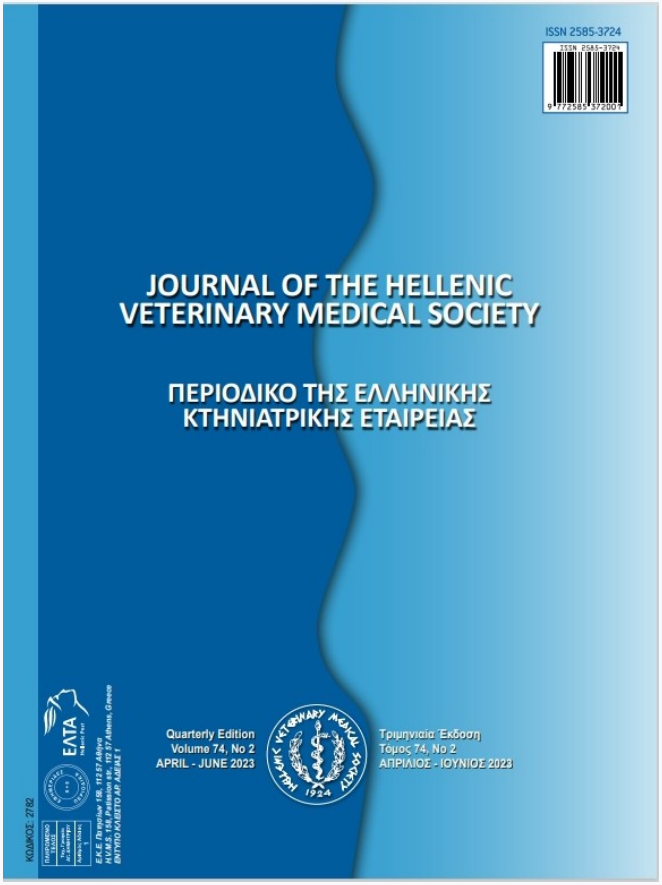
ePublishing

ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΤΕΚΜΗΡΙΩΣΗΣ
EKT NATIONAL DOCUMENTATION CENTRE

Journal of the Hellenic Veterinary Medical Society

Vol 74, No 3 (2023)



Diagnostic Performances of Clinical and Hematological Parameters in Cats Naturally Infected with Feline PanleukopeniaVirus

E Gülersoy, C Balıkçı, BB Erol, A Şahan, İ Günal

doi: 10.12681/jhvms.30721

Copyright © 2023, E Gülersoy, C Balıkçı, BB Erol, A Şahan, İ Günal

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0.

To cite this article:

Gülersoy, E., Balıkçı, C., Erol, B., Şahan, A., & Günal, İ. (2023). Diagnostic Performances of Clinical and Hematological Parameters in Cats Naturally Infected with Feline PanleukopeniaVirus: Clinical Parameters in Cats with Feline Panleukopenia Virus. *Journal of the Hellenic Veterinary Medical Society*, *74*(3), 6051–6062. https://doi.org/10.12681/jhvms.30721

https://epublishing.ekt.gr | **e-Publisher:** EKT | **Downloaded at:** 27/03/2026 02:22:24

J HELLENIC VET MED SOC 2023, 74 (3): 6051-6062
ΠΕΚΕ 2023, 74 (3): 6051-6062

Research article
Ερευνητικό άρθρο

Diagnostic Performances of Clinical and Hematological Parameters in Cats Naturally Infected with Feline PanleukopeniaVirus

E. Gülersoy[1,*], C. Balıkçı[1], B.B. Erol[2], A. Şahan[1], İ. Günal[1]

[1]*Harran University, Faculty of Veterinary Medicine, Department of Internal Medicine, Şanlıurfa, Türkiye*

[2]*Selçuk University, Faculty of Veterinary Medicine, Department of Internal Medicine, Konya, Türkiye*

ABSTRACT: Feline panleukopenia (FP) virus, which is closely related to canine parvovirus, is a fatalvirus that affects mitotically active tissues such as intestinal cells, lymphoid tissue and bone marrow in cats of all ages and causes a wide variety of clinical findings. Despite its high incidence, there is still a need for studies on the effectiveness of demographic, routine clinical and hemogram data on the diagnosis of FP, which has not been investigated as much as canine parvoviral infection. The Panleukopenia Group of the study consisted of 50 naturally infected cats with panleukopenia, and the Control Group consisted of 10 healthy cats of similar age and body weight. Information on sex, age, body weight, breed and origin of all cats was recorded. Venous blood samples were obtained from the cats eligible for inclusion in the study, and the diagnostic efficacy of clinical examination findings and demographic data along with hemogram parameters were investigated. Most of the Panleukopenia Group cats were indoor and were bought from a breeder. The most prominent clinical finding of the diseased cats was loss of appetite. This was followed by dehydration, stagnation, depression, vomiting, diarrhea and ocular discharge. In clinical examination, respiratory rate, pulse and body temperature values were higher in the Panleukopenia Group ($p<0.017$). As a result of hemogram analysis, it was determined that WBC, lymphocyte, monocytes, granulocytes, RBC, Hct, RDW, Hb and THR levels were lower in the Panleukopenia Group ($p<0.040$). As a result of the ROC analysis, it was determined that from clinical examination parameters, respiratory rate had excellent, pulse and body temperature had good; from hemogram parameters, WBC and granulocyte had outstanding, lymphocyte and RDW had excellent, monocytes, Hct and THR had good, RBC and Hb had acceptable diagnostic performances. As a result, it was concluded that demographic data and clinical findings along with abnormal leukograms such as leukopenia, lymphopenia and granulocytopenia and abnormal hemogram patterns such as anemia and thrombocytopenia may be helpful in the diagnosis of FP in triage and in cases where antibodies bind to viral epitopes resulting in false negatives.

***Keywords*:** Cat; demography; diagnosis; hematology;panleukopenia

Corresponding Author:
Harran University, Faculty of Veterinary Medicine, Department of Internal Medicine, 63200, Şanlıurfa, Türkiye
E-mail address: egulersoy@harran.edu.tr

Date of initial submission: 05-07-2022
Date of acceptance: 22-10-2022

INTRODUCTION

Feline panleukopenia (FP) infection is a fatal and highly contagious viral disease of cats caused by feline parvovirus, which is a DNA virus. Common reservoirs of FP are shelters, pet shops, breeders, stray cats and unvaccinated cats (Truyenet al., 2009). For this reason, FP is more important especially in animal shelters, multi-cathouseholds and among unvaccinated cat populations (Pandey, 2022). Although cats of any age can be affected by the infection, young, weak and unvaccinated cats are more susceptible. Death from FP is most common in cats aged between 3 and 5 months (Stuetzerand Hartmann, 2014). Although faecal-oraltransmission is the most common route, transmission through other secretions and urine is also possible. The average incubation period of the disease varies between 4-7 days, but in some cats this period can be extended up to 2 weeks (Rice, 2017).

The virus causes cytopathic effects in rapidly growing and dividing tissues such as bone marrow, lymphoid tissue, intestines and developing fetus (Evermannand Kennedy, 2011). The clinical manifestations of FP are nonspecific, especially in the early stages of the disease and in severely affected kittens. The peracute form is characterized by septic shock and sudden death. Acute early findings of the disease are lethargy, pyrexia, anorexia and vomiting. Although FP virus is closely related to canine parvovirus, hemorrhagicdiarrhea in cats is not a reliable finding, unlike canine hemorrhagicparvoviral enteritis (Hartmann and Hein, 2002). The development of functional immunosuppression is dependent on cellular depletion due to infection of lymphoid tissue. In addition, the bone marrow is also affected and virus replication occurs in early progenitor cells with severe effects on myeloid cell populations. Cytopeniaoccurs due to bone marrow depression, due to active viral replication in hematopoietic cells and abnormal hematological findings such as leukopenia, neutropenia and anemia, which are the most common non-neoplastic findings of FP (Parrish, 1995;Truyenand Parrish, 2000).

Hemogram analysis is important both in forming a differential diagnosis list and in deciding on the initiation of the vaccination program when applying to clinics and/or hospitals for diagnostic and treatment purposes. Since FP is also a vaccine-preventable disease, vaccination provides prevention and protection of the population from other potential diseases, including FP (Weiss andWardrop, 2010). Despite the ongoing studies on FP, the number of studies investigating the diagnostic efficiency of clinical findings, environmental aspects and routine hematological analysis is limited (Kruse et al., 2010;Awadet al., 2018). Therefore, rapid and accurate diagnosis with routine parameters is still difficult, especially in triage (Litster andBenjanirut, 2014). The aim of this study is to investigate the clinical findings, hemogram parameters and environmental aspectswhich can be used in the suspicion and/or diagnosis of FP, and to optimize the effectiveness of these parameters in early diagnosis before deciding to apply the faecal antigen detection test.

MATERIALS AND METHODS

We informed and received the permission of the owners of the cats included in this study for taking samples used in the present study. Samples were collected as per standard sample collection procedure without any harm to animals.

Animal material

The animal material of the study was consisted of a total of 60 cats; 50 cats naturally infected with panleukopenia (Panleukopenia Group) and 10 healthy cats (Control Group). All were brought to Harran University Veterinary Faculty Animal Hospital either for diagnosis and treatment or routine check-up. Information on sex, age, body weight, breed and origin of all cats was recorded.

All cats included in the study were owned, unvaccinated, some with outdoor access, but mostly indoor and fed on commercial dry food. All cats were mixbreed and 52% were female and 48% were male. All cats were selected from similar ages and body weights in order to avoid the influence of the physiological differences on clinical and hemogram parameters. The median age of the Control Group was 5 (3-6) and the Panleukopenia Group was 4.5 (3-7) months. Body weights were 1.05 (0.7-1.3) kg in the Control Group and 1 (0.6-1.65) kg in the Panleukopenia Group. There was no statistical difference in the comparison of median age and body weight between the groups ($p>0.908$ and $p>0.565$, respectively). Anamnestic data revealed that the duration of clinical symptoms ranged from 1 to 7 days in the Panleukopenia Group. Demographic data of Panleukopenia Group are presented in Table 1.

Table 1. Demographic data of Panleukopenia Group

Condition	Number of cats	Percentage (%)
Housing condition		
Multicat	13	26
Single-cat household	37	74
Total	50	100
Environment		
Indoor	44	88
Outdoor	6	12
Total	50	100
Origin		
Shelter	12	24
Stray	8	16
Pet shop	12	24
Breeder	18	36
Total	50	100

Clinical examinations

Clinical examinations including lung and heart auscultation, evaluation of mucous membrane, capillary refill time (CRT) and palpable lymph nodes along with abdominal palpationwere performed by the same personnel with the same examination protocol. Feline ataxia was not present in any of the cats with suspected panleukopenia in the present study. Thus, it was ensured that the diseased cats in the present study exposed the virus naturally via the faecal-oral route, not in utero.

Application of rapid diagnostic test kits

Faecal samples were obtained from FP suspected cats with anal or rectal swabs. At first, swabs were wetted with sterile isotonic and the sample was taken rectally in cases where there was no faeces in the anus and perineum. Due to its low-to-moderate sensitivity (50-80%) and good-to-excellent specificity (94.2-100%), the IDEXX SNAP® Parvo test was used for diagnosis (Neuereret al., 2008) and the tests were performed by trained research assistants at the central laboratory according to the manufacturer's instructions. Positive results were recorded as weakly positive or positive according to color intensity.

Inclusion/exclusion criterias

Inclusion criteria to suspect FP were the presence of clinically compatible findings (absence of diarrhea, vomiting, lethargy and fever in kittens; presence of anorexia, hyporexia, lethargy, vomiting and diarrhea in older cats) and abnormal laboratory findings (leukopenia, anemia, thrombocytopenia) along with positive faecal IDEXX SNAP® Parvo test result (Hartmann et al., 2007). Cats with a previous history of disease or with blood transfusion were not included in the study. All cats included in the study were examined for FeLV and FIV (IDEXX SNAP FIV/FeLV Combo Test®, IDEXX Laboratories) using rapid diagnostic test kits measuring p27 antigen for FeLV (sensitivity of 98.6% and specificity of 98.2%) and antibodies for FIV (sensitivity of 93.5% and specificity of 100%). All cats were tested once and cats with insufficient/suspicious results were excluded from the study. Although anamnestic data revealed that all the cats included in the study have been dewormed only once so far, microscopic faecal examinations were performed and no parasites and/or eggs were found.

Blood sampling and performing hemogram analysis

Venous blood samples were obtained from all the cats with minimal restraint and patient stress by vena cephalica or vena jugularis venepuncture (1-2 mL). Hematological parameters (leukocyte (WBC), lymphocyte, monocyte, granulocyte, erythrocyte (RBC), mean corpuscular volume (MCV), haematocrit (Hct), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), reticulocyte distribution width (RDW), hemoglobin (Hb) and thrombocyte (THR)) were measured from blood samples with K_3EDTA using an automated hematologyanalyzer (Sysmex poch-100i®, Canada) within 5-10 minutes after sampling. All results were compared with laboratory reference values.

Statistical analysis

Data analysis was evaluated using SPSS 25.00 (SPSS for Windows®) statistical software and one sample Kolmogorov-Smirnov test was applied to determine whether all data were parametric or non-parametric. Non-parametric data were evaluated as median (min, max) using Mann-Whitney U, Kruskal-Wallis test. After the null hypothesis test, in order to determine the optimal cut-off values and to discuss the issues of bias and confounding, receiver operating characteristic curve (ROC) analyses was performed for further investigation of diagnostic effectiveness of aforementioned clinical and haematological parameters. Observed power (Op or post hoc power) was obtained by performing general linear model univariate analysis using the same statistical software. A non significant result may indicate a correct statistical decision or Type 2 error, but since low Op cannot make this distinction, Op was considered <0.5 (< 50%) for non significant tests, and low Op value was interpreted due to the small sample size. Diagnostic performance were evaluated with parameters including area under curve (AUC>0.600), P value (<0.05), sensitivity and specificity (>70%), and observed power (Op, %). Definitions of AUC values were compared with previously reported scientific data (Yang andBerdine, 2017). Statistical significance was regarded as $p<0.05$.

RESULTS

The most prominent clinical finding of the Panleukopenia Group was loss of appetite (46 out of 50 cats, 92%). Other findings were dehydration (41 out of 50, 82%), stagnation (38 out of 50, 76%), depression (30 out of 50, 60%), vomiting (27 out of 50, 54%), diarrhea (27 out of 50, 54%) and ocular discharge (24 out of 50, 48%), respectively.Although pain and thickened intestinal loops on abdominal palpation are commonly reported (Sykes, 2009), the findings in the current study were very mild/unremarkable.The clinical findings and percent distribution of panleukopenic cats are presented in Table 2, and the bar chart is presented in Figure 1.

As a result of the clinical examination, respiratory rate, pulse and body temperature values of the Panleukopenia Group were observed to be higher than those of the Control Group ($p<0.017$). No statistical difference was detected in the CRT value ($p>0.05$). Clinical examination results are presented in Table 3.

As a result of hemogram analysis, it was determined that WBC, lymphocyte, monocytes, granulocytes, RBC, Hct, RDW, Hb and THR levels of the Panleukopenia Group were lower than those of the Control Group ($p<0.040$). No statistical difference was observed between the groups in terms of MCV,

Table 2. Clinical findings and percentage distributions of the Panleukopenia Group

Clinical Findings	Number of cats	Percentage (%)
Vomiting	27 out of 50	54
Diarrhea	27 out of 50	54
Ocular discharge	24 out of 50	48
Loss of appetite	46 out of 50	92
Stagnation	38 out of 50	76
Depression	30 out of 50	60
Dehydration	41 out of 50	82

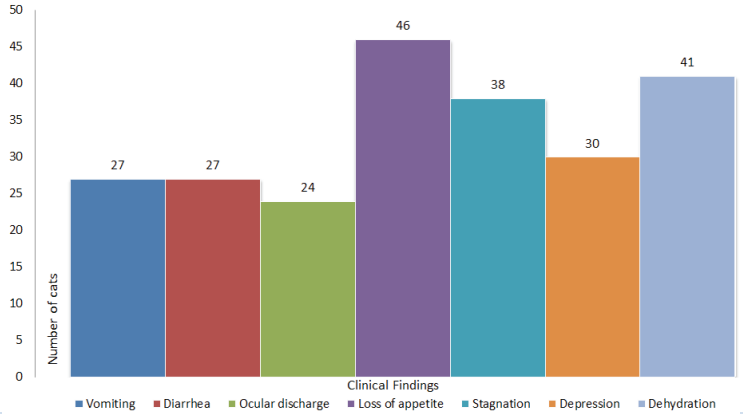


Figure 1. Bar chart of the clinical findings of the Panleukopenia Group

MCH and MCHC levels (p>0.05). Hemogram analysis results are presented in Table 4.

Comparative ROC analysis was performed to evaluate the diagnostic performances of clinical and hematological parameters in the diagnosis of FP, which were previously determined to be statistically different in the comparison between the groups. As a result of the comparative ROC analysis of the clinical examination parameters, it was determined that the respiratory rate had excellent (AUC: 0.805), and the pulse and body temperature values had good (AUC: 0.729 and AUC: 0.772, respectively) diagnostic performances. Comparative ROC analysis of diagnostic performances of clinical examination parameters are presented in Table 5 and ROC curves are presented in Figure 2.

As a result of the comparative ROC analysis of the hemogram parameters, it was determined that WBC and granulocyte had outstanding (AUC: 0.992 and AUC: 0.971, respectively), lymphocyte and RDW had excellent (AUC: 0.890 and AUC: 0.841, respectively), monocytes, Hct and THR had good (AUC:

Table 3. Clinical examination results

Parameters	Control Group (n:10) median (min, max)	Panleukopenia Group (n:50) median (min, max)	P value
Respiratory rate (breaths/min)	48 (38, 80)	68 (40, 94)	0.005
Heart rate (beats/min)	123 (106, 144)	138 (96, 160)	0.017
Body temp (°C)	38.4 (37.9, 39)	39.25 (36.7, 40.5)	0.001
CRT (seconds)	3 (2, 3)	2 (1, 4)	0.214

Body temp: Body temperature, CRT: Capillary refill time

Table 4. Hemogram analysis results

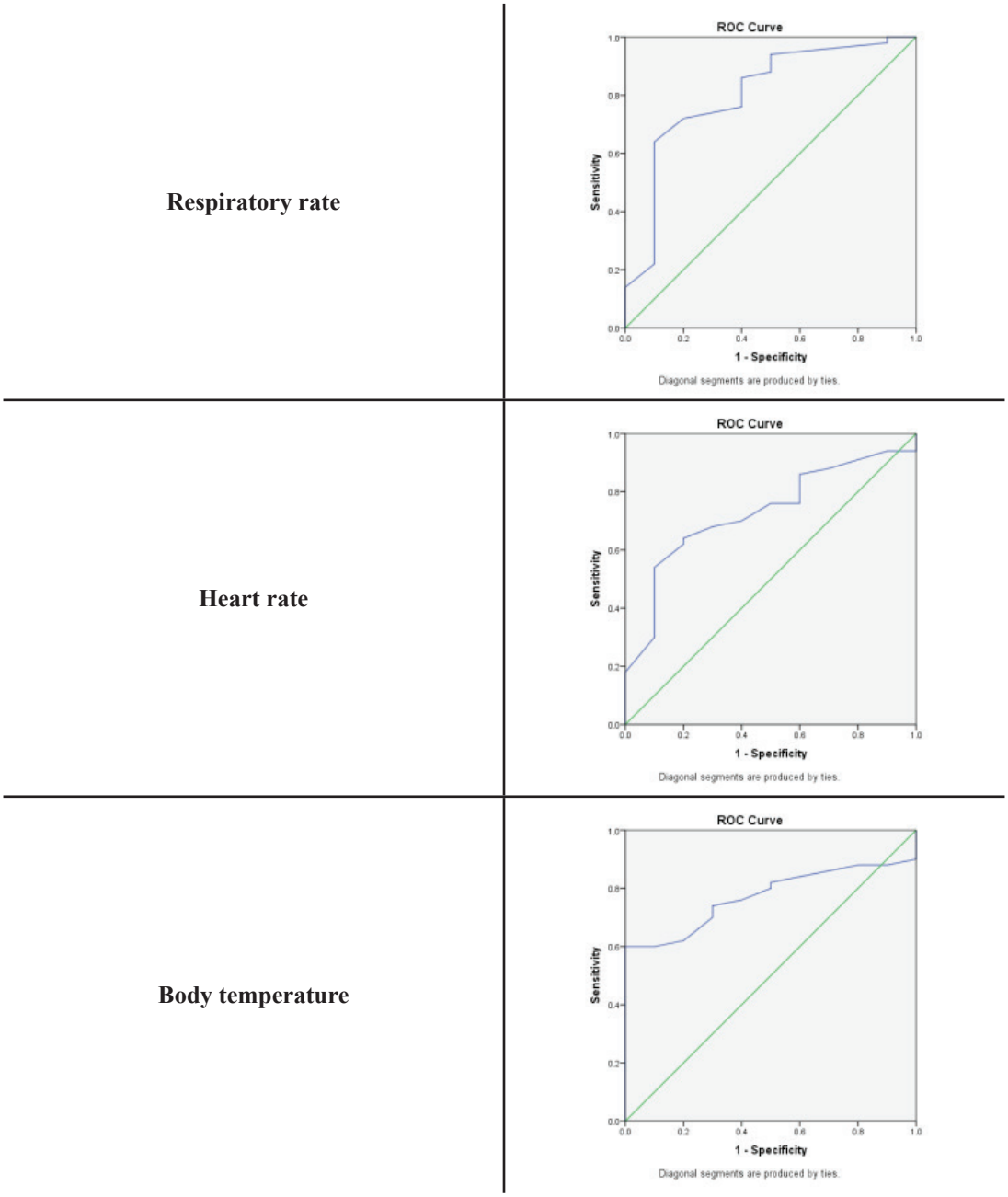
Parameters	Control Group (n:10) Median (min, max)	Panleukopenia Group (n:50) Median (min, max)	P value
WBC (10^9 cells/liter)	**11.83 (9.12, 18.84)**	**5.1 (0.33, 10.07)**	**0.000**
Lymphocyte (10^9 cells/liter)	**4.37 (1.78, 6.37)**	**1.9 (0.26, 5.9)**	**0.000**
Monocyte (10^9 cells/liter)	**0.87 (0.17, 1.83)**	**0.36 (0.02, 2.69)**	**0.025**
Granulocyte (10^9 cells/liter)	**6.97 (4.62, 12.52)**	**1.55 (0.05, 6.43)**	**0.000**
RBC (M/mm^3)	**10.4 (6.42, 13.29)**	**7.74 (2.3, 14.96)**	**0.039**
MCV (fl)	47.8 (43, 73.5)	45.5 (30, 80.2)	0.474
Hct (%)	**50 (33, 62.3)**	**35.95 (15.4, 70.6)**	**0.018**
MCH (pg)	12.35 (9.3, 20.2)	13.2 (7.2, 28)	0.750
MCHC (g/dl)	26.95 (20.5, 38.4)	28.25 (17.6, 37.1)	0.232
RDW	**16.8 (14.3, 18.1)**	**12.7 (7.9, 28.8)**	**0.000**
Hb (g/dl)	**12.55 (9.8, 16.8)**	**10.55 (3.8, 17.4)**	**0.040**
THR (M/mm^3)	**170.5 (55, 296)**	**84.5 (14, 273)**	**0.031**

WBC: Leukocyte, RBC: Erythrocyte, MCV: Mean corpuscular volume, Hct: Hematocrit, MCH: Mean corpuscular haemoglobin, MCHC: Mean corpuscular haemoglobin concentration, RDW: Reticulocyte distribution width, Hb: Hemoglobin, THR: Thrombocyte

Table 5. ROC-based diagnostic performances of clinical examination parameters

Parameters	AUC	Std. Er.	P value	Asymp. 95% CI		Cut-off	Sensitivity (%)	Spesifity (%)	Op (%)
				Lower Bound	Upper Bound				
Respiratory rate	0.805	0.081	0.002	0.647	0.963	62	72	80	91.3
Heart rate	0.729	0.077	0.023	0.577	0.881	128	68	70	59.3
Body temp	0.772	0.060	0.007	0.655	0.889	38.65	74	70	61.4

Body temp: Body temperature, AUC: Area under curve, Std. er.:Standart error, CI: Confidence interval, Op: Observed power



Diagonal segments are produced by ties.

Figure 2. ROC curves of clinical examination parameters

0.771, AUC: 0.720 and AUC: 0.750, respectively), RBC and Hb had acceptable diagnostic performances (AUC: 0.686 and AUC: 0.659, respectively). Comparative ROC analysis of diagnostic performances of hemogram parameters are presented in Table 6 and ROC curves are presented in Figure 3.

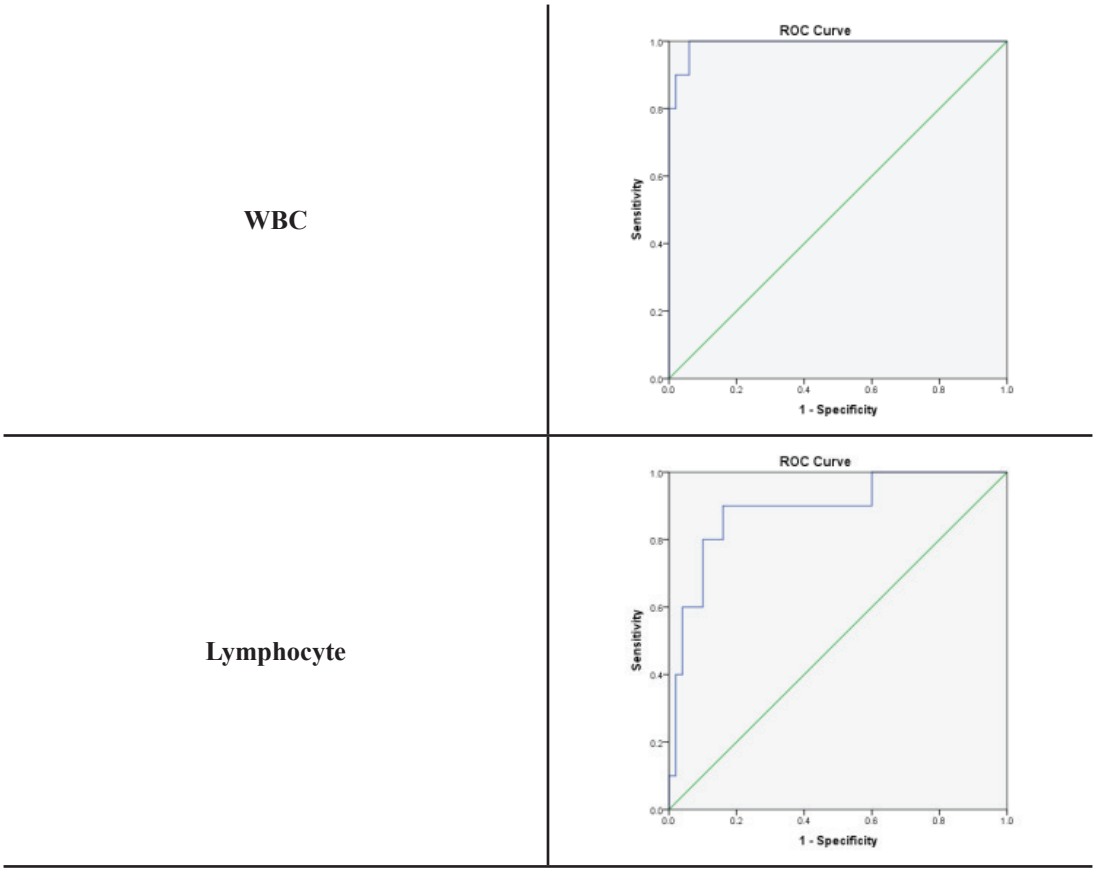
DISCUSSION

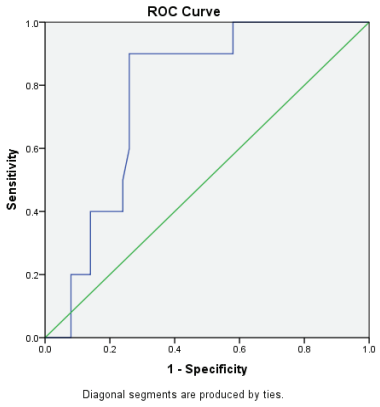
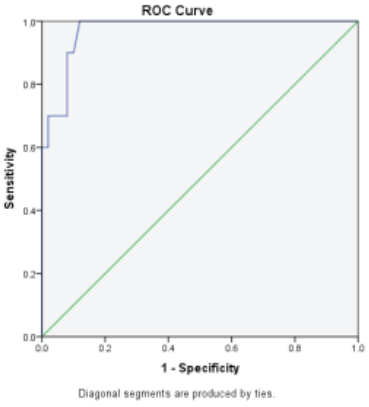
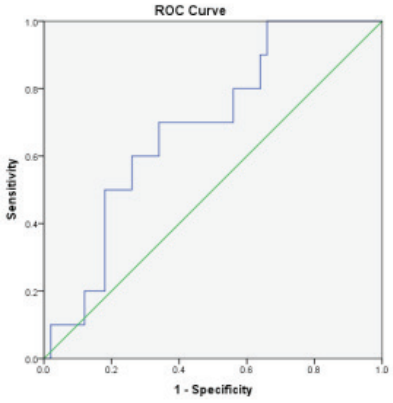
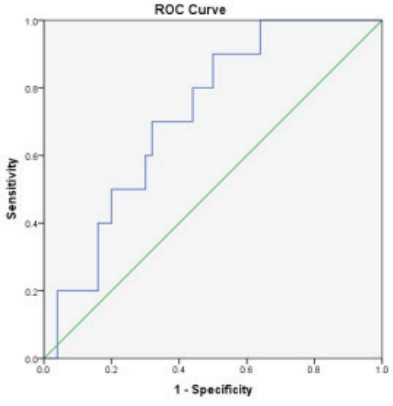
In this study, clinical findings, hemogram parameters and demographic data including environmental aspects and origin were investigated together in order to evaluate which factors and parameters were effective in the diagnosis and predisposition of the disease and important data were obtained.

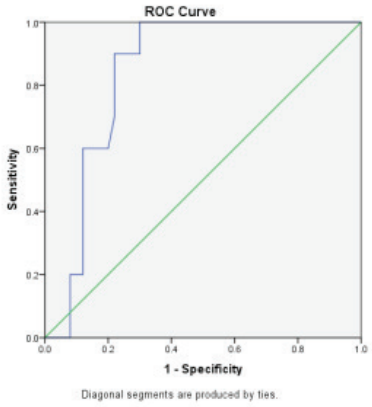
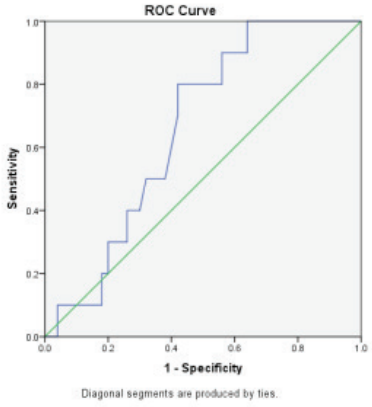
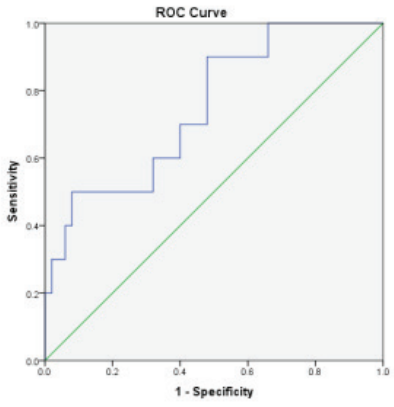
Table 6. ROC-based diagnostic performances of hemogram parameters

Parameters	AUC	Std. Er.	P value	Asymp. 95% CI		Cut-off	Sensitivity (%)	Spesifity (%)	Op (%)
				Lower Bound	Upper Bound				
WBC	0.992	0.008	0.000	0.976	1.000	8.43	100	94	100
Lym	0.890	0.059	0.000	0.774	1.000	3.16	90	84	99.9
Monocyte	0.771	0.064	0.007	0.645	0.897	0.61	90	74	53.6
Gra	0.971	0.019	0.000	0.933	1.000	4.56	100	88	100
RBC	0.686	0.082	0.065	0.525	0.847	8.60	70	64	46.2
Hct	0.720	0.075	0.029	0.573	0.867	46.05	70	68	55.1
RDW	0.841	0.050	0.001	0.743	0.939	14.25	100	70	68.4
Hb	0.659	0.075	0.115	0.512	0.806	11.70	80	54	33.6
THR	0.750	0.082	0.013	0.589	0.911	136.5	60	68	84.8

WBC: Leukocyte, Lym: Lymphocyte, Gra: Granulocyte, RBC: Erythrocyte, Hct: Hematocrit, RDW: Reticulocyte distribution width, Hb: Hemoglobin, THR: Thrombocyte, AUC: Area under curve, Std. er.:Standart error, CI: Confidence interval, Op: Observed power



Monocyte	
Granulocyte	
RBC	
Hct	

RDW	
Hb	
THR	

WBC: Leukocyte, RBC: Erythrocyte, Hct: Hematocrit, RDW: Reticulocyte distribution width, Hb: Hemoglobin, THR: Thrombocyte. Diagonal segments are produced by ties.

Figure 3. ROC curves of hemogram parameters

Cats begin shedding the virus a few days to 6 weeks after exposure to FP virus. The virus is highly resistant and persists for years at room temperature and in organic matter (Sykes, 2009). In previous reports, it was reported that indirect transmission has an important place in the spread of infection, as domestic cats have a higher incidence of disease than outdoor cats or those having access to outside. It was demonstrated that contaminated clothing, cages and even insects may be an important factor in this type of contamination (Truyenet al., 2009). In the present study, the fact that most of the cats with FP were bought from breeders and were indoor cats living in single-cat households, may be related to the inadequacy of control strategies in breeders, the vaccination status of queens and the risk of exposure of kittens to potential reservoir cats. Thus, it can be said that persistent viral, unsuitable breeders and populous environments in shelters play an important role in the transmission of the disease (Sykes, 2009). In addition, stress and

behavioral disorders associated with early weaning may also make cats more susceptible to viral diseases (Pandey,2022). Demographic data obtained as a result of the present study indicate that although breeders help kittens make a good start in their life, they should undergo health check-ups (Green and Mellor, 2011). Moreover, due to the extreme physicochemical stability of FP, it should be taken into consideration that contaminated cages, litter trays, food and water bowls, shoes and clothing can play an important role in transmission, and attention to hygiene is of utmost importance (Truyenet al., 2009).

The severity of clinical findings in FP cases varies depending on age, immune status, and presence of concomitant disease, and these findings may range from subclinical infection to peracute syndrome which is characterized by sudden death (Foley et al., 1999). The most common non-specific findings are anorexia, lethargy, fever, dehydration, vomiting and diarrhea, especially in older cats (Greene, 2012). After faecal-oral transmission, the virus replicates mainly in macrophages of the oropharynx and regional lymph nodes, and then spreads throughout the body (Cohn and Langdon, 2008). Since intestinal crypt cells are also mitotically active cells, the virus replicates and damages intestinal villi causing malabsorption and increased permeability and diversifies clinical findings (Stuetzerand Hartmann, 2014). Death is usually due to complications such as bacterial translocation, secondary bacterial infections, sepsis, dehydration, and disseminated intravascular coagulopathy (DIC) (Addie et al., 1998). In the present study, loss of appetite, dehydration and stagnation were more prominent among the clinical findings in cats with FP compared to other clinical findings. This is related to the fact that the virus mostly affects rapidly dividing intestinal epithelial cells. Other findings, such as ocular discharge, may be associated with secondary bacterial infections resulting from immunosuppression. Since the clinical findings of the disease are milder in 1-2 month old cats and more severe in 3-10 month old cats (Awadet al., 2018), the evaluation of variable clinical findings with demographic data helps in the diagnosis of FP and can give an idea about the presence of any coexisting disease.Hyperpnea, weak pulse strength, pallor of the mucous membranes and fever, which are evident in the initial period of the disease and decrease with the progression of the disease, are reported in cats with FP (Mayuret al., 2016). Previous studies have reported that mucosal hyperemia, variable pulse quality and hyperpnea are due to peripheral vasodilation and subsequent vasoconstriction associated with septicemia (Riya et al., 2020). In the present study, compared to the Control Group, the higher respiratory rate, pulse and body temperature of the Panleukopenia Group ($p<0.017$) may be associated with the development of sepsis. In addition, tachypnea, hyperpnea and tachycardia may be the result of anemia (Sykes and Hartmann, 2014). In previous studies, FP-infected shelter cats that were not lethargic and had fever at first examination had a higher survival rate (Litster andBenjanirut, 2014). In the present study, the ROC-based findings (excellent diagnostic performance of respiratory rate (AUC: 0.805) and good diagnostic performances of heart rate and body temperature (AUC: 0.729 and AUC: 0.772, respectively), Table 5) were consistent with the parameters to be evaluated. Evaluation of respiratory rate in addition to other clinical parameters may help diagnose cats with suspected panleukopenia in triage and initiate early treatment protocols.

Evaluation of laboratory data and comparison with reference values is very important in routine practice (Harvey, 2017). Although the diagnosis of FP is made by the detection of FP antigen in faeces, it is essential to evaluate the anamnesis, clinical findings and hematological abnormalities (Stuetzerand Hartmann, 2014). As the virus infects all tissues, including lymphoid tissue, with cell-free viremia, cellularity decreases and results in immunosuppression (Parrish, 1995;Truyenand Parrish, 2000). Thus, abnormal leukogram patterns often occur in cats with FP. The most prominent finding is a decrease in total WBC counts which is characterized by neutropenia and lymphopenia (Shelton et al., 1990). There are several mechanisms for the development of neutropenia. These are increased use in tissue, bone marrow damage, lack of neutrophil production and sequestration of neutrophils as a result of endotoxemia due to viral disease (Weiss andWardrop, 2010). Monocytopenia, an indicator of poor prognosis, is frequently reported and associated with myelotoxicity (Kruse et al., 2010). In the present study, WBC, lymphocyte, monocyte and granulocyte levels were found to be lower in the Panleukopenia Group compared to the Control Group ($p<0.025$). The abnormal leukogram patterns detected in the present study can be explained by the direct cytopathic effects of the virus on the bone marrow. In addition, conditions that contribute to the development of cytopenia, persistent or cyclic neutropenia and lymphopenia include thymic atrophy, myelosuppressive syndrome and depletion of the paracortical regions of the lymph nodes

(Sykes, 2010; Hartmann, 2011). In the present study, it was determined that, WBC and granulocyte had outstanding (AUC: 0.992 and AUC: 0.971, respectively), lymphocyte had excellent (AUC: 0.890), and monocyte had good (AUC: 0.771) diagnostic performances (Table 6). Evaluation of the aforementioned abnormal parameters, especially WBC and granulocyte counts, together with clinical findings can provide useful information about both prognosis and when forming a differential diagnosis list.

The most common hematological abnormalities observed in cats with FP are anemia (low RBC, Hb, and Hct), low RDW level, and thrombocytopenia (Shelton et al., 1990). Anemia, which is an important and serious complication of infection, may occur due to bone marrow depression, sepsis and inflammatory condition. Due to the long lifespan of erythrocytes, anemia is not evident unless intestinal blood loss is severe. Nevertheless, non-regenerative anemia is a common finding for FP. Anemia cases that are not severe may be masked by dehydration in cases of panleukopenia (Truyenet al., 2009). Another common abnormality in cats with FP is thrombocytopenia (Kruse et al., 2010). In the hemogram analysis of the present study, the RBC, Hct, RDW, Hb and THR levels of the Panleukopenia group were lower compared to the Control group ($p<0.0040$). Anemia in cats with FP may be associated with chronicity of the disease as well as with the suppression of bone marrow, immune system and inflammation due to opportunistic infections. Other possible mechanisms are structural changes of the bone marrow due to cytokines or direct cytopathic effects of the virus (Gleichand Hartmann, 2009).RDW reflects the extent of anisocytosis, which is a condition that is characterized by pronounced heterogeneity in the volume of circulating erythrocytes. It has also been reported that RDW may be a prognostic marker in various viral diseases (Uffenet al., 2019). Although low RDW levels of the panleukopenic cats in the present study indicate isocytosis, it may be associated with macrocytic anemia (Ramachandran et al., 2022). In addition, thrombocytopenia may be related to the damage caused by the virus to the progenitor cells of the bone marrow. Moreover, decreased thrombocyte counts also affect the immune system and the defense mechanisms of the whole body become disrupted. This also explains the various clinical findings ranging from ocular discharge to anorexia of the panleukopenic cats in the present study (Banchereauet al., 2000). In the comparative ROC analysis of the present study, it was determined that RDW had excellent (AUC: 0.841), THR had good (AUC: 0.750), RBC and Hb had acceptable (AUC: 0.686 and AUC: 0.659, respectively) diagnostic performances (Table 6). Hematological parameters of diagnostic importance determined in the present study can be used to support the suspicion of panleukopenia in triage when evaluated together with clinical findings.

The absence of clinical findings and immunosuppression in all cats with FP is associated with the important role of immunity in the disease, and WBC counts are important for the diagnosis and prognosis of the infection. It has been reported that the most severe clinical findings and death in panleukopenic cats are observed during the period when WBC counts are lowest. However, it was reported that leukopenia alone is not associated with the outcome of the disease and should be evaluated together with neutropenia (Truyenet al., 2009; Kruse et al., 2010).

This study has some limitations.The tropism of the virus to rapidly growing and dividing tissues and progenitor cells is the reason why many systems are affected in the body, and it is recommended to investigate the presence of anemia and thrombocytopenia along with leukogram patterns in the evaluation of prognosis. However, the fact that serum biochemistry was not investigated and blood smear was not examined in the present study can be considered as a limitation. Although the small sample size scenario is common in medical tests, a comprehensive study of small sample size properties of various methods for the construction of the confidence/credible interval (CI) for the AUC has been by and large missing in the literature. As previously reported (Feng et al., 2017) it was observed that the larger the true AUC value and the smaller the sample size, the larger the discrepancy among the results of different approaches. Therefore, another limitation of this study is the limited and unequal numbers of animals between the two groupswhich may influence the results of the ROC-based diagnostic performance analyses. Therefore, evaluating the clinical findings, demographic data and hematochemical parameters in a larger number of naturally infected cats may reveal the effects of the virus on the results of routine examination and analysis in more detail.

CONCLUSIONS

Feline panleukopenia infection remains a threat to feline health. Unvaccinated cats are particularly susceptible to the disease. Environmental precautions, isolation and treatment of infected animals are

important for the protection of the feline population. Despite the high incidence of FP, there is still a need both for routine clinical and molecular studies on this subject, which has not been studied as much as canine parvoviral infection (Pandey, 2022). As a result, it was concluded that demographic data and clinical findings along with abnormal leukogram patterns such as leukopenia, lymphopenia, granulocytopenia and hematological abnormalities such as anemia and thrombocytopenia may be helpful in the diagnosis of FP in triage and in cases where antibodies can bind to viral epitopes and give false negatives. In addition, the investigation of aforementioned parameters may help in deciding on the initiation of appropriate vaccination programs and may contribute to the prevention of other potential diseases, including FP, and to the protection of the feline population.

ACKNOWLEDGEMENTS

The authors thank their institutions and/or faculties.

CONFLICTS OF INTEREST

The authors have no declaration of competing interests.

REFERENCES

Addie DD, Toth S, Thompson H, Greenwood, Jarrett NJO (1998) Detection of feline parvovirus in dying pedigree kittens. Vet Rec 142:353-356.

Awad RA, Khalil WKB, Attallah GA (2018) Epidemiology and diagnosis of feline panleukopenia virus in Egypt: Clinical and molecular diagnosis in cats. Vet World 11:578-584.

Banchereau J, Briere F, Caux C, Davoust J, Lebecque S, Liu, YJ, Pulendran B, Palucka K (2000)Immunobiology of dendritic cells. Annu Rev Immunol 18:767-811.

Cohn LA, Langdon P (2008) Viral Infections. In: Handbook of Small Animal Practice. 5th ed, Saunders, Philadelphia: pp 576-586.

EvermannJF,Kenned MA (2011) Viral Infections. Small Animal Pediatrics, 11:119-129.

Feng D, Cortese G, Baumgartner R (2017)A comparison of confidence/credible interval methods for the area under the ROC curve for continuous diagnostic tests with small sample size. Stat Methods Med Res 26:2603-2621.

Foley JE, Orgad U, Hirsh DC, Poland A, Pedersen NC (1999). Outbreak of fatal salmonellosis in cats following use of a high-titer modified-live panleukopenia virus vaccine. J Am Vet Med 214:43-64, 67-70.

Gleich S,Hartmann K (2009) Hematology and serum biochemistry of feline immunodeficiency virus-infected and feline leukemia virus-infected cats.J Vet Intern Med 23:552-558.

Green T, Mellor D (2011) Extending ideas about animal welfare assessment to include 'quality of life' and related concepts. N Z Vet J 59:263 - 271.

Greene CE (2012) Feline enteric viral infections.In: Infectious diseases of the dog and cat, 4thed, St. Louis: pp80-91.

Hartmann K,Hein J (2002)Feline panleukopenie.Praxisrelevantefragenanhandeines.Fallbeispiels.TierarztlPrax30:393-99.

Hartmann K (2011) Clinical aspects of feline immunodeficiency and feline leukemia virus infection.VetImmunolImmunopathol 143:190-201.

Hartmann K, Griessmayr P, SchulzB, Greene CE, Viddyashankar AN, Jarrett O,Egberink HF (2007) Quality of different in-clinic test systems for feline immunodeficiency virus and feline leukaemia virus infection. J Felin Med Surg9:439-445.

Harvey JW (2017)The feline blood film: Techniques and erythrocyte morphology. J Felin Med Surg 19:529-540.

Kruse BD, Unterer S, Horlacher K, Sauter-Louis C, Hartmann K (2010) Prognostic Factors in Cats with Feline Panleukopenia. J Vet Intern Med 24:1271-1276.

Litster A,Benjanirut C (2014)Case series of feline panleukopenia virus in an animal shelter. J Felin Med Surg 16:346-353.

Mayur TC, Ansar KC, Ramesh PT (2016) Diagnosis of feline panleukopenia and feline leukemia virus using rapid test kits.Int J AgricVetSci 4:72-75.

Neuerer FF, Horlacher K, Truyen U, Hartmann K (2008)Comparison of different in-house test systems to detect parvovirus in faeces of cats.J Felin Med Surg10:247-251.

Pandey S (2022) Feline Panleukopenia Infections: Treatment and Control in Nepal.EJ Vet Med 2:10-14.

Parrish CR (1995) Pathogenesis of feline panleukopenia virus and canine parvovirus.BailliersClinHaematol8:57-71.

Ramachandran P, Gajendran M, Perisetti A, Elkholy KO, Chakraborti A, Lippi G,Goyal H (2022)Red Blood Cell Distribution Width in Hospitalized COVID-19 Patients. Front Med (Lausanne) 7:582403.

Rice JK (2017) Successful Treatment of Feline Panleukopenia: A Guideline for Rescuers and Veterinarians, Part I. J Vet Med Sci6:2.

Riya B, Rathish RL, Deepa PM, John L, Janus A, Vijaykumar K (2020) Clinical Manifestations in cats with feline panleukopenia. Vet AnimSci51:97 - 100.

Shelton GH, Linenberger ML, Grant CK, Abkowitz JL (1990) Hematologic manifestations of feline immunodeficiency virus infection. Blood 76:1104-1109.

Stuetzer B, Hartmann K (2014) Feline parvovirus infection and associated diseases. Vet J 201:150-155.

Sykes JE (2010)Immunodeficiencies caused by infectious diseases.VetClin North Am Small Anim 40:409-423.

Sykes JE, Hartmann K (2014) Feline Leukemia Virus Infection. Canine and Feline Infectious Diseases, 14:224-238.

Sykes JE (2009) Viral Infections.VetEmergCrit Care 478-482.

Truyen U, Addie D,Belák S, Boucraut-Baralon C, Egberink H, Frymus T,-Gruffydd-Jones T, Hartmann K, Hosie MJ, Lloret A, Lutz H, Marsilio F, Pennisi MG, Radford AD, Thiry E, Horzinek MC (2009) Feline Panleukopenia: ABCD Guidelines on Prevention and Management. J Felin Med Surg11:538-546.

TruyenU, Parrish CR (2000)Epidemiology and pathology of autonomous parvoviruses. In: Contributions to microbiology: parvoviruses, 4thed, Basel: pp149-162.

Uffen JW, Oomen P, de Regt M, Oosterheert JJ, &Kaasjager K (2019) The prognostic value of red blood cell distribution width in patients with suspected infection in the emergency department. BMC Emerg Med 19:1-7.

Weiss DJ, Wardrop KJ (2010)Normal hematology of the cat. In: Schalm's Veterinary Hematology. 6th ed, Wiley, Iowa: pp 832-837.

Yang S, Berdine G (2017)The receiver operating characteristic (ROC) curve. Southwest RespirCritCare Chron5:34-36.