schaeffer DJ. Utility and prognostic significance of neutrophil-to-lymphocyte ratio in dogs with septic peritonitis. Vet Rec. 2018; 54(6): 351-359. DOI: 10.5326/JAAHA-MS-6808
20. Sänger F, Unterer S, Werner M, and Dörfelt R. C-reactive protein as a tool for monitoring response to treatment in dogs with acute hemorrhagic diarrhea syndrome. Front Vet Sci. 2023; 9: 1019700. DOI: 10.3389/fvets.2022.1019700
21. Cortellini S, Seth M, and Kellett-Gregory LM. Plasma lactate concentrations in septic peritonitis: A retrospective study of 83 dogs (2007-2012). J Vet Emerg Crit Care. 2015; 25(3): 388-395. DOI: 10.1111/vec.12234
22. Sarpong KJ, Lukowski JM, and Knapp CG. Evaluation of mortality rate and predictors of outcome in dogs receiving outpatient treatment for parvoviral enteritis. J Vet Med Assoc. 2017; 251(9): 1035-1041. Available at: https://avmajournals.avma.org/view/journals/javma/251/9/javma.251.9.1035.xml
23. Boonsri B, Chaengcheroen T, Jitprasert J, Suriyawong C, and Chantawong P. Comparative prognostic performance of quick sequential organ failure assessment, lactate, systemic inflammatory response syndrome criteria, and neutrophil-to-lymphocyte ratio for mortality prediction in critically ill dogs and cats. Vet World. 2026; 19(5): 2208-2220. DOI: 10.14202/vetworld.2026.2208-2220
24. Silverstein DC, and Hopper K, editors. Small animal critical care medicine. 3rd ed. St. Louis: Elsevier; 2020. Available at: https://www.elsevier.com/books/small-animal-critical-care-medicine/silverstein/978-0-323-76446-3
25. Mortier F, Strohmeyer K, Hartmann K, and Unterer S. Acute haemorrhagic diarrhoea syndrome in dogs: 108 cases. Vet Rec. 2015; 176(24): 627. DOI: 10.1136/vr.103090