STUDIES ON DIAGNOSTIC AND PROGNOSTIC EVALUATION OF LEUKOCYTIC ALTERATIONS IN DIFFERENT PATHOLOGICAL CONDITIONS OF DOGS

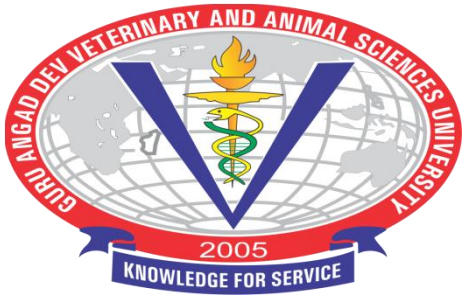
Thesis

Submitted to Guru Angad Dev Veterinary and Animal Sciences University in partial fulfillment of the requirements for the degree of

MASTER OF VETERINARY SCIENCE
in
VETERINARY PATHOLOGY
(Minor Subject: Veterinary Microbiology)

By

Gagandeep Kaur
(L-2017-V-67-M)



Department of Veterinary Pathology
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CERTIFICATE – I

This is to certify that the thesis entitled, **"Studies on diagnostic and prognostic evaluation of leukocytic alterations in different pathological conditions of dogs"** submitted for the degree of **M.V.Sc.,** in the subject of **Veterinary Pathology** (Minor Subject: Veterinary Microbiology) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Gagandeep Kaur (L-2017-V-67-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled, **"Studies on diagnostic and prognostic evaluation of leukocytic alterations in different pathological conditions of dogs"** submitted by **Gagandeep Kaur (L-2017-V-67-M)**, to the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.V.Sc.**, in the subject of **Veterinary Pathology** (Minor Subject: **Veterinary Microbiology**) has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an external examiner.

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ABSTRACT

The present project was carried out with the objective to study the leukocytic indices and morphology in various pathological conditions of dogs and to classify these leukocytic disorders with a view to determine their diagnostic and prognostic value. The leukogram findings of 3374 cases were retrospectively analyzed to determine the incidence of various pathological conditions. For prospective study, blood samples of 300 cases of dogs confirmed for different pathological conditions and 10 apparently healthy dogs, were subjected to estimation of total leukocyte count (TLC), differential leukocyte count (DLC), hemoglobin (Hb) and platelet count. DLC was done manually by counting 200 cells and absolute counts were calculated. Different morphological alterations in leukocytes were noted and graded and these findings were then correlated with the diagnosis and prognosis of different pathological conditions. These findings were also correlated with the other diagnostic techniques such as biochemistry, ultrasonography, radiography, echocardiography, electrocardiography and cytology. Leukocytosis along with left shift was most prevalent in pyometra and parasitic infections in dogs. Leukopenia was mainly associated with parasitic and viral diseases, whereas leukemoid response was mainly associated with neoplasms. Significant association of absolute neutrophilia with cardiac disorders, relative neutrophilia and left shift with hepato-renal dysfunction, absolute eosinophilia with GIT disorders and viral infections, relative eosinophilia with viral diseases, absolute lymphocytosis and atypical lymphocytes with neoplasms was observed, whereas relative lymphocytosis and granular lymphocytes were significantly associated with skin affections. Toxic changes in neutrophils were mainly associated with skin affections, neoplasms, viral diseases and parasitic infections. Absolute neutrophilia and absolute eosinophilia appeared to be significantly associated with good prognosis. Granular and atypical lymphocytes were associated with poor prognosis. Thus, it can be concluded that the evaluation of alterations in leukocytes number and morphology especially of neutrophils and lymphocytes may be helpful in diagnosis and in accessing prognosis of different pathological conditions of dogs.

Keywords: Blood, Clinical Pathology, Cytology, Disease Diagnosis, Dogs, Hematology, Leukocytes, Prognosis.

Signature of Major Advisor **Signature of the Student**

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ABBREVIATIONS USED

%	:	Per cent
±	:	Plus-minus
µl	:	Microliter
ALKP	:	Alkaline Phosphatase
ALT/SGPT	:	Alanine Amino Transferase/Serum Glutamic-Pyruvic Transaminase
AST/SGOT	:	Aspartate Amino Transferase/Serum Glutamic-Oxaloacetic Transaminase
BUN	:	Blood Urea Nitrogen
CBC	:	Complete Blood Count
CD	:	Canine Distemper
CPV	:	Canine Parvo virus
DLC	:	Differential Leukocyte Count
E	:	Eosinophil
Fig	:	Figure
FNAB	:	Fine Needle Aspiration Biopsy
GGT	:	Gamma-glutamyl Transferase
GIT	:	Gastrointestinal
Hb	:	Haemoglobin
HCT	:	Hematocrit
L	:	Lymphocyte
LGL	:	Large Granular Lymphocyte
L:P	:	Lymphocyte to platelet ratio
M	:	Monocyte
N	:	Neutrophil
n	:	Number of cases
N:L ratio	:	Neutrophil to lymphocyte ratio
No.	:	Number
PCV	:	Packed Cell Volume
SE	:	Standard Error
TLC	:	Total Leukocyte Count
TVT	:	Transmissible Venereal Tumor
USG	:	Ultrasonography
UTI	:	Urinary Tract Infections

CHAPTER I

INTRODUCTION

Leukocyte responses are useful clinically because blood leukocyte numbers and morphology are relatively stable in health but may change dramatically in disease. Although leukocyte responses seldom are pathognomonic for a specific disease, they may provide clinical information to establish a list of differential diagnoses, to assess the patient's response to treatment, or to suggest a prognosis (Latimer and Rakich 1989). Prognosis or mortality prediction by investigating different laboratory parameters is currently in demand in both human and veterinary medicine (Jitpean *et al* 2014). Hematology of infected dogs can help in giving an idea about the severity of infection and thus can guide in deciding the treatment protocol (Andrea *et al* 2017). Therefore, proper interpretation of the leukocyte changes will aid in revealing the true nature of the physiological or pathological state of the animal (Herder and Prasse 1972).

The basic function of the white blood cell is to defend the body from infectious disease processes, as well as being involved in removal of dead cells and damaged tissue. Evaluating the leukogram, including a total white cell count, a differential cell count, absolute numbers of specific leukocytes and examination of morphology on a blood smear, can identify abnormalities that may suggest specific diseases such as a viral or bacterial infection or even a neoplastic process. Neutrophils and lymphocytes are the most numerous and well-studied leukocytes in the blood. Hence it is the pattern of change in these cell types that forms the basis of interpretation of the leukogram in general (Schultze 2010). Under the influence of an inflammatory disease, the tissue demand for neutrophils will be observed by changes in the white blood cell and differential counts. The total number of neutrophils summoned by the tissue will reflect the intensity of the disease, and the types of neutrophils responding to the tissue demand will indicate the severity of the disease (Herder and Prasse 1972).

Disorders in leukogram can be classified as quantitative or qualitative. In quantitative alterations, all cells appear normal but are present in abnormal quantities, either in excess or in defect of normal values. In qualitative defects, abnormal appearing cells or extrinsic cells are found in circulation (Jacob 2016). These

alterations can give good information regarding the underlying disease. Absolute cell numbers, rather than relative percentages, which can be misleading, should be used in interpreting the leukocyte response (Herder and Prasse 1972).

Since neutrophils constitute the majority of blood leukocytes, so changes in total leukocyte count usually parallel changes in the absolute count of neutrophils (Nivy *et al* 2013) and therefore, leukocytosis is mainly due to neutrophilia and seen in conditions of acute inflammation, sepsis, or some chronic suppurative lesions like pyometra, abscess, pleuritis, and peritonitis (Latimer and Rakich 1989). A marked elevation of the total white blood cell count has been shown to be the most characteristicaly altered blood parameter in pyometra (Schepper *et al* 1987). Eosinophilia and basophilia is seen concurrently in many diseases of allergic or parasitic origin, both of which could involve the skin, lungs (heartworm, lungworm), and gastrointestinal tract (inflammatory bowel disease and intestinal parasites). Lymphocytosis can be observed in animals with chronic infectious or inflammatory diseases such as chronic canine ehrlichiosis, hypoadrenocorticism, viral infections and lymphoid neoplasia such as lymphosarcoma or lymphoid leukemia. Extreme elevations in lymphocyte counts can occur in chronic lymphocytic leukemia (Latimer and Rakich 1989). Monocytosis can be seen in subacute and chronic inflammation, excess endogenous or exogenous glucocorticoids administration. Other causes of monocytosis include infections due to bacteria (including rickettsia), fungi, and protozoa (Stockham *et al* 2003).

Leukopenia is most often caused by decrease in neutrophils (neutropenia) which is seen in viral infection and parasitic infections, eosinopenia seen in systemic stress and steroid therapy (Herder and Prasse 1972), lymphopenia seen in severe stress or following administration of corticosteroids and also due to pathogens such as canine distemper virus, canine parvovirus etc. as produce atrophy or directly destroy lymphoid tissue (Latimer and Rakich 1989). Lymphopenia is also frequently observed in patients with advanced cancers and has been documented as an independent negative prognostic factor for survival in metastatic breast cancer and advanced soft tissue sarcoma (Mutz *et al* 2013).

The term leukemoid response is applied when a marked leukocytosis is present, most commonly associated with a neutrophilia and severe left shift. It denotes a blood picture resembling that of chronic myelogenous leukaemia, however the

inciting cause is increased tissue demand for neutrophils and not a myeloproliferative disorder (Stockham *et al* 2003).

The storage pool of neutrophils can be quickly depleted if tissue demand for neutrophils is high. In such cases, particularly in conditions associated with an acute systemic inflammatory response syndrome (SIRS), band neutrophils, immature in morphology and potentially function, can be released from the marrow (Lambert *et al* 2016). The magnitude of neutrophylic leucocytosis or the degree of shift toward immature band forms roughly parallels the magnitude or severity of any inflammation (Schepper *et al* 1987). A left shift with presence of band neutrophils is the hallmark of acute inflammation which may be regenerative (mature neutrophils predominate with fewer bands), indicating a normal response to inflammation or degenerative (bands exceed the number of mature neutrophils) which indicates neutrophil production is not able to meet demand and is associated with a guarded or poor prognosis. Canine patients are more likely to die if they presented with a degenerative left shift, suggesting a link between an increased proportion of circulating band neutrophils and poor outcome (Lambert *et al* 2016). Hyposegmentation (i.e., left shift), and infrequently the presence of early neutrophil precursors in the peripheral blood (i.e., metamyelocytes and myelocytes) may occur with pathologic neutrophilia due to dwindling bone marrow mature neutrophil reserves. Generally, the more acute and severe tissue neutrophil demand is, the greater is the left shift (Nivy *et al* 2013).

Pathologic morphological abnormalities in neutrophils (toxic changes) often occur in diseases that lead to maturation defects within the bone marrow (Nivy *et al* 2013). Toxic changes in neutrophils are divided into 3 categories: nuclear, cytoplasmic, and giant neutrophils. The most commonly noted and important changes are the cytoplasmic ones, which include diffuse basophilia, granulation, foamy vacuolation, and the presence of Dohle bodies. Nuclear changes include pyknosis, vacuolation, polyploidy, hyposegmentation, and ring-form formation. Giant neutrophils are larger compared to normal neutrophils, and their cytoplasm stains uniformly dark-gray to blue, and may, in many cases, contain a hyposegmented nucleus. Giant neutrophils may reflect further manifestation of toxicity as a result of skipped cellular divisions during the maturation process (Aroch *et al* 2005). Toxic

changes are frequent with degenerative left shifts (Burton *et al* 2013). The presence of neutrophil toxicity has been associated with systemic rather than localized processes, and has been traditionally linked with bacterial infections (bacteremia, abscesses and septicemia), severe inflammatory processes, myeloproliferative disorders, and drug toxicity. Neutrophil toxicity may precede changes in neutrophil numbers and appearance of neutrophilic bands, and thus can be a sensitive early prognostic and diagnostic aid (Aroch *et al* 2005).

Lymphocyte morphology is also subject to wide variability due to various immunological stimuli both in inflammatory and infectious diseases (particularly viral) as well as in neoplastic disorders (leukaemias and lymphomas), resulting in circulating lymphocytes with morphological abnormalities in various quantities (Palmer *et al* 2015). Rare reactive lymphocytes can be found in most blood samples, but an increased number indicates an inflammatory disease or an immune response (Stockham *et al* 2003). Atypical lymphocytes are pleomorphic, neoplastic lymphocytes, such as those seen in lymphoma or some leukaemias (Garland 2011) and these changes can also be seen secondary to reactive processes such as chronic inflammatory or infectious diseases as in ehrlichiosis (Qurollo *et al* 2013). Large granular lymphocyte (LGL) are characterized by small eosinophilic granules in the cytoplasm of large lymphocytes (Jacob 2016). Canine patients are often reported to have a LGL morphology (Elliott and Villiers 2018). Granular lymphocyte expansion can occur due to various infectious diseases (Lamy *et al* 2017). Interest in large granular lymphocytes (LGLs) has grown due their tumoricidal activity, antiviral effects, and possible immunoregulatory functions (McDonough and Moore 2000).

The systemic inflammatory response has been associated with elevation in several peripheral blood and serum systemic inflammatory biomarkers in human patients and dogs. The complete blood count (CBC), one of the most common laboratory tests performed in both human and veterinary medicine, offers the possibility to easily and quickly calculate the relationships between different types of cells viz. neutrophils, lymphocytes, and platelets. Neutrophil to lymphocyte ratio (N:L), platelet to lymphocyte ratio (P:L), mean platelet volume to platelet ratio (MPV/PLT), and platelet large cell ratio index (PLCRi) have been proven as biomarkers of systemic inflammatory response and as potential diagnostic/prognostic

biomarkers in patients with both inflammatory and neoplastic conditions (Rejec *et al* 2017). Baseline neutrophil to lymphocyte ratio was initially found to be associated with survival in patients with solid tumors (Mutz *et al* 2013). It is also a good diagnostic index to detect complications in canine babesiosis (Omobowale *et al* 2017).

Although the diagnosis of a disease occasionally can be based solely on a complete blood cell (CBC) count, the hemogram may contribute valuable information in the diagnosis, surveillance, and formulation of a prognosis regarding the future progression of a disease in an individual (Roland 2014).

So, keeping in view that the leukocyte count and morphology are associated with disease diagnosis and at times may indicate prognosis, the present study was planned with the following objectives:

1. To study the leukocytic indices and morphology in various pathological conditions of dogs.
2. To classify these leukocytic disorders with a view to determine their diagnostic and prognostic value.

CHAPTER II

REVIEW OF LITERATURE

2.1 Leukocytic alterations and neutrophil toxicity

Aroch *et al* (2005) compared 248 dogs with neutrophil toxicity with negative controls and found that dogs with neutrophil toxicity had a significantly higher prevalence of leukocytosis, leukopenia, neutrophilia, neutropenia and anemia. The severity of neutrophil toxicity was positively associated with neutropenia, and negatively associated with leukocytosis and neutrophilia. They concluded that evaluation of blood smears for neutrophil cytoplasmic toxicity provided useful clinical information and it could serve as a good prognostic predictor.

Weltan *et al* (2008) retrospectively examined records of 182 dogs with leukocytosis and 179 dogs with normal leukocyte values (Control Group). Hematologic and serum protein data, and final diagnosis were compared between groups. On comparison it was found that, significantly more dogs in the leukocytosis group had infections, complicated babesiosis, immune-mediated hematologic disease, and necrosis. Hospitalization time and neutrophil, lymphocyte, and monocyte counts were significantly higher and hematocrit (HCT), eosinophil count, platelet count, and serum albumin concentration were lower in dogs in the leukocytosis group. They concluded that moderate to marked leukocytosis, caused by neutrophilia with a severe left shift, is more likely to indicate serious disease in dogs including bacterial or fungal infections, immune-mediated hematologic disease, complicated babesiosis, and necrosis. The magnitude of the total neutrophil count taken together with the degree of left shift had a significant impact on outcome.

2.2 Leukocytic alterations in different pathological conditions of dogs

2.2.1 Viral Diseases

Ezeibe and Udegbunam (2008) studied the haematological parameters of five dogs experimentally infected with canine distemper virus (CDV). They found that the red blood cell (RBC) count and PCV were significantly lower in the CDV infected dogs. There was initial leukopaenia along with lymphopaenia but later lymphocytosis occurred and led to leukocytosis. Thus, it was suggested that canine distemper leads to anaemia and immunosupression in affected dogs and both lymphopaenia (early cases) and lymphocytosis (late cases) were features of canine distemper.

Kalli *et al* (2010) retrospectively reviewed ninety-four puppies with natural canine parvo virus (CPV) enteritis. They found that, lymphopenic and hypoalbuminemic dogs were hospitalized for 1.9 and 2.5 more days, respectively, compared to those without these abnormalities. The odds of non-survival were higher in those puppies with evidence of systemic inflammatory response syndrome (SIRS) at the time of admission. In summary, a strong association between lymphopenia or hypoalbuminemia upon admission and duration of hospitalization (DOH) was confirmed in puppies with natural CPV enteritis, and SIRS appeared to herald a poor prognosis.

A total of 50 diarrheic puppies were analyzed by Castro *et al* (2013) and they compared the clinical and laboratory findings in puppies naturally infected with canine coronavirus (CCoV) and/or canine parvo virus (CPV) with findings in uninfected puppies. Lymphopenia was the only parameter related to CCoV infection that was statistically significant; while leukopenia, lymphopenia, thrombocytopenia, hypoglycemia, and hypoproteinemia were correlated with CPV infection. They concluded that these indicators could be useful to determine clinical outcome in puppies with CCoV and CPV enteritis.

Shah *et al* (2013) analyzed haematology and serum biochemistry data of fifteen cases of canine parvovirus (CPV) diagnosed by a dot-ELISA kit. The frequent hematological abnormalities observed were microcytic hypochromic non-regenerative anemia, lymphopenia, sometimes associated with either leukopenia or leukocytosis often showing shift to left and thrombocytopenia. The levels of blood urea nitrogen (BUN), creatinine, alkaline phosphatase (ALKP) and alanine amino transferase (ALT) were elevated while the total protein (TP) and albumin levels were decreased.

Salem (2014) examined thirty-five diarrheic dogs for clinical signs and hematologic, and serum biochemical alterations associated with canine parvo virus (CPV) and canine distemper virus (CDV) as causative agent and found that anemia, leucopenia, neutropenia and lymphopenia were the most observed hematologic alterations in both viruses. Serum biochemistry revealed increase in alanine aminotransferase (ALT) and alkaline phosphatase (ALKP), triglycerides with decrease in albumin, sodium and chloride as the most observed serum biochemical

alterations in CPV while increase in blood urea nitrogen (BUN) and triglycerides and decrease in sodium level were observed in CDV.

Amaravathi *et al* (2016) studied three cases of canine parvovirus (CPV). Hematology revealed microcytic hypochromic non-regenerative anemia, lymphopenia, leukopenia and thrombocytopenia. The levels of alkaline phosphatase (ALKP) and alanine amino transferase (ALT) were elevated while the total protein (TP) and albumin levels were decreased.

Roble *et al* (2016) conducted hematological examinations of 45 canine parvo virus (CPV) suspected dogs. Common hematological observations were panleukopenia, neutropenia, anemia and thrombocytopenia. Multivariate analysis revealed that neutrophil and total white blood cell (WBC) counts, age category and vaccination status, and the presence of lethargy, inappetence and vomiting were found significantly associated. Absolute neutrophil count was a significant predictor. They were of the view that complete blood count remains very important in assessing the disease and among these absolute neutrophil count was found to be a good predictor of the disease, which indicates its potential use especially if in-clinic tests are unavailable.

Bhargavi *et al* (2017) detected canine parvovirus (CPV) infection in fourteen pups by positive test with Sandwich lateral flow immunochromatography assay and also analyzed the hematobiochemical changes associated with it. The prominent hematological changes were anaemia, lymphopenia, thrombocytopenia and neutrophilia. Significantly elevated blood urea nitrogen (BUN) and significantly decreased serum potassium levels were among the important biochemical alterations noticed in CPV positive pups.

Buragohain *et al* (2017) collected blood from a total of 167 clinically canine distemper suspected dogs to analyze haematological and biochemical alterations. The haematological parameters measured included total erythrocyte count (TEC), haemoglobin (Hb) concentration, packed cell volume (PCV), total leukocyte count (TLC), platelets count, etc. The mean TEC, Hb concentration, PCV, and platelets count were found lower than the standard range in all canine distemper infected dogs. The TLC was found within the normal range with absolute lymphocyte count recorded towards the lower value of the normal range. These findings, suggested that canine distemper results anaemia with immunosuppression in affected dogs.

Biochemical analysis of serum samples revealed increase level of alkaline phosphatase and aspartate aminotransferase, whereas the alanine aminotransferase level remains same.

Andrea *et al* (2017) did hematological analysis of blood collected from thirteen canine parvovirus (CPV) suspected dogs with vomition and hemorrhagic diarrhea as predominant clinical signs. The most common hematological finding in all dogs was anemia while leukocyte and platelet abnormalities were different in each individual. They concluded that monitoring of hematological changes prior to treatment can help decide on a better line of treatment thereby increasing the chances of survival in affected dogs.

2.2.2 Parasitic infections

Mundim *et al* (2008) did evaluation of the hematological aspects of dogs infected naturally by Hepatozoon species. Of the 115 dogs for whom peripheral blood films were evaluated, majority presented parasitemia by Hepatozoon species solely, while others had combination of Hepatozoon species, Babesia species and Ehrlichia species. The majority of hematological alterations noticed were normochromic-normocytic anemia, leukocytosis, neutrophilia, and nuclear deviation of neutrophils to the left. The findings of this study confirmed that Hepatozoon species causes hematological alterations of varied intensity, which, albeit not specific to canine hepatozoonosis, reinforce the notion that the discovery of the agent in dogs, even with low parasitemia, should be taken into consideration.

Shipov *et al* (2008) were retrospectively studied 40 cases of canine monocytic ehrlichiosis (CME). The dogs were assigned as survivors and non-survivors, and their clinicopathological findings were compared. Dogs in the non-survivor group had significantly lower white blood cell (WBC), hematocrit (HCT), and platelet (PLT) counts. Pronounced pancytopenia was found as a risk factor for mortality. Severe leucopenia, severe anemia and hypokalemia were each found to predict mortality with a probability of 100%. In contrast, WBC counts above $5.18x10^3$/mL, platelet counts above $89.5x10^3$/mL 1, PCV > 33.5%, and serum potassium concentration above 4.75 mmol/L, each provided 100% prediction for survival. These prognostic indicators can be easily obtained at presentation, are inexpensive, and may be useful aids when treatment and prognosis are being considered.

Sakina *et al* (2012) did Various haematobiochemical parameters of thirty five dogs suffering from demodectic mange. Parameters like Hb, PCV, TLC, TEC, DLC, blood glucose, total protein, albumin of affected dogs and control were studied. In the affected group, the mean values of Hb, PCV and TEC were significantly lower than the control group. The mean values of TLC were significantly higher suggestive of leukocytosis along with increase in neutrophilic and eosinophilic count than healthy control. Lymphopenia was also observed in the affected group. The mean blood glucose levels, total protein and albumin was significantly lower in the affected group.

Vojta *et al* (2012) did hematological and biochemical analyses of 14 apparently asymptomatic, but Hepatozoon-positive dogs. Haematological analyses showed severe eosinophilia, leukocytosis, neutrophilia, decreased values of HCT and Hb, monocytosis, lymphocytosis, thrombocytopenia and thrombocytosis where platelet aggregates were detected. Biochemical analyses of dog sera demonstrated highly increased ALKP and ALT and creatine kinase (CK) while AST and gamma-glutamyl transferase (GGT) were slightly increased. They concluded that clinical signs and laboratory findings in the initial phase of Hepatozoon infection, or in the infection of weak intensity, were quite unspecific and similar to those observed in other diseases commonly found in dogs.

Janus *et al* (2014) studied haemato-biochemical changes in 20 dogs suffering from demodicosis. Detailed haematological and blood biochemical analysis were done in the dogs as per standard techniques Haematology revealed a reduction in red blood cell (RBC) count, Hb value, platelet count and and an increase in neutrophil count. Serum biochemical analysis revealed increase in total protein and globulin reduction in serum albumin level.

Reddy *et al* (2014) conducted a study on sixteen dogs with scabies. Haematological abnormalities included reduced total erythrocyte count and haemoglobin concentration levels. Affected dogs also showed leukocytosis with neutrophilia, eosinophilia and monocytosis. Biochemical changes included reduced mean total serum protein and serum albumin levels when compared with healthy dogs.

Salem and Farag (2014) conducted a study on thirteen dogs to establish hematological alterations in canine babesiosis affected dogs. Thrombocytopenia,

monocytosis, and lymphocytosis, along with a significant reduction in red cell parameters, were the most commonly recorded hematologic alterations. They concluded that thrombocytopenia should be considered as the hallmark of the disease because it was the most consistent hematologic abnormality observed in 100% of the babesiosis affected dogs.

Abdel Haleem *et al* (2015) collected blood samples from 15 dogs suffering from generalized demodicosis to find out the changes associated with hemato-biochemical parameters. They were of the conclusion that, reduced levels of packed cell volume (PCV), hemoglobin, and total erythrocyte count (TEC), along with presence of leukocytosis, neutrophilia, lymphopenia and increased total serum protein and globulin with decrease in serum albumin level were the most consistent hematological and biochemical alterations associated with generalized demodicosis.

Bhadesiya and Raval (2015) collected blood samples from 29 dogs of which 18 were positive for naturally occurring ehrlichiosis. The hematological changes evinced lowered platelet counts, hemoglobin (Hb), Total Erythrocyte Count (TEC), Packed Cell Volume (PCV), whereas among Differential Leukocyte Count (DLC), mean values of lymphocytes and eosinophils were decreased, neutrophils and monocytes were increased. Serum biochemistry revealed increase in serum glutamic pyruvic transaminase (SGPT), serum glutamic oxaloacetic transaminase (SGOT) and creatinine levels. Results suggested that estimation of hematobiochemical parameters holds importance in a complete diagnostic approach for dogs with naturally occurring ehrlichiosis.

Choudhary *et al* (2015) studied haematological and biochemical alterations in 40 positive cases of canine ehrlichiosis. Haematology indicated anemia and thrombocytopenia as the mean values of erythrocyte count, haemoglobin, packed cell volume and thrombocytes were decreased but there was no significant change in the leukocyte count. Serum chemistry indicated hypoalbuminemia and hyper-globulinemia.

Adebayo *et al* (2016) conducted a study on 103 babesiosis-suspected dogs. They found that, the packed cell volume between the cases was not significantly different and normal leukogram was observed in 62% of the Babesia-positive cases while 22.2% and 15.8% had leukocytosis and leukopenia, respectively. They concluded that, both packed cell volume (PCV) and white blood cell (WBC) counts

were not sensitive indicators for monitoring the progression and prognosis of babesiosis in dogs.

Gianopoulos *et al* (2016) with the aim to analyze quantitative and qualitative leukocyte abnormalities in dogs with ehrlichiosis, evaluated archived blood smears from 13 experimentally infected and 20 naturally *Ehrlichia canis* infected dogs. In experimentally infected dogs, they found significant decreases in neutrophil, monocyte, lymphocyte, and eosinophil counts, and a mild left shift. Neutrophil toxicity was rarely seen, but reactive lymphocytes were observed frequently. Naturally infected dogs had variable patterns of leukocyte changes. They were of the view that acute canine monocytic ehrlichiosis (CME) could be evaluated and monitored based on several discrete quantitative and qualitative leukogram changes indicative of concurrent inflammation, antigenic stimulation, and stress.

Fonseca *et al* (2017) analyzed the haematological findings of dogs that were seropositive for *E. canis* and they found no significant difference in erythrogram and platelet count parameters, except that dogs seropositive for *E. canis* showed lower values for hematocrit when compared with seronegative dogs. Thus, they were of the view that, the hematological findings were nonspecific, with both anemia and thrombocytopenia being identified in some dogs, but with most values of the erythrogram and the platelet count falling within the normal range for canines.

Frezoulis *et al* (2017) with the objective to further clarify the causes of canine pancytopenia retrospectively reviewed medical records of 119 dogs with and 238 without pancytopenia. The mean white blood cell counts were lower in dogs with ehrlichiosis and parvoviral enteritis compared to dogs with leishmaniasis, while platelet counts were lower in ehrlichiosis compared to leishmaniasis or parvoviral enteritis. Total protein concentrations were lower in dogs with parvoviral enteritis. They concluded that infectious diseases were the leading causes of canine pancytopoenia in endemic areas; with severe leukopoenia (ehrlichiosis, parvoviral enteritis), thrombocytopenia (ehrlichiosis), and hypoprotenaemia (parvoviral enteritis) as potentially useful disease-specific diagnostic determinants.

Gonde *et al* (2017) studied haematobiochemical alterations of 41 naturally occurring cases of canine babesiosis. Blood parameters of the affected dogs revealed significant decrease in Hb, TEC, PCV and thrombocytes and lymphocytes indicative of haemolytic anemia, neutrophilia, lymphopenia, moderate to severe thrombo-

cytopenia. was found in *B. gibsoni* affected animals. The affected dogs showed significant increase in serum bilirubin, ALT, AKP, BUN and creatinine indicative of multiple organ dysfunctions. They concluded that haemato-biochemical changes could be beneficial in determination of the severity of babesiosis in dogs.

Jain *et al* (2017) examined a total of 150 dogs for the presence of hemoparasites *Babesia gibsoni*. by light microscopy Hematological parameters were analysed. Parameters such as red blood cell (RBC) count, white blood cell count, hemoglobin (Hb), hematocrit, (HCT), mean corpuscular volume (MCV), red cell distribution width (RDW), and platelet (PLT) count were estimated. infection. Animals exhibited a near normal leukogram while the erythrogram values were below the normal range including decreased RBC, Hb, and HCT that were suggestive of anemia. Anisocytosis was suggested by the high values of RDW. Severe thrombocytopenia was also observed in *B. gibsoni* positive animals. Thus, anemia and thrombocytopenia were the significant hematological alterations in chronic *B. gibsoni* infection.

Omobowale *et al* (2017) conducted a study on 17 babesiosis infected dogs further sub-divided into the uncomplicated & complicated groups and another 17 apparently healthy dogs to describe some hematological changes by analyzing blood samples for full blood count and erythrocyte morphology. They found that Babesia negative dogs had lower neutrophil/lymphocyte ratio when compared with Babesia positive dogs. Complicated groups had higher neutrophil/lymphocyte ratio. Anisocytosis was the commonest encountered erythrocytic morphological abnormality. They concluded that neutrophil/lymphocyte ratio is a good diagnostic index to detect complications in babesiosis.

Panda *et al* (2017) conducted a study on a total of 198 blood samples collected from babesiosis suspected dogs. Examination of blood smears revealed an overall incidence of 8.07% (16/198). The hematological evaluation of the blood samples of the 16 dogs revealed reduced values of hemoglobin (Hb), red blood cell (RBC) count, platelet, and packed cell volume (PCV). Leukocytes abnormalities included decrease in white blood cell (WBC) count, neutropenia, lymphocytosis and monocytosis. Thus, anemia, thrombocytopenia, and monocytosis were the most common hematological

alterations observed during the investigation with thrombocytopenia being the most consistent hematologic abnormality observed in 100% of the affected dogs.

Petrov *et al* (2018) studied 34 *Ehrlichia canis* positive dogs to analyze the typical changes in hematological and blood biochemical parameters and found that severe thrombocytopenia, mild to marked non regenerative anaemia and hypoalbuminemia were statistically significant different hematologic changes present regarding the red blood cells count, platelet count, hematocrit and hemoglobin before and after treatment. Hypoalbuminaemia was the only serum biochemistry parameter with significant change before and after treatment, as well. They concluded that thrombocytopenia, anemia and hypoalbuminemia were the characteristic laboratory findings in patients with canine monocytic ehrlichiosis.

Nwufoh *et al* (2019) evaluated the clinicopathological features of dogs infested with *Sarcoptes scabiei* var. *canis*. The PCV, Hb, RBC, WBC, platelets, lymphocytes, neutrophils, monocytes, eosinophils, TP, albumin, globulin, ALT, AST, ALKP, creatinine, BUN, and glucose levels were examined for 6 weeks following establishment of mites. Haematological values of infested dogs differed significantly from healthy dogs including increased lymphocytes and elevated neutrophil count with exceptions to monocytes and eosinophils. Total protein, albumin, and globulin and ALKP values were altered significantly while creatinine values were significantly lower in infested dogs.

Priyanka *et al* (2019) conducted a study on thirty naturally occurring cases of chronic canine monocytic ehrlichiosis (CME). They analyzed the haematobiochemical changes in dogs at the time of admission. Haematology revealed normocytic normochromic anemia, thrombocytopenia, decreased leukocyte count, while serum biochemistry revealed increased levels of blood urea nitrogen (BUN), creatinine, alanine transaminase (ALT), and alkaline phosphatase (ALKP).

2.2.3 Neoplastic Conditions

Jain *et al* (1991) examined Blood smears from 49 dogs and cats believed to have myeloproliferative disorders. Chief hematologic abnormalities included circulating blast cells in 98% of the cases, with 36.7% cases having >30% blast cells, and thrombocytopenia and anemia in approximately 86 to 88% of the cases. Leukocytosis (57.1%) was nearly three times more common than leukopenia.

Morris *et al* (1993) compared eleven cases of canine lymphoid leukaemia with 13 cases of canine lymphoma. There was a marked difference in haematological parameters with the leukaemic dogs showing more severe changes than those with lymphoma. More leukaemic dogs were anaemic, thrombocytopenic and had a pronounced leucocytosis when compared to lymphoma dogs. The majority of leukaemic dogs had circulating prolymphocytes/lymphoblasts which accounted for more than 30 percent of the total white blood cell count as compared to less than 20 per cent of the total white blood cell count in lymphoma dogs. Neutropenia was more pronounced in leukaemic dogs but absolute numbers of mature lymphocytes was found to be increased in both conditions. The most commonly elevated parameters in the lymphoma dogs were y-glutamyl transferase and aspartate amino transferase while in the leukaemic dogs, aspartate aminotransferase and alkaline phosphatase were most frequently elevated. Urea and creatinine were raised in both hypercalcaemic dogs.

Adam *et al* (2009) evaluated 64 cases of morphologically and immunologically confirmed leukaemia and categorized them as acute lymphoid leukaemia (ALL), chronic lymphoid leukaemia (CLL) and acute myeloid leukaemia (AML). Dogs with ALL had significantly more severe neutropenia and thrombocytopenia than those with CLL and had significantly more cytopenias. The severity and numbers of cytopenias seen in ALL and AML were not significantly different. Twenty-one of the leukaemia cases showed one cytopenia, fourteen had two cytopenias and twenty- one cases had pancytopenia. Anaemia was the most common cytopenia seen. Total white blood cell counts were not different between the groups. The atypical cell counts with in the peripheral blood were significantly higher in ALL than AML. This study strengthend the hypothesis that acute leukaemias gave rise to more profound cytopenias, affecting more cell lines, than chronic leukaemias.

Tasca *et al* (2009) retrospectively studied results of 210 cases of hemato-poietic neoplasia in dogs to characterize hematologic abnormalities. Based on cell morphology cases were classified as: acute lymphoblastic leukemia (ALL, n=51), acute myeloid leukemia (AML, n=33), chronic lymphocytic leukemia (CLL, n=61), and leukemic high-grade lymphoma (L-HGL, n=65). Anemia was found in 85% of all cases and was significantly more severe in ALL and AML compared with CLL and L-HGL. Neutropenia was seen in 64–78% of acute leukemias (AML and ALL) in

contrast to no cases of CLL and 11% of L-HGL. Thrombocytopenia was seen in 88–90% of acute leukemias in contrast to 15% of CLL and 40% of L-HGL. Thrombocytopenia was more prevalent (71% vs 22%) and significantly more severe in T-cell vs B-cell L-HGL. They concluded that a standard CBC was useful in suggesting the type of hemoproliferative disorder.

Thangapandiyan *et al* (2013) collected blood and sera samples from canines showing lymphadenopathy. Cytology, haematology, serology and ultra scanning were carried out. Four cases of lymphoma, one was diagnosed as lymphoblastic leukemia which had a mean leucocyte count of 1,21,000/µL and differential count of lymphoblast was 98% and neutrophil 2% in the peripheral blood smear. It also had a severe anaemia (Hb: 3.5 g/dL). The other three dogs showed a normal differential count and mild anaemic changes. Mild anaemia observed in this study was a common finding. Hypercalcemia was observed in all the four dogs. High BUN in two and hypoglobulinemia in two dogs were also observed.

Kumar *et al* (2017) evaluated and compared the hematobiochemical parameters of 40 dogs suffering with transmissible venereal tumor (TVT) with the healthy dogs. An insignificantly reduced haemoglobin, PCV, and TEC were noticed in the TVT affected dogs when compared to that of apparently healthy dogs. The total leukocyte count and neutrophils were significantly increased, lymphocytes significantly decreased, but no variation in the mean monocytes and eosinophils were noticed. Platelets in TVT suffering dogs were significantly decreased. The mean BUN and serum Creatinine were found to be non-significantly different when compared to apparently healthy dogs. A significantly decreased serum protein, significantly high ALT, AST and ALKP levels were recorded among dogs of TVT when compared to that of apparently healthy cases.

Rejec *et al* (2017) retrospectively assessed complete blood count (CBC) indices of dogs with with oropharyngeal tumors (OT) in comparison to CBC indices of healthy dogs (HD). Neutrophil to lymphocyte ratio (NLR), platelet to lymphocyte ratio, mean platelet volume to platelet ratio, and platelet large cell ratio index (PLCRi) were evaluated. Both NLR and PLCRi were significantly higher in dogs with OT when compared to HD and could, therefore, indicate a tumor associated systemic inflammatory response. They concluded that the CBC indices, namely, NLR and

PLCRi, were found to be associated with oral neoplastic conditions and could be used as biomarkers of a systemic inflammatory response.

Thangapandiyan *et al* (2017) conducted a study to find out the haematological alterations in 41 dogs affected with lymphoma. Whole blood samples were collected and complete blood counts were estimated. There was a significant decrease in the packed cell volume (PCV), total erythrocyte count (TEC), haemoglobin (Hb), total leucocyte count (TLC) and platelets. Decreased haemoglobin in 30 cases, TEC in 33 dogs, PCV in 32 dogs, platelets in 16 dogs and TLC in 3 dogs and elevated TLC in 9 cases were observed. In conclusion, normocytic and normochromic anemia was the major morphological classification of anemia in dogs with lymphoma with decreased values of haemoglobin, PCV, and TEC. Both leucocytosis and leucopenia and thrombocytopenia were also observed.

Kayar *et al* (2018) analyzed twenty dogs affected by malignant lymphoma. They were subjected to a clinical examination and complete blood count (CBC), leucocyte differential count (LDC), serum biochemical profile and thymidine kinase (TK) test. They found regional or general lymphadenopathy to be the only clinical sign in 35% of the dogs while isn the remaining cases, at least one abnormality connected to canine malignant lymphoma was found. Between ill and healthy dogs, a p-value of < 0.001 was calculated for the haematological parameters: red blood cell count, haemoglobin, haematocrit, platelet, neutrophils and monocytes; for biochemical parameters the following p-values were calculated: blood urea nitrogen $P < 0.01$; aspartate aminotransferase, alkaline phosphatase and TK < 0.001, and Calcium $P < 0.05$. They were of the opinion that, canine malignant lymphoma must be considered as a possibility in the case of anaemic medium-age and old dogs with non-specific clinical features, at least one enlarged lymph node, and elevated ALKP and TK concentrations.

Kumar *et al* (2018) evaluated and compared the hematobiochemical parameters of 40 dogs suffering with mammary tumors with the healthy dogs. In dogs affected with mammary tumours an insignificant decrease of mean haemoglobin, packed cell volume (PCV) and total erythrocyte count (TEC), whereas an insignificant elevation of total leukocyte (WBC) count and neutrophils, decrease in lymphocytes and normal monocytes as well as eosinophils were found. Similarly, an insignificant decrease was noticed with respect to platelet levels when compared to

that of apparently healthy ones. Serum biochemical estimations in dogs with mammary tumours revealed an insignificant decrease in blood urea nitrogen (BUN) values while an insignificant increase in serum Creatinine, alanine aminotransferase (ALT), Aspartate Aminotransferase (AST), Alkaline phosphatase (ALKP) and total protein was observed.

2.2.4 Pyometra

Fransson *et al* (1997) conducted a study on 60 bitches with pyometra. Blood samples from bitches showed marked hematological changes. These included higher total WBC counts and a more marked left shift in the differential WBC count. Toxic degeneration of neutrophils was present. The serum ALKP level was slightly higher.

Ravishankar *et al* (2004) studied twenty-nine clinical pyometra cases. Haematological studies indicated a normocytic, normochromic anaemia and leucocytosis with absolute neutrophilia in pyometra. Biochemical estimations revealed elevation of serum urea nitrogen, creatinine, AST, ALT, ALKP and globulin and hypoalbuminaemia.

Jena *et al* (2013) studied haematological parameters in twenty eight bitches affected with pyometra and found that haemoglobin, packed cell volume (PCV), total erythrocyte count (TEC) and lymphocyte count were decreased in the bitches affected with pyometra. The total leucocyte count (TLC), neutrophil count and monocyte count were increased in pyometra. They were of the conclusion that normocytic and normochromic anaemia, leukocytosis, a predominant absolute neutrophilia with shift to left, lymphopenia, monocytosis with normal eosinophil count were the most consistent findings in all the bitches affected with pyometra.

Lakshmikanth *et al* (2016) conducted a study to evaluate the haemato-biochemical changes in open and closed pyometra groups. Clinically healthy dogs served as control. Normocytic normochromic anemia, lymphopenia, eosinopenia, significantly higher total leukocyte count (TLC) and neutrophil count with increase in band neutrophils was evident in both pyometra affected groups when compared to control dogs. A slight monocytosis was observed in closed pyometra. Among hepatic enzymes alanine aminotransferase (ALT) did not show any significant changes, while aspartate aminotransferase (AST) was significantly increased in closed pyometra. Hyperglobulinemia with hypoalbuminemia with unaltered total protein concentration

was consistent with open and closed pyometra. The creatinine concentrations were significantly higher in open and closed pyometra when compared to healthy control dogs.

Shah *et al* (2016) conducted a study on canine pyometra to assess the alteration in clinico-haemato-biochemical status before and after ovariohysterectomy. A total of six bitches were subjected to ultrasonography and blood analysis. Ultrasonography revealed uterine diameters ranging from 1.3 to 5.0 cm. Haematology revealed leukocytosis, neutrophilia and lymphopenia. Serum biochemistry revealed elevated levels of blood urea nitrogen (BUN), creatinine, and alkaline phosphatase (ALKP). They found that, the mean haemato-biochemical parameters returned to normal by day ten post-surgery and related the changes in haemato-biochemical profile to the degree of improvement of the clinical conditions of the bitches.

Shah *et al* (2017) studied haematological and biochemical changes in eight bitches affected with Pyometra (both open and closed type). They were clinically examined and diagnosed for pyometra based on case history, clinical signs, ultrasonography or radiography, gross examination of pus filled uterus during and after the ovariohysterectomy. The blood collected was subjected to haematological and biochemical studies and haematology of pyometra cases showed leucocytosis, neutrophilia, lymphocytopenia and normocytic and normochromic anemia. Biochemically, the increased BUN and creatinine and hyperproteinemia were observed. The alterations in the haematological and biochemical parameters were found to be more marked in cases where the cervix was closed.

Babu *et al* (2018) made an attempt to assess the haemato-biochemical changes in normal healthy and pyometra affected dogs. The haematolological parameters studied revealed alterations including significant decrease in the total erythrocyte count (TEC), haemoglobin (Hb), and packed cell volume (PCV) with normocytic and normochromic anaemia in pyometra cases. The leucogram revealed leucocytosis, predominant absolute neutrophilia with regenerative shift to left, lymphopenia with normal eosinophil count in pyometra dogs. No significant changes were noticed among the biochemical parameters including serum creatinine and alanine aminotransferase (ALT).

Samantha *et al* (2018) studied ten clinical cases of cystic endometrial hyperplasia-pyometra complex in dogs. All the dogs were subjected to ultrasound examinations and haemato-biochemical studies. Ultrasound examination revealed the presence of uterine exudates such as blood, mucus, pus and cystic endometrial hyperplasia. Among the haematological parameters, the mean red blood cell (RBC), haemoglobin and packed cell volume (PCV) values were lower than the normal physiological levels suggestive of anaemia. The mean platelet count in dogs affected with pyometra was found to be less than the normal physiological value in dogs. The mean TLC values and neutrophil count were highly above the normal physiological range suggestive of leukocytosis and neutrophilia. The mean monocyte count was also elevated than the normal animals. The lymphocyte count was below the normal physiological range in the affected dogs. Among the biochemicals blood urea nitrogen (BUN) and creatinine values were increased while Total protein and alanine aminotransferase (ALT) appeared to be well within the normal ranges. They concluded that the analysis of various parameters helps in the assessment of the clinical status of the bitches and in prediction of the prognosis.

2.2.5 Gastro intestinal (GIT) Disorders

Sharma *et al* (2008) collected blood from 40 dogs having hemorrhagic diarrhea which was subjected to estimation of haematological values. Haematological finding showed a marked decrease in haemoglobin, packed cell volume and platelet values in haernorrhagic gastroenteritis affected dogs. Majority of the dogs showed leucocytosis where as nine cases showed leucopenia. Neutrophilia with lymphopenia was seen in majority of the cases while four cases showed neutropenia with lymphocytosis.

Bhat *et al* (2013) selected eighteen dogs suffering from enteritis and collected blood from them which was subjected to estimation of hematological and biochemical parameters and these findings were compared with twelve healthy dogs that served as control. They concluded that packed cell volume (PCV) and total erythrocyte count (TEC) remained almost similar between healthy dogs and dogs affected with diarrhea but mean total leukocyte count (TLC) value was significantly higher as compared to the control group. Biochemical investigation revealed hypoglycemia, hypoproteinemia, hypokalemia, hypochloremia and increase in blood urea nitrogen in the dogs suffering from enteritis.

Dash *et al* (2017) conducted a study on 120 dogs showing the symptoms of haemorrhagic gastro enteritis to reveal the haematological, serum biochemical alterations. Significant variations were found in both hematological and sero-biochemical parameters. Hematology revealed low mean hemoglobin value, TEC, PCV values and a fall in TLC value. The serological examination revealed low mean AST value and ALT values. The mean BUN value was also low.

2.2.6 Renal Dysfunction

Bradea *et al* (2013) with the purpose to evaluate changes in hematological parameters conducted a study on a number of 12 dogs with chronic kidney disease (CKD). They found decreased levels of hematocrit and hemoglobin that suggested anaemia. Platelets number was near the upper limit and in severe cases were increased. White blood cells series registered inconstant and uncharacteristic modifications such as lymphopenia in 4 dogs, granulocytes increased levels in 3 and an increase in lymphocytes over monocytes ratio in 4 dogs. They were of the conclusion that complete blood count in CKD provides useful information about the progress of the disease as well as anemia type appreciation offering additional information for therapeutic protocol.

Kandula and Karlapudi (2015) conducted a study on 79 dogs with renal insufficiency and analyzed blood samples for hematobiochemical parameters. They established that total erythrocyte count (TEC), hemoglobin, and packed cell volume (PCV) were significantly lower and total leukocyte count TLC) was significantly higher with neutrophilic leukocytosis, lymphopenia and eosinopenia. The serum chemistry revealed significantly higher levels of blood urea nitrogen (BUN), creatinine, phosphorous and potassium whereas total proteins, albumins, calcium, sodium and chloride levels were significantly lower. They concluded that haemato-biochemical alterations could be effectively used for clinical diagnosis of renal insufficiency in dogs.

Sharma *et al* (2015) revealed the haemato-biochemical changes in 24 dogs suffering from chronic renal failure (CRF). These dogs showed significantly decreased haemoglobin, PCV and TEC and increased TLC along with neutrophilia and lymphopenia. There were no changes in eosinophil, monocyte and basophil counts. Thrombocytopenia recorded in 70.83 % of CRF suffered dogs. Significant increase

was observed in mean value of BUN and creatinine in CRF suffered dogs. Increase in mean value of alkaline phosphatase and gamma-glutamyl transferase was also observed.

Das *et al* (2017) screened 248 geriatric dogs suffering with chronic kidney diseases (CKD) based on typical clinical signs related to urinary system problem out of which 33 were diagnosed with CKD. Detailed hematology of the dogs suffered with CKD showed significant decrease in Hb, PCV, and TEC and significant increase in TLC, neutrophil and eosinophil counts. Serum biochemical alterations revealed significant increase in glucose, creatinine, BUN, phosphorus and protein and decrease in albumin. They concluded that haemato-biochemical changes in geriatric affected dogs should be routinely undertaken to screen the CKD at an early stage.

Devipriya *et al* (2018) conducted study on a total of 77 dogs confirmed for renal insufficiency. Haematology results showed highly significant reduction in packed cell volume, significant reduction in haemoglobin and total erythrocyte count and increase in total leucocyte count, however differential leucocyte count did not differ significantly between healthy and affected dogs. Serum urea nitrogen, creatinine and phosphorus levels were significantly increased whereas total protein was reduced compared to the healthy dogs. They concluded that estimation of haematological and serum biochemical parameters in dogs suspected for renal disorders could help in early diagnosis of disease.

Sumit *et al* (2018) with the purpose to evaluate changes in haemato-biochemical and electrolyte parameters conducted a study on 30 dogs suffering from chronic kidney disease (CKD). Major alteration in hematological profile were overall lower levels of hemoglobin, TEC, PCV values and platelet count in all the affected dogs. Affected dogs revealed higher mean TLC count and percentage lymphocytes as compared to reference values. Biochemical parameters revealed rise in electrolyte parameters such as BUN, serum creatinine and phosphorus which were directly proportional to the severity of disease and loss of the renal function, while inversely proportional to the prognosis of the disease. They concluded that complete blood count and serum characteristics in CKD provides useful information about the progress of the disease as well as anemia type appreciation.

Karunanithy *et al* (2019) carried out a study on 78 dogs that were diagnosed as cases of renal failure. The haematological and serum biochemical parameters were analyzed. Haematology revealed significantly reduced levels of haemoglobin, total erythrocyte count, lymphocytes, platelet count and significantly increased levels of total leucocyte count, neutrophils, eosinophils, while monocyte count was found to be statistically non-significant in comparison to healthy dogs. The serum concentration of creatinine, BUN, total protein, albumin, A:G ratio, alkaline phosphatase and phosphorus were increased significantly as compared to healthy dogs. However, changes in serum globulin, Sodium, Potassium values were non-significant.

2.2.7 Urinary tract infections (UTI)

Punia *et al* (2018) carried out a study on 22 dogs suffering from urinary tract infection to determine the haemato-biochemical alterations. Major haematological alterations observed were significant decrease in the hemoglobin level and significant increase in the total leukocyte count as compared to the reference values. On biochemical examination, major changes observed were significant increase in the values of blood urea, creatinine, phosphorous and potassium. They concluded that blood urea and creatinine values can be used as prognostic indicators in dogs affected with UTI.

Roopali *et al* (2018) carried out a study on ten dogs to investigate the haemato-biochemical changes in urinary tract infection and compared the findings with the control group. Blood collected was subjected for the estimation of various haemaobiochemical parameters. Haemoglobin, packed cell volume (PCV), total erythrocyte count (TEC) and lymphocytes were significantly reduced in affected dogs when compared to the healthy control group indicative of severe anaemia. Total leukocyte count (TLC) and neutrophil count were significantly increased in the affected animals compared to the control group suggestive of bacterial infection. There was significant elevation of BUN and creatinine along with significant decrease in the total protein, albumin and globulin in the affected dogs as compared to the healthy control group.

Yogeshpriya *et al* (2018) retrospectively studied 32 cases of urinary tract infection and analyzed the haematobiochemical changes. Haematological alterations included markedly increased ESR values, total leucocyte count and neutrophils values,

decreased lymphocyte values. The mean values of eosinophils, basophils, monocytes and platelets values were found within the normal range. Biochemistry revealed hypoalbuminemia and increased urea concentration.

Sarma and Kalita (2019) carried out a study on 30 clinical cases of dogs having urinary system disorders and compared their haematological and biochemical parameters with the healthy controls. Haematology revealed significantly reduced haemoglobin, increased TLC, increased lymphocyte count and non-significant increase in neutrophil count in comparison to the animals of control group. Biochemical parameters revealed significant elevation of blood urea nitrogen (BUN) and serum creatinine in all the affected cases of urinary system disorders in comparison to control group.

2.2.8 Hepatic Dysfunction

Tantary *et al* (2014) did haematological and biochemical tests of fourty nine dogs suffering from various hepatic disorders and compared them with control group. They found that in acute hepatitis, the mean values of Hb, PCV, TEC and platelet count were decreased non-significantly, while in chronic hepatitis, mean values of Hb, PCV, TEC and platelet count were decreased significantly from that of healthy control group. In acute hepatitis, the mean values of ALT, AST and ALKP were significantly increased whereas the values of GGT, bilirubin, creatinine and BUN were found to be non-significantly increased as compared to control group. In chronic hepatitis, the mean values ALT, AST, ALKP and BUN were significantly increased whereas the values of GGT, bilirubin and creatinine were non-significantly increased. In Cholestasis/ cholangiohepatitis, the mean values ALT, AST, ALKP, GGT, bilirubin and BUN were found to be significantly increased as compared to control group while creatinine decreased non-significantly from that of control group. Total protein, albumin, plasma glucose and cholesterol values were decreased significantly whereas globulin and albumin to globulin (A:G) ratio were found to be decreased non-significantly as compared to control group.

2.2.9 Cardiac disorders

Vishnurahav *et al* (2017) conducted a study on a total of twenty-five cases of dilated cardiomyopathy and compared them with twenty apparently healthy ones. Blood was subjected to haemato-biochemical examinations. A statistically significant

decrease in the mean values of volume of packed red blood cells and lymphocytes was recorded. Statistically significant increase was noticed in the mean values of granulocyte and total leucocyte count. Statistically significant increase was noticed in the mean values of creatine kinase-MB and blood urea nitrogen.

Thirunavukkarasu *et al* (2018) carried out a study on the dogs with clinical signs suggestive of cardiac failure. Baseline haematology panel, and baseline serum biochemistry panel of the cases was examined. No significant changes were observed in the routinely assessed hematological parameters in dogs with heart disease. Among biochemical parameters only significant hypernatremia was observed.

2.2.10 Immune mediated hemolytic anaemia (IMHA)

McManus and Craig (2001) retrospectively studied 34 cases of dogs with immune-mediated hemolytic anemia (IMHA) to correlate severity of leukocytosis with severity of postmortem lesions in dogs with IMHA. They found that moderate to marked leukocytosis was associated with moderate to severe postmortem lesions. None of the dogs with mild lesions had moderate or marked leukocytosis. They also observed neutrophilic left shifts and toxic change in neutrophils. They concluded that moderate to marked leukocytosis, neutrophilic left shift, and toxic change in neutrophils in dogs with IMHA should alert clinicians to the potential for moderate to severe tissue injury, which could complicate treatment and worsen prognosis.

2.3 Prognostic usefulness of leukocytes

Kuplulu *et al* (2009) conducted a study with the aim to investigate the prognosis in 30 bitches with pyometra that were ovariohysterectomized. They compared the serum biochemical and haematological parameters of the dead and recovered bitches with pyometra after the operative approach. It was found that the level of band neutrophils in the bitches that died was higher than 10% and there was lymphopenia along with a marked monocytosis resulting in a highly negative correlation. Among biochemicals, the increased serum BUN and creatinine levels were significantly correlated. A significant tendency was apparent for increasing mortality in bitches with pyometra whose BUN and creatinine levels were high. They came to the conclusion that the elderly azotemic dogs having high BUN and creatinine concentration along with over 10% band neutrophils would likely end up with

mortality within 3 days after surgery and thus BUN and creatinine concentrations together with band neutrophil level may serve as a good prognostic predictor.

Bastan *et al* (2013) with the purpose to evaluate the prognostic usefulness of some parameters in dogs with canine parvo virus (CPV) conducted a study on 59 animals which consisted of 39 ill and 20 healthy puppies. Complete physical examination and laboratory variables such as complete blood count (CBC) and serum biochemistry were performed on their first admission to clinic and on following every day before treatment until discharge or death. Despite aggressive treatment with available therapy, 14 of 39 dogs died. Non-survivor dogs had significantly lower leukocyte, lymphocyte, monocyte and granulocyte counts but had significantly higher serum urea and creatinine concentrations than those of survivor dogs. This study demonstrates that leukocyte, lymphocyte, granulocyte, monocyte counts, serum urea and creatinine concentrations were useful parameters for predicting the prognosis of dogs with CPV.

Sant'Anna *et al* (2014) with the aim to identify markers associated with clinical worsening of dogs with pyometra prospectively evaluated 80 dogs with pyometra. The findings of hematological, biochemical and blood lactate levels were compared between groups of dogs that were discharged and those who required prolonged hospitalization. The variables such as systemic inflammatory response syndrome (SIRS), hyperlactatemia and increased creatinine were analyzed. They were of the conclusion that, the presence of SIRS and elevated serum creatinine >2.5mg/mL were effective in predicting the worsening of the disease and could be used as prognostic markers of canine pyometra.

Novacco *et al* (2015) with the aim to predict the prognostic factors in canine acute leukaemias conducted a retrospective study and did analysis of the haematological findings and concluded that a normal neutrophil count at presentation significantly prolonged survival time. Additionally, he found that, there was a trend for anaemic dogs to have shorter survival compared with those without anaemia,

Eichenberger *et al* (2016) conducted a study to evaluate prognostic markers associated with poor outcomes in acute *Babesia canis* infections by comparing the results of routine laboratory profiles, hand-held lactate and glucose analyzer, and the acute phase response in 2 groups of naturally infected dogs (7 survivors and 8

nonsurvivors). It was found that nonsurvivors showed significantly higher concentrations of lactate, triglycerides and phosphate and lower hematocrit, leukocyte counts, total serum protein concentrations, and thrombocyte counts when compared to survivors. It was concluded that poor outcome in acute *B. canis* infection was indicated by changes in the laboratory profile like moderate anemia, severe thrombocytopenia, mild to moderate leukopenia, hyperlactatemia, moderately increased serum phosphate, and triglyceride concentrations, and moderately decreased total serum protein concentrations.

Davies *et al* (2018) conducted a retrospective study with the aim to describe the prognostic factors in 42 cases of multicentric centroblastic diffuse large B-cell lymphoma in canines. They were of the opinion that absence of anaemia at diagnosis and a pretreatment neutrophils: lymphocytes ratio (NLR) below 9.44 were associated with longer progression-free survival for the first remission (PFS1) while lymphocytes: monocytes ratio (LMR) above 1.43, and NLR below 11.44 were independently predictive of longer overall survival (OS).

CHAPTER III

MATERIALS AND METHODS

3.1 Retrospective analysis

Clinical records of dogs presented to the Department of Teaching Veterinary Clinical Complex (TVCC), Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana during the calendar year 2016 and 2017 were retrospectively reviewed to identify the various pathological conditions associated with leukocyte alterations in dogs. The data extracted from the records included haematological parameters and diagnosis. The leukogram findings of 3374 cases were analyzed, the incidence of various disease conditions was recorded and correlated with the leukocyte alterations.

3.2 Prospective Studies

Medical records of dogs whose blood samples collected at the time of admission and submitted to the Clinical Diagnostic Laboratory of the Department of Teaching Veterinary Clinical Complex (TVCC), GADVASU, Ludhiana from July 2018 to march 2019 were included as a part of the prospective study. The data collected from the medical records included case related information- signalment, history, physical examination findings at time of admission (i.e. general condition of animal, rectal temperature, mucous membrane colour etc.), other ancillary diagnostic test results, final diagnosis and outcome/prognosis. All samples were subjected to estimation of the haematological parameters including total leukocyte count (TLC), differential leukocyte count (DLC) (neutrophil, band cells, metamyelocyte, myelocyte, eosinophil, basophil, lymphocyte, monocyte), haemoglobin (Hb), and platelet count and were compared with reference values (Table 1) according to (Jain 1986) The comparison was also done with the values of apparently healthy dogs.

Table 1: Normal hematological values of the dog (Jain 1986)

Parameter	Range	Percentage
Leukocytes/µl	6,000-17,000	-
Neutrophil (band)	0-300	0-3
Neutrophil (mature)	3,000-11,500	60-77
Lymphocyte	1,000-4,800	12-30
Monocyte	150-1,350	03-10
Eosinophil	100-1,250	02-10
Basophil	Rare	Rare
Hemoglobin (g/dl)	12.0-18.0	-
Thrombocytes ($\times 10^5$/µl)	02-05	-

3.2.1 Processing of blood samples and preparation of blood smears

Blood samples from dogs collected into tubes containing ethylene diamine tetra acetic acid (EDTA) anticoagulant and submitted to the Clinical Diagnostic Laboratory, TVCC were processed within 30 minutes to 1 hour of collection. The total leukocyte count (TLC) and hemoglobin (Hb) were performed manually in 194 cases using Neubauer chamber and platelets were calculated upon blood smear examination using the formula: platelets per microliter = number of platelets per 100 x oil field × 20,000 (Harvey 2012), whereas, automated hematological counter (ADVIA 2120 Hematology System) was used to perform these parameters in 106 cases. Thin blood smears were prepared on clean grease free slides, air dried and stained manually with Romanowsky-type stains (Leishman stain solution- BTL Research Labs) for examination under light microscope using oil immersion. The photographs were taken on the microscope (BX 61, Olympus Corporation, Japan) by examining the smears at low power and at oil immersion.

3.2.2 Microscopic evaluation of blood smears

Blood smear evaluation was mainly directed to ascertain the differential leukocyte count (DLC) and to examine and grade the different types of morphological

abnormalities in the leukocytes viz. toxic changes in neutrophils and different types of lymphocytes.

The differential leukocyte count (DLC) viz. neutrophil, band cells, metamyelocyte, myelocyte, eosinophil, basophil, lymphocyte and monocyte was performed manually to determine the lineage by counting 200 leukocytes upon examination of Romanowsky type stained blood smears and was further used to calculate the absolute counts of different leukocytes and their percentage (Gianopoulos *et al* 2016).

3.2.2.1 Classification of left shift

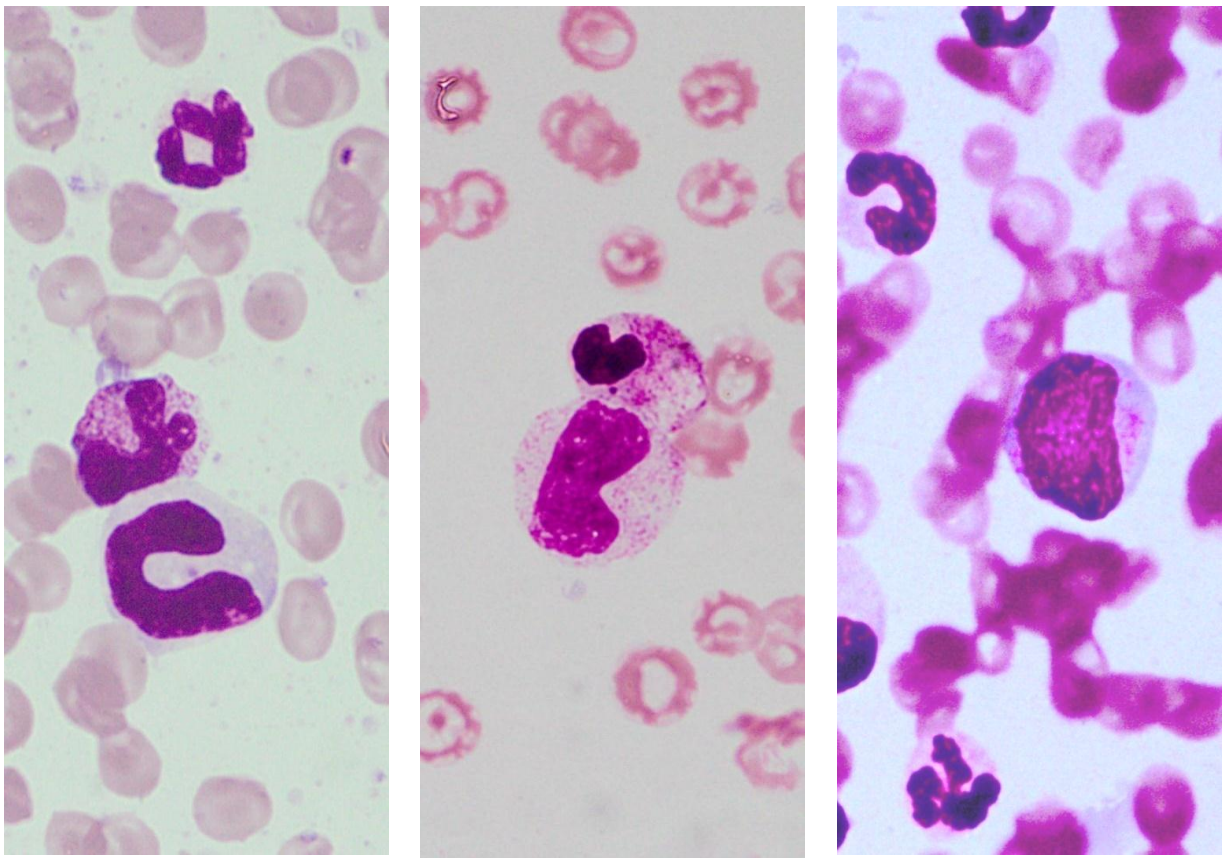
Severity of left shift was defined based on immaturity of neutrophils (Fig. 1): bands (1+ or slight), band and metamyelocytes (2+ or moderate), and band, metamyelocytes and myelocytes (3+ or marked) as per Stockham and Scott (2008).

3.2.2.2 Grading of toxic changes in neutrophils

Grading of overall neutrophil toxicity: The severity of neutrophil toxicity was assessed by screening 100 neutrophils on blood smear examination and the final grade of which was based on both the severity of morphologic change and approximate percentage of cells affected (Aroch *et al* 2005). The criteria for grading of toxic changes in neutrophils is depicted in Table 2 and Figure 2. The presence of Dohle bodies, cytoplasmic basophilia, and cytoplasmic vacuolation was graded as mild (1), moderate (2), or marked (3) while giant toxic neutrophils presence was considered a marked abnormality and then adjusted for the percentage of affected neutrophils (<10% = mild, <10–30% = moderate, >30% = marked). The overall neutrophil toxicity was calculated as sum of scores of the individual neutrophil morphologic abnormalities. Results were interpreted as follows:

- Mild neutrophil toxicity - score of 1–6
- Moderate toxicity included - score of 7–12
- Marked toxicity- total score >12

In addition to these changes presence of doughnut nucleus was also considered as toxic change.



Band cell **Metamyelocyte** **Myelocyte**

Fig. 1: Grading of left shift based on presence of band cells, metamyelocyte and myelocyte

Table 2: Grading of toxic changes in neutrophils (Aroch *et al* 2005)

Morphologic Change Intensity	Cells affected in peripheral blood smear		
	<10	**10-30**	**>30**
Dohle bodies			
Mild	1	1	1
Moderate	1	1	2
Marked	2	2	3
Basophilia			
Mild	1	1	2
Moderate	2	2	3
Marked	2	3	3
Vacuolation			
Mild	1	1	2
Moderate	2	2	3
Marked	2	3	3
Giant toxic neutrophils	3	3	3

Grading of toxic granulation: Neutrophils with toxic granules were defined by the presence of dark blue to purple colored granules in the cytoplasm and were graded according to Tejeswini *et al* (2012) by adopting the criteria shown in Table 3 depending upon the intensity of staining. The criteria was slightly modified as the categories were combined as: mild with score 1, moderate with score 2 and marked with score 3 and 4 for sake of ease in grading (Fig. 3).

These changes were then correlated with the grade of overall neutrophil toxicity to determine the final grade of neutrophil toxic changes.

Table 3: Grading of toxic granulation in neutrophils (Tejeswini *et al* 2012)

Grade	Morphology
0	Normal granulated neutrophils
1	Scattered granules in the cytoplasm with associated increase in stain intensity
2	Increased number of granules in the cytoplasm with associated increase in stain intensity
3	Numerous granules in the cytoplasm with intense blue black staining properties
4	Numerous coarse granules crowding the cytoplasm

3.2.2.3 Grading of lymphocyte alterations

The morphological alterations in the lymphocytes viz. activated, granular and atypical lymphocytes (Fig. 4) were classified as none, rare, few or many as per the classification system of Gianopoulos *et al* (2016). The criteria adopted for classification based on the number of lymphocytes showing the changes is shown in Table 4. If no morphological changes were observed in the lymphocytes they were graded as none, if one to five lymphocytes were observed with morphological changes they were graded as rare. If number of lymphocytes with morphological changes were observed to be between five to fifteen, and more than fifteen, then they were classified as few and many, respectively.

Table 4: Criteria for classifying lymphocyte abnormalities

Class	None	Rare	Few	Many
Number of lymphocytes affected	0	1 to 5	5 to 15	>15

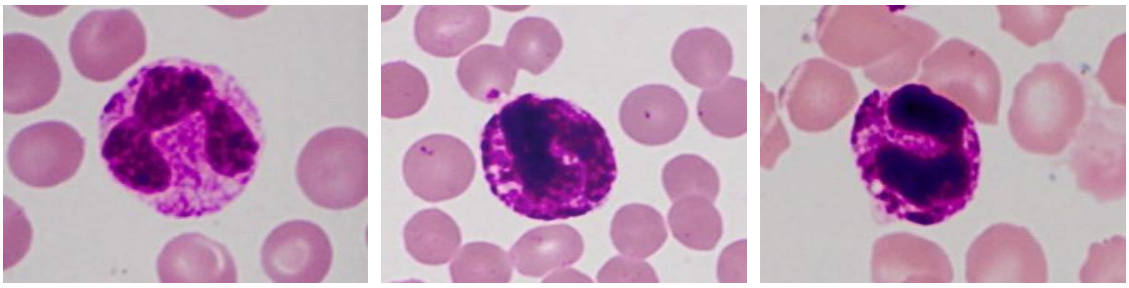
3.2.3 Correlation of the leukocyte alterations with different pathological conditions diagnosed using ancillary techniques

The different leukocyte alterations observed were correlated with other diagnostic techniques as follows:

3.2.3.1 Blood biochemical analysis

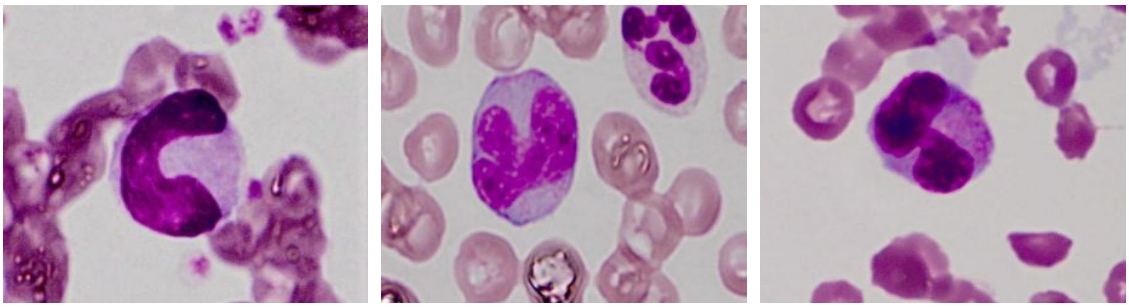
Blood biochemical analysis when done included following parameters- Total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline

Grading on basis of Dohle body



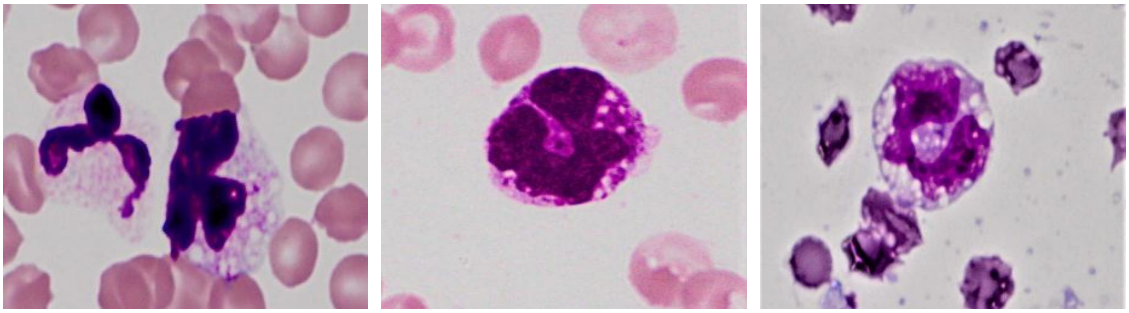
Mild **Moderate** **Severe**

Grading on basis of cytoplasmic basophilia

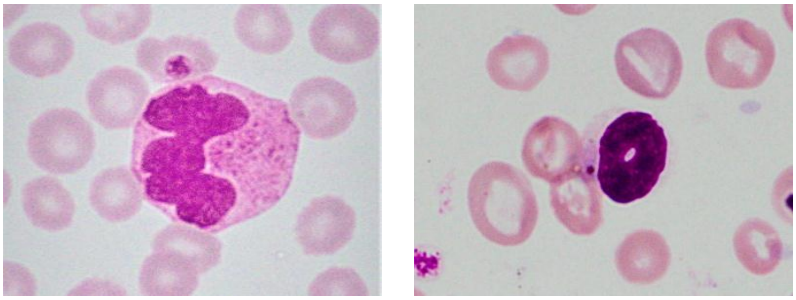


Mild **Moderate** **Severe**

Grading on basis of vacuolation

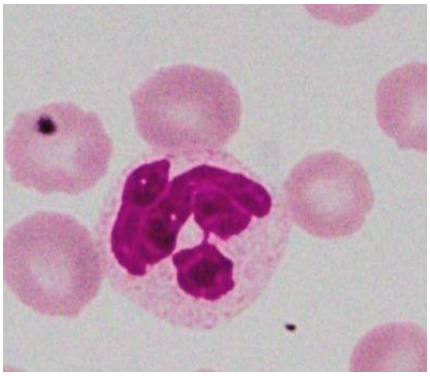


Mild/Foamy **Moderate** **Severe**

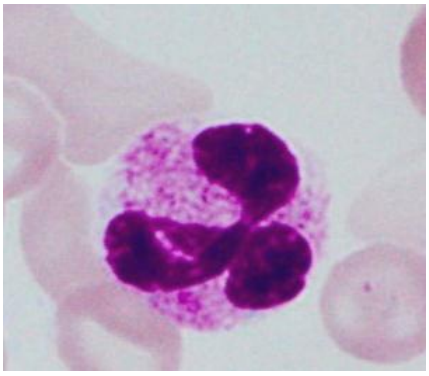


Giant neutrophil **Doughnut nucleus**

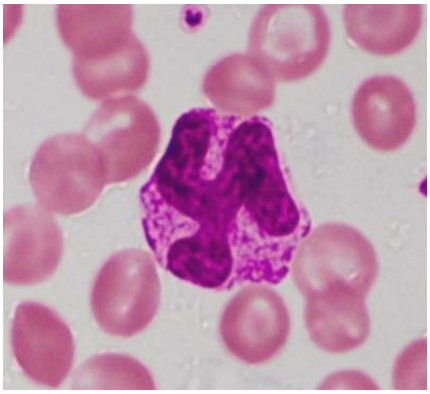
Fig. 2: Grading of toxic changes in neutrophils



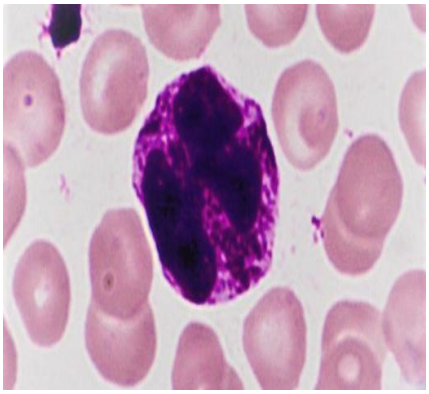
Normal granulation



Mild granulation

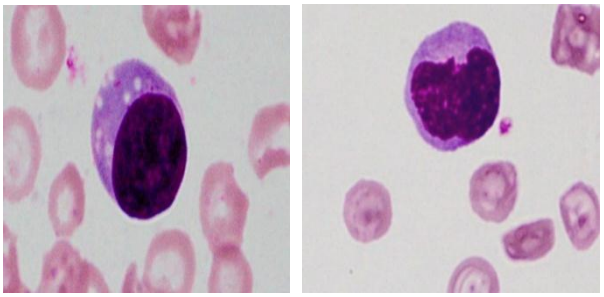


Moderate granulation

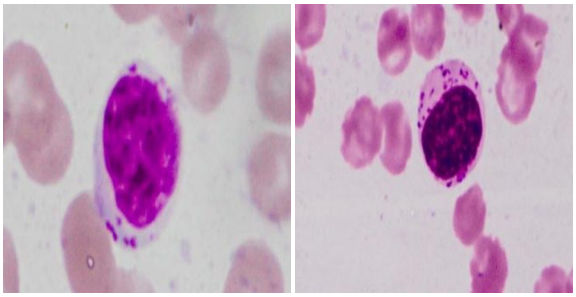


Marked granulation

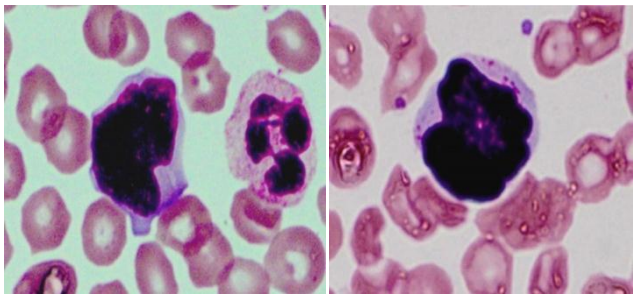
Fig. 3: Criteria for grading toxic granulation



Activated lymphocytes



Granular lymphocyte



Atypical lymphocytes

Fig. 4: Morphologic alterations of lymphocytes

phosphatase (ALKP), gamma-glutamyl transferase (GGT), total protein, albumin, creatinine and blood urea nitrogen (BUN). The results were compared with the apparently healthy dogs. The blood serum biochemical analysis when done was performed on fresh serum which was separated by centrifugation within 1 hour. Serum biochemical concentrations were analyzed using automatic biochemistry analyzer Vitros 350 Chemistry (Ortho Clinical Diagnostics, Johnson-Johnson). The serum samples were kept stored at -20˚C for further analysis if required.

3.2.3.2 Cytological examination

Where ever possible fine needle aspiration biopsies (FNAB) were also analyzed to correlate them with leukocyte alterations and pathologic condition. The cytological specimens submitted for analysis such as peritoneal fluid, fine needle aspiration biopsy (FNAB), impression smears etc. were routinely stained with Romanowsky-type stains (Leishman stain solution- BTL Research Labs) and evaluated under light microscope. Special stains including May Grunwald Giemsa (Himedia) and Papanicolaou (Himedia) were also performed on the FNAB from the lymph nodes suspected for lymphoma, wherever possible.

3.2.3.3 Parasitological examination

Results of blood smear examination for hemoprotozoa, skin scrapings for mange/mites and faecal samples for presence of ova/oocyts were correlated with the leukocyte alterations in various pathological conditions.

3.2.3.4 Other diagnostic tests

Findings of radiography (Siemens), ultrasonography (Philips), echocardiography (GE Logiq P5 colour doppler machine equipped with sector probe 4S, 5S and 11S) and electrocardiography (BPL cardiart 8108 six channel ECG machine) in different pathological conditions of dogs were also correlated with leukocyte alterations.

3.2.4 Assessment of prognosis

Prognosis of canine patients with different pathological conditions was assessed for a minimum of 2 months in every case and based on the outcome was classified into three categories viz. good, fair and poor. Good prognosis indicated a favorable outcome, fair prognosis indicated a lingering condition and poor prognosis indicated the unfavorable outcome or canine patients that died.

3.2.5 Apparently healthy dogs

A total of 10 apparently healthy dogs that came for regular checkup and had normal physical examination findings were also included in the study for the purpose of comparison.

3.2.6 Statistical analysis

The data was analyzed by using Chi Square test, Independent T- test and Logistic regression in Statistical Analysis Software (SAS-version 9.3, Institute, CARY, USA) and using post hoc tests for inter group comparisons in SPSS software (IBM SPSS Statistics 24). The analysis was carried out to correlate the leukocyte alterations observed with the diagnosis and prognosis in the different pathological conditions of dogs.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Retrospective analysis

4.1.1 Incidence of various pathological conditions of dogs

A total of 3374 cases were retrospectively reviewed to determine the incidence of the various pathological conditions associated with leukocytic disorders in the dogs and are summarized in Table 5.

Table 5: Various pathological conditions of dogs as analyzed in retrospective study

S. No.	Pathological conditions	Number of cases (n)
1.	**General pathological conditions**	
a.	Renal dysfunction	606
b.	Hepatic dysfunction	542
c.	Gastro-intestinal (GIT) disorders	251
d.	Urinary tract infections (UTI)	248
e.	Ascites	228
f.	Respiratory tract affections	209
g.	Skin affections	201
h.	Pyometra	196
i.	Hepato-renal dysfunction	152
j.	Bone fracture	111
k.	Cardiac disorders	43
2.	**Viral and bacterial diseases**	
a.	Canine distemper (CD)	125
b.	Parvo viral infection	119
c.	Brucellosis	19
3.	**Parasitic infections**	
a.	Ehrlichiosis	129
b.	Hookworm infestation	28
c.	Babesiosis	27
d.	Demodicosis	18
e.	Hepatozoonosis	14
4.	**Neoplasms**	
a.	Lymphoma	40
b.	Transmissible venereal tumor (TVT)	35
c.	Mammary tumor	26
d.	Lymphocytic leukemia	07

In the group of general disease conditions maximum cases recorded were that of renal dysfunction (606) followed by hepatic dysfunction (542), gastrointestinal (GIT) disorders (251), urinary tract infections (UTI) (248), ascites (228), respiratory tract affections (209), skin affections (201), pyometra (196), hepato-renal dysfunction (152), bone fracture (111) and cardiac disorders (43).

Among viral and bacterial diseases maximum cases recorded were that of canine distemper (CD) (125) followed by parvo viral infection (119) and brucellosis (19).

Among parasitic infections maximum cases recorded were that of ehrlichiosis (129) followed by hookworm infestation (28), babesiosis (27), demodicosis (18) and hepatozoonosis (14).

Among neoplasms maximum cases recorded were that of lymphoma (40) followed by transmissible venereal tumor (TVT) (35), mammary tumor (26) and lymphocytic leukaemia (7).

4.1.2 Leukogram findings in retrospective study

The analysis of the leukogram in retrospective study (Table 6) revealed range of total leukocyte count (TLC) from 110 – 3,80,000/µl along with mean and median value of 23094.64 ± 35.84/µl and 17780/µl respectively. These values were found to be increased in comparison to the reference values.

The range of neutrophil (N) percent (%) count was 2 – 98 with mean and median value of 84.58 ± 0.22 and 88 respectively. These values were increased in comparison to the reference values. Similar trend was observed in absolute counts of neutrophils (N Absolute) with range of 0 - 372400/µl and mean and median values of 20241.19 ± 338.01/µl and 14775.20/µl.

The range of lymphocytes (L) percent count was 0 – 98 with mean and median value of 13.66 ± 0.21 and 10 respectively. The mean value was within range but median value was less when compared with reference values. The absolute count of lymphocytes (L Absolute) was in the range of 0 - 156613.8/µl with mean and median value of 2498.78 ± 85.18/µl and 1734.2/µl respectively. These values were within range when compared to the reference values.

Table 6: Leukogram findings in dogs

Parameter	Range	Mean ± SE	Median	Reference values
TLC/µl	110 - 380000	23094.64 ± 35.84	17780	6000 – 17000
N (%)	2 – 98	84.58 ± 0.22	88	60 -77
N Absolute/µl	0 – 372400	20241.19 ± 338.01	14775.2	3000 – 11500
L (%)	0 – 98	13.66 ± 0.21	10	12 – 30
L Absolute/µl	0 - 156613.8	2498.78 ± 85.18	1734.2	1000 – 4800
M (%)	0 -10	0.07 ± 0.008	0	3 – 10
M Absolute/µl	0 - 2504.4	13.06 ± 1.64	0	150 – 1350
E (%)	0 – 48	1.67 ± 0.06	0	2 -10
E Absolute/µl	0 - 40449.6	318.75 ± 19.16	0	100 – 12501

The monocytes (M) percent and absolute count (M Absolute) range was 0 - 10 and 0 - 2504.4/µl respectively with mean value of 0.07 ± 0.008 and 13.06 ± 1.64/µl respectively. These values were less when compared with the reference values.

The eosinophil (E) percent count range was 0 – 48 with mean value of 1.67 ± 0.06/µl which was less than the reference values. The range of absolute (E Absolute) count of eosinophil was 0 - 40449.6/µl with mean value of 318.75 ± 19.16/µl which was within normal limits when compared with reference values.

4.1.3 Correlation of total leukocyte count disorders and pathological conditions of dogs (retrospective study)

The leukocytic disorders observed in different pathological conditions of dogs in retrospective study are shown in Table 7 and Figure 5. The most common TLC related leukocytic disorder observed was leukocytosis (1741) followed by leukopenia (212) and leukemoid response (123).

In the leukocytosis group maximum cases of renal dysfunction and hepatic dysfunction (284 each) followed by pyometra (170), ascites (136), urinary tract infections (134), GIT disorders (123), skin affections (106), respiratory tract affections (102), hepato-renal dysfunction (96), viral and bacterial diseases (94), parasitic infections (90), bone fracture (52), neoplasms (50) and cardiac disorders (20) cases were observed.

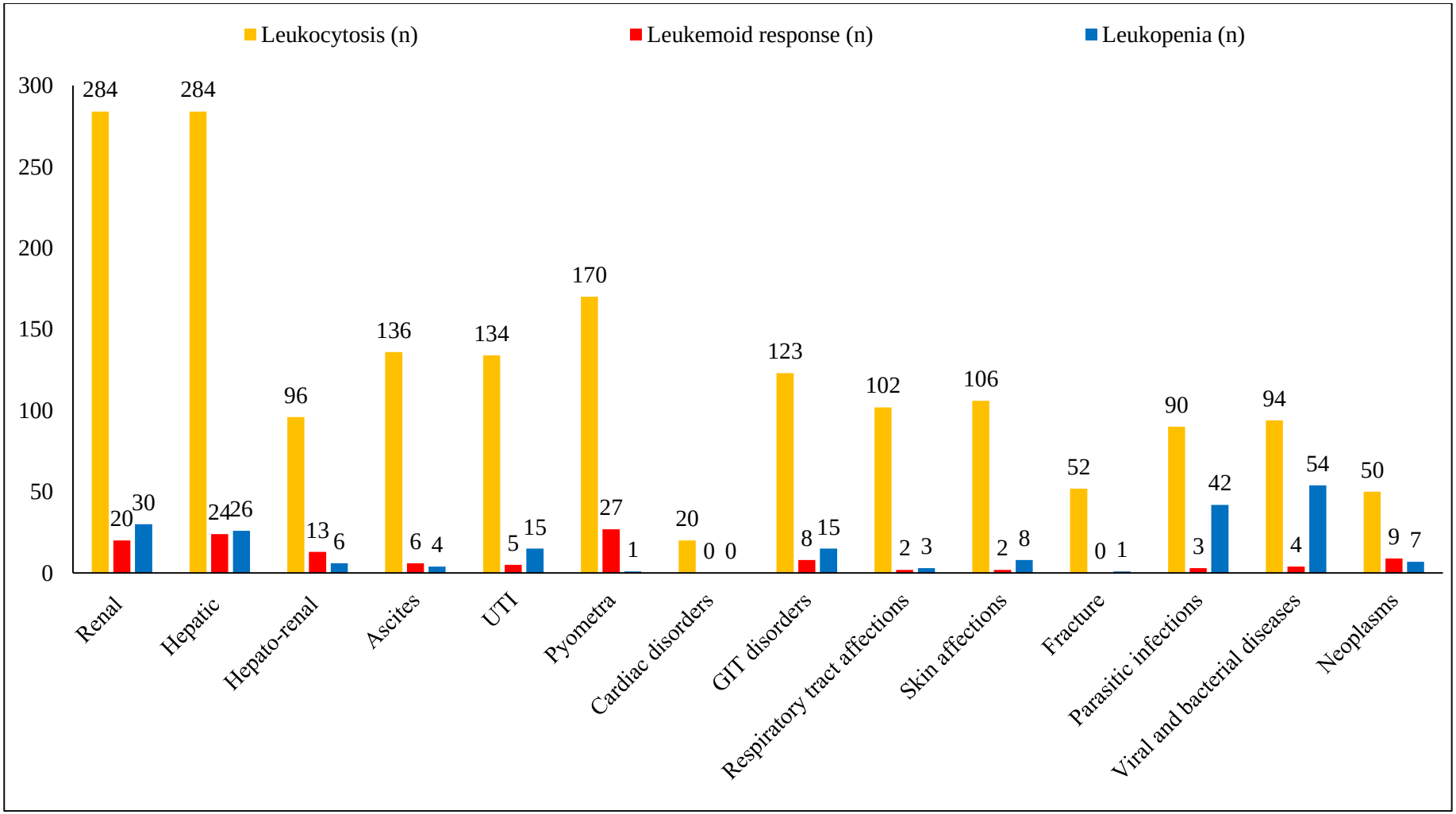


Fig. 5: Correlation of total leukocyte count disorders in different pathological conditions of dogs

In the leukemoid response group maximum cases of pyometra (27) followed by hepatic dysfunction (24), renal dysfunction (20), hepato-renal dysfunction (13), neoplasms (9), gastro-intestinal (GIT) disorders (8), ascites (6), urinary tract infections (5), viral and bacterial diseases (4), parasitic infections (3), respiratory tract affections and skin affections (2 each) were observed.

In the leukopenia group maximum cases of viral and bacterial diseases (54) followed by parasitic infections (42), renal dysfunction (30), hepatic dysfunction (26), urinary tract infections and GIT disorders (15 each), skin affections (8), neoplasms (7), hepato-renal dysfunction (6), ascites (4), respiratory tract affections (3), pyometra and bone fracture (1 each) were observed.

Table 7: Correlation of total leukocyte count disorders and different pathological conditions of dogs

Pathological conditions	**No. of cases with Leukocytosis**	**No. of cases with Leukemoid response**	**No. of cases with Leukopenia**
Renal dysfunction	284	20	30
Hepatic dysfunction	284	24	26
Gastro-intestinal (GIT) disorders	123	08	15
Urinary tract infections (UTI)	134	05	15
Ascites	136	06	04
Respiratory tract affections	102	02	03
Skin affections	106	02	08
Pyometra	170	27	01
Hepato-renal dysfunction	96	13	06
Bone fracture	52	-	01
Cardiac disorders	20	-	-
Viral and bacterial diseases	94	04	54
Parasitic infections	90	03	42
Neoplasms	50	09	07
Total	1741	123	212

4.1.4 Correlation of differential leukocyte count disorders and pathological conditions of dogs (retrospective study)

In the DLC related leukocytic disorders (Fig. 6 and Table 8) most common was relative neutrophilia (833) followed by absolute neutrophilia (263), relative lymphocytosis (83), absolute eosinophilia (58), absolute lymphocytosis (41) and relative eosinophilia (30).

In the relative neutrophilia groups maximum cases of renal dysfunction (190) followed by hepatic dysfunction (142), viral and bacterial diseases (75), urinary tract infections (68), GIT disorders (52), respiratory tract affections (52), ascites (50), parasitic infections (48), skin affections (46), bone fracture (32), hepato-renal dysfunction (28), neoplasms (24), cardiac disorders (15) and pyometra (12) were observed.

In the absolute neutrophilia group maximum cases of renal dysfunction (53), followed by hepatic dysfunction (49), viral and bacterial diseases (22), respiratory tract affections (21), ascites and GIT disorders (20), skin affections (14), bone fracture (13), neoplasms (12), parasitic infections and hepato-renal dysfunction (10), urinary tract infections (9), pyometra (6) and cardiac disorders (4) were observed.

In the relative lymphocytosis group maximum cases of viral and bacterial diseases (16) followed by parasitic and GIT disorders (13 each), renal dysfunction (10), hepatic dysfunction (9), skin affections (5), respiratory tract affections and neoplasms (4 each), ascites and urinary tract infections (3), bone fracture (2) and pyometra (1) were observed.

In the absolute lymphocytosis group maximum cases of parasitic infections (8) followed by viral and bacterial diseases (6), hepatic dysfunction, respiratory tract affections and skin affections (5 each), urinary tract infections (3), renal dysfunction, pyometra and neoplasms (2 each), bone fracture, cardiac and GIT disorders (1 each) were observed.

In the relative eosinophilia group maximum cases of hepatic dysfunction (5) followed by parasitic infections (4), renal dysfunction, GIT disorders and bone fracture (3 each), ascites, pyometra, respiratory tract affections, skin affections and neoplasms (2 each), urinary tract infections and viral and bacterial diseases (1 each) were observed.

In the absolute eosinophilia group maximum cases of skin affections (10) followed by respiratory tract affections and parasitic infections (8), urinary tract infections (7), GIT disorders and bone fracture (5), renal dysfunction, hepatic dysfunction, pyometra and viral and bacterial diseases (3 each), ascites (2) and neoplasms (1) were observed.

Table 8: Correlation of differential leukocyte count disorders and different pathological conditions of dogs

Pathological conditions	No. of cases with Relative neutrophilia	No. of cases with Absolute neutrophilia	No. of cases with Relative lymphocytosis	No. of cases with Absolute lymphocytosis	No. of cases with Relative eosinophilia	No. of cases with Absolute eosinophilia
Renal dysfunction	190	53	10	02	03	03
Hepatic dysfunction	142	49	09	05	05	03
Gastro-intestinal (GIT) disorders	52	20	13	01	03	05
Urinary tract infections (UTI)	68	09	03	03	01	07
Ascites	50	20	03	-	02	02
Respiratory tract affections	51	21	04	05	02	08
Skin affections	46	14	05	05	02	10
Pyometra	12	06	01	02	02	03
Hepato-renal dysfunction	28	10	-	-	-	-
Bone fracture	32	13	02	01	03	05
Cardiac disorders	15	04	-	01	-	-
Viral and bacterial diseases	75	22	16	06	01	03
Parasitic infections	48	10	13	08	04	08
Neoplasms	24	12	04	02	02	01
Total	833	263	83	41	30	58

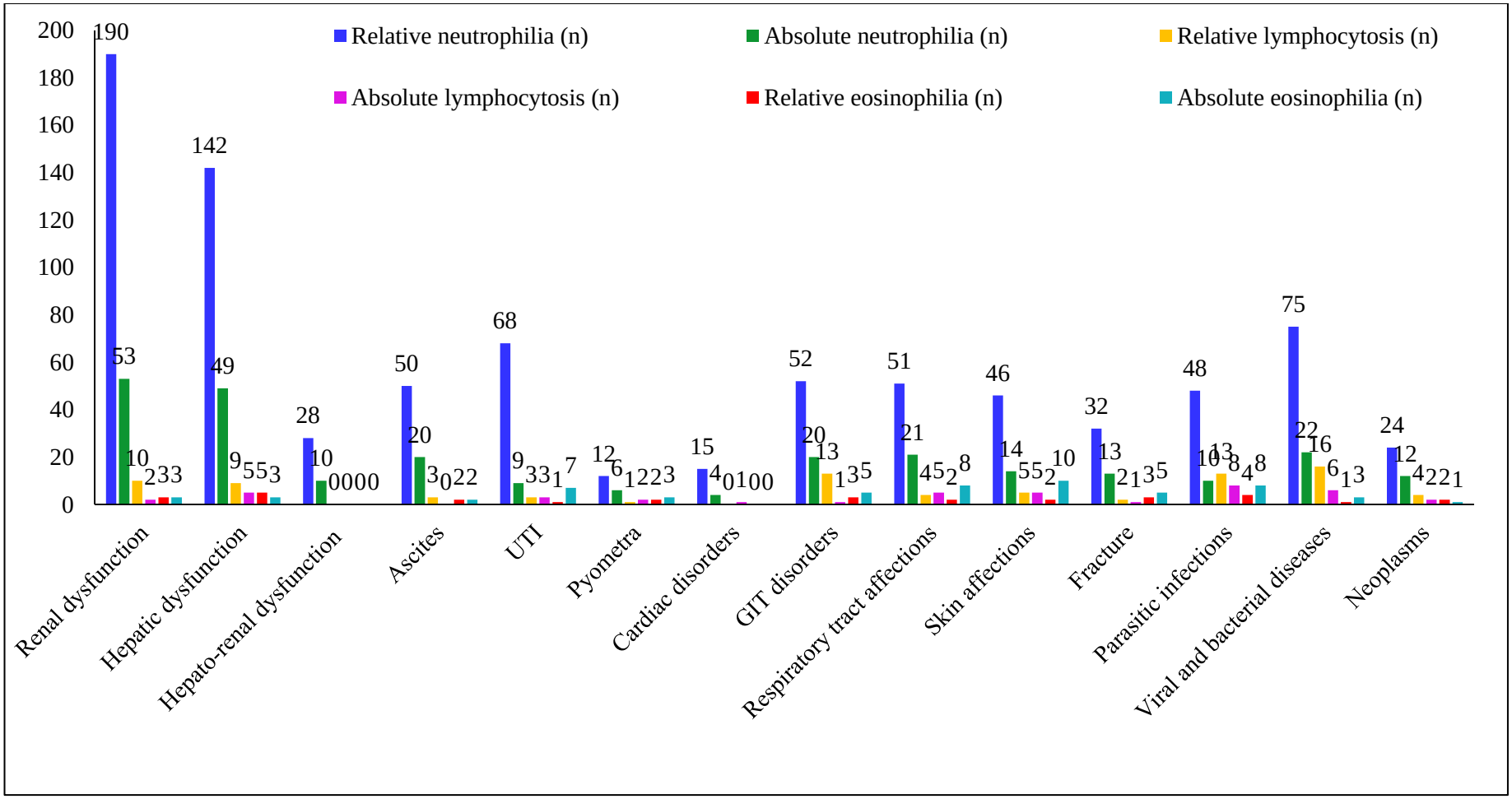


Fig. 6: Correlation of differential leukocyte count disorders in different pathological conditions of dogs

4.1.5 Incidence of left shift and toxic changes in different pathological conditions of dogs (retrospective study)

The incidence of left shift and toxic changes is shown in Table 9 and Figure 7 and 8. Maximum left shift was recorded in pyometra in 79 cases (40.3%) followed by hepatic dysfunction in 117 cases (21.5%), hepato-renal in 32 cases (21.05%), GIT disorders in 49 cases (19.5%), skin affections in 39 cases (19.4%), ascites in 44 cases (19.2%), UTI in 45 cases (18.1%), respiratory tract affections in 37 cases (17.7%), neoplasms in 18 cases (16.6%), renal dysfunction in 98 cases (16.1%), viral diseases in 41 cases (15.5%), bone fracture in 14 cases (12.6%), parasitic infections in 26 cases (12.03%) and cardiac disorders in 05 cases (11.6%).

Table 9: Incidence of left shift and toxic changes in different pathological conditions of dogs

Pathological conditions	No. of cases (n)	Left shift present (n)	Left shift (% cases)	Toxic changes present (n)	Toxic changes (% cases)
Renal dysfunction	606	98	16.1	131	21.6
Hepatic dysfunction	542	117	21.5	126	23.2
Gastro-intestinal (GIT) disorders	251	49	19.5	54	20.7
Urinary tract infections (UTI)	248	45	18.1	48	19.3
Ascites	228	44	19.2	56	24.5
Respiratory tract affections	209	37	17.7	46	22
Skin affections	201	39	19.4	53	26.3
Pyometra	196	79	40.3	36	18.3
Hepato-renal dysfunction	152	32	21.05	32	21.05
Bone fracture	111	14	12.6	27	24.2
Cardiac disorders	43	05	11.6	13	30.2
Viral diseases	263	41	15.5	51	19.3
Parasitic infections	216	26	12.03	31	14.3
Neoplasms	108	18	16.6	16	14.8

Maximum toxic changes were recorded in cardiac disorders in 13 cases (30.2%) followed by skin affections in 53 cases (26.3%), ascites in 56 cases (24.5%), bone fracture in 27 cases (24.2%), hepatic dysfunction in 126 cases (23.2%),

respiratory tract affections in 46 cases (22%), renal dysfunction in 131 cases (21.6%), hepato-renal dysfunction in 32 cases (21.05%), GIT disorders in 54 cases (20.7%), viral diseases in 51 cases (19.3%), UTI in 48 cases (19.3%), pyometra in 36 cases (18.3%), neoplasms in 16 cases (14.8%) and parasitic infections in 31 cases (14.3%).

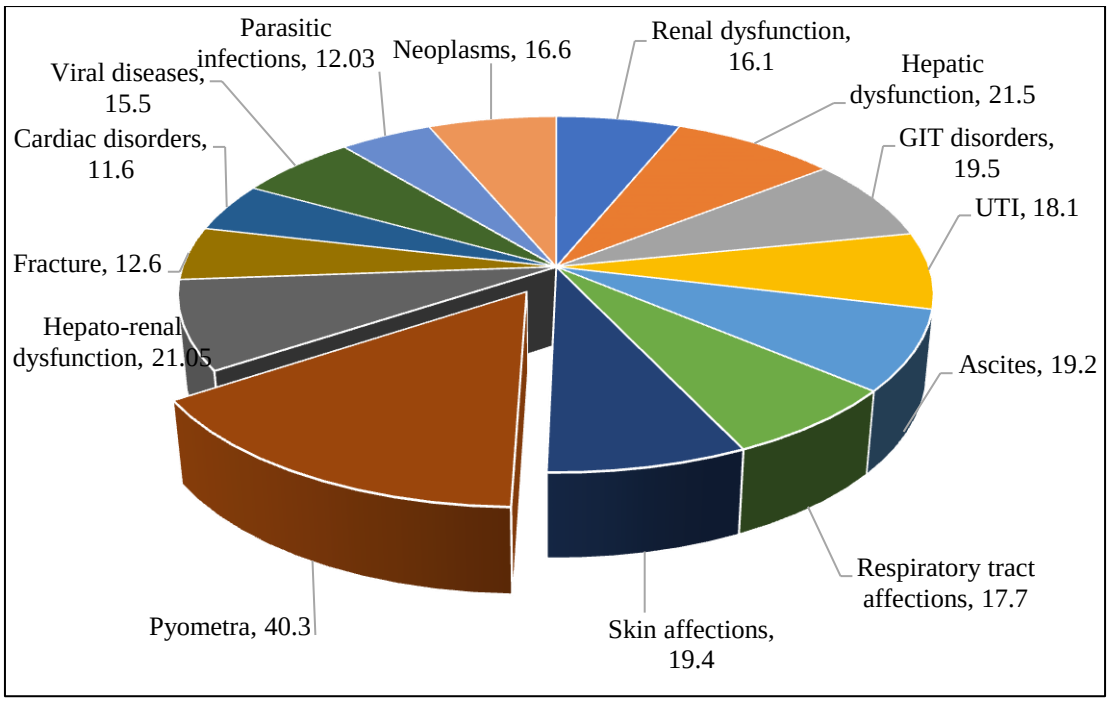


Fig. 7: Incidence of left shift in different pathological conditions of dogs

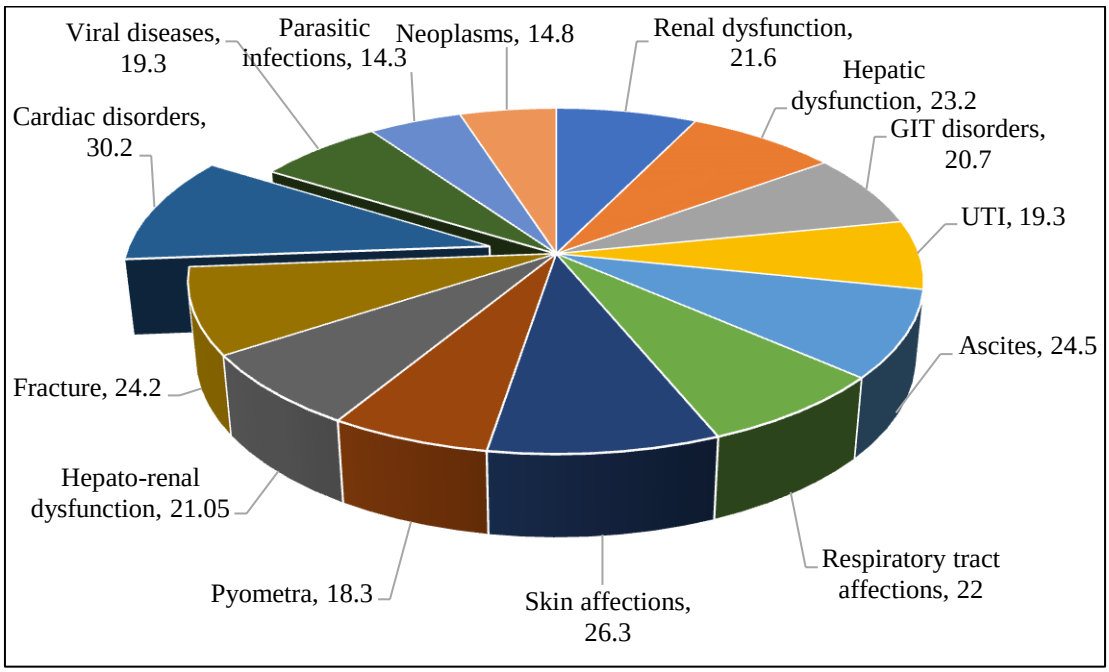


Fig. 8: Incidence of toxic changes in neutrophils in different pathological conditions of dogs

4.1.6 Chi Square analysis of left shift and toxic changes in neutrophils with pathological conditions (retrospective study)

There were no significant differences observed in pathological conditions like hepatic dysfunction, gastro-intestinal (GIT) disorders, urinary tract infections (UTI), ascites, respiratory tract affections, skin affections, hepato-renal dysfunction, bone fracture, cardiac disorders, brucellosis and neoplasms with respect to left shift and toxic changes observed in the neutrophils.

Significant differences were observed in renal dysfunction (P <0.05) and pyometra (P <0.01) with respect to left shift only whereas, no significant differences were observed with respect to toxic changes in these conditions. On the other hand, significant differences were observed in pathologic conditions like viral diseases (P <0.05) and parasitic infections (P <0.05) with respect to left shift and toxic changes. The values for various pathological conditions in dogs are depicted in Table 10.

Table 10: Correlation of leukocyte findings with different pathological conditions

Pathological conditions	No. of cases	Left shift (*P*-value)	Toxic changes (*P*-value)
Renal dysfunction	606	0.0473*	0.8225
Hepatic dysfunction	542	0.0994	0.2220
Gastro-intestinal (GIT) disorders	251	0.8414	0.9268
Urinary tract infections (UTI)	248	0.7330	0.4419
Ascites	228	0.9178	0.2099
Respiratory tract affections	209	0.6116	0.7900
Skin affections	201	0.8923	0.0691
Pyometra	196	<.0001**	0.3049
Hepato-renal dysfunction	152	0.5177	0.9444
Bone fracture	111	0.0795	0.4254
Cardiac disorders	43	0.2129	0.1488
Viral diseases	244	0.0371*	0.0162*
Brucellosis	19	0.7175	0.9807
Parasitic	216	0.0471*	0.0274*
Neoplasms	108	0.0965	0.2849

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2. Prospective studies

4.2.1. Haematological parameters in apparently healthy dogs

A total of 10 samples from apparently healthy dogs were analyzed for the purpose of comparison and the haematological parameters observed in this group of dogs are depicted in Table 11.

The analysis of the haematological parameters revealed total leukocyte count (TLC) range of 6880-19100/µl along with mean and median value of 11027 ± 1047.51/µl and 10560/µl respectively. These values were within normal range when compared with the reference values.

The range of neutrophil and band cell percentage was 41-86.5 and 0 – 3 respectively. The mean and median value for neutrophil percentage was 68.25 ± 4.66 and 75 respectively and for band percentage 0.9 ± 0.37 and 0.25 respectively. Similarly, the range of absolute count of neutrophils and band cells was 4093.6 - 14611.5/µl and 0 - 477.5/µl respectively with mean and median value of 7583.57 ± 971.34/µl and 7448.77/µl respectively for absolute count of neutrophil and 111.01 ± 51.23/µl and 26.02/µl respectively for absolute count of band cell. These values were within normal range when compared with reference values as shown in Table 11.

The range of lymphocyte percentage and for absolute count of lymphocytes was 10 – 57 and 1041-7518.3/µl respectively along with mean and median value of 27 ± 4.93 and 20.25 respectively for lymphocyte percentage and 2929.65 ± 610.14/µl and 2180.25/µl for absolute count of lymphocytes. These values were also within the normal range when compared with reference values as shown in Table 11.

The range of monocyte percentage and for absolute count of monocyte was 0-4 and 0 - 286.5/µl respectively along with mean and median value of 01.05 ± 0.36 and 0.75/µl respectively for monocyte percentage and 110.8 ± 32.72/µl and 85.02/µl for absolute count of monocyte. These values were low in comparison to the reference values as shown in Table 11.

The range of eosinophil percentage and for absolute count of eosinophil was 1.5 - 6.5 and 103.2 - 565.5/µl respectively along with mean and median value of 2.8 ± 0.50 and 2.5 respectively for eosinophil percentage and 291.96 ± 42.67/µl and 309.3/µl for absolute count of eosinophil absolute count. These values were again within the normal range when compared with the reference values as shown in Table 11.

Table 11: Haematological parameters in apparently healthy dogs (n=10)

Parameter	Range	Mean ± SE	Median	Reference values	Average
TLC/µl	6880 – 19100	11027 ± 1047.51	10560	6000 - 17000	11500
N (%)	41 - 86.5	68.25 ± 4.66	75	60 -77	70
N absolute/µl	4093.6 - 14611.5	7583.57 ± 971.34	7448.77	3000 - 11500	7000
Band (%)	0 – 03	0.9 ± 0.37	0.25	0 – 03	0.8
Band absolute/µl	0 - 477.5	111.01 ± 51.23	26.02	0 – 300	70
L (%)	10 – 57	27 ± 4.93	20.25	12 - 30	20
L absolute/µl	1041-7518.3	2929.65 ± 610.14	2180.25	1000 - 4800	2800
M (%)	0 – 04	01.05 ± 0.36	0.75	03 - 10	5.2
M absolute/µl	0 - 286.5	110.8 ± 32.72	85.02	150 - 1350	750
E (%)	1.5 - 6.5	2.8 ± 0.50	2.5	02 -10	04
E absolute/µl	103.2 - 565.5	291.96 ± 42.67	309.3	100 - 12501	550
Hemoglobin (g/dl)	9.7 – 17	13.50 ± 0.64	13.4	12 - 18	15
Platelet ($\times 10^3$/µl)	35 – 582	241.9 ± 55.52	204	02 - 05	-

The range of hemoglobin was 9.7 – 17 g/dl along with mean and median value of 13.50 ± 0.64 g/dl and 13.4 g/dl respectively and these were within the normal limits when compared with reference values. The platelets were also in the range of 35 – 582×10^3/µl with mean and median value of 241.9 ± 55.52×10^3/µl and 204×10^3/µl respectively which were again within normal limits.

4.2.2 Haematological parameters in pathological conditions of dogs

A total of 300 blood samples of dogs were analyzed for prospective study and different types of leukocyte alterations were correlated with different pathological conditions of dogs. The haematological parameters are given in Table 12.

The total leukocyte count (TLC) varied from 300 – 173720/µl in different pathological conditions of dogs with the mean and median value of 26022.93 ± 1342.12/µl and 19800/µl respectively. These values were raised in comparison to both the reference values and apparently healthy group of dogs.

The range of neutrophil percentage and absolute count of neutrophil was 0.5 - 98.5 and 188 – 123375/µl respectively. The mean and median value for neutrophil percentage was 77.24 ± 0.98 and 82.5 respectively and for neutrophil absolute count 19468.57 ± 880.51/µl and 15145.82/µl respectively. These values were increased in comparison to both the reference and the apparently healthy dogs. There was also increase in the number of immature neutrophils viz. band cells, metamyelocytes and myelocytes indicating left shift in different pathological conditions. The band cells percentage were in range of 0 – 67, followed by metamyelocytes percentage in range of 0-10 and myelocyte percentage in the range of 0-01. The mean and median values for band cells percentage were 8.09 ± 0.63 and 04 respectively followed by metamyelocytes percentage and myelocytes percentage with mean value of 0.32 ± 0.06 and 0.01 ± 0.005 respectively. Similar trend was observed in the absolute counts of these immature cells with band cell absolute count range of 0 – 63217/µl followed by metamyelocytes in range of 0 – 6568/µl and myelocytes in range of 0 – 821/µl. The band cell absolute counts had a mean and median value of 2740.91 ± 337.16/µl and 798.87/µl respectively, followed by metamyelocytes with mean of 118.80 ± 29.36/µl and myelocytes with mean of 7.59 ± 3.39/µl. These values were markedly increased in comparison with the reference values and apparently healthy dogs.

Table 12: Haematological parameters in pathological conditions of dogs

Parameter	Range	Mean ± SE	Median	Reference values	Average
TLC/µl	300 - 173720	26022.93 ± 1342.12	19800	6000 – 17000	11500
N (%)	0.5 - 98.5	77.24 ± 0.98	82.5	60 -77	70
N absolute/µl	188 - 123375	19468.57 ± 880.51	15145.82	3000 – 11500	7000
Band (%)	0 – 67	8.09 ± 0.63	04	0 – 03	0.8
Band absolute/µl	0 - 63217	2740.91 ± 337.16	798.87	0 – 300	70
Metamyelocyte (%)	0 - 10	0.32 ± 0.06	0	-	-
Metamyelocyte absolute/µl	0 - 6568	118.80 ± 29.36	0	-	-
Myelocyte (%)	0 – 01	0.01 ± 0.005	0	-	-
Myelocyte absolute/µl	0 - 821	7.59 ± 3.39	0	-	-
L (%)	1 - 99.5	12.30 ± 0.80	08	12 – 30	20
L absolute/µl	82 - 139925	3473.42 ± 752.83	1548.75	1000 – 4800	2800
M (%)	0 – 06	0.27 ± 0.04	0	03 – 10	5.2
M absolute/µl	0 - 4343	75.99 ± 18.19	0	150 – 1350	750
E (%)	0 – 26	1.73 ± 0.18	0.5	02 -10	04
E absolute/µl	0 - 5582.5	309.58 ± 35.01	98.6	100 – 12501	550
Hemoglobin(g/dl)	1.4 - 20	10.3 ± 0.21	10.3	12 – 18	15
Platelet ($\times 10^3$/µl)	07 - 1132	261.74 ± 10.70	234	02 – 05	-

The range of lymphocytes percentage and absolute count was 1 - 99.5 and 82 - 139925/µl respectively with mean and median value of 12.30 ± 0.80, 08 respectively for lymphocyte percentage and 3473.42 ± 752.83/µl, 1548.75/µl respectively for absolute count of lymphocytes. These values were within normal limits but with a varied range in comparison to reference values and apparently healthy dogs.

The range of monocytes percentage and absolute count was 0 - 06 and 0 - 4343 respectively with mean value of 0.27 ± 0.04 and 75.99 ± 18.19/µl for monocytes percentage and absolute count respectively. These values were decreased in comparison to reference values and apparently healthy dogs.

The range of eosinophils percentage and absolute count was 0 – 26 and 0 - 5582.5 respectively. The mean and median value for eosinophils percentage was 1.73 ± 0.18 and 0.5 respectively and for absolute count of eosinophils 309.58 ± 35.01/µl and 98.6/µl respectively. These values were reduced in comparison to reference values.

The range of hemoglobin was 1.4 - 20 with mean and median value of 10.3 ± 0.21 g/dl and 10.3 g/dl respectively. These values were reduced in comparison to reference values and apparently healthy dogs.

The range of platelets was 07 - 1132 with mean and median value of 261.74 ± 10.70×10^3/µl and 234×10^3/µl respectively. These values were comparable with reference values and apparently healthy dogs.

4.2.3 Incidence of different pathological conditions of dogs

A total of 300 blood samples of dogs were analyzed for prospective study and different types of leukocytic disorders were then correlated with the clinical diagnosis and prognosis in these pathological conditions. The different pathological conditions recorded are summarized in Table 13.

Among the general disease conditions maximum cases of hepatic dysfunction (57) were recorded followed by renal dysfunction (42), hepato-renal dysfunction and pyometra (33), respiratory tract affections (20), gastro-intestinal (GIT) disorders (17), urinary tract infections (UTI) (14), ascites (9), cardiac disorders (05) and skin affections (04).

Among neoplasms maximum cases recorded were of lymphoma (11) followed by transmissible venereal tumor (TVT) (05), lymphocytic leukaemia (04), mammary tumor (03), melanoma (1) and malignant histiocytosis (1).

Among the parasitic infections maximum cases recorded were of ehrlichiosis (11) followed by demodicosis (09), hookworm infestation (02) and hepatozoonosis (02).

Among the viral diseases maximum cases of canine distemper (CD) (11) were recorded followed by parvo viral infection (06).

Table 13: Incidence of different pathological conditions of dogs

S. No.	Pathological conditions	Number of cases (n)
1.	**General pathological conditions**	
a.	Hepatic dysfunction	57
b.	Renal dysfunction	42
c.	Hepato-renal dysfunction	33
d.	Pyometra	33
e.	Respiratory tract affections	20
f.	Gastro-intestinal (GIT) disorders	17
g.	Urinary tract infections (UTI)	14
h.	Ascites	09
i.	Cardiac disorders	05
j.	Skin affections	04
2.	**Neoplasms**	
a.	Lymphoma	11
b.	Transmissible venereal tumor (TVT)	5
c.	Lymphocytic leukemia	04
d.	Mammary tumor	3
e.	Melanoma	1
f.	Malignant histiocytosis	1
3.	**Parasitic infections**	
a.	Ehrlichiosis	11
b.	Demodicosis	09
c.	Hookworm infestation	02
d.	Hepatozoonosis	02
4.	**Viral diseases**	
a.	Canine distemper (CD)	11
b.	Parvo viral infection	06
5.	Apparently healthy dogs	10

A total of 10 samples from apparently healthy dogs were also analyzed for the purpose of comparison.

4.2.4 Haematology findings in different pathological conditions of dogs

The haematological changes in different pathological conditions were analyzed and compared with the apparently healthy dog group and the reference values and are discussed below.

4.2.4.1 Hepatic dysfunction

The hematology findings of different cases of hepatic dysfunction revealed mean values of hemoglobin ($p<0.05$), lymphocytes ($p<0.01$), and monocytes ($p<0.05$) to be significantly lower than the apparently healthy dogs, while neutrophils ($p<0.05$) were significantly higher and TLC (>0.05) was non-significantly higher than the apparently healthy dogs. Neutrophil to lymphocyte (N:L) ratio and platelets were insignificantly increased than the apparently healthy dogs. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes along with mild to moderate toxic changes in neutrophils (Fig. 9). The mean of hematological values of apparently healthy dogs and dogs with hepatic dysfunction are presented in Table 14.

Similar findings of reduced hemoglobin and increased TLC and neutrophils were observed by Elhiblu *et al* (2015). Neutrophilic leukocytosis along with left shift was indicative of inflammatory response of chronic hepatitis (Elhiblu *et al* 2015) and the anemia was attributed to increased transient time of erythrocytes through the spleen due to reduced portal blood flow and/or fragility of red blood cells due to high levels of bile acids (Rothuizen and Meyer 2000, Bush 2002, Chikazawa *et al* 2013, Elhiblu *et al* 2015). In the present study insignificant increase in platelet count was observed as compared to the apparently healthy dogs which was contrary to the findings of Tantary *et al* (2014) and Elhiblu *et al* (2015) as they found the platelet count values to be significantly reduced in hepatic dysfunction.

Table 14: Hematological changes in apparently healthy dogs and dogs having hepatic dysfunction

Parameter	Apparently healthy dogs (n=10)	Hepatic dysfunction (n=57)	P value
TLC/µl	11027 ± 1047.51	22721.75 ± 1626.36	.563
N (%)	68.25 ± 4.66	83.03 ± 1.03	.019*
N absolute/µl	7583.57 ± 971.34	19523.28 ± 1432.4	.118
Band (%)	0.9 ± 0.37	5.89 ± 0.83	.576
Band absolute/µl	111.01 ± 51.23	1454.27 ± 249.63	.991
Metamyelocyte (%)	0	0.19 ± 0.07	.999
Metamyelocyte absolute/µl	0	65.14 ± 27.06	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	7.42 ± 0.71	.000**
L absolute/µl	2929.65 ± 610.14	1353.6 ± 01.71	1.000
M (%)	1.05 ± 0.36	0.23 ± 0.08	.017*
M absolute/µl	110.8 ± 32.72	77.7 ± 32.52	1.000
E (%)	2.8 ± 0.50	1.45 ± 1.31	.781
E absolute/µl	291.96 ± 42.67	238.96 ± 43	1.000
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	21.02 ± 3.64	.390
Hemoglobin (g/dl)	13.58 ± 0.64	9.94 ± 0.49	.020*
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	291.61 ± 23.23	.983

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2.4.2 Renal dysfunction

The hematology findings of different cases of renal dysfunction revealed mean values of hemoglobin (p<0.01), lymphocytes (p<0.01), and monocytes (p<0.05) to be significantly lower than the apparently healthy dogs, while TLC and neutrophils were higher than the apparently healthy dogs but values did not reach statistical

significance (p>0.05). N:L ratio was insignificantly increased and platelets were insignificantly decreased in comparison to the apparently healthy dogs. Mild to severe left shift was observed as indicated by band cells, metamyelocytes and myelocytes along with mild to moderate toxic changes in neutrophils (Fig. 10). The mean of hematological values of apparently healthy dogs and dogs having renal dysfunction are presented in Table 15.

Table 15: Hematological changes in apparently healthy dogs and dogs having renal dysfunction

Parameter	Apparently healthy dogs (n=10)	Renal dysfunction (n=42)	P value
TLC/µl	11027 ± 1047.51	25385.23 ± 3174.11	.353
N (%)	68.25 ± 4.66	80.6 ± 2.21	.150
N absolute/µl	7583.57 ± 971.34	20922.62 ± 2744.47	.084
Band (%)	0.9 ± 0.37	6.35 ± 1.2	.525
Band absolute/µl	111.01 ± 51.23	2262.12 ± 561.40	.857
Metamyelocyte (%)	0	0.35 ± 0.19	.934
Metamyelocyte absolute/µl	0	120.1± 61.92	.995
Myelocyte (%)	0	0.02 ± 0.02	.992
Myelocyte absolute/µl	0	7.5 ± 7.5	1.000
L (%)	27 ± 4.93	11.5 ± 1.83	.007**
L absolute/µl	2929.65 ± 610.14	1858.5 ± 257.09	1.000
M (%)	1.05 ± 0.36	0.17 ± 0.09	.010*
M absolute/µl	110.8 ± 32.72	39.08 ± 20.50	.998
E (%)	2.8 ± 0.50	0.92 ± 0.21	.421
E absolute/µl	291.96 ± 42.67	175.29 ± 39.33	.989
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	22.53 ± 3.98	.327
Hemoglobin (g/dl)	13.58 ± 0.64	8.5 ± 0.56	.000
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	223.02 ± 23.68	1.000

*Significant difference between groups (P <0.05).

**Significant difference between groups (P <0.01).

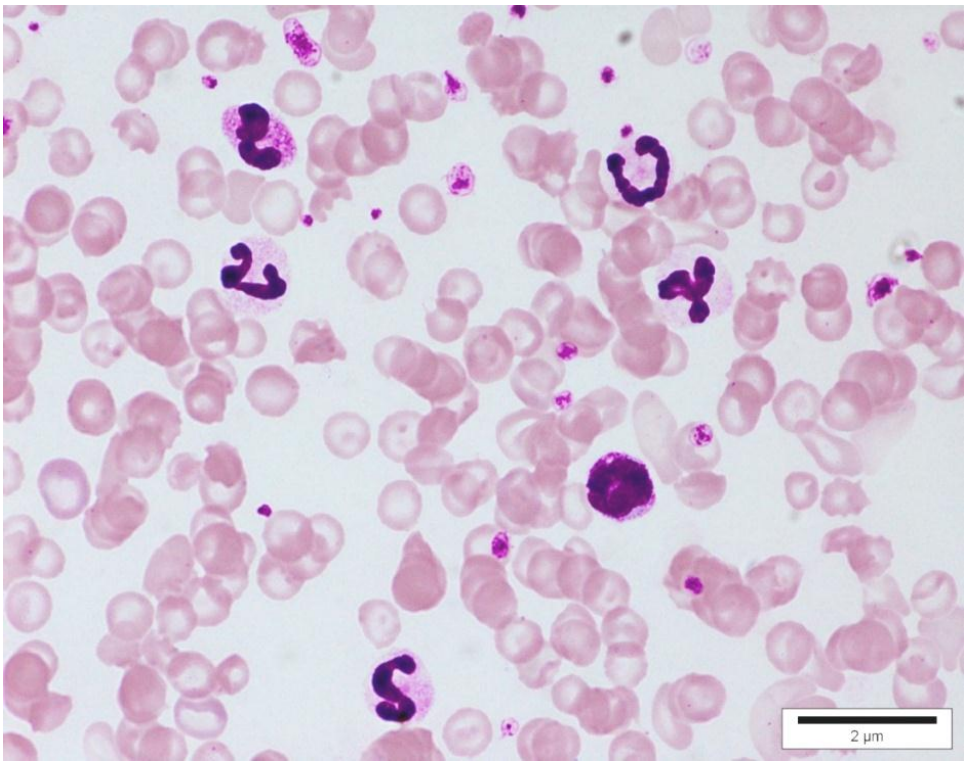


Fig. 9: Blood smear showing neutrophilia with mild left shift and mild toxic changes in neutrophils, anaemia and pleomorphic platelets in a case of hepatic dysfunction. Leishman stain x 100X, Bar=2 µm

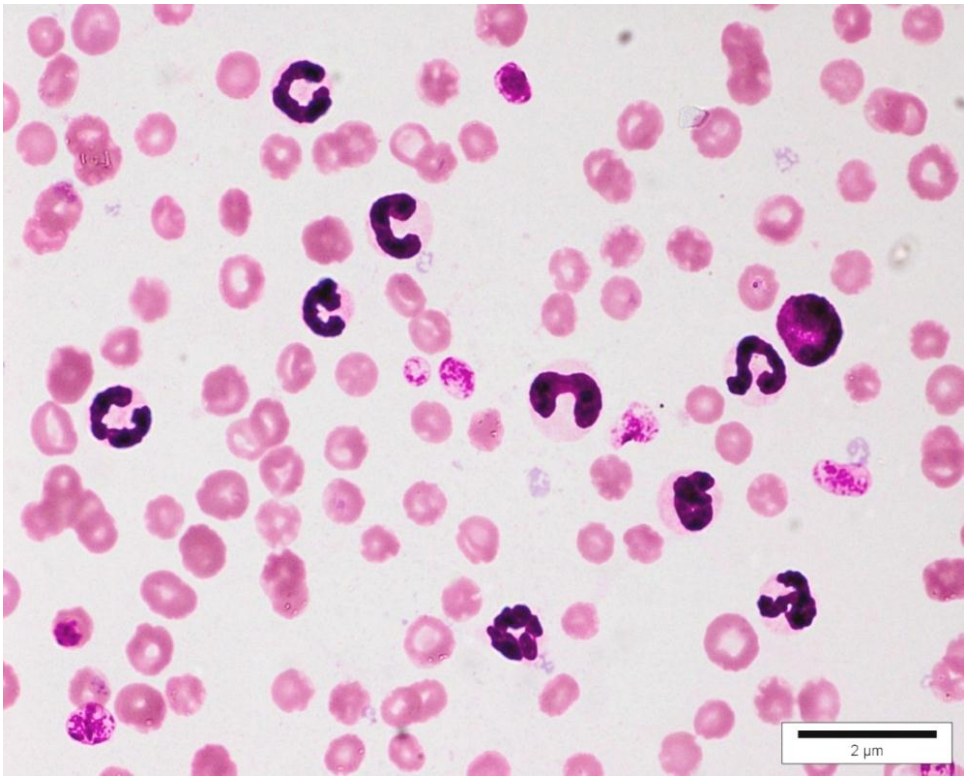


Fig. 10: Blood smear showing leukocytosis with mild left shift, anaemia and activated platelets in a case of renal dysfunction. Leishman stain x 100X, Bar=2 µm

Leukocytosis observed in renal failure dogs was in agreement with Robinson *et al* (1989), Devipriya *et al* (2018) and Sumit *et al* (2018). Increase in the mean value of neutrophil count and decrease in lymphocyte count were in concurrence with Kralova *et al* (2010), who stated neutrophilia and lymphopenia as constant findings in renal failure. High TLC has been reported owing to primary inflammatory diseases of urinary system and engrossment of other body system and tissues (Osborne *et al* 1972). The dogs suffering from renal dysfunction showed lower mean values of haemoglobin which suggested that the affected dogs were suffering from anaemia possibly due to various pathogenesis involved such as shortened survival period and haemolysis of red blood cells due to uremia (Ly *et al* 2004), loss of blood in gastrointestinal tract as melena and haematemesis, loss from urinary tract in haematuria, due to poor platelet production (Castaldi *et al* 1966) and due to deficiency of erythropoietin production by the diseased kidneys (Silverberg *et al* 2002). Similar findings of lower haemoglobin were reported by Pradhan and Roy (2012), Sharma *et al* (2015) and Sumit *et al* (2018).

4.2.4.3 Hepato-renal dysfunction

The hematology findings of different cases of hepato-renal dysfunction revealed significantly lower mean values of hemoglobin ($p<0.05$) and lymphocytes ($p<0.01$), while, significantly higher neutrophils ($p<0.01$) were observed in comparison to the apparently healthy dogs. Neutrophil to lymphocyte (N:L) ratio was significantly higher in comparison to the apparently healthy dogs. TLC (>0.05) was insignificantly higher than the apparently healthy dogs and platelets were insignificantly reduced. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes along with mild to moderate toxic changes in neutrophils (Fig. 11). The mean of hematological values of apparently healthy dogs and hepato-renal dysfunction group are presented in Table 16.

Leukocytosis with left shift and toxic changes were in accordance with Elhiblu *et al* (2015) who observed these changes in liver cirrhosis while Devipriya *et al* (2018) and Sumit *et al* (2018) observed leukocytosis in renal dysfunction. Normochromic, normocytic anemia was the most commonly noted hematological change in patients with chronic kidney disease (Bradea *et al* 2013).

Table 16: Hematological changes in apparently healthy dogs and dogs having hepato-renal dysfunction

Parameter	Apparently healthy dogs (n=10)	Hepato-renal dysfunction (n=33)	P value
TLC/µl	11027 ± 1047.51	24420.3 ±2781.01	.464
N (%)	68.25 ± 4.66	87.89 ± 1.7	.004**
N absolute/µl	7583.57 ± 971.34	21362.69 ± 2433.49	.080
Band (%)	0.9 ± 0.37	4.53 ± 1.06	.915
Band absolute/µl	111.01 ± 51.23	1606.19 ± 545.64	.998
Metamyelocyte (%)	0	0.04 ± 0.02	1.000
Metamyelocyte absolute/µl	0	11.83 ± 7.05	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	6.93 ± 1.19	.000
L absolute/µl	2929.65 ± 610.14	1319.31± 198.31	1.000
M (%)	1.05 ± 0.36	0.33 ± 0.18	.066
M absolute/µl	110.8 ± 32.72	65.72 ± 34.73	1.000
E (%)	2.8 ± 0.50	0.25 ± 0.08	.142
E absolute/µl	291.96 ± 42.67	54.54 ± 19.74	.863
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	35.25 ± 8.08	.020*
Hemoglobin (g/dl)	13.58 ± 0.64	9.81 ± 0.7	.023*
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	177.20 ± 27.29	.932

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2.4.4 Pyometra

The hematology findings of different cases of pyometra revealed mean values of TLC and absolute count of neutrophils (p<0.05), band cells (%) and absolute count (p<0.01), absolute count of metamyelocyte and myelocyte (p<0.05) to be significantly higher than the apparently healthy dogs while lymphocytes (p<0.01) to be significantly lower than the apparently healthy dogs. Leukemoid response was observed in 2 cases of pyometra (Fig. 12). Insignificant increase in N:L ratio and

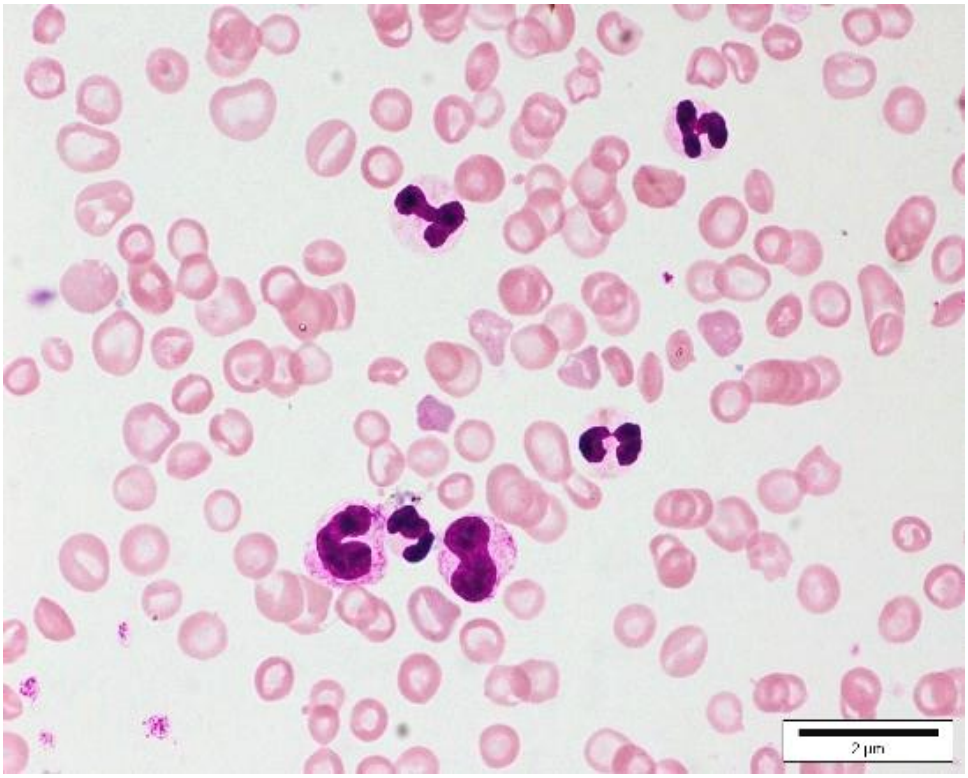


Fig. 11: Blood smear showing leukocytosis with moderate left shift as indicated by band cell and metamyelocyte, anaemia and thrombocytopenia in a case of hepato-renal dysfunction. Leishman stain x 100X, Bar=2 µm

platelet count were observed in comparison to apparently healthy dogs. Mild to severe left shift was observed as indicated by band cells, metamyelocytes and myelocytes along with mild to moderate toxic changes in neutrophils (Fig. 13). Hemoglobin was lower in pyometra affected group than the apparently healthy dogs but did not reach the statistical significance. The mean of hematological values of apparently healthy dogs and having pyometra are presented in Table 17.

Table 17: Hematological changes in apparently healthy dogs and dogs having pyometra

Parameter	Apparently healthy dogs (n=10)	Pyometra (n=33)	P value
TLC/µl	11027 ± 1047.51	35946.36 ± 4904.23	.016*
N (%)	68.25 ± 4.66	65.31 ± 3.12	1.000
N absolute/µl	7583.57 ± 971.34	22587.17 ± 28888.35	.045*
Band (%)	0.9 ± 0.37	22.27 ± 3.16	.000**
Band absolute/µl	111.01 ± 51.23	9634.07 ± 2186.29	.000**
Metamyelocyte (%)	0	0.96 ± 0.30	.068
Metamyelocyte absolute/µl	0	546.07 ± 227.85	.019*
Myelocyte (%)	0	0.09 ± 0.03	.050
Myelocyte absolute/µl	0	58.2 ± 27.95	.037*
L (%)	27 ± 4.93	9.53 ± 1.25	.002**
L absolute/µl	2929.65 ± 610.14	2564.22 ± 262.58	1.000
M (%)	110.8 ± 32.72	138.17 ± 60.11	.999
M absolute/µl	1.05 ± 0.36	0.4 ± 0.16	.777
E (%)	2.8 ± 0.50	1.4 ± 0.49	.130
E absolute/µl	291.96 ± 42.67	418.42 ± 173.18	1.000
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	20.40 ± 5.85	.489
Hemoglobin (g/dl)	13.58 ± 0.64	10.65 ± 0.54	.134
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	261.06 ± 25.33	1.000

*Significant difference between groups (P <0.05).

**Significant difference between groups (P <0.01).

Marked neutrophilic leukocytosis with shift to left in the present study occured because pyometra being a severe bacterial infection stimulates bone marrow to release more number of immature neutrophils into the peripheral circulation in an attempt to combat the infection (Fransson *et al* 1997, Mojzisova *et al* 2000, Shah *et al* 2017). Leukemoid response observed in 2 cases of pyometra in the present study was in accordance with Cox and Joshua (1979) who observed leukocytosis ranging from 14,000 to 1, 80,000/µl in pyometra. In agreement with the present study, lymphopenia have been well documented in bitches with pyometra (Samantha *et al* 2018). The low lymphocyte count may be due to absolute increase in neutrophil count as a result of severe suppurative inflammation of the uterus or may also be induced by endotoxaemia and bacterial products. The anemia has been suggested to be caused by decreased erythropoiesis, so called anemia of chronic disease, and by loss of erythrocytes into the uterine lumen (Nath *et al* 2009) or can be attributed to toxic depression of bone marrow and or loss of red cells into the uterine lumen (Samantha *et al* 2018).

4.2.4.5 Respiratory tract affections

The hematology findings of the different cases of respiratory tract affections revealed insignificant increase in TLC and neutrophils and decreased lymphocytes, while, significantly lower monocytes (p <0.05) were observed when compared to apparently healthy dogs. Insignificant increase in N:L ratio and platelet count were observed in comparison to apparently healthy dogs. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes along with mild to moderate toxic changes in neutrophils (Fig. 14). Platelet count was increased in comparison to apparently healthy dogs but did not reach statistical significance (p >0.05). The mean of hematological values of apparently healthy dogs and dogs having respiratory tract affections are presented in Table 18.

Increase in TLC and neutrophils was also reported by Ning *et al* (2016) in community-acquired pneumonia in children and by Mondal *et al* (2004) in goats with caprine mycoplasmal pneumonia. In addition, Mondal *et al* (2004) also reported anaemia in goats which was contrary to the findings of the present study. Neutrophilia might be due to increased demand of neutrophils for phagocytic activity in the presence of foreign protein in the system (Mondal *et al* 2004).

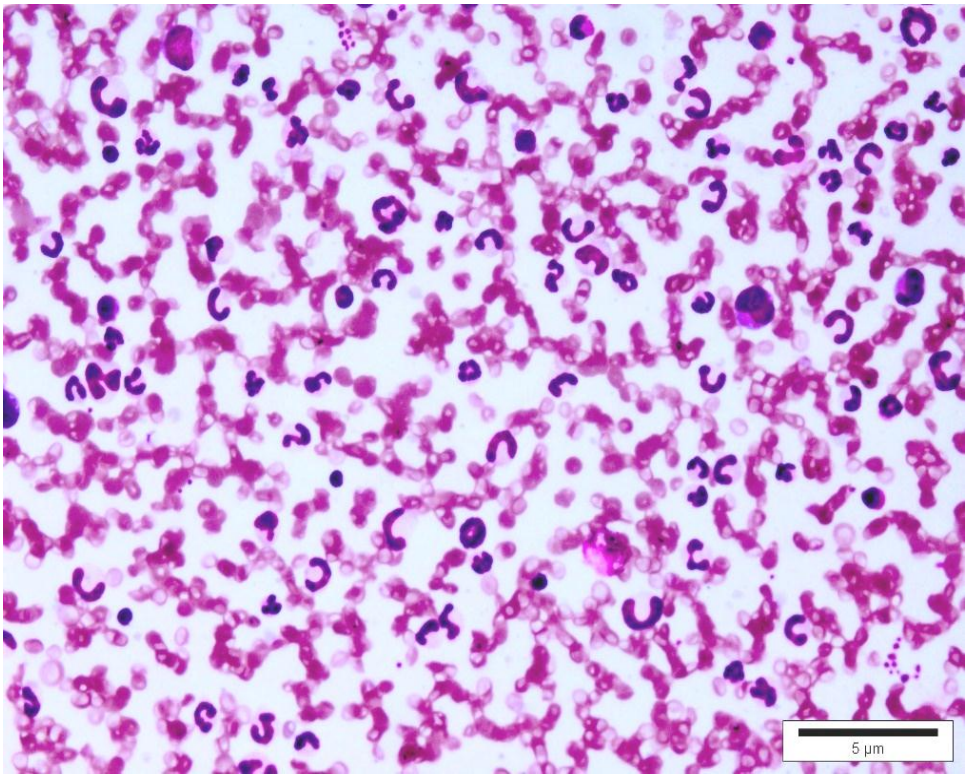


Fig. 12: Leukemoid response in pyometra suspected case. (TLC= 164200/ microliter) Leishman stain x 40X, Bar=5 µm

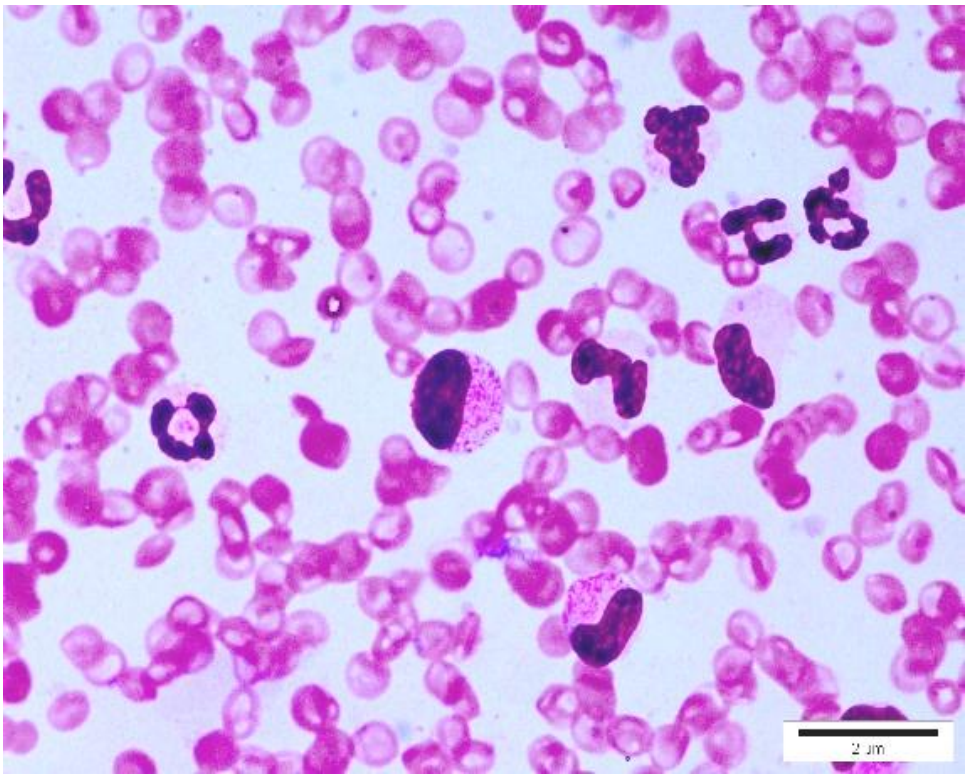


Fig. 13: Blood smear showing leukocytosis with severe left shift and mild toxic changes in case of pyometra. Leishman stain x 100X, Bar=2 µm

Table 18: Hematological changes in apparently healthy dogs and dogs having respiratory tract affections

Parameter	Apparently healthy dogs (n=10)	Respiratory Tract Affections (n=20)	P value
TLC/µl	11027 ± 1047.51	21586 ± 2652.14	.796
N (%)	68.25 ± 4.66	78.27 ± 2.68	.462
N absolute/µl	7583.57 ± 971.34	17262.16 ± 2465.86	.471
Band (%)	0.9 ± 0.37	4.72 ± 0.79	.923
Band absolute/µl	111.01 ± 51.23	1181.71± 334.95	1.000
Metamyelocyte (%)	0	0.05 ± 0.05	1.000
Metamyelocyte absolute/µl	0	16.55 ±16.55	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	13.52 ± 2.32	.059
L absolute/µl	2929.65 ± 610.14	2557.42 ± 454.40	1.000
M (%)	1.05 ± 0.36	0.17 ± 0.09	.024*
M absolute/µl	110.8 ± 32.72	29.15 ± 14.53	.997
E (%)	2.8 ± 0.50	3.25 ± 0.75	1.000
E absolute/µl	291.96 ± 42.67	538.99 ± 132.21	.883
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	14.08 ± 4.69	.939
Hemoglobin (g/dl)	13.58 ± 0.64	13.03 ± 0.55	1.000
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	318.4 ± 31.93	.872

*Significant difference between groups (P <0.05).

4.2.4.6 Gastro-intestinal (GIT) disorders

The hematology of the different cases of GIT disorders revealed insignificantly increased TLC and absolute count of neutrophils and significantly reduced monocytes (p<0.05), while, platelets were reduced in comparison to apparently healthy dogs. Insignificant increase in N:L ratio was observed in comparison to the apparently healthy dogs. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes along with mild toxic changes in neutrophils (Fig. 15). The mean of hematological values of apparently healthy dogs and GIT disorders group are presented in Table 19.

Table 19: Hematological changes in apparently healthy dogs and dogs having GIT disorders

Parameter	Apparently healthy dogs (n=10)	GIT disorders (n=17)	P value
TLC/µl	11027 ± 1047.51	22477.05 ± 3260.60	.749
N (%)	68.25 ± 4.66	67.5 ± 3.94	1.000
N absolute/µl	7583.57 ± 971.34	15965.4 ± 2785.20	.671
Band (%)	0.9 ± 0.37	11.47 ± 4.19	.051
Band absolute/µl	111.01 ± 51.23	2674.86 ±1059.36	.819
Metamyelocyte (%)	0	0.41 ± 0.18	.927
Metamyelocyte absolute/µl	0	93.52 ± 60.27	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	16.26 ± 3.09	.235
L absolute/µl	2929.65 ± 610.14	2817.4 ± 477.45	1.000
M (%)	1.05 ± 0.36	0.17 ± 0.08	.032*
M absolute/µl	110.8 ± 32.72	42.6 ± 21.46	1.000
E (%)	2.8 ± 0.50	4.17 ± 1.15	.863
E absolute/µl	291.96 ± 42.67	883.25 ± 277.49	.080
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	10.24 ± 2.47	.999
Hemoglobin (g/dl)	13.58 ± 0.64	13.41 ± 0.71	1.000
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	103.47 ± 45.70	.971

*Significant difference between groups (P <0.05).

The increase in mean TLC value was in accordance with Bhat *et al* (2013). In the present study, increase in neutrophils might be due to general reaction of immune system to bacterial infection and inflammatory processes in GIT (Berghoff and Steiner, 2011). Thrombocytopenia could be due to loss of blood through vomitus and faeces, increased destruction and/or aggregation, decreased production and disseminating intravascular coagulation. In addition to these factors, erratic sampling leading to formation of blood clot at the time of collection also causes lowering of platelet values (Sharma *et al* 2008).

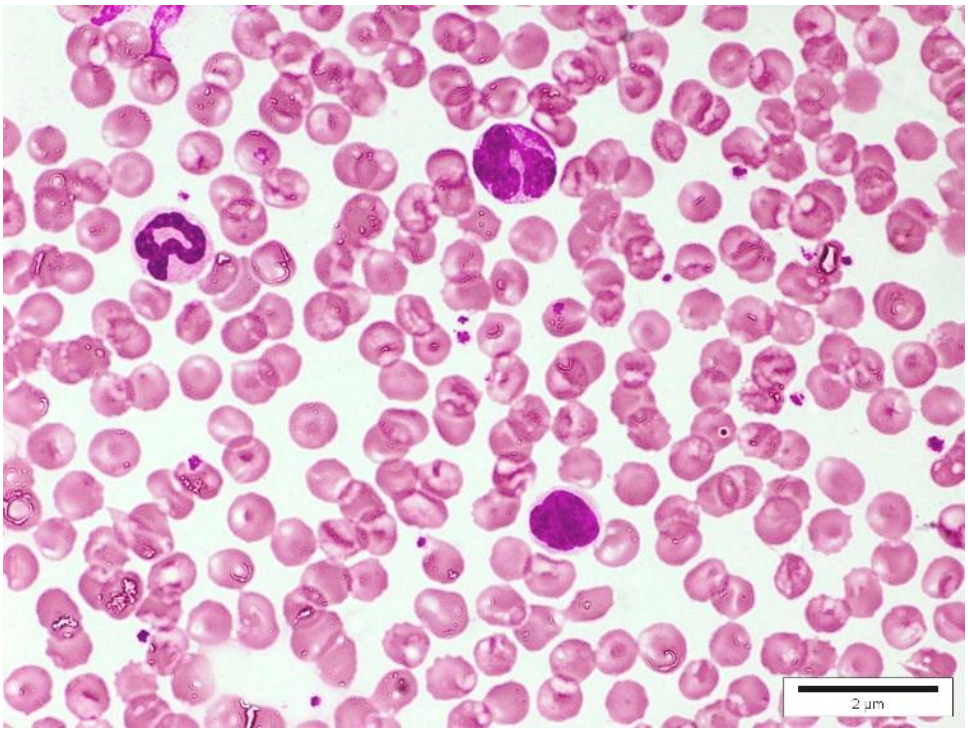


Fig. 14: Blood smear showing mild left shift and toxic changes in neutrophils in a case of pneumonia. Leishman stain x 100X, Bar=2 µm

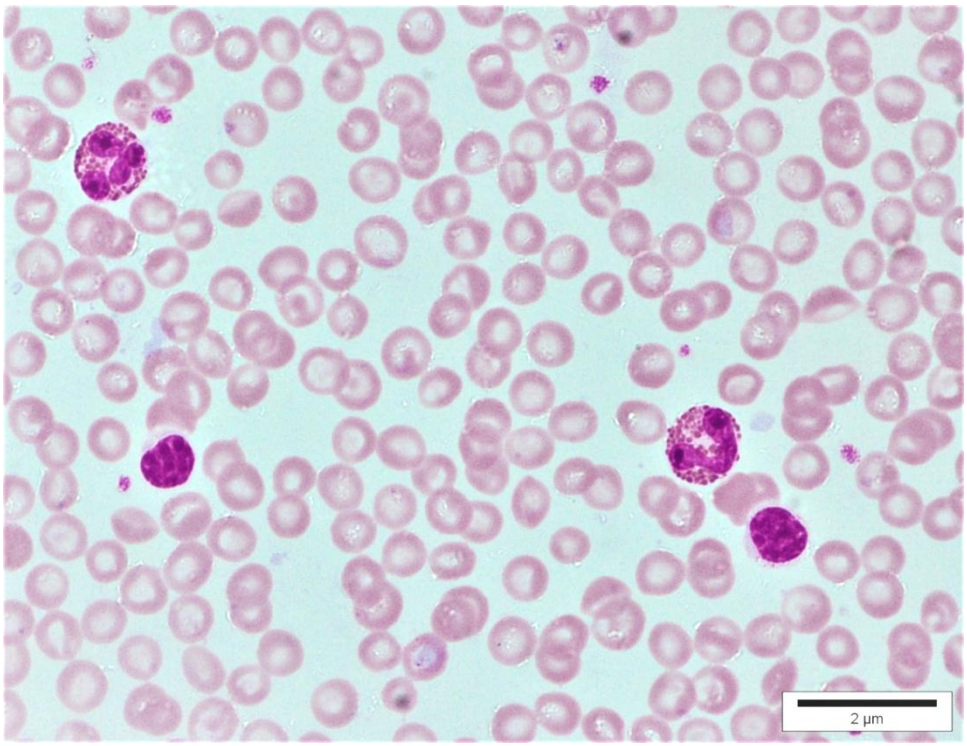


Fig. 15: Blood smear showing eosinophils in a case of gastritis. TLC= 18000/ µl, eosinophils=12%. Leishman stain x 100X, Bar=2 µm

4.2.4.7 Urinary tract infections (UTI)

The hematology of the UTI cases revealed insignificant increase in TLC and neutrophils (p >0.05), whereas, significantly reduced lymphocytes (p <0.01) were observed in comparison to the apparently healthy dogs. Insignificant increase in N:L ratio and platelet count was also observed. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes along with mild to moderate toxic changes in neutrophils (Fig. 16). The mean of hematological values of apparently healthy dogs and dogs having UTI are presented in Table 20.

Table 20: Hematological changes in apparently healthy dogs and dogs having UTI

Parameter	Apparently healthy dogs (n=10)	UTI (n=14)	P value
TLC/µl	11027 ± 1047.51	24927.85 ± 4658.35	.582
N (%)	68.25 ± 4.66	82.39 ± 2.96	.172
N absolute/µl	7583.57 ± 971.34	20858.9 ± 4032.81	.203
Band (%)	0.9 ± 0.37	7.07 ± 2.47	.572
Band absolute/µl	111.01 ± 51.23	1854.01 ± 709.94	.987
Metamyelocyte (%)	0	0.32 ± 0.18	.990
Metamyelocyte absolute/µl	0	95.42 ± 56.94	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	8.17 ± 1.43	.005**
L absolute/µl	2929.65 ± 610.14	1778.56 ± 354.44	1.000
M (%)	1.05 ± 0.36	0.35 ± 0.19	.175
M absolute/µl	110.8 ± 32.72	105.37 ± 72.15	1.000
E (%)	2.8 ± 0.50	1.67 ± 0.85	.967
E absolute/µl	291.96 ± 42.67	235.56 ± 81.85	1.000
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	17.37 ± 3.16	.827
Hemoglobin (g/dl)	13.58 ± 0.64	12.48 ± 0.84	.990
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	268.07 ± 61.04	1.000

*Significant difference between groups (P <0.01).
**Significant difference between groups (P <0.01).

Increased values of TLC count were similar to the findings of Thirunavukkarasu *et al* (2010) and Punia *et al* (2018). Neutrophil count was observed to be on the higher side in affected dogs which was in accordance with the findings of Mrudula *et al* (2005), Kralova *et al* (2010) and Thirunavukkarasu *et al* (2010). Leucocytosis with increased neutrophil count might occur due to variable extent of stress as in cystitis and nephritis in dogs, as well as, a sign of induction of body defence mechanism against bacterial infection. There was not much alteration seen in values of monocytes, basophils and eosinophil's in dogs affected from UTIs (Yogeshpriya *et al* 2018).

4.2.4.8 Ascites

The hematology of the ascites cases revealed insignificantly increased TLC ($p > 0.05$), significantly increased absolute count of neutrophils ($p < 0.05$) and significantly reduced lymphocytes ($p < 0.05$) and hemoglobin ($p < 0.05$) in comparison to apparently healthy dogs. Insignificant increase in N:L ratio and platelet count was also observed in comparison to apparently healthy dogs. Mild left shift was observed as indicated by the presence of band cells along with mild toxic changes in neutrophils (Fig. 17). The mean of hematological values of apparently healthy dogs and dogs having ascites are presented in Table 21.

Leukocytosis reported in the present study, may be due to stress (Pradeep *et al* 2017). Washabau (2010) observed severe leukocytosis and neutrophilia in dogs with granulomatous hepatitis, hepatic cirrhosis, hepatic abscess and hepatic neoplasia. These findings were similar to the findings of Tantary *et al* (2014), Saravanan *et al* (2014) and Elhiblu *et al* (2015). Decrease in hemoglobin is attributed to increased degradation of erythrocytes due to increased transit time through spleen because of reduced portal blood flow and or increased fragility of erythrocytes due to high levels of bile acids, besides impaired bone marrow responses, decreased erythrocyte survival time, decreased nutrient uptake due to inappetance or anorexia and reduced availability of micronutrients from liver (Bush 2002).

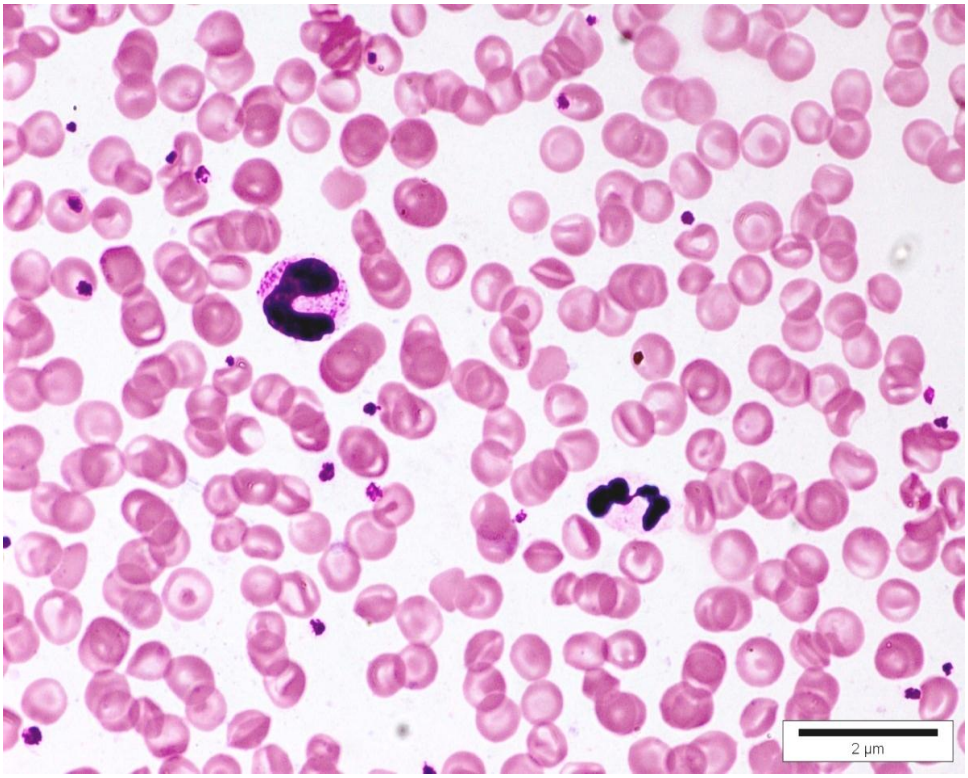


Fig. 16: Blood smear showing band cell with mild toxic changes and a normal neutrophil in a case suspected for UTI. Leishman stain x 100X, Bar=2 µm

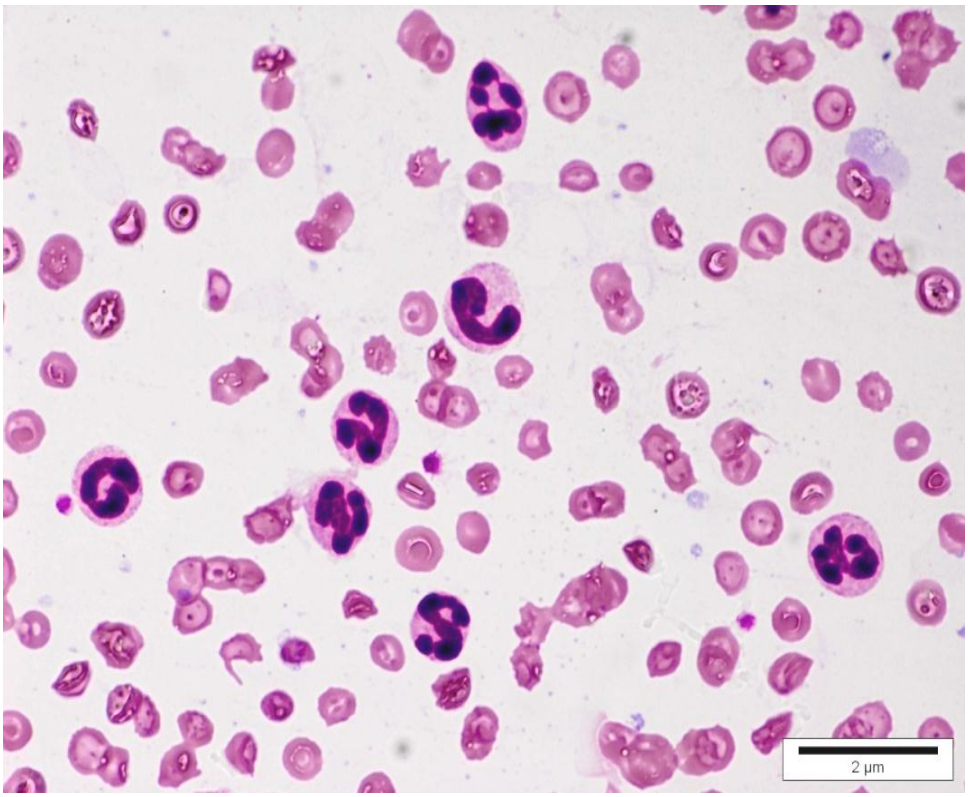


Fig. 17: Blood smear showing leukocytosis with left shift and toxic changes in neutrophils in a case suspected for ascites. Leishman stain x 100X, Bar=2 µm

Table 21: Hematological changes in apparently healthy dogs and dogs having ascites

Parameter	Apparently healthy dogs (n=10)	Ascites (n=09)	P value
TLC/µl	11027 ± 1047.51	32261.11 ± 6558.96	.224
N (%)	68.25 ± 4.66	85.55 ± 1.51	.103
N absolute/µl	7583.57 ± 971.34	27232.43 ± 5143.79	.036*
Band (%)	0.9 ± 0.37	6.38 ± 1.35	.801
Band absolute/µl	111.01 ± 51.23	2622.12 ± 1264.85	.920
Metamyelocyte (%)	0	0	1.000
Metamyelocyte absolute/µl	0	0	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	7.38 ± 1.61	.010*
L absolute/µl	2929.65 ± 610.14	2242.53 ± 494.17	1.000
M (%)	1.05 ± 0.36	0.16 ± 0.16	.082
M absolute/µl	110.8 ± 32.72	33 ± 33	1.000
E (%)	2.8 ± 0.50	0.5 ± 0.27	.493
E absolute/µl	291.96 ± 42.67	131.02 ± 57.80	.999
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	19.48 ± 4.39	.797
Hemoglobin (g/dl)	13.58 ± 0.64	9.17 ± 1.15	.046*
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	340.12 ± 61.19	.839

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2.4.9 Cardiac disorders

The hematology of the cases with cardiac disorders revealed insignificant increase in TLC and neutrophils (p >0.05) and insignificant decrease in hemoglobin, lymphocytes and platelet count (p >0.05) in comparison to the apparently healthy dogs. In addition, insignificant increase in N:L ratio was also observed in comparison to the apparently healthy dogs. Mild left shift was observed as indicated by band cells along with mild toxic changes in neutrophils (Fig. 18). The mean of hematological values of apparently healthy dogs and dogs having cardiac disorders are presented in Table 22.

Leukocytosis observed was in accordance with the findings of Deepti and Yathiraj (2015). Neutrophilia indicates an acute stage of infection, which may also lead to cardiac complication (Khomeriki and Morozov 1998). Several authors had reported similar findings (Farabaugh *et al* 2004), Martin *et al* (2009) and Sesh *et al* (2014). The low platelet count and anaemia suggested ischaemia indicating cardio-vascular system (CVS) disorder (Reece William O 2004, Richardson *et al* 1996). Similar findings of reduced platelet count and anaemia, were also reported by Sesh *et al* (2013).

Table 22: Hematological changes in apparently healthy dogs and dogs having cardiac disorders

Parameter	**Apparently healthy dogs (n=10)**	**Cardiac disorders (n=05)**	**P value**
TLC/µl	11027 ± 1047.51	23284 ± 7189.16	.924
N (%)	68.25 ± 4.66	85.7 ± 2.98	.234
N absolute/µl	7583.57 ± 971.34	20286.04 ± 6672.8	.560
Band (%)	0.9 ± 0.37	4.2 ± 1.50	.998
Band absolute/µl	111.01 ± 51.23	1256.04 ± 776.65	1.000
Metamyelocyte (%)	0	0	1.000
Metamyelocyte absolute/µl	0	0	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	9.4 ± 2.76	0.98
L absolute/µl	2929.65 ± 610.14	1632.9 ± 511.63	1.000
M (%)	1.05 ± 0.36	0.1 ± 0.1	.147
M absolute/µl	110.8 ± 32.72	16.3 ± 16.3	1.000
E (%)	2.8 ± 0.50	0.6 ± 0.29	.738
E absolute/µl	291.96 ± 42.67	92.72 ± 45.36	.998
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	27.40 ± 18.07	.568
Hemoglobin (g/dl)	13.58 ± 0.64	9.36 ± 0.86	.172
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	160.25 ± 86.24	.988

4.2.4.10 Skin affections

The hematology of different cases of skin affections revealed no significant changes between the apparently healthy dogs and dogs having skin affections (Table 23). TLC and neutrophil count were within normal range but with mild left shift as indicated by band cells along with relative rise in lymphocytes, anaemia and thrombocytopenia (p >0.05) in comparison to the reference values and apparently healthy dogs. Mild toxic changes in neutrophils were also observed (Fig. 19).

Table 23: Hematological changes in apparently healthy dogs and dogs having skin affections

Parameter	Apparently healthy dogs (n=10)	Skin affections (n=4)	P value
TLC/µl	11027 ± 1047.51	12550 ± 6099.93	1.000
N (%)	68.25 ± 4.66	58.12 ± 6.4	.864
N absolute/µl	7583.57 ± 971.34	8380 ± 4691.16	1.000
Band (%)	0.9 ± 0.37	6.12 ± 2.51	.962
Band absolute/µl	111.01 ± 51.23	1153.75 ± 941.72	1.000
Metamyelocyte (%)	0	0.5 ± 0.35	.981
Metamyelocyte absolute/µl	0	124.75 ± 106.29	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	34.12 ± 8.74	.957
L absolute/µl	2929.65 ± 610.14	2737.5 ± 880.53	1.000
M (%)	1.05 ± 0.36	0.12 ± 0.12	.235
M absolute/µl	110.8 ± 32.72	14.5 ± 14.5	1.000
E (%)	2.8 ± 0.50	1 ± 0.70	.931
E absolute/µl	291.96 ± 42.67	139.5 ± 80.77	1.000
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	3.28 ± 1.88	1.000
Hemoglobin (g/dl)	13.58 ± 0.64	9.5 ± 1.02	.274
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	149.66 ± 110.44	.986

The occurrence of left shift was in accordance with Andonova *et al* (2014) who suggested that the depicted haematological change was the result of inflammatory response. The insignificant relative rise in lymphocytes was in accordance with Latimer (1995) who observed lymphocytosis in allergic dermatitis which could be due to persistent antigenic stimulation by chronic secondary bacterial infection or inflammatory reaction (Sharma *et al* 2015). The lower values of haemoglobin are in accordance with the findings of Lodh and Das (2014) and Thapa and Sarkar (2018) indicating anaemia in infected dogs and it might be due to loss of skin protein due to excessive scratching and stress arising from the diseases (Deb *et al* 2000). This is particularly seen in dogs suffering from pyoderma, scabies and demodex.

4.2.4.11 Neoplasms

Neoplasms were confirmed and classified as lymphoma (11cases), transmissible venereal tumor (TVT) (5 cases), lymphocytic leukemia (4 cases), mammary tumours (3 cases), melanoma (1 case) and malignant histiocytosis (1case).

The haematology of different cases of neoplasms (Table 24) revealed statistically significant increase in TLC (p <0.01), neutrophil percentage (p <0.01) and absolute count (p <0.05), lymphocyte absolute count (p <0.01) along with statistically non-significant decrease in values of hemoglobin and platelet count (p >0.05) in comparison to apparently healthy animals. Non-significant increase in N:L ratio was observed in dogs having neoplasms when compared to the apparently healthy animals. Mild to moderate left shift, mild to moderate toxic changes in neutrophils along with morphological alterations in lymphocytes viz. activated lymphocytes, granular lymphocytes and atypical lymphocytes were observed.

Cases of lymphoma involving lymph node revealed reduced mean hemoglobin (9.7±1.01g/dl), leukocytosis (28456.36±7728.61/µl) with neutrophilia (20269.78± 4492.61/µl), increase in absolute count of lymphocytes (5043.27±2963.79/µl) and thrombocytopenia (148.3± 30.67x10^5/µl) in comparison to apparently healthy dogs. Mild (6 cases) to moderate (2 cases) left shift along with mild toxic changes in neutrophils (10 cases) were observed. Morphological alterations in lymphocytes were observed in 7 cases (few in 3 cases, rare in 3 cases, many in 1 case) with presence of activated lymphocytes in five cases, granular lymphocytes in three cases and atypical lymphocytes in four cases (Fig. 20).

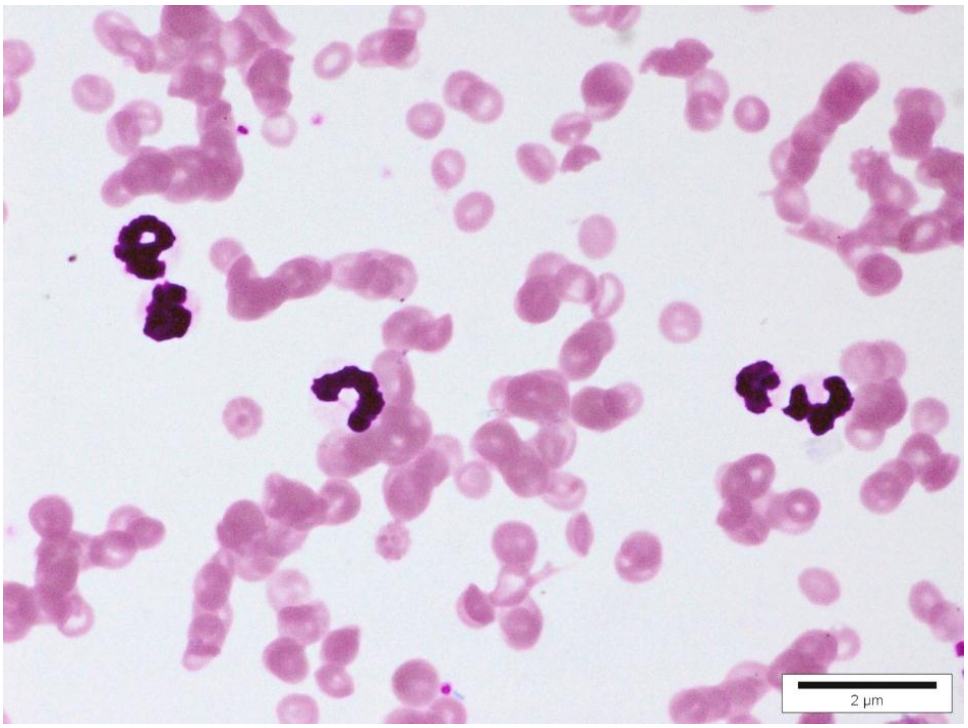


Fig. 18: Blood smear showing neutrophilia with mild left shift, anaemia and thrombocytopenia in a case of cardiac disorder. Leishman stain x 100X, Bar=2 µm

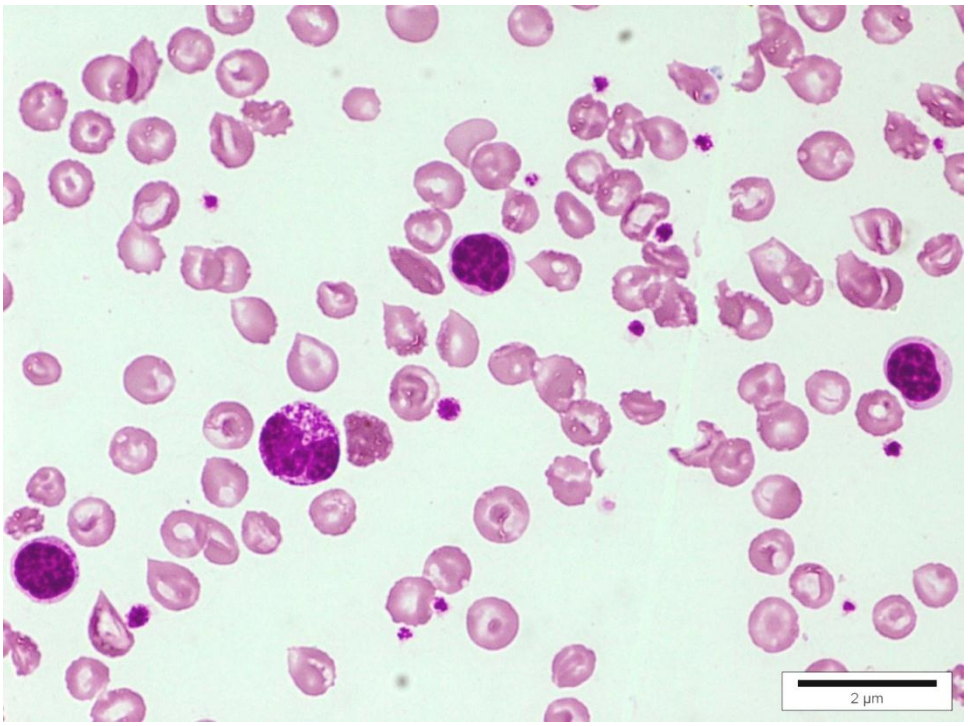


Fig. 19: Blood smear showing moderate toxic changes in neutrophil and granular lymphocyte in a case of pododermatitis. Leishman stain x 100X, Bar=2 µm

Table 24: Hematological changes in apparently healthy dogs and dogs having neoplasms

Parameter	Apparently healthy dogs (n=10)	Neoplasms (n=25)	P value
TLC/µl	11027 ± 1047.51	46978.80 ± 10076.62	.000**
N (%)	68.25 ± 4.66	70.12 ± 5.49	.000**
N absolute/µl	7583.57 ± 971.34	23379.42 ± 4982.08	.039*
Band (%)	0.9 ± 0.37	4.92 ± 1.12	.878
Band absolute/µl	111.01 ± 51.23	3106.95 ± 1388.71	.600
Metamyelocyte (%)	0	0.12 ± 0.05	1.000
Metamyelocyte absolute/µl	0	103.70 ± 70.57	.999
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	22.90 ± 5.91	.978
L absolute/µl	2929.65 ± 610.14	19768.59 ± 8375.09	.003**
M (%)	1.05 ± 0.36	0.20 ± 0.10	.023*
M absolute/µl	110.8 ± 32.72	192.01 ± 173.20	.996
E (%)	2.8 ± 0.50	1.74 ± 0.47	.956
E absolute/µl	291.96 ± 42.67	428.11 ± 124.03	.998
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	12.87 ± 2.86	.965
Hemoglobin (g/dl)	13.58 ± 0.64	10.5 ± 0.73	.126
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	193.18 ± 28.24	.994

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

Haematological examination in a case of GIT lymphoma revealed leukemoid response with marked neutrophilia and left shift (Fig. 21). Similarly, Kayar *et al* (2018) reported anaemia, leukocytosis and thrombocytopenia as the most common clinicopathologic abnormalities in lymphoma. Thangapandiyan *et al* (2017) also reported anemia to be most frequently encountered abnormality in lymphoma and is generally consistent with a chronic disease, but can also be related to haemolysis or be of bone marrow origin or due to complex interactions between tumour cells and the patient's homeostatic control of erythrocyte manufacture and metabolism mediated

via inflammatory cytokines. Leukocytosis was often detected in dogs with lymphoma, reflecting the inflammatory condition related to the tumor. Thrombocytopenia occurs in 15 to 56% of dogs with lymphoma and was related to the immune-mediated destruction and ⁄ or bone marrow involvement (Neuwald *et al* 2014 and Thangapandiyan *et al* 2017). Lymphocytes were found to be increased in comparison to apparently healthy animals which was in opposition to the findings of Mutz *et al* (2013) who reported lymphopenia.

Cases of lymphocytic leukemia revealed reduced hemoglobin (10.2±2.59 g/dl), marked leukocytosis (120292±27088.99/µl) with absolute lymphocytosis (104250.3±24258.67/µl), decreased neutrophil percentage (13±6.64) and thrombocytopenia (165±54.69/µl) in comparison to apparently healthy dogs. Mild left shift was observed in three cases and mild toxic changes were observed in two cases. Neoplastic changes in lymphocytes such as granular and atypical lymphocytes (Fig. 22) were present in all four cases (many in 4 cases). These findings were in concurrence with Morris *et al.* (1993).

The mean hemoglobin in TVT was reduced (11.08±1.05 g/dl), TLC (26936±7784.68/µl) was increased along with increased neutrophils (84.3±3.15%), decreased lymphocytes (8.6±1.69%) and increased platelet count (269.5±77. 59×10^3/µl) when compared with apparently healthy dogs. Mild left shift (4 cases) and mild (3 cases) to moderate (1 case) toxic changes in neutrophils were observed along with morphological alterations in lymphocytes (Fig 23) which were observed in four cases (rare in 3 cases, few in 1 case) with presence of activated lymphocytes (2 cases), granular lymphocytes (2 cases) and atypical lymphocytes (1 case). The reduced mean hemoglobin of TVT affected dogs was in accordance with Kumar *et al* (2017), Kabuusu *et al* (2010) and Cizmeci *et al* (2012) who reported anaemia in dogs affected with TVT because of continuous bleeding. The leucocytosis in TVT dogs was explained to be because of tumoural bleeding and lower urinary system infection as reported by Cizmeci *et al* (2012) and Kumar *et al* (2017). Similar findings were also reported by Behera *et al* (2012) and Girmabirhan and Mersha (2015). Increased neutrophils and decreased lymphocytes were in agreement with Kabuusu *et al* (2010). In the present study, the platelets in TVT suffering dogs were increased in comparison to the apparently healthy dogs which was contrary to the results of Behera *et al* (2012), Girmabirhan and Mersha (2015) and Kumar *et al* (2017). Increased platelet

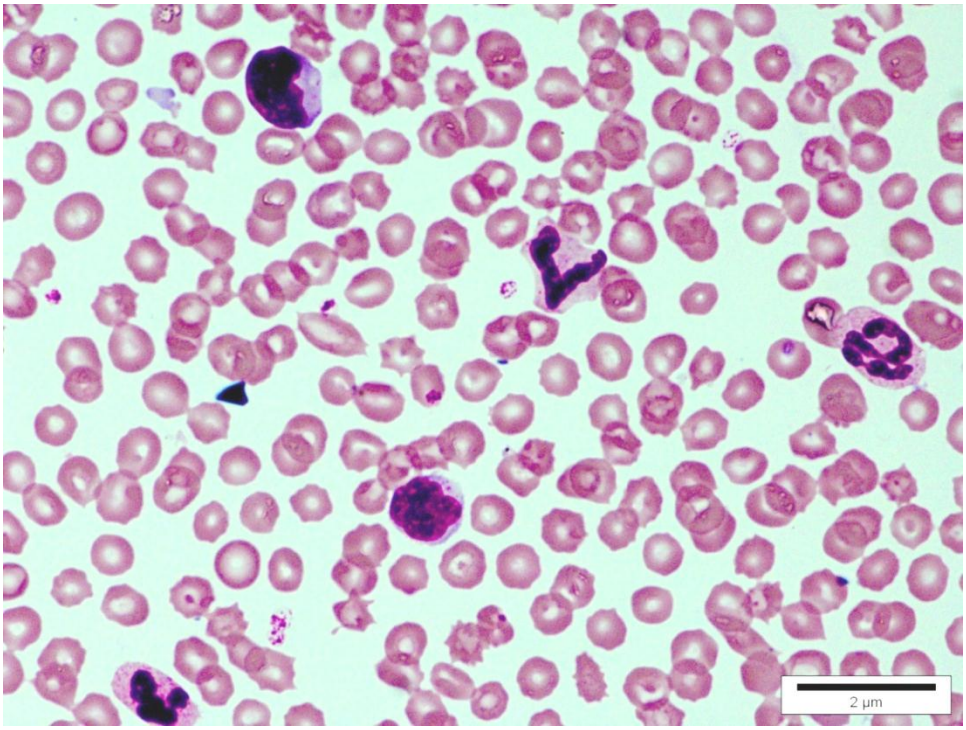


Fig. 20: Blood smear showing mature neutrophils with mild toxic changes, band cell, activated and granular lymphocytes in a case of lymphoma. (TLC=15300/µl) Leishman stain x 100X, Bar=2 µm

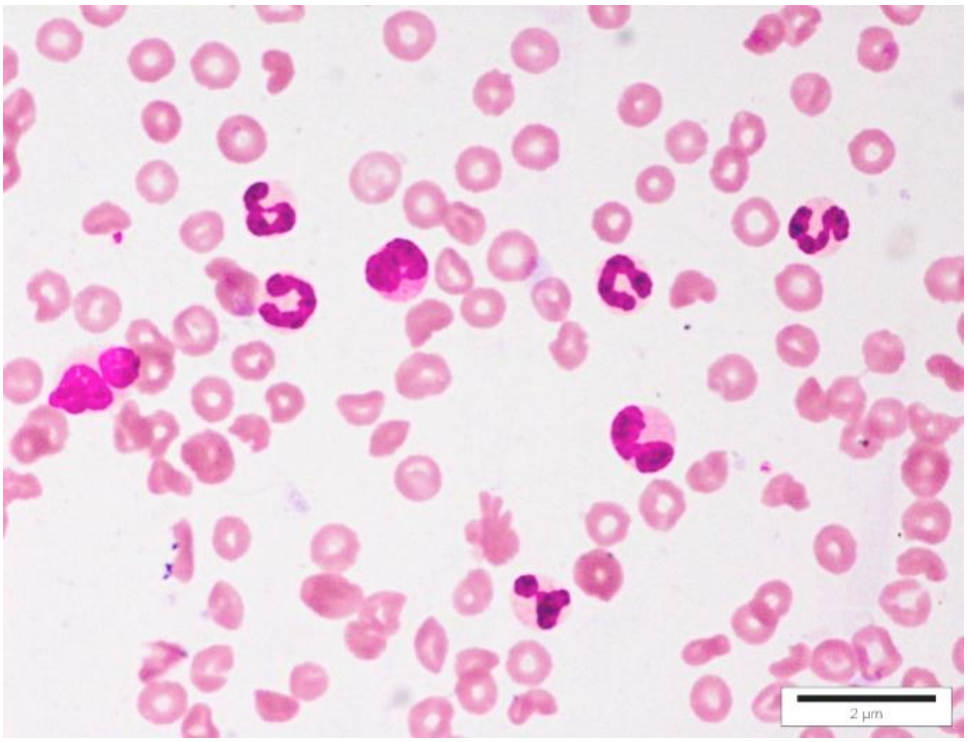


Fig. 21: Blood smear showing leukocytosis with left shift in a case suspected for GIT lymphoma (TLC= 72400/µl). Leishman stain x 100X, Bar=2 µm

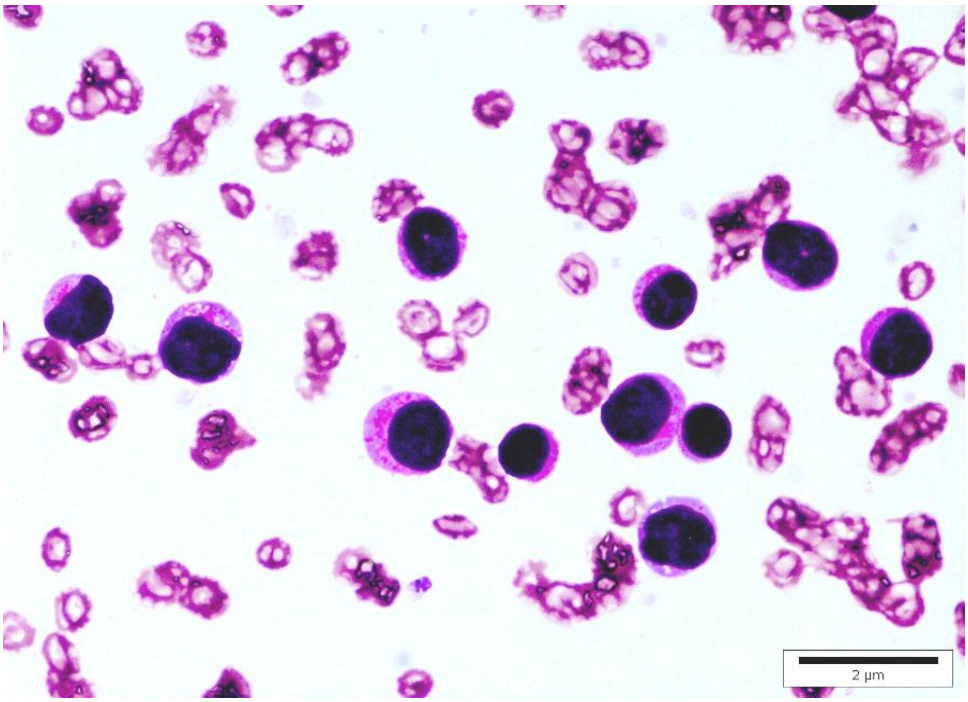


Fig. 22: Blood smear showing numerous pleomorphic lymphocytes indicative of Lymphocytic leukaemia (TLC= 145000/µl, lymphocytes=98%). Leishman stain x 100X, Bar=2 µm

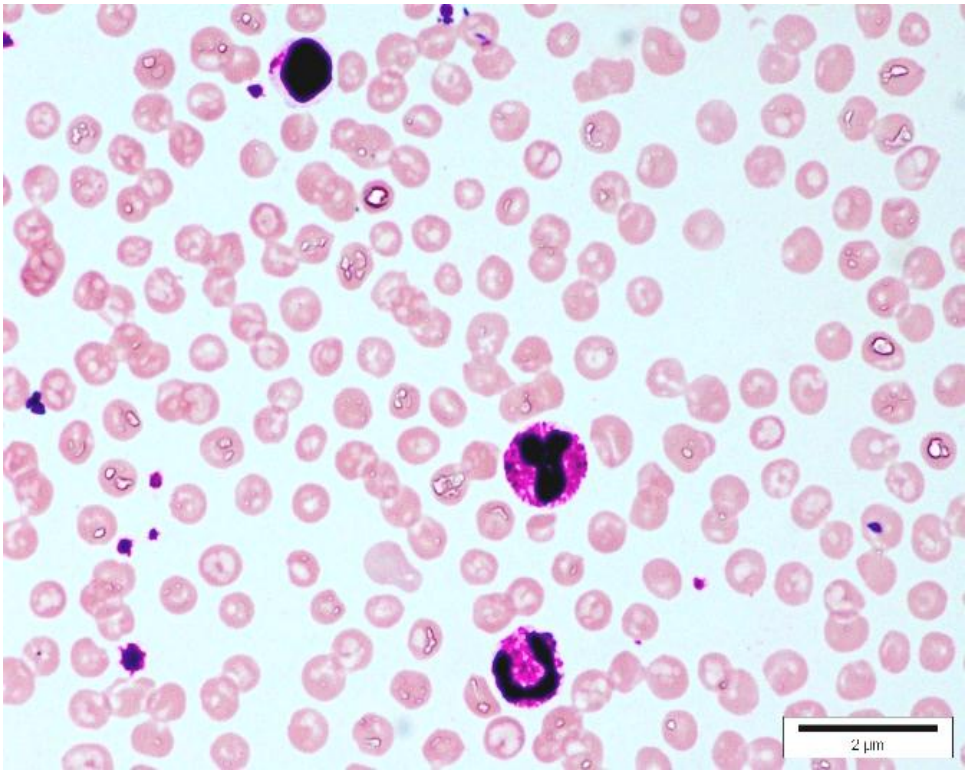


Fig. 23: Blood smear showing toxic neutrophils and granular lymphocyte in a case suspected of TVT. Leishman stain x 100X, Bar=2 µm

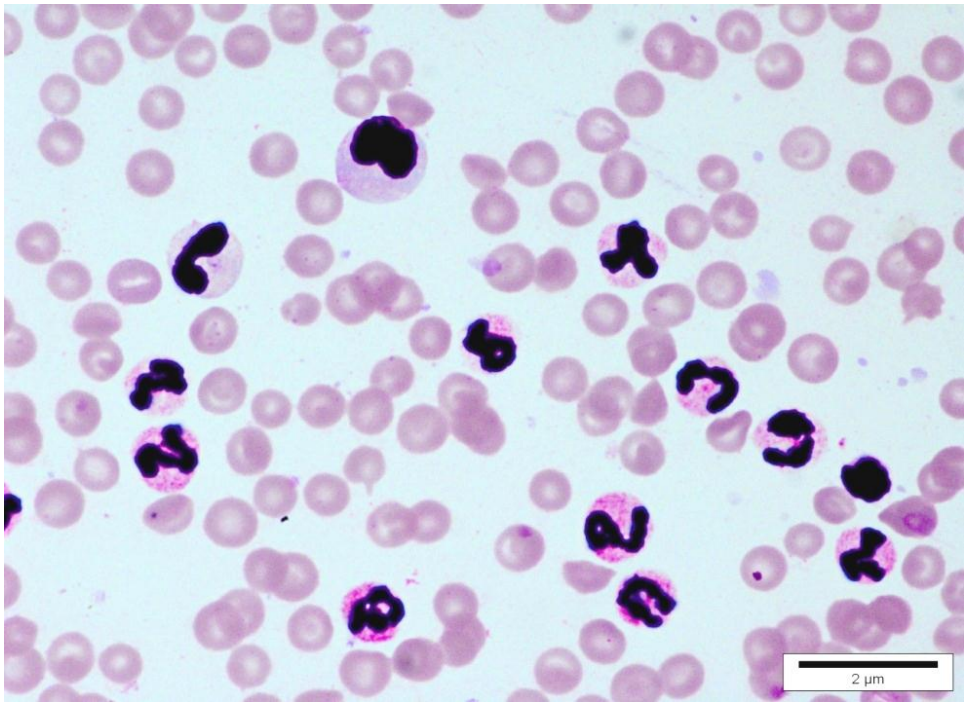


Fig. 24: Blood smear of a case of mammary tumor showing leukocytosis with neutrophilia, band cells, metamyelocytes and toxic changes in neutrophils along with anaemia. Leishman stain x 100X, Bar=2 µm

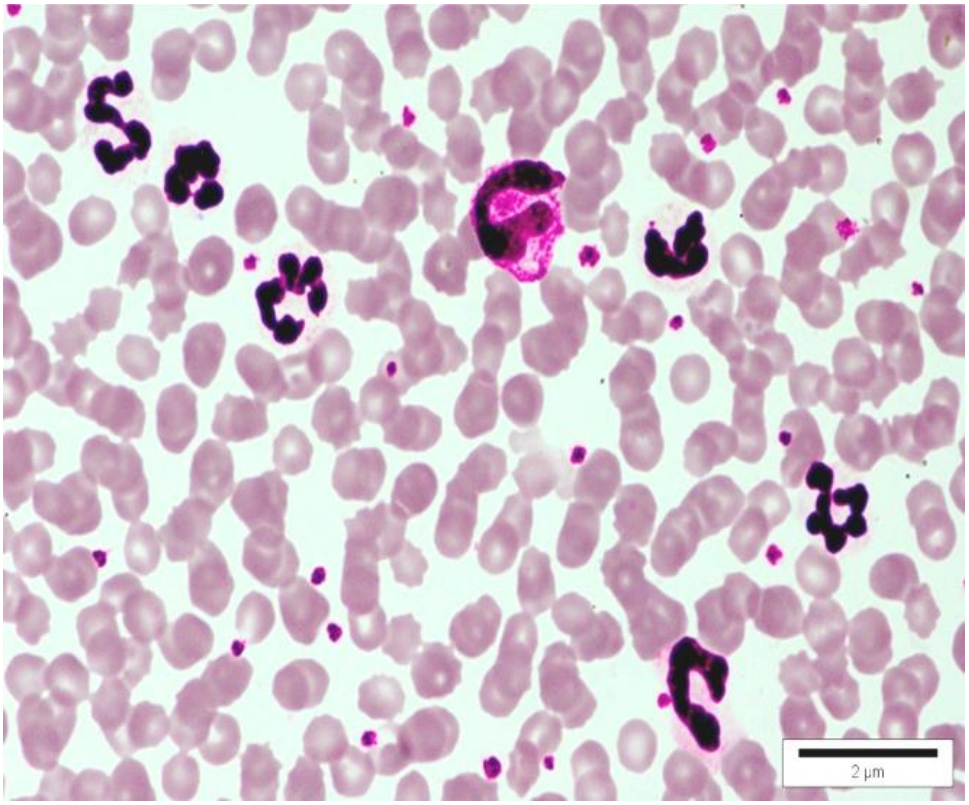


Fig. 25: Blood smear showing leukocytosis with mild left shift and moderate toxic changes in neutrophil in case suspected for melanoma. Leishman stain x 100X, Bar=2 µm

counts were observed in dogs treated with glucocorticoids and vincristine drugs including transmissible venereal tumor (TVT), lymphoma, and carcinoma, inflammatory diseases and neoplasms. These diseases are common causes of thrombocytosis (Rocha *et al* 2019).

In the cases of mammary tumor, the mean hemoglobin (12.13±2.21g/dl) was slightly reduced, TLC was very high in fact it was leukemoid response (71996.67± 46299.78/µl), with increased neutrophils (81.3±3.63%), decreased lymphocytes (5.3±1.3%) and increased mean platelet count (272±133.55×10^3/µl) in comparison to apparently healthy dogs. Mild (1 case) to moderate (2 cases) left shift along with mild toxic changes in neutrophils all the three cases were observed (Fig. 24). Morphological alterations in lymphocytes were observed in two cases (2 few) with presence of activated lymphocytes. The reduced mean value of hemoglobin and elevation of total leukocyte count and neutrophils was in accordance with the findings of Kumar *et al* (2018) and these findings were indicative of inflammatory reaction and possible bacterial infection in the tumour affected dogs (Todarova *et al* 2005, Mohapatra *et al* 2016, Kumar *et al* 2018). The platelets were found to be increased in comparison to the apparently healthy animals which was in conflict with the findings of Kumar *et al* (2018) who reported decreased platelet count.

The hematological examination of a case of melanoma revealed increased hemoglobin (17 g/dl), TLC (25820/µl) with neutrophilia (87%), decreased lymphocytes (4%) along with increased platelet count (294×10^3/µl) in comparison to apparently healthy animals. Mild left shift was observed with moderate toxic changes in neutrophils (Fig. 25). No morphological alterations in lymphocytes were observed. These findings of leukocytosis with neutrophilia and reduced lymphocyte count were in accordance with Gandini *et al* 2016 who reported that patients with melanoma which are presented with distant metastases had higher leukocytes, neutrophils and monocytes, and lower lymphocytes compared to Stage I–III patients.

The hematological examination a case of malignant histiocytosis revealed anaemia with reduced hemoglobin (6.4 g/dl), leukopenia with reduced total leukocyte count (3790/µl), increased neutrophils (81%), decreased lymphocytes (4%) along with thrombocytopenia with reduced platelet count (84000/µl) in comparison to the apparently healthy animals. These findings were in accordance with Banihashem *et al.* (1996) as they reported pancytopenia. Mild toxic changes in neutrophils were observed along with few granular lymphocytes (Fig. 26).

4.2.4.12 Parasitic infections

The hematology of different cases of parasitic infections revealed significantly reduced hemoglobin (p <0.01), TLC and neutrophils within normal range but presence of left shift (Fig. 27) as indicated by increase in band cells, metamyelocytes and myelocytes along with monocytopenia in comparison to the apparently healthy dogs. The mean neutrophil count was higher than the apparently healthy dogs. Mild to moderate toxic changes in neutrophils were observed. The mean of hematological values of apparently healthy dogs and dogs with parasitic infections are presented in Table 25.

Table 25: Hematological changes in apparently healthy dogs and dogs having parasitic infections

Parameter	Apparently healthy dogs (n=10)	Parasitic infections (n=24)	P value
TLC/µl	11027 ± 1047.51	14743.33 ± 2500.63	1.000
N (%)	68.25 ± 4.66	69.06 ± 3.29	1.000
N absolute/µl	7583.57 ± 971.34	10900.73 ± 2153.97	.998
Band (%)	0.9 ± 0.37	6.47 ± 1.81	.901
Band absolute/µl	111.01 ± 51.23	1193.37 ± 405.07	1.000
Metamyelocyte (%)	0	0.21 ± 0.13	.978
Metamyelocyte absolute/µl	0	28.02 ± 16.09	1.000
Myelocyte (%)	0	0.02 ± 0.02	.953
Myelocyte absolute/µl	0	1.23 ± 1.21	1.000
L (%)	27 ± 4.93	20.97 ± 3.19	1.000
L absolute/µl	2929.65 ± 610.14	2931.05 ± 702.08	1.000
M (%)	1.05 ± 0.36	0.67 ± 0.20	.977
M absolute/µl	110.8 ± 32.72	67.96 ± 18.05	1.000
E (%)	2.8 ± 0.50	2.56 ± 0.84	1.000
E absolute/µl	291.96 ± 42.67	248.91 ± 55.70	1.000
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	9.80 ± 2.95	.999
Hemoglobin (g/dl)	13.58 ± 0.64	9.19 ± 0.69	.001**
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	318.58 ± 73.08	1.000

**Significant difference between groups (P <0.01).

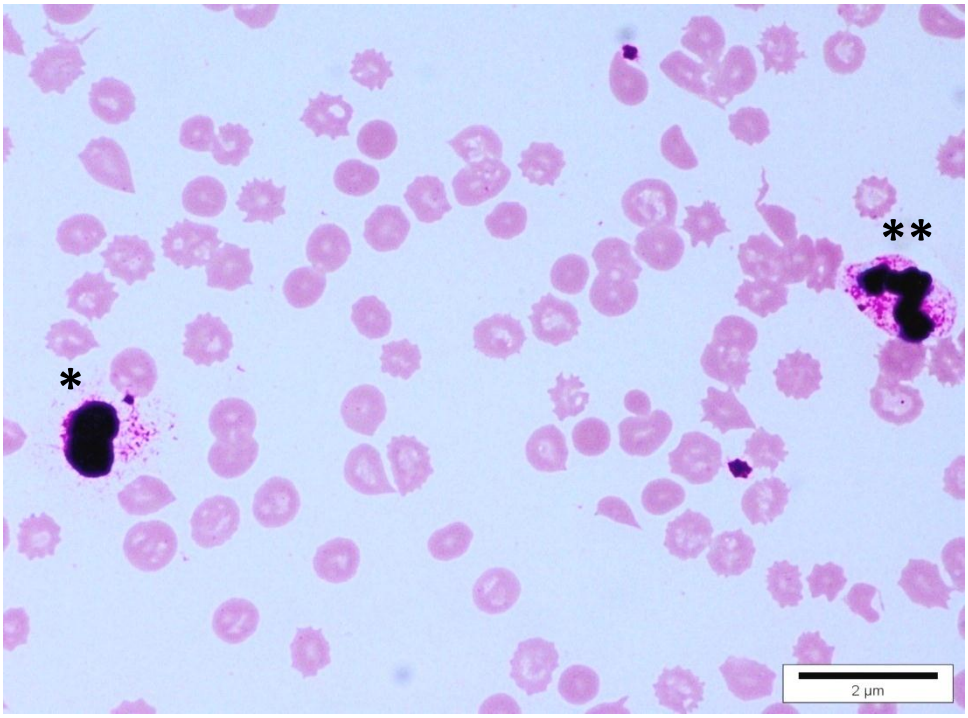


Fig. 26: Blood smear showing toxic changes in neutrophil (**) and a lymphocyte (*) in case suspected for malignant histiocytosis. Leishman stain x 100X, Bar=2 µm

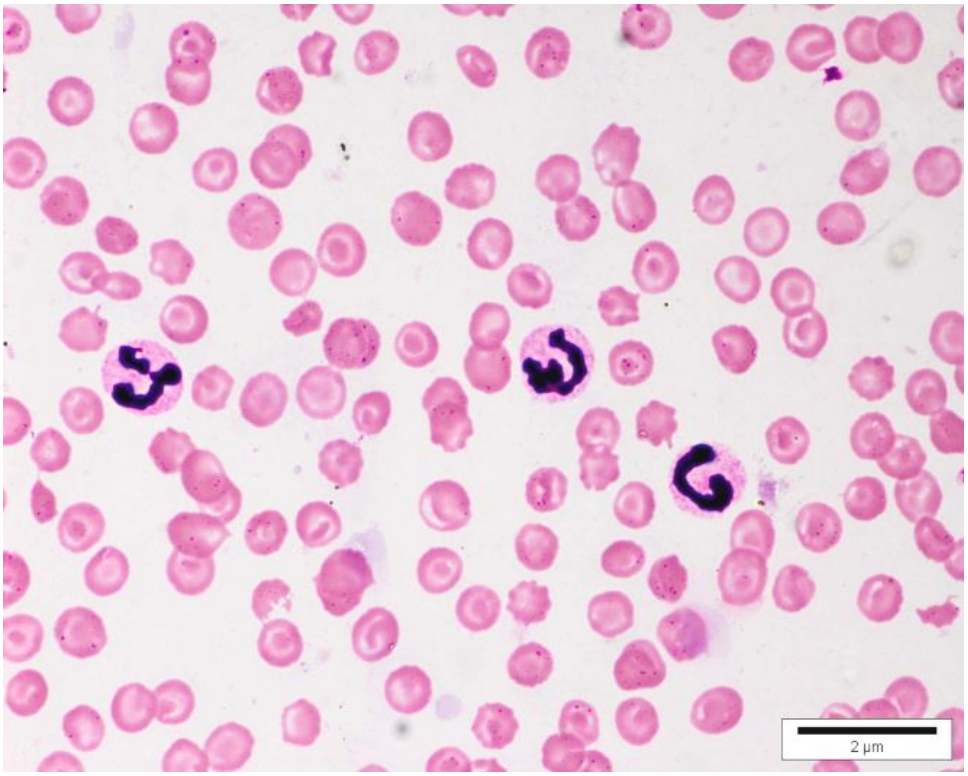


Fig. 27: Blood smear showing mild left shift, target cells in a case of demodicosis. Leishman stain x 100X, Bar=2 µm

The reduced haemoglobin (Hb) concentration in dogs with demodicosis as indicated by decrease in Hb content may be due to the deteriorated condition of the affected dogs owing to reduced food intake, systemic illness, toxaemia and septicaemia caused by the mites as well as by secondary bacterial infection. This is in agreement with Pathak and Bhatia (1986). The generalized inflammation and response of leukocytes to prolonged antigenic stimulus in the form of chronic demodex mite infection may be responsible for the leukocytosis (Janus *et al* 2014). Platelet count falling within the normal range for canines was also observed by Fonseca *et al* 2017 indicating that, thrombocytopenia is not exclusive to canine ehrlichiosis and may be present in different diseases.

4.2.4.13 Viral Diseases

The haematology of different cases of viral diseases revealed no significant changes in comparison to the apparently healthy dogs except significantly lower monocytes (p <0.05) in the diseased group. Although, TLC and N:L was high, hemoglobin and lymphocytes were reduced but the values did not reach the statistical significance. Mild to moderate left shift was observed as indicated by presence of band cells and metamyelocytes. Mild to moderate toxic changes in neutrophils were also observed. Thrombocytosis was observed (Fig. 28) when compared with apparently healthy dogs but values did not reach statistical significance. This finding was contrary to the other authors finding (Shah *et al* 2013) as they observed thrombocytopenia in viral disease. The mean of hematological values of apparently healthy dogs and dogs with viral diseases are presented in Table 26.

In the present study, the cases of parvo viral infection revealed elevated TLC (18996.66 ±6184.6/µl), absolute count of neutrophils (15218.36 ± 5749.68/µl), anaemia (10.6 ± 2.09 g/dl), and thrombocytosis (443.4 ± 101.98x10^5/µl) in comparison to apparently healthy dogs. These findings were similar to Bhargavi *et al* (2017). Leukocytosis in the present study might be due to the invasion of bacteria on damaged intestinal tract as opined by Rai *et al* (1994) who stated that increased TLC in canine parvo virus (CPV) enteritis might be due to the progression of disease in which a reactive leukocytosis had occurred due to myeloid hyperplasia or collection of the samples at the later stages rather than in the initial stage of viraemia and also due to secondary bacterial infections. Neutrophilia recorded in this study simulated with the findings associated with secondary bacterial complications in parvoviral

enteritis (Bhargavi *et al* 2017). As the animal recovers from parvovirus infection, neutrophilia in peripheral blood and hyperplasia of the lymphoid, erythroid and myeloid cells is restored (Shah *et al* 2013)

Table 26: Hematological changes in apparently healthy dogs and dogs having viral diseases

Parameter	Apparently healthy dogs (n=10)	Viral Diseases (n=17)	P value
TLC/µl	11027 ± 1047.51	17962 ± 3268.01	.986
N (%)	68.25 ± 4.66	70.97 ± 5.32	1.000
N absolute/µl	7583.57 ± 971.34	13869.95 ± 2614.58	.905
Band (%)	0.9 ± 0.37	9.52 ± 2.55	.170
Band absolute/µl	111.01 ± 51.23	1957.74 ± 1016.49	.972
Metamyelocyte (%)	0	0.79 ± 0.58	.299
Metamyelocyte absolute/µl	0	73.07 ± 36.83	1.000
Myelocyte (%)	0	0	1.000
Myelocyte absolute/µl	0	0	1.000
L (%)	27 ± 4.93	14.67 ± 3.73	.112
L absolute/µl	2929.65 ± 610.14	1578.82 ± 274.53	1.000
M (%)	1.05 ± 0.36	0.17 ± 0.12	.032*
M absolute/µl	110.8 ± 32.72	15.6 ± 13.72	.990
E (%)	2.8 ± 0.50	3.85 ± 1.67	.973
E absolute/µl	291.96 ± 42.67	467.16 ± 243.92	.990
Neutrophil to lymphocyte (N:L) ratio	3.6 ± 0.73	26.14 ± 12.05	.276
Hemoglobin (g/dl)	13.58 ± 0.64	11.94 ± 0.92	.829
Platelet ($\times 10^3$/µl)	241.9 ± 55.52	327.19 ± 48.07	.823

*Significant difference between groups (P <0.05).

In the present study, the cases of canine distemper (CD) revealed elevated TLC (17398.18 ± 3985.8/µl), absolute count of neutrophils (13134.45 ± 2781.07/µl) and reduced lymphocyte counts (1345.5 ± 346.23/µl) in comparison to apparently healthy dogs. Leukocytosis with neutrophilia observed in the present study was contrary to

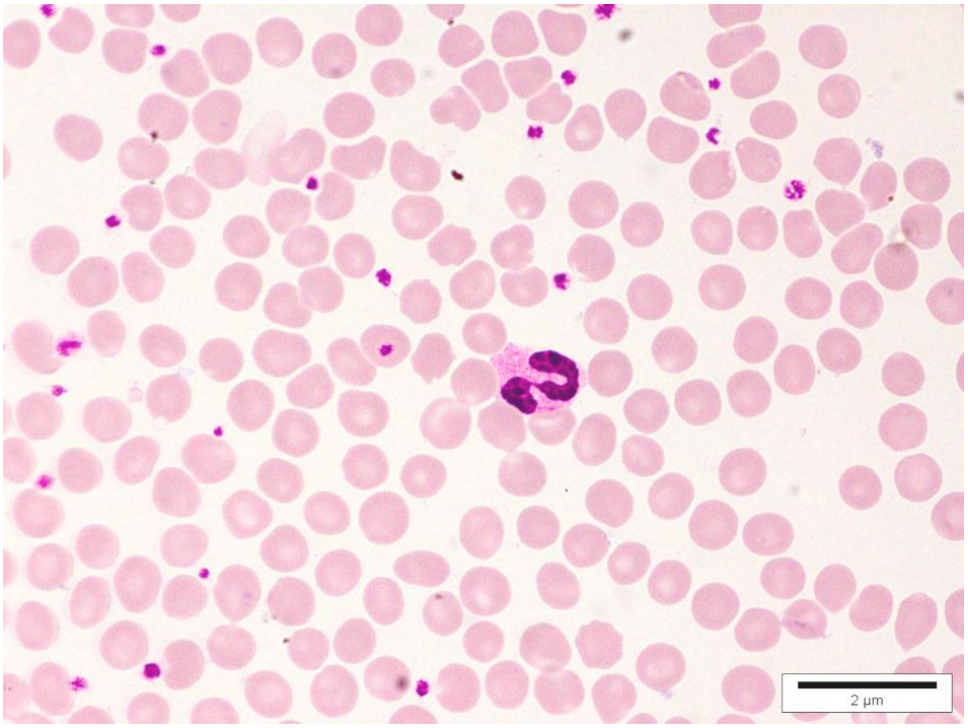


Fig. 28: Blood smear showing toxic changes in neutrophil and increased platelets in a case of canine distemper. Leishman stain x 100X, Bar=2 µm

the findings of Ezeibe and Udegbunam (2008) and Salem (2014) as they reported leukopenia with neutropenia. The reduced lymphocyte count was in harmony with Buragohain *et al* (2017).

4.2.5 Correlation of total leukocyte count disorders with different pathological conditions

The leukocytic disorders observed in different pathological conditions of dogs are shown in Table 27. The most common TLC related leukocytic disorder observed was leukocytosis (169) followed by leukopenia (19) and leukemoid response (10).

Among these leukocytic disorders in the leukocytosis group maximum cases of hepatic dysfunction (38) followed by pyometra (25), renal and hepato-renal dysfunction (20 each), neoplasms (6), respiratory tract affections and UTI (10 each), GIT disorders, parasitic infections and ascites (8 each), viral (06), cardiac disorders (02) and skin affections (1) were observed.

Among leukopenia maximum cases of parasitic infections (05) followed by hepatic dysfunction, renal dysfunction and viral diseases (3 each), UTI, hepato-renal dysfunction and skin affections (1 each) were observed.

Among the leukemoid response maximum cases of neoplasms (06) followed by pyometra (02), renal dysfunction and ascites (1 each) were observed.

Leukocytosis was significantly higher (p <0.05) in different pathological conditions of dogs viz. ascites, pyometra, parasitic infections and neoplasms. The presence of leukocytosis associated with solid tumors has been documented for many decades (McCoach *et al* 2015). Leukopenia was significantly higher in parasitic infections (p <0.01) and viral diseases (p <0.05). Leukemoid response was highly significant (p <0.01) in neoplasms. Many neoplastic conditions have been associated with severe leukocytosis or a leukemoid response (Weltan *et al* 2008). Leukemoid response in mammary tumor was in accordance with Nobin *et al* (2015) while in lymphocytic leukemia in accordance with Thangapandiyan *et al* (2013).

Other pathological conditions were not significantly associated with the total leukocyte count disorders. The values for different pathological conditions are given in Table 27.

Table 27: Correlation of total leukocyte count disorders with different pathological conditions of dogs

Pathological conditions	Leukocytosis		Leukemoid response		Leukopenia	
	No. of cases	*P* value	No. of cases	*P* value	No. of cases	*P* value
Hepatic dysfunction	38	0.0558	0	0.1193	03	0.7124
Renal dysfunction	21	0.4534	01	0.7108	03	0.8163
Hepato-renal dysfunction	20	0.5184	0	0.2582	01	0.4089
Pyometra	25	0.0124*	02	0.3549	0	0.1133
Respiratory tract affections	10	0.3360	0	0.3900	0	0.2287
GIT disorders	08	0.4798	0	0.4305	0	0.2697
UTI	10	0.2147	0	0.4767	01	0.8986
Ascites	08	0.0398*	01	0.1869	0	0.4283
Cardiac disorders	02	0.4868	0	0.6754	0	0.5576
Skin affections	01	0.2193	0	0.7085	01	0.1228
Neoplasms	12	0.0115*	06	0.0001**	02	0.2433
Parasitic infections	08	0.0047**	0	0.4606	05	0.0009**
Viral diseases	06	0.1542	0	0.7329	03	0.0209*
Total	169		10		19	

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

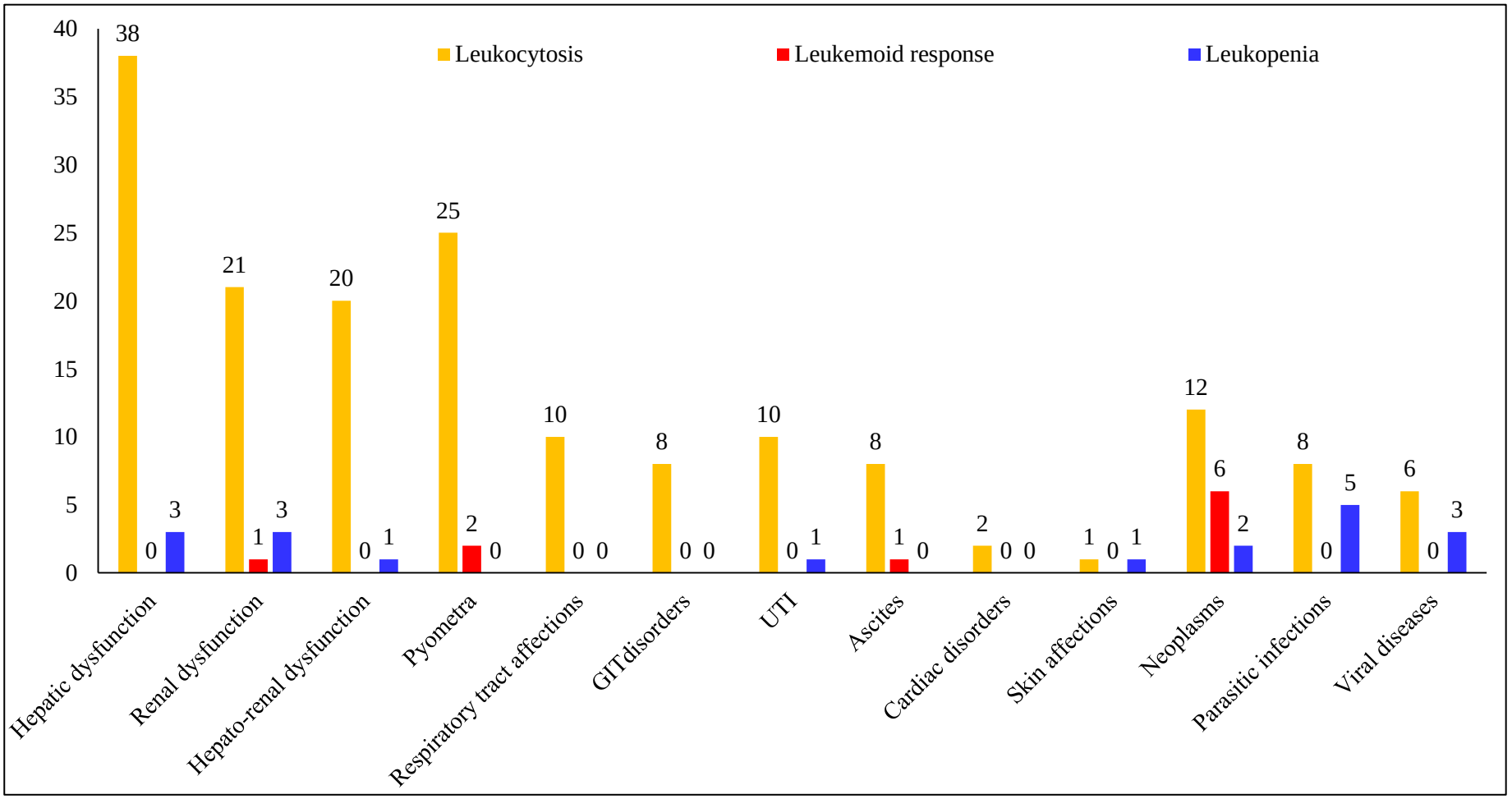


Fig. 29: Correlation of total leukocyte count disorders with different pathological conditions of dogs

4.2.6 Correlation of differential leukocyte count disorders with different pathological conditions of dogs

In the DLC related leukocytic disorders (Table 28) most common were relative neutrophilia (49) followed by absolute neutrophilia (33), relative lymphocytosis (13), absolute eosinophilia (06), absolute lymphocytosis (05) and relative eosinophilia (01).

Among relative neutrophilia maximum cases of hepatic and hepato-renal dysfunction (10) followed by renal dysfunction (08), respiratory tract affections (04), parasitic infections (04), viral diseases (04), neoplasms (03), GIT disorders (02), UTI (01), ascites (01), and cardiac disorders (1) were observed.

Among absolute neutrophilia maximum cases of renal dysfunction (08) followed by respiratory tract affections (05), neoplasms (04), hepatic dysfunction (04), hepato-renal dysfunction (03), pyometra (02), UTI (02), heart disease (02), viral disease (02), and parasitic disease (01) were observed.

Among relative lymphocytosis maximum cases of parasitic infections (05) followed by skin affections (03), viral diseases (03) and renal dysfunction (02) were observed.

Among absolute lymphocytosis group maximum cases of respiratory tract affections and GIT disorders (02) were observed followed by a single case of neoplasm.

In relative eosinophilia only viral disease (01) was observed while among absolute eosinophilia group maximum cases of GIT disorders (03) followed by a single case of pyometra, respiratory tract affections and viral disease were observed.

Relative neutrophilia was highly significant (p <0.05) in hepato-renal dysfunction and pyometra. Absolute neutrophilia was highly significant (p <0.05) in cardiac disorders and respiratory tract affections. Relative lymphocytosis was highly significant (p <0.01) in skin affections, parasitic infections and viral diseases. Absolute lymphocytosis was highly significant (p <0.01) in neoplasms and GIT disorders (p <0.05). Absolute lymphocytosis in the elderly raises the possibility of malignancy (Andrews *et al.* 2008) of neoplasms. Relative eosinophilia was highly significant (p <0.01) in viral infections while absolute eosinophilia was highly significant in GIT disorders (p <0.01) and viral infections (p <0.05). Other pathological conditions were not significantly associated with the differential leukocyte count disorders. The values for different pathological conditions are given in Table 28.

Table 28: Correlation of differential leukocyte count disorders with different pathological conditions of dogs

Pathological conditions	Relative neutrophilia		Absolute neutrophilia		Relative lymphocytosis		Absolute lymphocytosis		Relative eosinophilia		Absolute eosinophilia	
	No. of cases	*P* value	No. of cases	*P* value	No. of cases	*P* value	No. of cases	*P* value	No. of cases	*P* value	No. of cases	*P* value
Hepatic dysfunction	10	0.7835	04	0.2856	0	0.0742	0	0.1401	0	0.6276	0	0.2308
Renal dysfunction	08	0.6079	08	0.0723	02	0.8831	0	0.2191	0	0.6861	0	0.3181
Hepato-renal dysfunction	10	0.0214*	03	0.7102	0	0.1950	0	0.2842	0	0.7247	0	0.3844
Pyometra	01	0.0284*	02	0.3364	0	0.1950	0	0.9914	0	0.7247	01	0.6541
Respiratory tract affections	04	0.6461	05	0.0383*	0	0.3245	02	0.0575	0	0.7889	01	0.3212
GIT disorders	02	0.5998	0	0.1356	0	0.3663	02	0.0292*	0	0.8061	03	0.0001**
UTI	01	0.3407	02	0.6874	0	0.4147	0	0.5004	0	0.8246	0	0.5814
Ascites	01	0.6670	0	0.2842	0	0.5168	0	0.5922	0	0.8602	0	0.6635
Cardiac disorders	01	0.8230	02	0.0366*	0	0.6313	0	0.6917	0	0.8962	0	0.7474
Skin affections	0	0.3737	0	0.4790	03	0.0001**	0	0.7233	0	0.9073	0	0.7736
Neoplasms	03	0.2924	04	0.1667	0	0.7445	01	0.0001**	0	0.9924	0	0.9063
Parasitic infections	04	0.2988	01	0.5821	05	0.0001**	0	0.4847	0	0.8182	0	0.5703
Viral diseases	04	0.1086	02	0.5164	03	0.0014**	0	0.7568	01	0.0001**	01	0.0319*
Total	49		33		13		05		01		06	

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

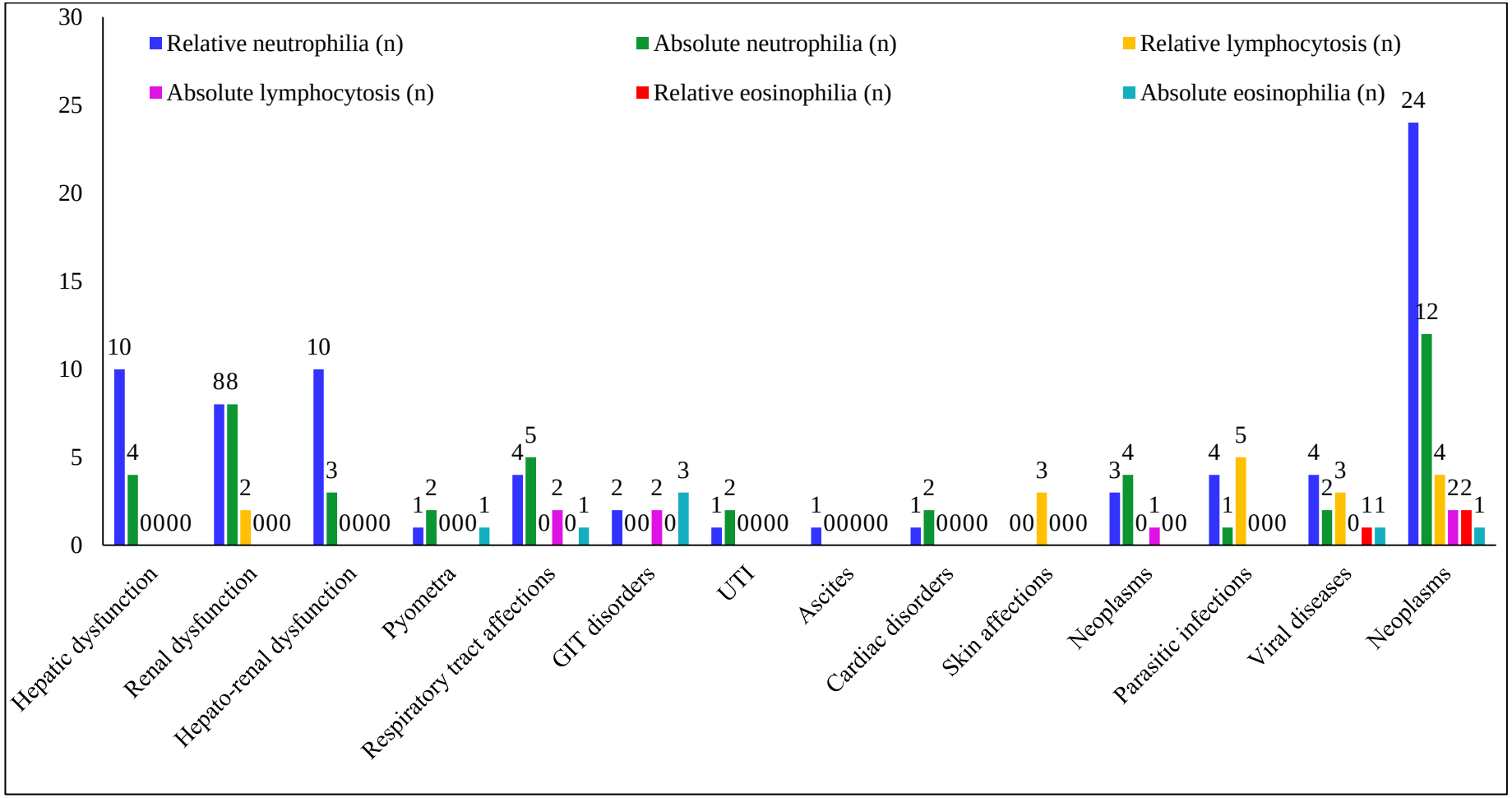


Fig. 30: Correlation of differential leukocyte count disorders with different pathological conditions of dogs

4.2.7 Incidence of left shift and toxic changes in different pathological conditions of dogs

The incidence of left shift and toxic changes is shown in Table 29 and Figure 31 and 32. Maximum left shift was recorded in pyometra in 30 cases (90.9%) followed by ascites in 08 cases (88.8%), hepatic dysfunction in 48 cases (84.2%), UTI in 11 cases (78.5%), viral diseases in 13 cases (76.4%), neoplasms in 19 cases (76%), respiratory tract affections in 15 cases (75%), GIT disorders in 11 cases (64.7%), parasitic infections in 15 cases (62.5%), cardiac disorders in 03 cases (60%), renal dysfunction in 25 cases (59.5%), hepato-renal dysfunction in 18 cases (54.5%), skin affections in 2 cases (50%). Left shift was highly prominent in all the pathological conditions of dogs when compared with the apparently healthy dogs in which left shift was present in a single case only (10%).

Maximum toxic changes were recorded in GIT disorders and viral diseases in 17 cases (100%), ascites in 9 cases (100%), cardiac disorders in 5 cases (100%) followed by pyometra in 32 cases (96.9%), hepatic dysfunction in 55 cases (96.4%), respiratory tract affections in 19 cases (95%), hepato-renal dysfunction in 31 cases (93.9%), renal dysfunction in 39 cases (92.8%), UTI in 13 cases (92.8%), parasitic infections in 21 cases (87.5%), neoplasms in 21 cases (84%), and skin affections in 2 cases (50%). Toxic changes were more prominent in all pathological conditions of dogs except skin affections (50%) when compared to the apparently healthy dogs in which toxic changes were present in 7 cases (70%).

Table 29: Incidence of left shift and toxic changes in different pathological conditions of dogs

Pathological conditions	No. of cases	Mild left shift	Moderate left shift	Severe left Shift	Total no. of cases with left shift (%)	Mild toxic changes	Moderate toxic changes	Total no. of cases with toxic changes (%)
Hepatic dysfunction	57	39	09	0	48 (84.21)	47	08	55 (96.49)
Renal dysfunction	42	16	08	01	25 (59.52)	35	04	39 (92.85)
Hepato-renal dysfunction	33	16	02	0	18 (54.54)	28	03	31 (93.93)
Pyometra	33	15	09	06	30 (90.90)	26	06	32 (96.96)
Respiratory tract affections	20	14	01	0	15 (75)	18	01	19 (95)
GIT disorders	17	06	05	0	11 (64.70)	17	0	17 (100)
UTI	14	07	04	0	11 (78.57)	12	01	13 (92.85)
Ascites	09	08	0	0	8 (88.88)	09	0	09 (100)
Cardiac disorders	05	03	0	0	3 (60)	05	0	05 (100)
Skin affections	04	0	02	0	2 (50)	02	0	02 (50)
Neoplasms	25	15	04	0	19 (76)	19	02	21 (84)
Parasitic infections	24	12	02	01	15 (62.5)	20	01	21 (87.5)
Viral diseases	17	09	04	0	13 (76.47)	16	01	17 (100)
Apparently healthy dogs	10	01	0	0	1 (10)			07 (70)

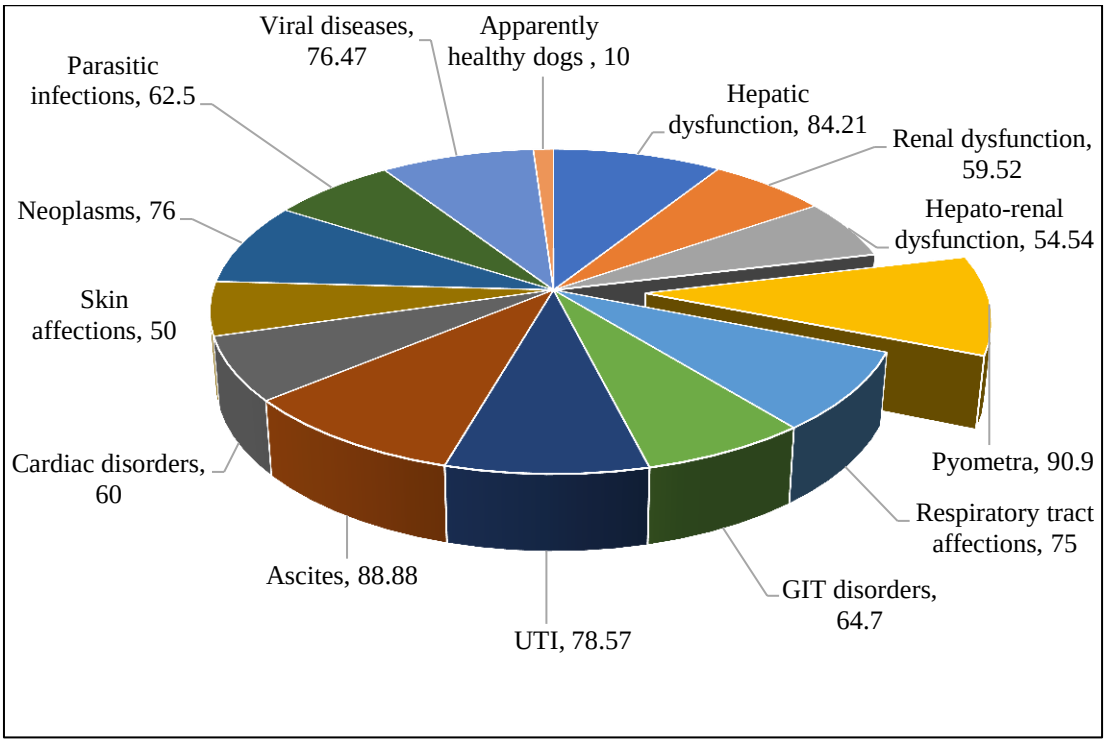


Fig. 31: Incidence of toxic changes in neutrophils in different pathological conditions of dogs

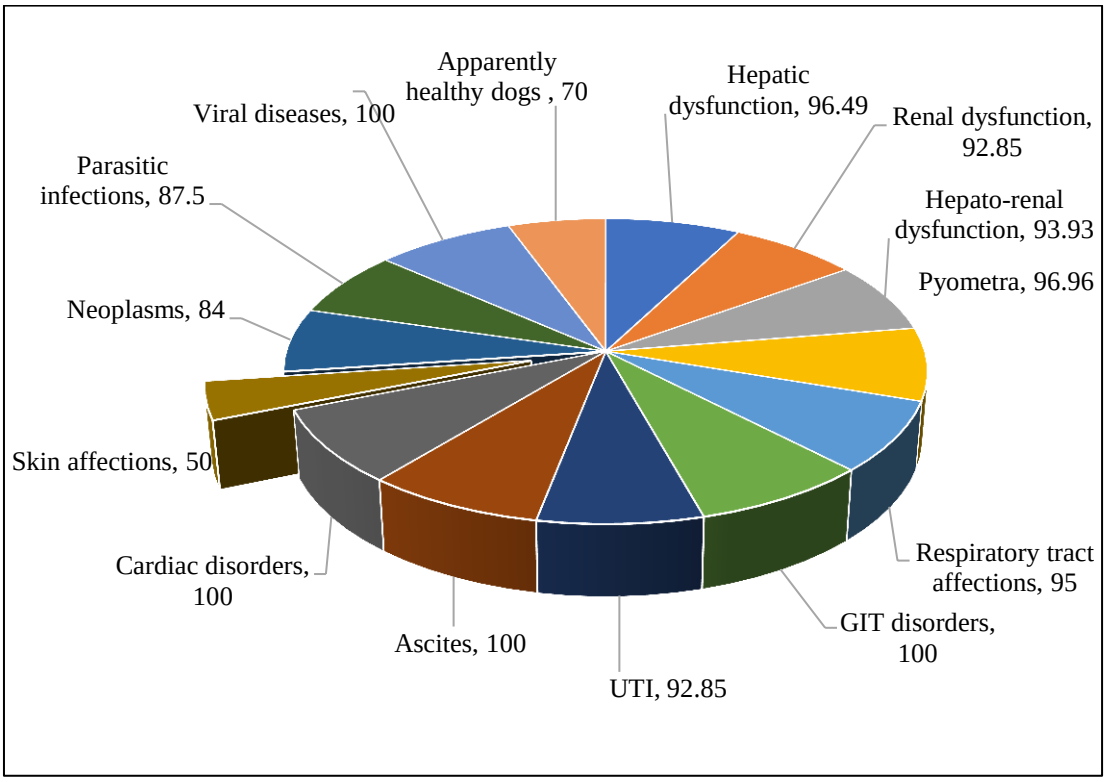


Fig. 32: Incidence of left shift in different pathological conditions of dogs

4.2.8 Chi Square analysis of left shift and toxic changes in neutrophils with pathological conditions

Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with pathological conditions revealed significant left shift in pyometra, renal dysfunction, hepatic dysfunction and hepato-renal dysfunction (p <0.05) whereas, significant toxic changes were associated only with skin affections and neoplasms (P <0.01). Left shift and toxic changes in neutrophils revealed no significance with other pathological conditions of dogs viz. respiratory tract affections, GIT disorders, UTI, ascites, cardiac disorders, parasitic infections and viral diseases the values for which are depicted in Table 30.

Table 30: Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with different pathological conditions

Pathological conditions	No. of cases	Left shift (*P*-value)	Toxic changes (*P*-value)
Hepatic dysfunction	57	0.0298*	0.3306
Renal dysfunction	42	0.0393*	0.8163
Hepato-renal dysfunction	33	0.0133*	0.9456
Pyometra	33	0.0127*	0.4089
Respiratory tract affections	20	0.8085	0.8000
GIT disorders	17	0.4483	0.2697
UTI	14	0.6116	0.8986
Ascites	09	0.2675	0.4283
Cardiac disorders	05	0.5216	0.5576
Skin affections	04	0.3058	0.0003**
Neoplasms	25	0.9611	0.0035**
Parasitic infections	24	0.0848	0.2534
Viral diseases	17	0.2572	0.5438

*Significant difference between groups (P <0.05).

**Significant difference between groups (P <0.01).

4.2.9 Incidence of morphological alterations in lymphocytes in different pathological conditions of dogs

Incidence of morphological alterations in lymphocytes viz. activated lymphocytes, granular lymphocytes and atypical lymphocytes is depicted in Table 31. Maximum morphological alterations in lymphocytes were observed in skin affections

in 4 cases (100%) followed by respiratory tract affections in 16 cases (80%), parasitic infections in 19 cases (79.1%), GIT disorders in 13 cases (76.4%), neoplasms in 18 cases (72%), viral diseases in 12 cases (70.5%), renal dysfunction in 27 cases (64.2%), pyometra in 21 cases (63.6%), UTI in 8 cases (57.1%), ascites in 5 cases (55.5%), hepato-renal dysfunction in 18 cases (54.5%), hepatic dysfunction in 26 cases (45.6%) and cardiac disorders in 2 cases (40%).

The morphological alterations in lymphocytes were more prominent in all the pathological conditions of dogs except in hepatic dysfunction and cardiac disorders when compared to the apparently healthy dogs where these changes were present in 5 cases (50%).

Table 31: Morphological alterations in lymphocytes in different pathological conditions

Pathological conditions	No. of cases	None	Rare	Few	Many	(%) cases alterations present in lymphocytes
Hepatic dysfunction	57	31	20	05	01	45.6
Renal dysfunction	42	15	19	05	03	64.28
Hepato-renal dysfunction	33	15	13	04	01	54.54
Pyometra	33	12	18	02	01	63.63
Respiratory tract affections	20	04	11	02	03	80
GIT disorders	17	04	06	06	01	76.47
UTI	14	06	06	02	0	57.14
Ascites	09	04	04	01	0	55.55
Cardiac disorders	05	03	0	02	0	40
Skin affections	04	0	01	03	0	100
Neoplasms	25	07	09	04	05	72
Parasitic infections	24	05	06	07	06	79.16
Viral diseases	17	05	09	03	0	70.58
Total	300	111	122	46	21	63
Apparently healthy dogs	10	05	05	0	0	50

4.2.10 Correlation of various types of lymphocytes with different pathological conditions

Activated lymphocytes were not found to be associated with pathologic disorders of dogs. Granular lymphocytes were found to be significantly associated (P <0.05) with skin affections and neoplasms (P <0.01) whereas, atypical lymphocytes were significantly associated with hepatic dysfunction (P <0.05) and neoplasms (P <0.01). Other pathological conditions did not seem to have any significance with various types of lymphocytes viz. activated, granular and atypical. Values for different pathological conditions are depicted in Table 32.

Table 32: Correlation of various types of lymphocytes with pathological conditions

Pathological conditions	No. of cases	Activated lymphocyte (*P*-value)	Granular lymphocyte (*P*-value)	Atypical lymphocyte (*P*-value)
Hepatic dysfunction	57	0.1146	0.1060	0.0341*
Renal dysfunction	42	0.5805	0.6781	0.2869
Hepato-renal dysfunction	33	0.0654	0.5184	0.1239
Pyometra	33	0.4793	0.4016	0.4281
Respiratory tract affections	20	0.1289	0.1534	0.2422
GIT disorders	17	0.0845	0.4798	0.9832
UTI	14	0.4126	0.8891	0.3330
Ascites	09	0.2947	0.9891	0.5121
Cardiac disorders	05	0.9631	0.8324	0.5689
Skin affections	04	0.1373	0.0250*	0.6110
Neoplasms	25	0.9455	0.0078**	0.0001**
Parasitic infections	24	0.6443	0.2204	0.2198
Viral diseases	17	0.0700	0.1933	0.5626

*Significant difference between groups (P <0.05).

**Significant difference between groups (P <0.01).

4.2.11 Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with haematological findings

Among the leukocyte indices, it was found that the dogs with left shift had significantly (p <0.05) higher mean TLC, absolute neutrophil count, band cell; metamyelocyte; and myelocyte % and absolute counts, and monocyte, as well as significantly (p <0.05) lower lymphocyte and eosinophil % counts when compared to those in which left shift was absent (Table 33). The frequency of left shift was significantly higher in the neutropenia and neutrophilia groups (Nivy *et al* 2013). It also revealed significantly (p <0.05) higher platelet count, and significantly (p <0.05) lower average level of Hb in the dogs where left shift was present.

The dogs with toxic changes in neutrophils had significantly (p <0.05) higher average band cell % count, myelocyte % count, and absolute eosinophils and monocyte counts as well as significantly (p <0.05) higher average Hb and platelet counts when compared to those dogs in which toxic change was absent (Table 33). Aroch *et al* (2005) reported that dogs with neutrophil toxicity had significantly higher (P<0.05) higher WBC, and neutrophil, neutrophilic band, and monocyte counts as well as significantly lower hemoglobin concentration, eosinophil, lymphocyte, and basophil counts. In the present study findings regarding the eosinophils and hemoglobin were contrary to that of Aroch *et al* (2005). There was a significant (P<0.01) positive association between the occurrence of left shift and cytoplasmic toxicity (Nivy *et al* 2013).

Table 33: Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with haematological findings

Haematological parameter	No. of cases change absent	No. of cases change present	Mean of cases change absent	Mean of cases change present	Mean Difference	P value
Left shift						
Hb	82	218	11.2720 ± 0.4109	10.0606 ± 0.2480	1.2114	0.0115*
TLC	82	218	13533.5 ± 1553.6	30720.8 ± 1644.6	-17187.2	<.0001**
N absolute	80	218	10282.6 ± 862.2	22839.6 ± 1075.3	-12556.9	<.0001**
Band absolute	80	218	115.4 ± 10.7017	3704.4 ± 443.5	-3589.0	<.0001**
Band %	80	218	1.2000 ± 0.1275	10.6284 ± 0.7982	-9.4284	<.0001**
Metamyelocyte absolute	80	218	1.3125 ± 1.3125	161.9 ± 39.7597	-160.6	<.0001**
Metamyelocyte %	80	218	0.00625 ± 0.00625	0.4358 ± 0.0819	-0.4295	<.0001**
Myelocyte absolute	80	218	0	10.3867 ± 4.6288	-10.3867	0.0258*
Myelocyte %	80	218	0	0.0206 ± 0.00749	-0.0206	0.0064**
L %	80	218	16.4875 ± 1.7144	10.7752 ± 0.8766	5.7123	0.0015**
E %	80	218	2.7938 ± 0.4475	1.3417 ± 0.1854	1.4520	0.0034**
M absolute	80	218	27.7313 ± 7.5915	93.7101 ± 24.6258	-65.9788	0.0110*
Platelet count	72	202	213.3 ± 20.1269	279.0 ± 12.4241	-65.7371	0.0066**
Toxic changes						
Hb	19	281	8.6368 ± 0.8306	10.5103 ± 0.2203	-1.8735	0.0330*
Band %	17	281	4.4412 ± 1.3263	8.3185 ± 0.6644	-3.8773	0.0150*
Myelocyte absolute	17	281	0	8.0580 ± 3.5985	-8.0580	0.0259*
Myelocyte %	17	281	0	0.0160 ± 0.00583	-0.0160	0.0064**
E absolute	17	281	142.2 ± 57.9692	319.7 ± 36.8943	-177.5	0.0147*
M absolute	17	281	16.8176 ± 11.1700	79.5779 ± 19.2677	-62.7603	0.0054**
Platelet count	13	261	108.2 ± 25.1023	269.4 ± 10.9571	-161.2	<0.0001**

*Significant difference between groups (P <0.05).

**Significant difference between groups (P <0.01).

4.2.12 Correlation of different types of lymphocytes with haematological findings

Among leukocyte indices significantly (p <0.05) lower mean neutrophil % and absolute counts, as well as significantly (p <0.05) higher mean lymphocyte % counts and eosinophil absolute and % counts were found in group where activated lymphocytes were present in comparison to those where activated lymphocytes were absent (Table 34).

Again, among different types of lymphocytes *t*-tests revealed significantly (p <0.05) higher mean granular lymphocyte counts where activated lymphocytes were present (Table 34).

The dogs with granular lymphocytes had significantly (p <0.05) lower mean neutrophil % and absolute counts, monocyte absolute counts, as well as significantly (p <0.05) higher mean lymphocyte %, eosinophil % and absolute counts when compared to those where granular lymphocytes were absent. It also revealed significantly (p <0.05) higher mean Hb in the group where granular lymphocytes were present (Table 34).

The dogs with granular lymphocytes had significantly (p <0.05) higher average % of toxic neutrophils when compared to the group where granular lymphocytes were absent (Table 34).

Table 34: Correlation of different types of lymphocytes with haematological findings

Haematological parameter	No. of cases change absent	No. of cases change present	Mean of cases change absent	Mean of cases change present	Mean Difference	P value
Activated lymphocytes						
Hb	183	117	9.7623 ± 0.2790	11.3761 ± 0.3142	-1.6138	0.0002**
N absolute	181	117	21351.5 ± 1137.6	16555.7 ± 1352.4	4795.7	0.0076**
N %	181	117	79.5525 ± 1.2370	73.6838 ± 1.5744	5.8687	0.0035**
L %	181	117	9.9088 ± 1.0086	16.0214 ± 1.2450	-6.1125	0.0002**
E absolute	181	117	239.0 ± 38.9737	418.8 ± 64.6525	-179.9	0.0181*
E %	181	117	1.3039 ± 0.1900	2.3932 ± 0.3595	-1.0893	0.0081**
Granular L	183	117	1.7705 ± 0.3150	3.3162 ± 0.5615	-1.5457	0.0173*
Granular lymphocytes						
Hb	166	134	9.9608 ± 0.2992	10.9254 ± 0.2993	-0.9645	0.0250*
N absolute	164	134	21654.3 ± 1246.1	16793.5 ± 1193.1	4860.9	0.0058**
N %	164	134	81.6189 ± 1.2704	71.8993 ± 71.8993	9.7196	<.0001**
L %	164	134	8.5976 ± 0.8929	16.8507 ± 1.3082	-8.2532	<.0001**
E absolute	164	134	204.5 ± 27.5668	438.2 ± 68.7238	-233.8	0.0019**
E %	164	134	1.1433 ± 0.1765	2.4515 ± 0.3396	-1.3082	0.0008**
M absolute	164	134	106.3 ± 31.9215	38.8597 ± 9.8567	67.4824	0.0448*
% of toxic neutrophils	166	134	7.4880 ± 0.4582	9.8134 ± 0.6116	-2.3255	0.0026**
Activated L	166	134	1.0783 ± 0.1880	2.0000 ± 0.2895	-0.9217	0.0081**
Atypical lymphocytes						
N %	280	18	78.4071 ± 0.9095	59.2222 ± 59.2222	19.1849	0.0146*
L absolute	280	18	1933.2 ± 101.9	27432.2 ± 11195.4	-25498.9	0.0360*
L %	280	18	10.9268 ± 0.6369	33.8056 ± 7.2973	-22.8788	0.0061**
E absolute	280	18	319.7 ± 37.0808	152.5 ± 45.3874	167.2	0.0065**

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2.13 Correlation of leukocyte findings with clinical symptoms

4.2.13.1 Correlation of left shift with clinical symptoms

The chances of occurrence of left shift were significantly lower in the group where vaginal discharge was absent (OR=0.25, *P* <0.05) than the group where vaginal discharge was present. This indicates that, the chances of occurrence of left shift were 4 times more in the group where vaginal discharge was present as compared to the group where it was absent (Table 35).

The chances of occurrence of left shift were significantly higher in the group where hematuria was present (OR=2.46, *P* <0.01) and significantly lower in the group where history of stranguria was present (OR=<0.001, *P* <0.01) when compared with the group where polyuria was present (Table 35). This indicates that, the chances of occurrence of left shift was 0.4 times less in the group where polyuria was present as compared to the group where hematuria was present and 1000 times more in the group where polyuria was present as compared to the group where and stranguria was present.

The chances of occurrence of left shift were significantly lower in the group where history of melena (OR=0.59, *P* <0.01) was absent when compared with the group where history of melena was present (Table 35). This indicates that, the chances of occurrence of left shift were 1.6 times more in the group where history of melena was present as compared to the group where it was absent.

The chances of occurrence of left shift were significantly lower in the group where history of abdominal distension (OR=0.34, *P* <0.05) was absent when compared with the group where history of abdominal distension was present (Table 35). This indicates that, the chances of occurrence of left shift were 3 times more in the group where history of abdominal distension was present as compared to the group where it was absent.

The chances of occurrence of left shift were significantly higher in the group where lymph nodes were normal (OR=2.48, *P* <0.05) when compared with the group where lymph nodes were swollen (Table 35). This indicates that the chances of occurrence of left shift were 0.4 times less in the group where lymph nodes were swollen as compared to the group where lymph nodes were normal.

Table 35: Correlation of leukocyte findings with clinical symptoms

Clinical Symptoms	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Vaginal discharge absent	0.28	0.25	0.07	0.68	0.0145
Vaginal discharge present	Reference value				
Urination – hematuria present	0.92	2.46	0.40	20.08	<.0001
Urination – stranguria present	3.08	<0.001	<0.001	<0.001	<.0001
Urination – polyuria present	Reference value				
No defecation	0.35	0.59	0.26	1.24	0.0010
Defecation - melena	Reference value				
Abdominal distension absent	0.23	0.34	0.12	0.81	0.0237
Abdominal distension present	Reference value				
Lymph nodes normal	0.21	2.48	1.05	5.91	0.0368
Lymph nodes swollen	Reference value				

4.2.13.2 Correlation of toxic change in neutrophils with clinical symptoms

The chances of occurrence of toxic changes were significantly higher in the group where itching (OR=9.16, *P* <0.01), epistaxis (OR=5.90, *P* <0.05), subcutaneous nodules (OR=7.50, *P* <0.05) and alopecia (OR=59.91, *P* <0.01) were absent when compared with the groups where these were present. This indicates that, the chances of occurrence of toxic changes were almost nil (0.1 times) in the group where itching, epistaxis, subcutaneous (Sc) nodules and alopecia were present as compared to the group where these were absent (Table 36). Aroch *et al* reported no differences with respect to nasal discharge and skin mass between the neutrophil toxicity and control group but similar results were observed with respect to pruritis as it was more frequently observed in the control group.

The chances of occurrence of toxic changes were significantly lower in the group where vaginal discharge (OR=0.201, *P* <0.01), melena (OR=0.89, *P* <0.05), dyspnea (OR=0.412, *P* <0.05), and oral ulceration (OR=0.16, *P* <0.05) were absent when compared with the group where these were present (Table 36). This indicates that, the chances of occurrence of toxic changes were 5 times, 1.1 times, 2.4 times and 6.25 times more in the group where vaginal discharge, melena, dyspnea and oral ulceration were respectively present as compared to the group where these changes were absent. Similar findings were observed by Aroch *et al* (2005) with respect to vaginal discharge and melena as they were observed frequently where neutrophil toxicity was present.

Table 36: Correlation of toxic change in neutrophils with clinical symptoms

Clinical symptoms	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Itching absent	0.3456	9.168	2.193	34.766	0.0013
Itching present	Reference value				
Epistaxis absent	0.3818	5.909	1.174	24.886	0.0200
Epistaxis present	Reference value				
Sc nodules absent	0.4258	7.501	1.379	40.595	0.0180
Sc nodules present	Reference value				
Vaginal discharge absent	0.1991	0.201	0.089	0.430	<.0001
Vaginal discharge present	Reference value				
No defecation	0.2402	0.890	0.439	1.857	0.0148
Defecation – melena	Reference value				
Dyspnoea absent	0.2203	0.412	0.173	0.984	0.0443
Dyspnoea present	Reference value				
Oral ulceration absent	0.4568	0.164	0.021	0.916	0.0477
Oral ulceration present	Reference value				
Alopecia absent	0.6186	59.914	6.557	827.247	0.0009
Alopecia present	Reference value				

4.2.13.3 Correlation of activated lymphocytes with clinical symptoms

The chances of occurrence of activated lymphocytes were significantly lower in the groups where history of (history of) alopecia was absent (OR=0.194, *P* <0.05) when compared with the group where it was present. This indicates that, the chances of occurrence of activated lymphocytes were almost 5 times more in the group where alopecia was present as compared to the group where it was absent (Table 37).

Table 37: Correlation of activated lymphocytes with clinical symptoms

Clinical symptoms	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Alopecia absent	0.3370	0.194	0.043	0.0149	0.0149
Alopecia present	Reference value				

4.2.13.4 Correlation of granular lymphocytes with clinical symptoms

The chances of occurrence of granular lymphocytes were significantly lower in the group where itching was absent (OR=0.20, *P* <0.01) when compared with the group where it was present. This indicates that, the chances of occurrence of granular lymphocytes were 5 times more in the group where itching was present as compared to the group where it was absent (Table 38).

Table 38: Correlation of granular lymphocytes with clinical symptoms

Clinical symptoms	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Itching absent	0.2859	0.200	0.056	0.562	0.0049
Itching present	Reference value				
Nasal discharge absent	0.2859	3.200	1.140	11.386	0.0420
Nasal discharge present	Reference value				

The logistic regression analysis of granular lymphocytes with respect to. clinical history revealed that the chances of occurrence of granular lymphocytes were significantly higher in the group where nasal discharge was absent (OR=3.20, *P* <0.05) when compared with the group where it was present. OR the chances of

occurrence of granular lymphocytes were almost nil (0.3 times) in the group where nasal discharge was present as compared to the group where it was absent (Table 38).

4.2.13.5 Correlation of atypical lymphocytes with clinical symptoms

The chances of occurrence of atypical lymphocytes were significantly lower in the groups where vaginal discharge (OR=0.219, P <0.05), and subcutaneous nodules (OR=0.055, P <0.01) were absent and lymph nodes were normal (OR=0.138, P <0.01) when compared with the group where vaginal discharge and subcutaneous nodules (Sc nodules) were present and lymph nodes were swollen (Table 39). This indicates that, the chances of occurrence of atypical lymphocytes were almost 5 times and 20 times more in the group where vaginal discharge and subcutaneous nodules

Table 39: Correlation of atypical lymphocytes with clinical symptoms

clinical symptoms	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Vaginal discharge absent	0.3090	0.219	0.066	0.781	0.0139
Vaginal discharge present	Reference value				
Urination absent	0.5365	6.305	0.411	>999.999	0.7537
Urination – hematuria present	1.9794	0.911	<0.001	>999.999	0.2881
Urination – pyuria present	1.2430	71.234	1.169	>999.999	0.0695
Urination – strangurua present	1.4034	274.328	3.940	>999.999	0.0102
Urination- oliguria present	1.9997	1.536	<0.001	>999.999	0.4294
Urination – polyuria present	Reference value				
Sc nodules absent	0.4963	0.055	0.006	0.364	0.0034
Sc nodules present	Reference value				
Lymph nodes normal	0.3033	0.138	0.042	0.472	0.0011
Lymph nodes swollen	Reference value				

were respectively present and almost 8 times more when lymph nodes were swollen as compared to the groups where these changes were absent. Association of atypical lymphocytes with lymphadenopathy was in accordance with Ferrer (1998) who reported that human patients with mononucleosis type syndrome present with lymphadenopathy and an increased atypical lymphocyte count.

The chances of occurrence of atypical lymphocytes were significantly higher in the group where history of stranguria was present (OR=274.32, P <0.05) when compared with the group having polyuria. This indicates that, the chances of occurrence of atypical lymphocytes were nil in the group where polyuria was present in comparison to stranguria (Table 39).

4.2.14 Correlation of leukocyte findings with leukocytic disorders

4.2.14.1 Correlation of left shift and toxic changes in neutrophils with leukocytic disorders

The chances of occurrence of left shift were significantly lower in the group where anaemia was absent (OR=0.39, P <0.01) when compared with the group where anaemia was present. This indicates that, the chances of occurrence of left shift were 2.5 times more in the group where anaemia was present as compared to the group where it was absent (Table 40).

The the chances of occurrence of left shift were significantly lower in the group where neutrophilic leukocytosis was absent (OR=0.10, P <0.01) when compared with the group where neutrophilic leukocytosis was present (Table 40). This indicates that, the chances of occurrence of left shift were 10 times more in the group where neutrophilic leukocytosis was present as compared to the group where it was absent. The frequency of left shift was significantly higher in the neutropenia and neutrophilia groups (Nivy *et al* 2013).

The chances of occurrence of toxic changes were significantly higher in the group where absolute lymphocytosis (OR=11.41, P <0.05), relative eosinophilia (OR=58.73, P <0.01), and thrombocytopenia (OR=5.50, P <0.05) were absent when compared with the groups where these were present (Table 40). This indicates that, the chances of occurrence of toxic changes were almost nil in the groups where absolute lymphocytosis, relative eosinophilia and thrombocytopenia were present as compared to the group where these were absent. Aroch *et al* (2005) observed that the control dogs had a significantly (P <0.05) higher prevalence of eosinophilia.

The chance of occurrence of toxic changes was significantly lower in the group where leukocytosis was absent (OR=0.279, *P* <0.01) when compared with the group where it was present (Table 40). This indicates that, the chance of occurrence of toxic changes was almost 4 times more in the group where leukocytosis was present as compared to the group where it was absent. Aroch *et al* (2005) observed that the dogs with neutrophil toxicity had significantly (P, .05) higher prevalence of leukocytosis, leukopenia, neutropenia, neutrophilia, anemia, left shift, monocytosis, and monocytopenia compared to controls.

Table 40: Correlation of left shift and toxic changes in neutrophils with leukocytic disorders

Haematological findings	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Left shift					
Anaemia absent	0.16	0.39	0.20	0.75	0.005
Anaemia present	Reference value				
Neutrophilic leukocytosis absent	0.17	0.10	0.052	0.21	<.0001
Neutrophilic leukocytosis present	Reference value				
Toxic changes					
Absolute lymphocytosis absent	0.4932	11.418	1.348	77.985	0.0136
Absolute lymphocytosis present	Reference value				
Relative eosinophilia absent	0.5114	58.738	8.818	566.221	<.0001
Relative eosinophilia present	Reference value				
Leukocytosis absent	0.1355	0.279	0.162	0.470	<.0001
Leukocytosis present	Reference value				
Thrombocytopenia absent	0.3415	5.506	1.599	25.569	0.0125
Thrombocytopenia present	Reference value				

4.2.14.2 Correlation of different types of lymphocytes with leukocytic disorders

The chances of occurrence of activated lymphocytes were significantly lower in the groups where anaemia was absent (OR=2.028, P <0.01) when compared with the group where it was present. This indicates that, the chances of occurrence of activated lymphocytes were 0.5 times in the group where anaemia was present as compared to the group where it was absent (Table 41).

The chances of occurrence of activated lymphocytes were significantly lower in the groups where thrombocytosis was absent (OR=0.425, P <0.01) when compared with the group where it was present. This indicates that, the chances of occurrence of activated lymphocytes were 2 times more in the group where thrombocytosis was present as compared to the group where it was absent (Table 41).

The chances of occurrence of granular lymphocytes were significantly lower in the group where absolute eosinophilia was absent (OR=0.133, P <0.01) when compared with the group where it was present. This indicates that, the chances of occurrence of granular lymphocytes were 7.5 times more in the group where absolute eosinophilia was present as compared to the group where it was absent (Table 41).

The chances of occurrence of granular lymphocytes were significantly higher in the groups where neutrophilic leukocytosis (OR=3.851, P <0.01), absolute neutrophilia (OR=2.99, P <0.05) and relative neutrophilia (OR=3.953, P <0.01) were absent when compared with the group where these were present. This indicates that, the chances of occurrence of granular lymphocytes were almost nil in the groups where neutrophilic leukocytosis, absolute neutrophilia and relative neutrophilia were present as compared to the groups where these were absent (Table 41).

The chances of occurrence of atypical lymphocytes were significantly lower in the group where leukemoid response (OR=0.049, P <0.01), absolute neutrophilia(OR=0.142, P <0.01) and absolute lymphocytosis (OR=0.094, P <0.01) were absent when compared with the groups where these changes were present. This indicates that, the chances of occurrence of atypical lymphocytes were 25 times, 7 times and 11 times more in the groups where leukemoid response, absolute neutrophilia and absolute lymphocytosis were respectively present as compared to the groups where these were absent (Table 41).

Table 41: Correlation of different types of lymphocytes with leukocytic disorders

Haematological findings	Maximum likelihood standard error	Odd ratio (OR) estimate	95% confidence limits		P value
Activated lymphocytes					
Anaemia absent	0.1293	2.028	1.224	3.377	0.0063
Anaemia present	Reference value				
Thrombocytosis absent	0.1293	0.425	0.255	0.704	0.0009
Thrombocytosis present	Reference value				
Granular lymphocyte					
Neutrophilic leukocytosis absent	0.6741	3.851	1.921	8.253	0.0003
Neutrophilic leukocytosis present	Reference value				
Absolute neutrophilia absent	0.5482	2.993	1.195	8.023	0.0235
Absolute neutrophilia present	Reference value				
Relative neutrophilia absent	0.6872	3.953	1.726	9.720	0.0018
Relative neutrophilia present	Reference value				
Absolute eosinophilia absent	-1.0104	0.133	0.041	0.391	0.0004
Absolute eosinophilia present	Reference value				
Atypical lymphocyte					
Leukemoid response absent	0.3626	0.049	0.011	0.208	<.0001
Leukemoid response present	Reference value				
Absolute neutrophilia absent	0.3154	0.142	0.040	0.506	0.0020
Absolute neutrophilia present	Reference value				
Absolute lymphocytosis absent	0.3807	0.094	0.020	0.410	0.0019
Absolute lymphocytosis present	Reference value				

4.2.15 Correlation of leukocytic disorders with prognosis

Correlation of leukocytic disorders with prognosis was done and analysis revealed absolute neutrophilia and absolute eosinophilia to be significantly (p <0.05) associated with good prognosis. Other leukocytic disorders were not significantly associated with prognosis (p >0.05). The values for different leukocytic disorders are depicted in the Table 42.

Table 42: Correlation of leukocytic disorders with prognosis

Leukocytic disorder	Good prognosis (*P* value)	Fair prognosis (*P* value)	Poor prognosis (*P* value)
Leukocytosis	0.9617	0.1375	0.2681
Leukopenia	0.5256	0.7212	0.5382
Leukemoid response	0.6587	0.2218	0.6781
Relative neutrophilia	0.7980	0.5373	0.4820
Absolute neutrophilia	0.0280*	0.4448	0.0856
Relative lymphocytosis	0.0522	0.5108	0.5909
Absolute lymphocytosis	0.9227	0.3547	0.4478
Relative eosinophilia	0.3001	0.6879	0.4345
Absolute eosinophilia	0.010*	0.3210	0.0535

*Significant difference between groups (P <0.05).

4.2.16 Correlation of toxic changes and prognosis in different diseases

Toxic changes in neutrophils were present in a total of 279 cases in different pathological conditions of dogs. The presence of toxic changes in neutrophils was correlated with the prognosis i.e. good, fair and poor.

Among 279 cases that showed toxic changes in neutrophils 137 cases (49.1%) had a good prognosis, 102 cases (36.5%) showed poor prognosis and 40 cases (14.3%) showed fair prognosis. Correlation of toxic changes and prognosis is presented in Table 43 and Figure 33.

Among different pathological conditions where toxic changes in neutrophils were present maximum cases of good prognosis recorded were 26 (81.2%) in pyometra followed by respiratory tract affections in 15 cases (78.9%), GIT disorders in 13 cases (76.4%), viral diseases in 12 cases (70.5%), parasitic infections in 14

cases (66.6%), UTI in 8 cases (61.5%), skin affections in 1 case (50%), hepatic dysfunction in 22 cases (40%), renal dysfunction in 15 cases (39.4%), neoplasm in 6 cases (28.5%), cardiac disorders in 1 case (20%), ascites in 1 case and hepato-renal dysfunction in 3 cases (9.6%).

Table 43: Correlation of toxic changes and prognosis in different pathological conditions

Pathological conditions	No. of cases	No. of cases with good prognosis (%)	No. of cases with fair prognosis (%)	No. of cases with poor prognosis (%)
Hepatic dysfunction	55	22 (40)	07 (12.7)	26 (47.2)
Renal dysfunction	38	15 (39.4)	08 (21.05)	15 (39.4)
Hepato-renal dysfunction	31	03 (9.6)	04 (12.9)	24 (77.4)
Pyometra	32	26 (81.2)	04 (12.5)	02 (6.2)
Respiratory tract affections	19	15 (78.9)	01 (5.2)	03 (15.7)
GIT disorders	17	13 (76.4)	03 (17.6)	01 (5.8)
UTI	13	08 (61.5)	01(7.6)	04 (30.7)
Ascites	08	01 (12.5)	02 (25)	05 (62.5)
Cardiac disorders	05	01 (20)	02 (40)	02 (40)
Skin affections	02	03 (50)	-	01 (50)
Neoplasms	21	06 (28.5)	02 (9.5)	13 (61.9)
Parasitic infections	21	14 (66.6)	04 (19.4)	03 (14.2)
Viral diseases	17	12 (70.5)	02 (11.7)	03 (17.6)

Among 102 cases of poor prognosis that had toxic changes in neutrophils maximum cases of hepato-renal dysfunction with 31 cases (77.4%) followed by ascites with 8 cases (62.5%), neoplasms with 21 cases (61.9%), skin affections with a single case (50%), hepatic dysfunction with 26 cases (47.2%), cardiac disorders with 2 cases (40%), renal dysfunction with 15 cases (39.4%), UTI with 4 cases (30.7%), viral disease with 3 cases (17.6%), respiratory affections with 3 cases (15.7%), parasitic disease with 3 cases (14.2%), pyometra with 2 cases (6.2%) and GIT disorders with a single case (5.8%).

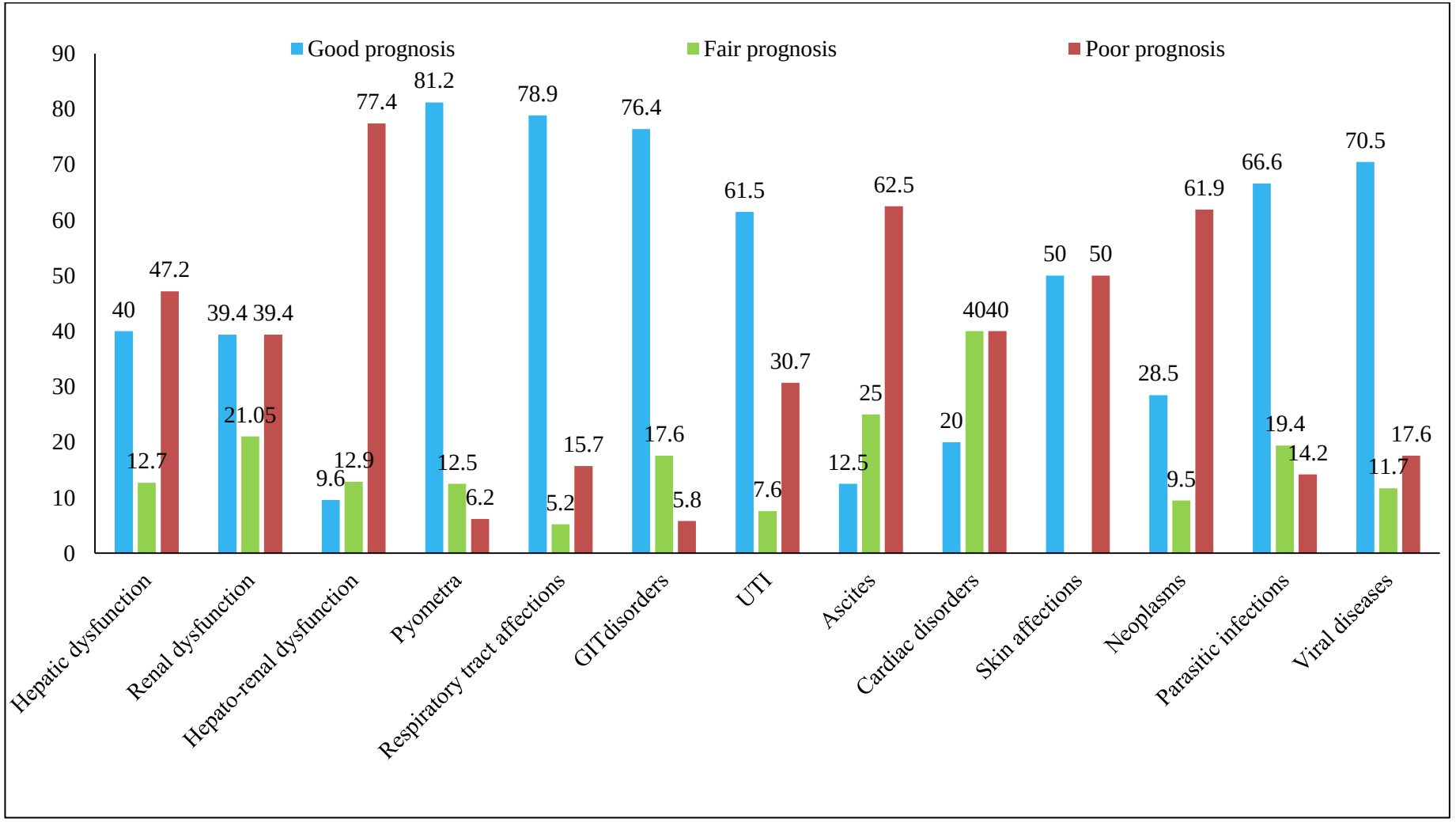


Fig. 33: Correlation of toxic changes with prognosis in different pathological conditions

Among 40 cases of fair prognosis that showed toxic changes in neutrophils maximum cases of cardiac disorders with 2 cases (40%), followed by ascites with 2 cases (25%), renal dysfunction with 8 cases (21.05%), parasitic disease with 4 cases (19.04%), GIT disorders with 3 cases (17.6%), hepato-renal dysfunction with 7 cases (12.7%), pyometra with 4 cases (12.5%), viral diseases with 2 cases (11.7%), neoplasm with 2 cases (9.5%), UTI with a single case (7.6%) and respiratory tract affections with a single case (5.2%).

4.2.17 Correlation of left shift with prognosis in different pathological conditions of dogs

Left shift in neutrophils was present in a total of 216 cases with different pathological conditions. The presence of left shift in different pathological conditions was correlated with the prognosis which was divided into 3 categories viz. good, fair and poor.

Among 216 where left shift in neutrophils was present, maximum cases had a good prognosis with 107 (49.5%) cases followed by poor prognosis in 79 (36.5%) cases and fair prognosis in 30 (13.8%) cases. Correlation of left shift and prognosis is presented in Table 44 and Figure 34.

Among different pathological conditions where left shift was present skin affections were found to have good prognosis in 2 (100%) cases in which left shift was present followed by 24 (80%) cases of pyometra, 11 (73.3%) cases of respiratory affections, 8 (72.7%) cases of GIT disorders, 10 (66.6%) cases of parasitic infections, 8 (61.5%) cases of viral disease, 13 (52%) cases of renal dysfunction, 5 (45.4%) cases of UTI, 47 (34.04%) cases of hepatic dysfunction, 1 (33.3%) case of cardiac disorders, 6 (31.5%) cases of neoplasms, 1 (14.2%) case of ascites and 2 (11.1%) cases of hepato-renal dysfunction.

Among different pathological conditions where left shift was present fair prognosis was observed in cardiac disorders in a single case (33.3%) followed by ascites in 2 (28.5%) cases, renal dysfunction in 6 (24%) cases, parasitic infections in 3 (20%) cases, GIT disorders in 2 (18.1%) cases, viral disease in 2 (15.3%) cases, pyometra in 4 (13.3%) cases, hepatic dysfunction in 6 (12.7%) cases, UTI in 1 (9.09%) case, respiratory affections in 1 (6.6%) cases, hepato-renal dysfunction in 1 (5.5%) cases and neoplasm in 1 (5.2%) case.

Table 44: Correlation of left shift and prognosis in different pathological conditions

Pathological conditions	No. of cases with good prognosis (%)	No. of cases with fair prognosis (%)	No. of cases with poor prognosis (%)
Hepatic dysfunction	16 (34.04)	06 (12.7)	25 (53.1)
Renal dysfunction	13 (52)	06 (24)	06 (24)
Hepato-renal dysfunction	02 (11.1)	01 (5.5)	15 (83.3)
Pyometra	24 (80)	04 (13.3)	02 (6.6)
Respiratory tract affections	11 (73.3)	01 (6.6)	03 (20)
GIT disorders	08 (72.7)	02 (18.1)	01 (9.09)
UTI	05 (45.4)	01 (9.09)	05 (45.4)
Ascites	01 (14.2)	02 (28.5)	04 (57.1)
Cardiac disorders	01 (33.3)	01 (33.3)	01 (33.3)
Skin affections	02 (100)		
Neoplasms	06 (31.5)	01 (5.2)	12 (63)
Parasitic infections	10 (66.6)	03 (20)	02 (13.3)
Viral diseases	08 (61.5)	02 (15.3)	03 (23.07)
Total	107 (49.5)	30 (13.8)	79 (36.5)

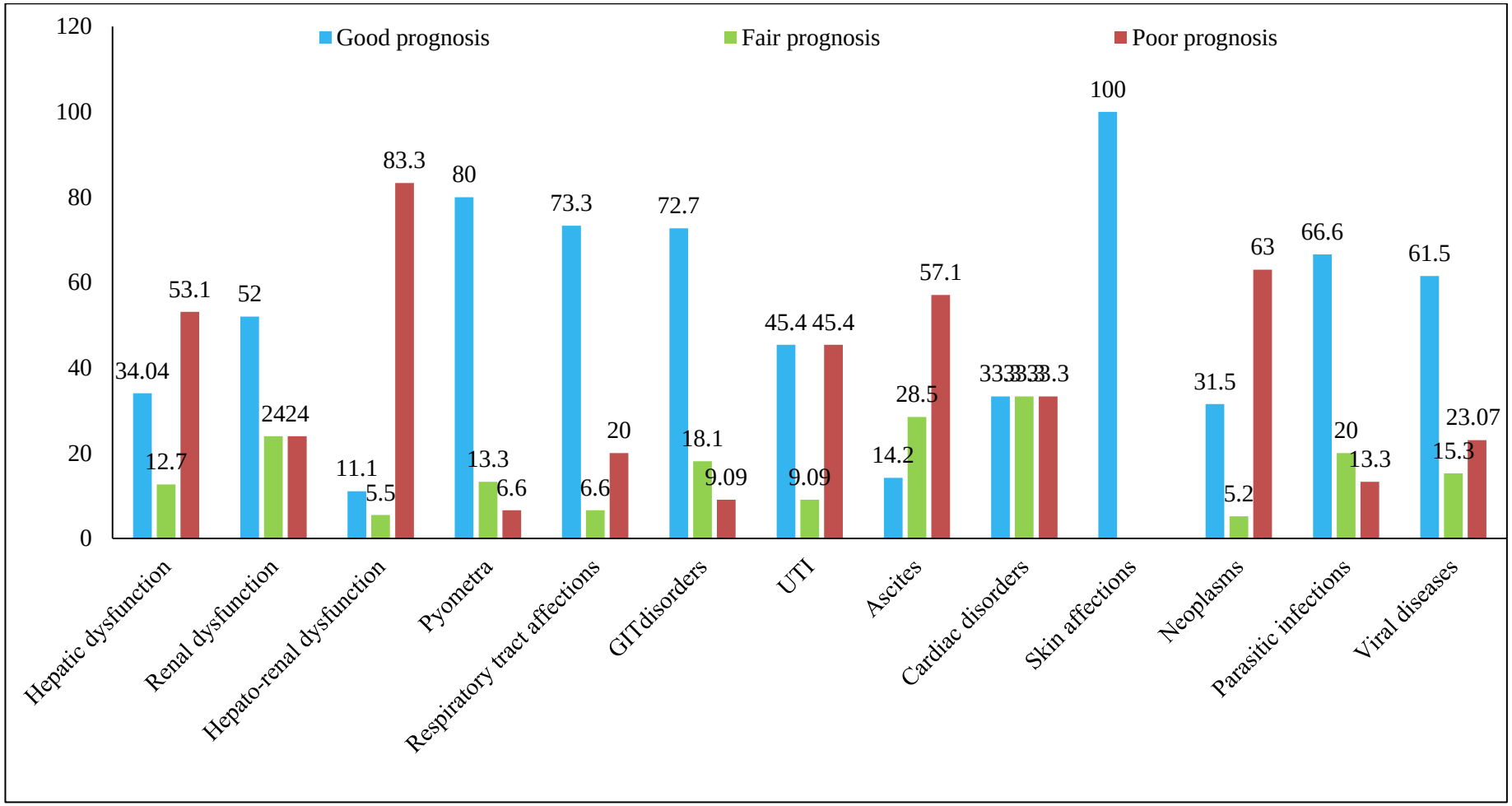


Fig. 34: Correlation of left shift with prognosis in different pathological conditions

Among different pathological conditions where left shift was present, maximum cases of poor prognosis were recorded in hepato-renal dysfunction in 15 (83.3%) cases followed by neoplasms in 12 (63%) cases, ascites in 4 (57.1%) cases, hepatic dysfunction in 25 (53.1%) cases, UTI in 5 (45.4%) cases, cardiac disorders in 1 (33.3%) case, renal dysfunction in 6 (24%) cases, viral disease in 3 (20%) cases, parasitic disease in 2 (13.3%) cases, GIT disorders in 1 (9.09%) case and pyometra in 2 (6.6%) cases.

4.2.18 Correlation of activated lymphocytes with prognosis in different pathological conditions of dogs

Activated lymphocytes were observed in a total of 116 cases in different pathological conditions of dogs and these were correlated with the 3 categories of prognosis. The correlation of activated lymphocytes with prognosis in different pathological conditions of dogs is shown in Table 45 and Figure 35.

Table 45: Correlation of activated lymphocytes with prognosis in different pathological conditions

Pathological conditions	Good prognosis	Fair prognosis	Poor prognosis
Hepatic dysfunction	07 (41.1)	01 (5.8)	09 (52.9)
Renal dysfunction	07 (41.1)	04 (23.5)	06 (35.2)
Hepato-renal dysfunction	01 (12.5)	02 (25)	05 (62.5)
Pyometra	09 (81.8)	02 (18.1)	-
Respiratory tract affections	09 (81.8)	-	02 (18.1)
GIT disorders	06 (60)	03 (30)	01 (25)
UTI	03 (75)	-	01 (25)
Ascites	-	01 (50)	01 (50)
Cardiac disorders	01 (50)	01 (50)	-
Skin affections	03 (100)	-	-
Neoplasms	04 (44.4)	-	05 (55.5)
Parasitic infections	10 (83.3)	01 (8.3)	01 (8.3)
Viral diseases	07 (70)	01 (10)	02 (20)
Total	67 (57.7)	16 (13.7)	33 (28.4)

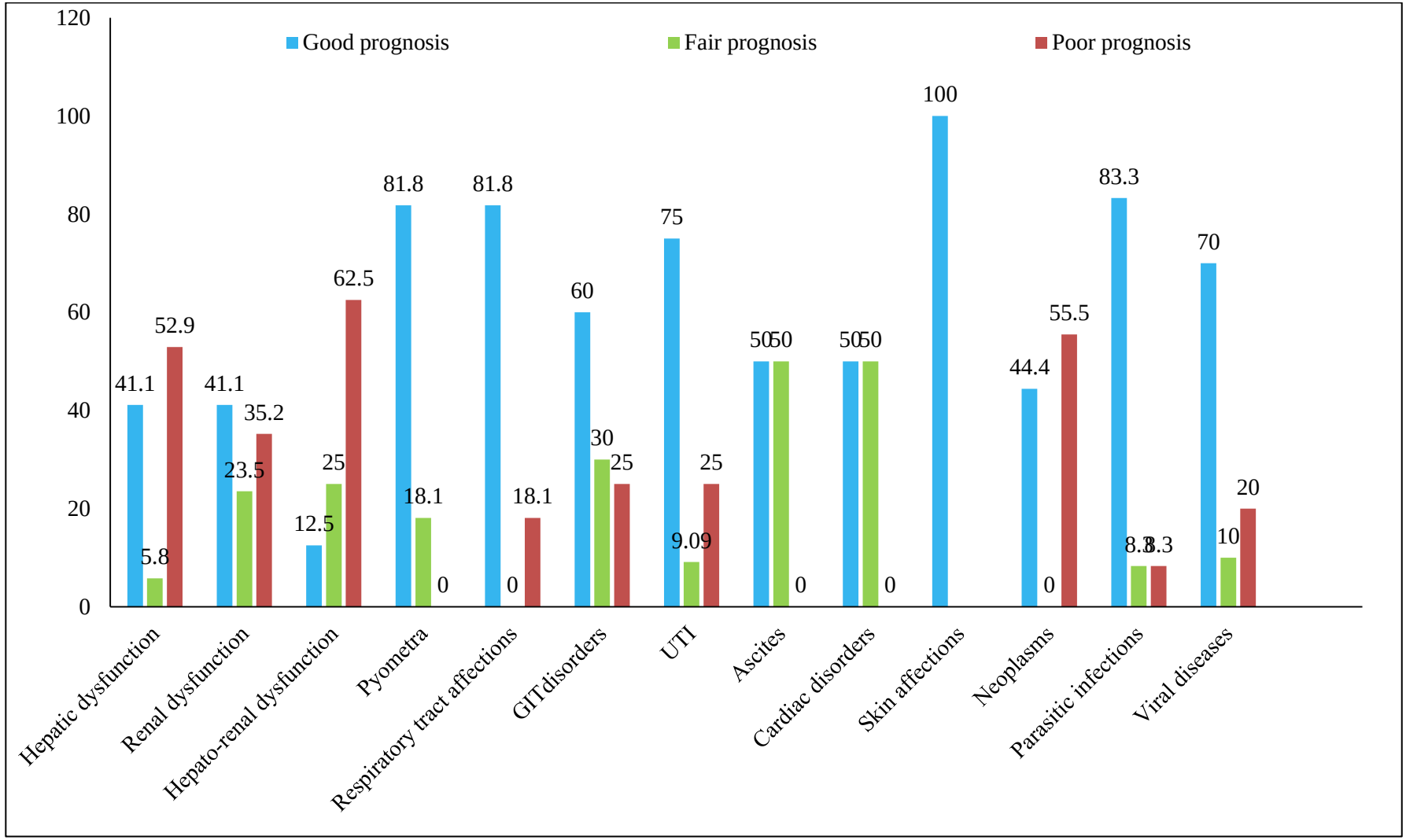


Fig. 35: Correlation of activated lymphocytes with prognosis in different pathological conditions

Among 116 cases in which activated lymphocytes were present 67 cases (57.7%) had a good prognosis, 33 cases (28.4%) had poor prognosis while 16 cases (13.7%) had fair prognosis.

Among the 67 cases of good prognosis that had activated lymphocytes in different pathological conditions maximum cases of skin affections 3 (100%) showed good prognosis followed by parasitic infections with 10 cases (83.3%), pyometra and respiratory tract affections with 9 cases (81.8%), UTI with 3 cases (75%), viral diseases with 7 cases (70%), GIT disorders with 6 cases (60%), cardiac disorders with 2 cases (50%), neoplasms with 9 cases (44.4%), hepatic dysfunction and renal dysfunction with 17 cases (41.1%) and hepato-renal dysfunction with a single case (12.5%).

Among the cases that showed poor prognosis with activated lymphocytes maximum cases were present in hepato-renal dysfunction with 5 cases (62.5%), followed by neoplasms with 5 cases (55.5%), hepatic dysfunction with 9 cases (52.9%), ascites with 1 case (50%), renal dysfunction with 6 cases (35.2%), UTI with 1 case (25%), viral disease with 2 cases (20%), respiratory tract affections with 2 cases (18.1%), GIT disorders with 1 case (10%), and parasitic disease with 1 case (8.3%).

Among the cases that showed fair prognosis maximum cases of ascites and cardiac disorders with 1 case (50%) followed by GIT disorders in 3 cases (30%), hepato-renal dysfunction with 2 cases (25%), renal dysfunction with 4 cases (23.5%), pyometra with 2 cases (18.1%), viral disease with 1 case (10%), parasitic disease with 1 case (8.3%) and hepatic dysfunction with 1 case (5.8%).

4.2.19 Correlation of granular lymphocytes with prognosis in different pathological conditions of dogs

Granular lymphocytes were observed in 132 cases in different pathological conditions of dogs and these were again correlated with 3 categories of prognosis and is depicted in Table 46 and Figure 36.

Among 132 cases, 68 (51.5%) showed good prognosis, 41 cases (31.01%) showed poor prognosis and 23 cases (17.4%) showed fair prognosis.

Among the cases of good prognosis maximum cases were 8 (88.8%) of GIT disorders followed by viral diseases with 4 cases (80%), respiratory tract affections with 9 cases (75%), skin affections with 3 cases (75%), parasitic infections with 10 cases (71.4%), pyometra with 12 cases (70.5%), UTI with 4 cases (66.6%), cardiac disorders with 1 case (50%), renal dysfunction with 8 cases (42.1%), hepatic dysfunction with 6

cases (30%), hepato-renal dysfunction with 2 cases (15.3%) and neoplasms with a single case (14.2%).

Among the cases of poor prognosis where granular lymphocytes were present maximum cases were of neoplasms with 6 cases (85.7%) followed by hepato-renal dysfunction with 8 cases (61.5%), hepatic dysfunction with 10 cases (50%), ascites with 2 cases (50%), renal dysfunction with 6 cases (31.5%), respiratory tract affections with 3 cases (25%), skin affections with a single case (25%), viral diseases with 1 case (20%), UTI with 1 case (16.6%), pyometra with 2 cases (11.7%) and parasitic infections with 1 case (7.1%).

Among the cases of fair prognosis where granular lymphocytes were present maximum cases recorded were that of ascites and cardiac disorders with 2 and 1 case respectively (50%) followed by renal dysfunction with 5 cases (26.3%), hepato-renal dysfunction with 3 cases (23.07%), parasitic infections with 3 cases (21.4%), hepatic dysfunction with 4 cases (20%), pyometra with 3 cases (17.6%), UTI with 1 case (16.6%) and GIT disorders with a single case (11.1%).

Table 46: Correlation of granular lymphocytes with prognosis in different pathological conditions

Pathological conditions	Good prognosis	Fair prognosis	Poor prognosis
Hepatic dysfunction	06 (30)	04 (20)	10 (50.1)
Renal dysfunction	08 (42.1)	05 (26.3)	06 (31.5)
Hepato-renal dysfunction	02 (15.3)	03 (23.07)	08 (61.5)
Pyometra	12 (70.5)	03 (17.6)	02 (11.1)
Respiratory tract affections	09 (75)	-	03 (25)
GIT disorders	08 (88.8)	01 (11.1)	-
UTI	04 (66.6)	01 (16.6)	01 (16.6)
Ascites	-	02 (50)	02 (50)
Cardiac disorders	01 (50)	01 (50)	-
Skin affections	03 (75)	-	01 (25)
Neoplasms	01 (14.2)	-	06 (85.7)
Parasitic infections	10 (71.4)	03 (21.4)	01 (7.1)
Viral diseases	04 (80)	-	01 (20)
Total	68 (51.5)	23 (17.4)	41 (31.01)

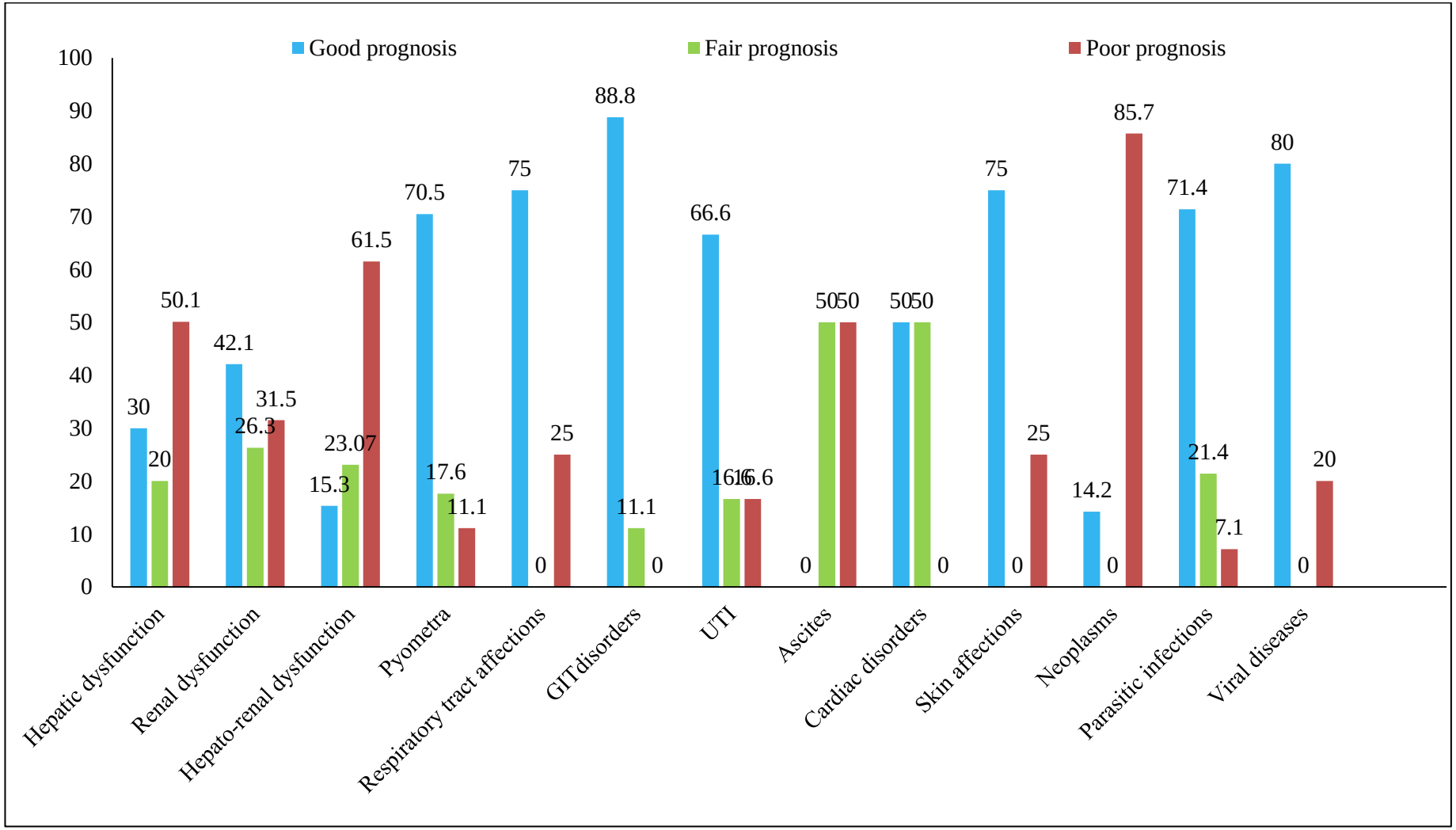


Fig. 36: Correlation of granular lymphocytes with prognosis in different pathological conditions

4.2.20 Correlation of atypical lymphocytes with prognosis in different pathological conditions of dogs

Atypical lymphocytes were again correlated with prognosis (Table 47 and Fig. 37). Maximum cases of poor prognosis with 10 cases (58.8%) followed by good prognosis with 5 cases (29.4%), and 2 cases (11.7%) of fair prognosis were recorded.

Among the cases of poor prognosis maximum cases were of renal dysfunction with a single case (100%), followed by neoplasms with 6 cases (75%), parasitic infections with 2 cases (66.6%).

Table 47: Correlation of atypical lymphocytes with prognosis in different pathological conditions of dogs

Pathological conditions	Good prognosis	Fair prognosis	Poor prognosis
Hepatic dysfunction	-	-	-
Renal dysfunction	-	-	01 (100)
Hepato-renal dysfunction	-	-	-
Pyometra	02 (66.6)	01 (33.3)	-
Respiratory tract affections	-	-	-
GIT disorders	01 (100)	-	-
UTI	-	-	-
Ascites	-	-	01 (100)
Cardiac disorders	-	-	-
Skin affections	-	-	-
Neoplasms	01 (12.5)	01 (12.5)	06 (75)
Parasitic infections	01 (33.3)	-	02 (66.6)
Viral diseases	-	-	-
Total	05 (29.4)	02 (11.7)	10 (58.8)

Among the cases of good prognosis GIT disorders with 1 case (100%) followed by pyometra with 2 cases (66.6%), parasitic infections with 1 case (33.3%) and neoplasms with 1 case (12.5%) were observed.

Among cases of fair prognosis maximum cases of pyometra with 1 case (33.3%) followed by neoplasms again with 1 case (12.5%) were observed.

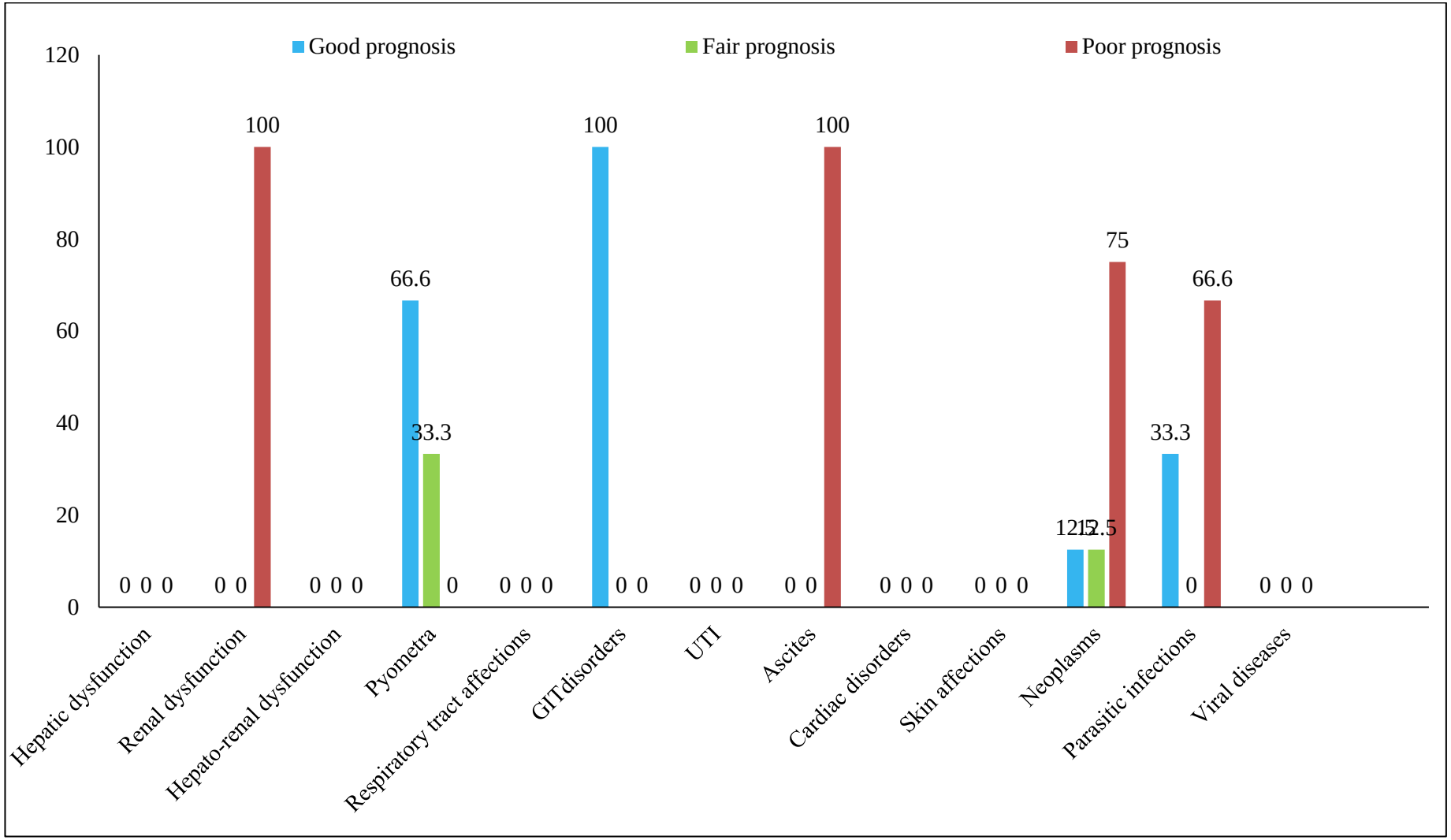


Fig. 37: Correlation of atypical lymphocytes with prognosis in different pathological conditions

4.2.21 Significance of leukocyte findings with prognosis

It was found that there were no significant differences between the prognosis group with respect to left shift (p >0.05). These findings were contrary to the findings of Nivy *et al* 2013 who reported that the presence of left shift was significantly associated with mortality. Toxic changes in neutrophils were marginally significant in the poor prognosis group (p value= 0.0661). Case fatality rate was significantly higher in dogs with neutrophil toxicity compared to controls (Aroch *et al* 2005). Activated lymphocytes were significantly associated with good and poor prognosis (p <0.01). Muris *et al* (2004) demonstrated that the percentage of activated cytotoxic T lymphocytes (CTLs) is a strong and independent prognostic marker in patients with primary nodal diffuse large B cell lymphomas. The presence of high percentages of activated cytotoxic T- lymphocytes in lymphoma biopsies of patients with Hodgkin's lymphoma and anaplastic large cell lymphoma is strongly associated with a poor prognosis. A high percentage of activated CTLs present in biopsy material of Hodgkin's disease patients is a strong indicator for an unfavorable clinical outcome (Oudejans *et al* 1997). Granular lymphocytes were found to be significantly associated with poor prognosis (p <0.05) and this finding was in accordance with Pandolfi *et al* (1990) as they reported that, high (>7000/mm^3) absolute peripheral granular lymphocyte count were significantly associated with increased mortality. Atypical lymphocytes were found to be marginally significant in the poor prognosis group (p value= 0.0661). atypical lymphocyte morphology is an important prognostic factor in stage A chronic lymphocytic leukemia and one which incurs no additional investigation or cost (Oscier *et al* 1997). The values for different leukocytic disorders with respect to prognosis are depicted in Table 48.

In addition to these alterations N:L ratio was also correlated with prognosis but it was not found to be associated with the prognosis in the present study (P = .085). The N:L ratio was not found to be a significant prognostic variable in this population of dogs was in agreement with Mutz *et al* (2013). The rationale for the N:L ratio is to compare the inflammatory response (i.e. neutrophils) produced by cancer to the host immunity. The association of poor clinical outcomes with a high N:L ratio may be related to the production of tumour-associated immunosuppressive inflammatory mediators (Porrata *et al* 2010).

Table 48: Correlation of leukocyte findings with prognosis

Leukocyte findings	Good prognosis (*P* value)	Fair prognosis (*P* value)	Poor prognosis (*P* value)
Left shift	0.4878	0.9754	0.4613
Toxic change	0.2686	0.3237	0.0661[a]
Activated lymphocytes	0.0090**	0.9814	0.0074**
Granular lymphocytes	0.3222	0.1103	0.0310*
Atypical lymphocytes	0.1082	.07975	0.0661[a]

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).
[a]Marginally significant differences between groups

4.2.22 Serum biochemical changes in different pathological conditions of dogs

Serum biochemical analysis of different pathological conditions was done wherever it was possible to do so and the mean values for the parameters like total bilirubin, serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), alkaline phosphatase (ALKP), total protein, albumin, gamma-glutamyl transferase (GGT), blood urea nitrogen (BUN) and creatinine are summarized in Table 49.

4.2.22.1 Hepatic dysfunction

Serum biochemical analysis in different cases (56) of hepatic dysfunction revealed elevation in total bilirubin, SGOT, SGPT, ALKP and GGT along with reduced total protein and albumin in comparison to apparently healthy dogs and reference values. These findings were in accordance with Tantary *et al* 2014. Increased serum bilirubin could be due to the damage of hepatocytes and decreased elimination. Bilirubinuria observed in few cases was suggestive of underlying hepatic disease. Elevations of plasma transaminases such as SGPT and SGOT were indicative of altered hepatocellular membrane permeability, hepatocellular necrosis and inflammation with degree proportional to number of injured hepatocytes (Kramer and Hoffman 1997). Serum SGOT and SGPT measurements were highly useful in detecting hepatocellular injury and monitoring clinical progress (Tennant and Center 2008 and Sarvanan *et al* 2014). Marked increase in activities of ALKP and GGT has been reported in conditions causing cholestasis, cholangiohepatitis, biliary cirrhosis,

biliary obstruction and cholecystitis of cholelithiasis (Tantary *et al* 2014). Liver being the main site of synthesis and degradation of most of the proteins, any hepatic disorder (chronic hepatitis and cirrhosis) are responsible for decrease in albumin concentration. Total plasma protein might also have decreased due to marked decline in the diet intake, malabsorption and ongoing protein losing enteropathies like gastroenteritis, gastrointestinal ulcerations and chronic gastritis (Tantary *et al* 2014).

4.2.22.2 Renal dysfunction

Serum biochemical analysis in different cases (42) of renal dysfunction revealed elevation in BUN, creatinine, SGOT, ALKP and GGT in comparison to apparently healthy dogs and reference values. Increase in mean value of BUN and creatinine is in agreement with findings of various authors; Kumar (2013), Ross *et al* (2007), Lees *et al* (2005) and Devipriya (2018). Suggestive reason of increased urea in renal failure may perhaps impaired ability of kidneys to excrete proteinaceous catabolites as a result of impairment of renal function. Marked reduction in glomerular filtration rate (GFR) which enhance tubular absorption of urea as reported by Osborne *et al* (1972) also and endogenous sources like rapid catabolism of body tissue or gastrointestinal bleeding causes abnormal elevation of BUN levels as reported by Srivastava *et al* (2011) also. Increased ALKP and GGT was observed in dogs suffering from chronic renal failure (CRF) by Sharma *et al* 2015 which was in agreement with the present study. Pradhan and Roy 2012 reported increased GGT values in CRF is might be due to its more release from the damaged renal tubular cells. Elevated serum ALKP might be due to secondary renal hyperparathyroidism as reported by Center (1996).

4.2.22.3 Hepato-renal dysfunction

Serum biochemical analysis in different cases (33) of hepato-renal dysfunction revealed elevated total bilirubin, SGOT, SGPT, ALKP, GGT, BUN and creatinine in comparison to apparently healthy dogs and reference values. Renal dysfunction has been reported as a frequent complication in patients with end-stage liver disease (Sampaio *et al* 2014). The increased in BUN and creatinine values could be attributed to impaired kidneys function associated with liver cirrhosis due to the decreased capacity of the liver to detoxify the harmful products (Elhiblu *et al* 2015).

Table 49: Mean serum biochemical changes in different pathological conditions of dogs

Pathological Conditions	No. of cases	No. of cases serum chemistry done	Total Bilirubin (mg/dL)	SGOT/AST (U/L)	SGPT/ALT (U/L)	ALKP (U/L)	Total Protein (g/dL)	Albumin (g/dL)	GGT (U/L)	BUN (mg/dL)	Creatinine (mg/dL)
Hepatic dysfunction	57	56	2.1±0.7	139.3±35.7	199.7±26.8	652.8±72.5	4.8±0.1	1.8±0.07	24.5±4.9	14.8±1.7	1.2±0.2
Renal dysfunction	42	42	0.7±0.2	76.2±18.7	44.1±3.1	219.6±42.2	5.4±0.1	2.03±0.07	6.8±1.3	86.8±7.3	7.04±0.8
Hepato-renal dysfunction	33	33	2.55±0.6	260.1±56.7	255.2±43.8	617.3±107.9	5.3±0.2	2.2±0.1	26.2±8.2	101.5±9.1	7.9±1.04
Pyometra	33	28	0.2±0.04	66.8±9.6	45.9±10.1	321.8±86.8	6.1±0.4	2.08±0.1	13.8±7.4	23.04±5.07	1.5±0.2
Respiratory tract affections	20	11	0.7±0.04	45.3±16.1	46.7±11.5	173.1±51.8	5.1±0.3	2.2±0.2	-	17.6±4.4	1.2±0.3
GIT disorders	17	04	0.3±0.1	118±0	30±14.0	238±0	5.8±0	1.5±0	-	20±9.4	1.25±0.11
UTI	14	09	0.25±0.09	64.6±29.2	45.4±10.4	216.6±52.0	6.9±0.7	2.7±0.3	9.4±4.4	67.1±21.3	2.1±0.7
Ascites	09	08	0.2±0.07	57.7±6.2	46.2±3.0	86.8±10.6	4.3±0.3	1.8±0.2	5.5±0.2	27.4±9.6	1.3±0.3
Cardiac disorders	05	05	0.1±0	15±0	59.2±12.9	141.8±28.9	3.95±0.3	1.8±0.2	-	17.6±6.3	1.08±0.2
Skin affections	4	03	0.2±0	78±0	48.3±7.1	291±0	5±0	1.6±0	-	6±0	0.8±0.1
Neoplasms	25	20	0.3±0.1	51.06±7.39	65.21±8.41	265.11±82.05	5.57±0.26	2.76±0.33	7.16±1.35	21.15±3.87	1.31±0.23
Parasitic infections	24	09	0.3±0.11	51±7.5	73.25±27.3	176.8±48.04	6.7±1.07	2.4±0.4	6.6±1.6	21.25±6.7	1.2±0.26
Viral diseases	17	10	0.3±0.06	66.71±13.37	68.3±15.88	211.5±47.06	5.31±0.56	2.8±0.22	9.66±3.75	15.85±5.59	0.82±0.09
Apparently healthy dogs	10	03	0.16±0.03	65±0	49.3±6.6	62.6±15.2	7.4±0.1	2.9±0.08	-	12.6±3.2	1.1±0.2

4.2.22.4 Pyometra

Serum biochemical analysis in different cases (28) of pyometra revealed elevated SGOT, ALKP, and GGT in comparison to apparently healthy dogs and reference values. The increase in SGOT and ALKP was in accordance with many authors (Shah *et al* 2016, Ravishankar *et al* 2004, Dabhi *et al* 2007, Sahoo *et al* 2012) while the rise in mean ALKP concentration in affected animals than the apparently healthy dogs was in accordance with Samantha *et al* 2018. This indicated that toxemia originating from pyometra may inhibit synthesis of liver enzymes and damage the hepatic membrane (Bigliardi *et al* 2004). Hepatocellular damage caused by septicemia and hepatic circulation and cellular hypoxia in dehydrated bitches and intrahepatic cholestasis could be attributed as the causes for rise of AST and ALKP (Ravishankar *et al* 2004).

4.2.22.5 Respiratory affections

Serum biochemical analysis in different cases (11) of respiratory affections revealed elevated ALKP and reduced total protein and albumin in comparison to apparently healthy dogs and reference values. Similar finding of reduced serum proteins was also reported by Mondal *et al* (2004) in goats with mycoplasmal pneumonia which might be due to utilization of serum proteins by mycoplasma organisms for their proliferation.

4.2.22.6 Gastrointestinal (GIT) disorders

Serum biochemical analysis in different cases (04) of GIT disorders revealed elevated SGOT, ALKP along with reduced albumin in comparison to apparently healthy dogs and reference values. These observations were in corroboration with the findings of Dharmadheeran *et al* 2003, Shah *et al* 2013 and Arora *et al* 2018. Decrease in albumin and increase SGOT in gastroenteritis infected dogs might be due to involvement of liver and severe protein losing enteropathy due to intestinal villi damage or intestinal haemorrhage (Grigonis *et al* 2002). Increase in ALKP might be due to hepatic hypoxia secondary to severe hypovolemia or the absorption of toxic substances due to loss of the gut barrier (Shah *et al* 2013).

4.2.22.7 Urinary tract infections (UTI)

Serum biochemical analysis in different cases (09) of UTI revealed elevated SGOT, ALKP, GGT, BUN and creatinine in comparison to apparently healthy dogs and reference values. Similar elevation of blood urea nitrogen (BUN) and creatinine in all the affected cases of urinary system disorders in comparison to control group was found by

Sarma and Kalita, 2019. These changes might have been occurred as a result of post renal uraemia due to obstruction of the excretory pathway from urethral calculi, cystic calculi, cystitis and tumour in urinary bladder. Reduction of glomerular filtration rate due to loss of renal function from renal cyst might be the cause of increase in BUN and creatinine. Vijaykumar *et al* (1999) observed mild elevation of blood urea nitrogen and creatinine in cystic calculi of a dog. Bhojne *et al* (2001) observed significant elevation of blood urea nitrogen in a dog with renal calculi. Erythropoietin deficiency might be the main cause of anaemia and reduction of glomerular filtration rate (GFR) due to loss of renal function might be the cause of increase in BUN and creatinine (Polzin *et al* 2000). Verma *et al* (2006) also observed similar findings in dogs with cystitis and cystic calculi. Rajathi *et al* (2006) observed elevated blood urea nitrogen in dogs with urolithiasis. Elevation of alkaline phosphatase in all the cases of urinary system disorders was also reported by Sarma and Kalita (2019) except in the cases of renal cyst and tumour in urinary bladder. The elevation of alkaline phosphatase might be due to tissue damage in as well as mineralization during cystic calculi and urethral calculi. Kaneko *et al* (2008) reported that there was elevation of alkaline phosphatase in serum during tissue damage and mineralization. Caswell (2011) reported that there was elevated alkaline phosphatase in the animals with tumour in the wall of urinary bladder.

4.2.22.8 Ascites

Serum biochemical analysis in different cases (08) of ascites revealed elevated SGOT, GGT along with reduced total protein and albumin in comparison to apparently healthy dogs and reference values. Solter *et al* (1994) stated that the high serum ALKP is a sensitive marker for cholestasis in most of the mammalian species including dogs. Decrease in total protein and albumin level noticed in ascitic dogs, could be due to the primary role of liver in the synthesis of major plasma protein as well as site of degradation and synthesis of many other proteins that is influenced by liver diseases in many ways (Webster 2005). Ascites leads to increased albumin distribution and lowers the blood albumin concentration, which decreases the plasma oncotic pressure and aggravates the ascites (Richter 2003, Tennant and Center 2008, Saravanan *et al* 2014).

4.2.22.9 Cardiac disorders

Serum biochemical analysis in different cases (05) of cardiac disorders revealed elevated ALKP along with reduced total protein and albumin in comparison to apparently healthy dogs and reference values. Jan *et al* (2018) reported serum creatinine,

SGPT and SGOT values to be significantly (P<0.01) higher in dogs with cardiac failure compared to dogs with normal cardiac function while values of ALKP was higher in cardiac failure group but did not varied significantly among the two groups.

4.2.22.10 Skin affections

Serum biochemical analysis in different cases (03) of skin affections revealed elevated SGOT, ALKP along with reduced albumin in comparison to apparently healthy dogs and reference values. Reduced albumin levels were also reported by Reddy *et al* (2016) and Sakina *et al* (2012) which might be due to loss of albumin through injured skin in cases of pyoderma. Elevated SGOT and ALKP along with ALT were reported by Kumar *et al* (2018), Dimri *et al* (2006), Arora *et al* (2013) and Abdel Haleem *et al* (2015). The elevation of these parameters could be due to the hepatic damage caused by toxic elements from mites (Kaneko *et al* 1997).

4.2.22.11 Neoplasms

Serum biochemical analysis in different cases (20) of neoplasms revealed elevated SGOT, SGPT, ALKP and GGT in comparison to apparently healthy dogs and reference values. SGPT, SGOT and ALKP levels were in agreement with the findings of Behera *et al* (2012), Girmabirhan and Mersha (2015) and Kumar *et al* (2017). While Albanese *et al* (2006) reported normal levels of total protein, BUN and serum creatinine in TVT dogs. serum biochemical parameters in mammary tumour cases did not show any deviations from the reference range (Pankaj *et al* 2014 and Kumar *et al* 2018). Blood serum biochemistry revealed markedly elevated ALKP, SGOT, GGT and BUN activity in dogs with malignant lymphoma (Kayar *et al* 2018).

4.2.22.12 Parasitic infections

Serum biochemical analysis in different cases (09) of parasitic infections revealed elevated SGOT, SGPT, ALKP and GGT in comparison to apparently healthy dogs and reference values. The levels of SGPT, SGOT, ALKP and bilirubin were significantly higher in the infected dogs. These changes may be due to the haemolysis and cellular damage to the hepatic cells. These findings were in accordance with Shah *et al* (2011) and Wadhwa *et al* (2011). Increase in level of ALKP was may be due to damage or abnormal function of biliary system (Crnogaj *et al* 2010). Increased activities of SGOT and SGPT were might be due to escape of these enzymes from the damaged hepatic parenchymal cells with necrosis or altered membrane permeability indicating hepatic dysfunction (Gupta *et al* 2002 and Kumar and Kumar 2018).

4.2.22.13 Viral diseases

Serum biochemical analysis in different cases (10) of viral diseases revealed elevated SGOT, SGPT, ALKP and GGT. Significant increase of SGOT and ALKP was also reported by Thakur and Thakur (2017), Dharamadheeran *et al* (2003) and Shah *et al* (2013). Amravathi *et al* (2016) and Apple *et al* (1994) reported elevated SGPT level whereas Buragohain *et al* (2017) reported SGPT level within normal range with increase in ALKP and SGOT. However increased level of SGPT was reported by worker (Apple *et al* 1994) and opined it is non-specific, they also reported that rise of SGOT level in blood were consistent finding. Increased SGOT might be due to involvement of liver (Grigonis *et al* 2002). Increase in ALKP might be due to hepatic hypoxia secondary to severe hypovolemia or the absorption of toxic substances due to loss of the gut barrier (Shah *et al* 2013).

4.2.22.14 Apparently healthy dogs

Serum biochemical analysis in different cases (03) of apparently healthy dogs revealed elevated SGOT only.

4.2.23 Correlation of leukocyte findings with serum biochemicals

Among the biochemicals, it was found that the dogs with left shift had significantly (p <0.05) higher total bilirubin, and significantly lower average levels of total protein, albumin, BUN, and creatinine when compared to those in which left shift was absent (Table 50). The higher frequency of hyperglobulinemia concurrently with hypoalbuminemia in the neutrophilia group most likely was due to a higher frequency of inflammatory conditions in this group. Inflammation is characterized by an acute phase response, where serum positive acute phase proteins (i.e., α- and β-globulins) and immunoglobulins (mostly γ-globulins) concentrations increase, while the hepatic production of albumin (a negative acute phase protein) is decreased (Nivy *et al* 2013).

Significantly (p <0.01) lower mean levels of SGOT were reported in dogs where activated lymphocytes and granular lymphocytes (p <0.05) were present in comparison to the group where these changes were absent.

Significantly (p <0.01) lower average levels of total bilirubin, SGOT, SGPT, and GGT were found in the group where atypical lymphocytes were present compared to those where atypical lymphocytes were absent.

Table 50: Correlation of leukocyte findings with serum biochemicals

Biochemical parameter	No. of cases change Absent	No. of cases change present	Mean of cases change absent	Mean of cases change present	Mean Difference	P value
Left shift						
Total Bilirubin	36	108	0.5806 ± 0.1322	1.5856 ± 0.3357	-1.0051	0.0061**
Total Protein	52	133	5.6981 ± 0.1660	5.2293 ± 0.1222	0.4688	0.0355*
Albumin	48	128	2.3896 ± 0.0960	2.0977 ± 0.0654	0.2919	0.0177*
BUN	56	142	66.8536 ± 8.3094	38.9535 ± 3.3503	27.9001	0.0026**
Creatinine	61	164	6.1721 ± 0.8511	2.2860 ± 0.2154	3.8861	<.0001**
Activated lymphocytes						
SGOT	98	54	135.5 ± 20.7318	71.9667 ± 7.8416	63.5333	0.0049**
Granular lymphocytes						
SGOT	91	61	133.6 ± 21.4697	82.0197 ± 12.0309	51.6287	0.0378*
Atypical lymphocytes						
Total bilirubin	135	9	1.4085 ± 0.2721	0.2222 ± 0.0521	1.1863	<.0001**
SGOT	142	10	117.3 ± 14.7504	50.3000 ± 6.6717	67.0394	<.0001**
SGPT	213	13	123.1 ± 11.5695	35.6923 ± 5.5969	87.4119	<.0001**
GGT	125	27	15.8880 ± 2.2895	6.4286 ± 1.4286	9.4594	0.0009**

*Significant difference between groups (P <0.05).
**Significant difference between groups (P <0.01).

4.2.24 Correlation of pathological conditions with ultrasound findings

Ultrasonography (USG) was performed for the diagnosis of pathological conditions namely; hepatic dysfunction (16), renal dysfunction (17), hepato-renal dysfunction (11), ascites (5), UTI (11), pyometra (18) and neoplasms (9). The USG findings are summarized in Table 51.

USG in the cases of hepatic dysfunction revealed hyperechoic liver in 11 cases, free anechoic fluid in abdomen in 10 cases and enlarged liver in 2 cases. These findings were similar to Elhiblu *et al* 2015 as they found generalized hyperechoic hepatic parenchyma with multiple hyperechoic lesions and irregular margins associated with cirrhotic liver.

USG in the cases of renal dysfunction revealed renal cortex hyperechoic in 6 cases, loss of corticomedullary differentiation in 2 cases, nephrocalcinosis in 1 case and hyperechoic liver in 4cases.

USG in the cases of hepato-renal dysfunction revealed renal cortex hyperechoic in 8 cases, hyperechoic liver in 4cases, free anechoic fluid in abdomen in 3 cases and hydronephrosis in 1 case.

USG in the cases of ascites revealed lots of free anechoic fluid in abdomen in 5 cases, hyperechoic liver in 2 cases and enlarged liver in 1 case. This finding was similar to Elhiblu *et al* 2015 and Sarvanan *et al* 2014 who found lots of free anechoic fluids in the abdominal cavity (ascites).

USG in the cases of UTI revealed distended urinary bladder with lots of debris suggestive of cystitis in 11 cases, thickness of urinary bladder in 5 cases, hyperechoic renal cortex in 5 cases, concretions in the urinary bladder in 4 and hyperechoic liver in 1 case. Yogeshpriya *et al* 2018 also reported thickness of the urinary bladder was the most common feature along with hyperechoic particles in the urinary bladder, thickened kidney cortex, hyperechoic kidney with reduced corticomedullary distinction and hyperechoic renal pelvis and diffuse increase in echogenicity of prostatic parenchyma in the cases with UTI.

USG in the cases of pyometra revealed distended uterine loops with anechoic lumen (Fig. 38) in 18 cases. These findings were confirmed after ovariohysterectomy was done and enlarged uterine horns were revealed (Fig. 39). These findings were in harmony with Samantha *et al* 2018.

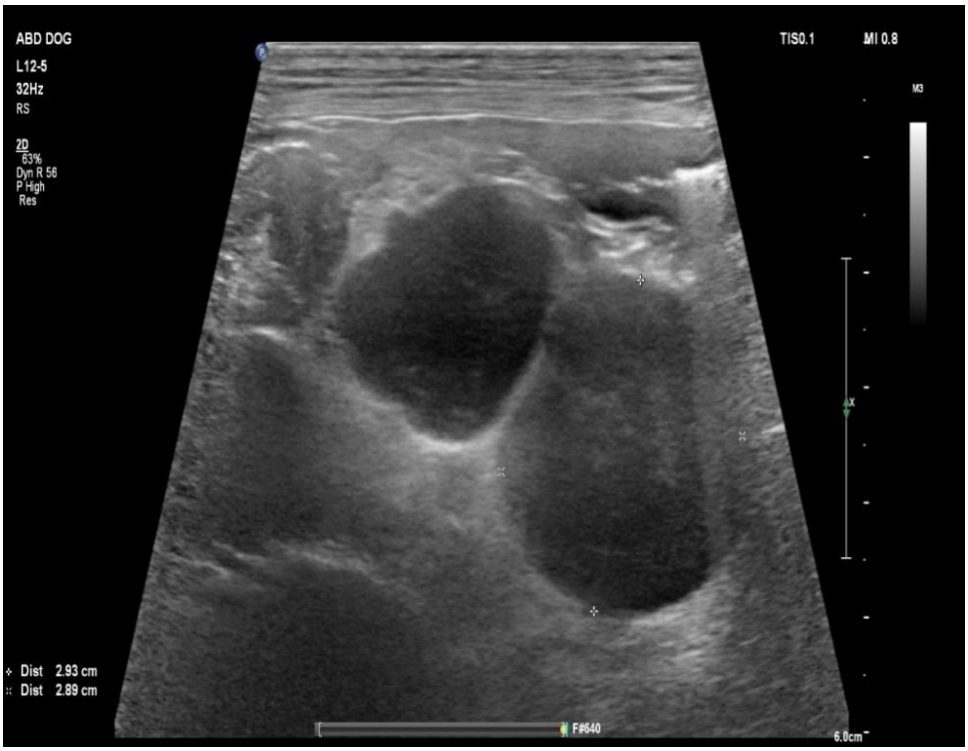


Fig. 38: Ultrasonograph showing hyperechoic areas indicative of enlarged uterine horn (Pyometra) in a dog

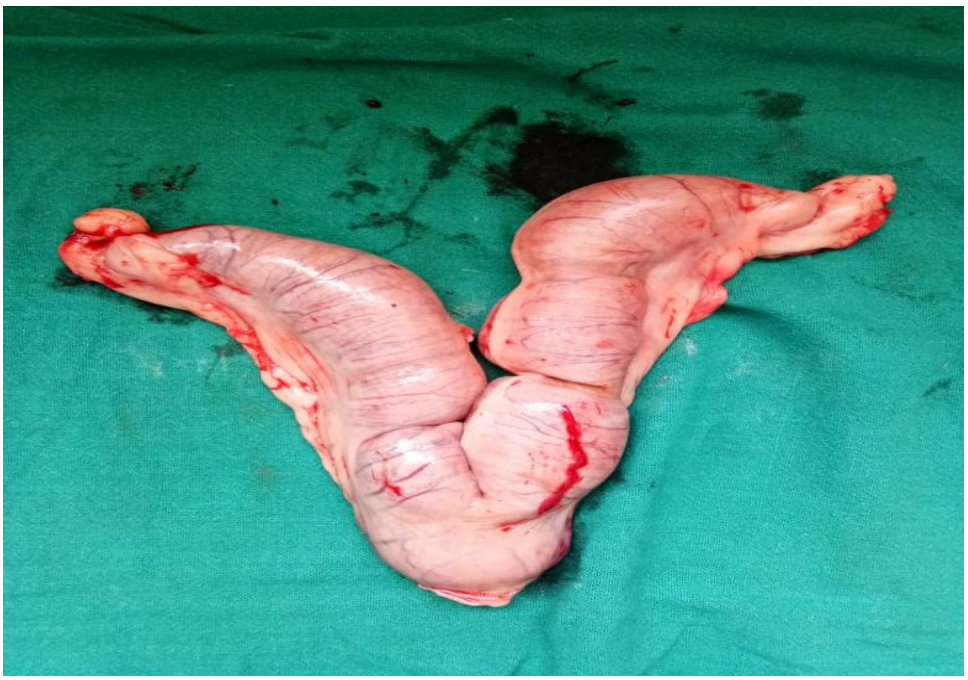


Fig. 39: Enlarged uterine horns in a dog with pyometra after ovariohysterectomy

Table 51: Correlation of pathological conditions with ultrasound findings

Pathological condition	No. of cases USG correlated	USG findings
Hepatic dysfunction	16	Hyperechoic liver (11) Free anechoic fluid in abdomen (10) Enlarged liver (2)
Renal dysfunction	17	Renal cortex hyperechoic (6) Loss of corticomedullary differentiation (2) Nephrocalcinosis (1) Hyperechoic liver (4)
Hepato-renal dysfunction	11	Renal cortex hyperechoic (8) Hyperechoic liver (4) Free anechoic fluid in abdomen (3) Hydronephrosis (1)
Ascites	5	Lots of anechoic free fluid in abdomen (5) Hyperechoic liver (2) Enlarged liver (1)
UTI	11	Urinary bladder distended with lots of debris suggestive of cystitis (11) Renal cortex hyperechoic (5) Concretions in the urinary bladder (4) Liver hyperechoic (1)
Pyometra	18	Uterine loops distended with anechoic lumen (18)
Lymphoma	6	No abnormality (2) Hyperechoic liver with presence of multiple nodules in liver (1 case), Enlarged spleen and hyperechoic liver (1 case), liver hyperechoic and enlarged, spleen severely congested and enlarged jejunal and inguinal lymphnodes (1 case), Enlarged spleen with heterogenous generalized honeycomb like pattern suggestive of spleenic tumor and markedly enlarged abdominal lymphnodes (1 case)
Lymphocytic leukemia	1	Heterogenous echotexture of spleen with a nodule protruding from its parenchyma
TVT	1	Two hypoechoic nodules measuring 1.45x1.7 cm cranial to the left kidney near stomach (may be lymph node)
Malignant histiocytosis	1	Liver revealed hyperechoic areas with rounded margins and large amount of echogenic fluid in abdomen suggestive of ascites.

Ultrasound examination was carried out in six canine patients out of 11 of which two were having no abnormality on ultrasonography. In four cases of lymphoma, hyperechoic liver with presence of multiple nodules in liver (1), enlarged spleen and hyperechoic liver (1), liver hyperechoic and enlarged, spleen severely congested and enlarged jejunal and inguinal lymphnodes (1), enlarged spleen with heterogenous generalized honeycomb like pattern suggestive of spleenic tumor and markedly enlarged abdominal lymphnodes (1) suggestive of lymphoma were observed.

Ultrasound examination was carried out in one case of lymphocytic leukemia in which heterogenous echotexture of spleen with a nodule protruding from its parenchyma was observed and this was suggestive of metastasis (Fig. 40). The ultrasound findings in cases of lymphoma and lymphocytic leukemia were in accordance with Kebede and Getaneh (2015) as they reported lymph nodes to be the most common organ involved in lymphoma, followed by liver and spleen. Presence of splenic tumor was in accordance with Morgenstern *et al* (1985) as they reported occurrence of splenic tumors with lymphoid tumors (Hodgkin's lymphoma histiocytic lymphoma and plasmacytoma).

Ultrasound examination was carried out in one case of TVT in which two hypoechoic nodules measuring 1.45x1.7 cm cranial to the left kidney near stomach (may be lymph node) were observed which were suggestive of metastasis (Fig. 41). The ultrasound finding was suggestive of metastasis and was in accordance with Ajadi *et al* (2010) as they reported evidence of metastasis as a sub-lumbar lymphadenopathy on abdominal radiograph.

Ultrasonography of liver revealed hyperechoic areas with rounded margins and large amount of echogenic fluid in abdomen suggestive of ascites. The ultrasound findings were in accordance with Ramirez *et al* (2002) as they reported liver to be the second most commonly affected organ after spleen with hepatomegaly, hyperechoic, hypoechoic and mixed echogenicity.

4.2.25 Correlation of pathological conditions with X-ray findings

Radiography of chest was used to correlate with the cardiac disorders and respiratory tract affections in the dogs. The findings are summarized in Table 52.

Radiography was performed in 4 cases of cardiac disorders in which we found severe atrium enlargement and pericardial effusion in 1 case, heart enlargement in 2 cases (Fig. 42) and rounding of heart in 1 case. Among 14 cases of respiratory tract

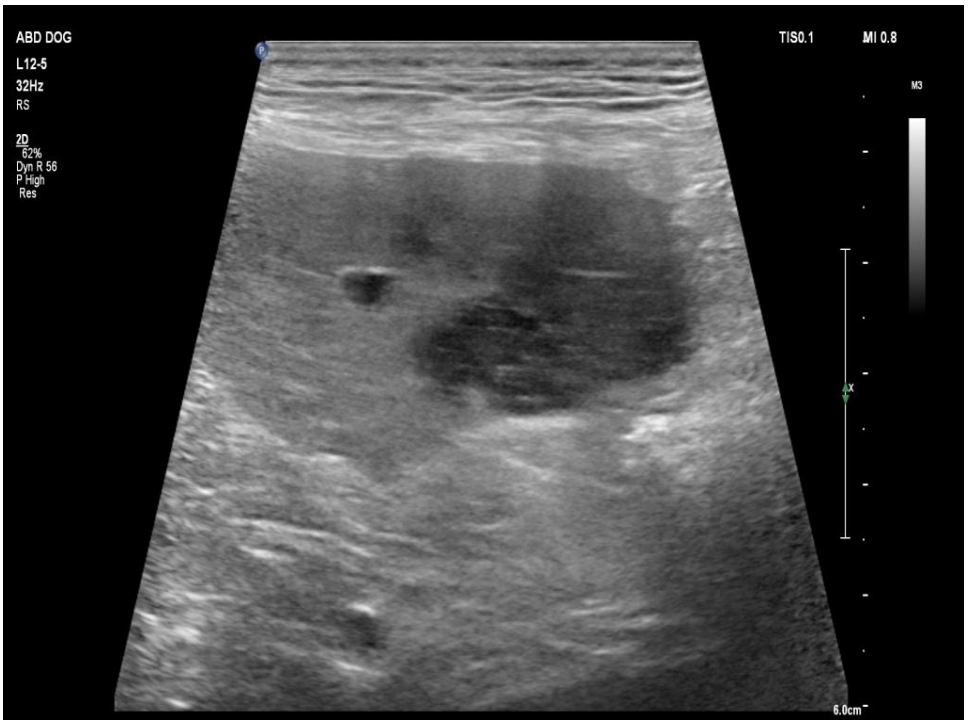


Fig. 40: Ultrasound of a case of lymphocytic leukemia showing heterogenous echotexture of spleen and nodule suggestive of metastasis to spleen

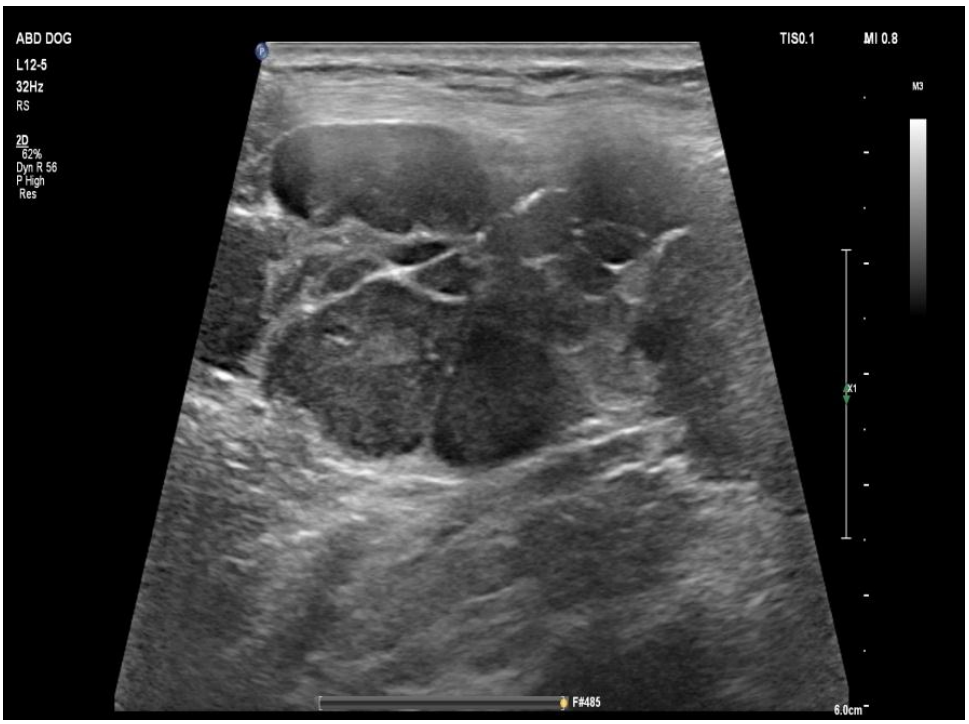


Fig. 41: Ultrasound of a case diagnosed with TVT showing presence of nodules cranial to the kidney indicative of metastasis

affections broncho-interstitial pattern in lungs was found in 11 cases which suggested pneumonia (Fig. 43) and in 3 cases pleural effusions were observed.

Table 52: Correlation of pathological conditions with X ray findings

Pathological condition	No. of cases X-ray correlated	X-ray findings
Cardiac disorders	4	Heart enlargement Rounding of heart
Respiratory tract affections	14	Broncho-interstitial pattern in lungs suggestive of pneumonia (11) Pleural effusions (3)

4.2.26 Correlation of pathological conditions with electrocardiography (ECG) and echocardiography findings

Electrocardiogram and echocardiography was correlated with a case of cardiac disorder which revealed peaked QRS complex suggestive of enlargement of left ventricle (Fig. 44). Echocardiography revealed enlargement of left atrium and left ventricle (Fig. 45).

4.2.27 Correlation of pathological conditions with cytology findings

Cytological examination was performed in the cases of neoplasms viz. lymphoma (11); lymphocytic leukaemia (1); transmissible venereal tumor (TVT) (3); melanoma (1) and malignant histiocytosis (1), in cases of ascites (5) and demodicosis (1) and the findings are summarized in Table 53.

Examination of fine needle aspiration biopsy (FNAB) from lymph nodes revealed large number of pleomorphic lymphocytes with prominent nucleoli and lymphoglandular bodies, suggestive of lymphoma (Fig. 46) in 10 cases of dogs. The cytology findings in lymphoma cases were in accordance with Kayar *et al* (2018). Although cytological examination of FNAB specimens has been generally accepted as a reliable technique for diagnosing malignant lymphoma in the dog, as the researchers stated, there have been no reports on the validity of FNAB technique in classifying lymphomas. For detection of the cells clonality and classification and more precise diagnosis immunophenotyping is needed (Kayar *et al* 2018).

Table 53: Correlation of pathological conditions with cytology findings

Pathological condition	No. of cases Cytological examination Done	Sample obtained	Cytology findings
Lymphoma	10	FNAB- Lymph node	Large number of pleomorphic lymphocytes with prominent nucleoli suggestive of lymphoma
GIT Lymphoma	1	FNAB- GIT	Numerous lymphoid cells showing pleomorphism indicating GIT Lymphoma
		FNAB- Liver	Significant number of pleomorphic lymphoid cells along with many neutrophils suggesting metastatic lymphoma with severe suppurative inflammation
		Peritoneal fluid	Significant number of pleomorphic lymphoid cells with numerous neutrophils indicating malignant ascites and marked secondary suppurative inflammation
		Final impression- GIT Lymphoma with mesenteric lymph node involvement, liver metastasis, early bone marrow involvement. End stage lymphoma	
Lymphocytic leukemia	1	FNAB-Lymph node and skin nodules	Large lymphoid cells infiltrating into the sites likely metastasis of leukemia into these sites.
Transvenereal tumor (TVT)	3	Impression smears	Discrete round cells with single prominent nucleoli and vacuoles in cytoplasm
Melanoma	1	Impression smears	Revealed pleomorphic cells with melanin pigment
Malignant histiocytosis	1	Ascitic fluid	Revealed round cells with eccentric nucleus and prominent cytoplasmic vacuolation
Ascites	5	Ascitic fluid	Basically transudate with few inflammatory cells
Demodicosis	1	Impression smear	*Demodex canis* with massive suppurative inflammation

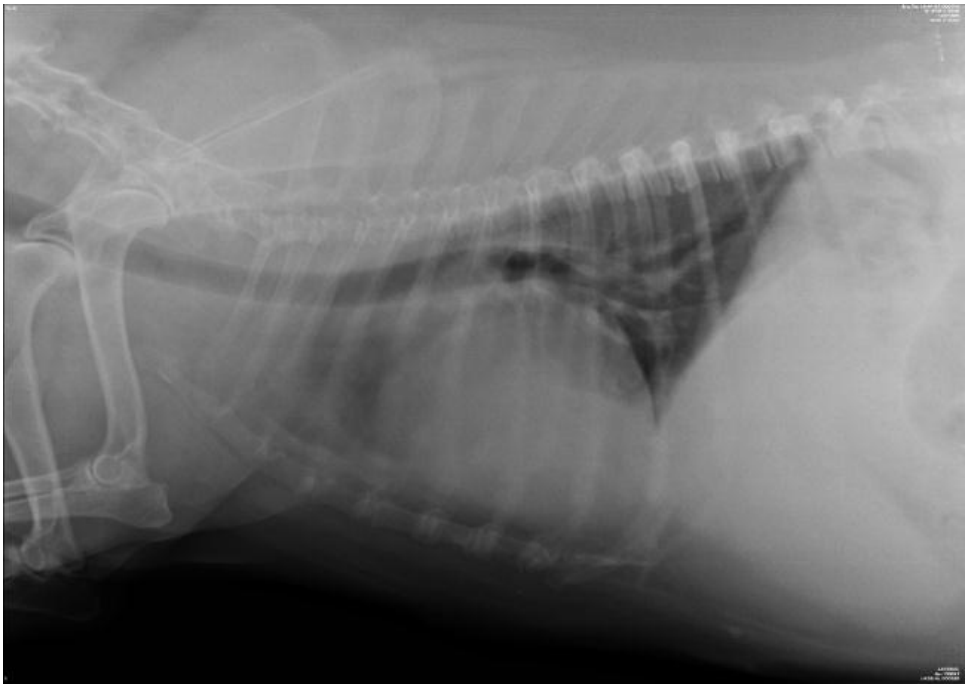


Fig. 42: Chest radiograph showing heart in 4th inter-costal space and lifted trachea suggestive of enlargement of heart

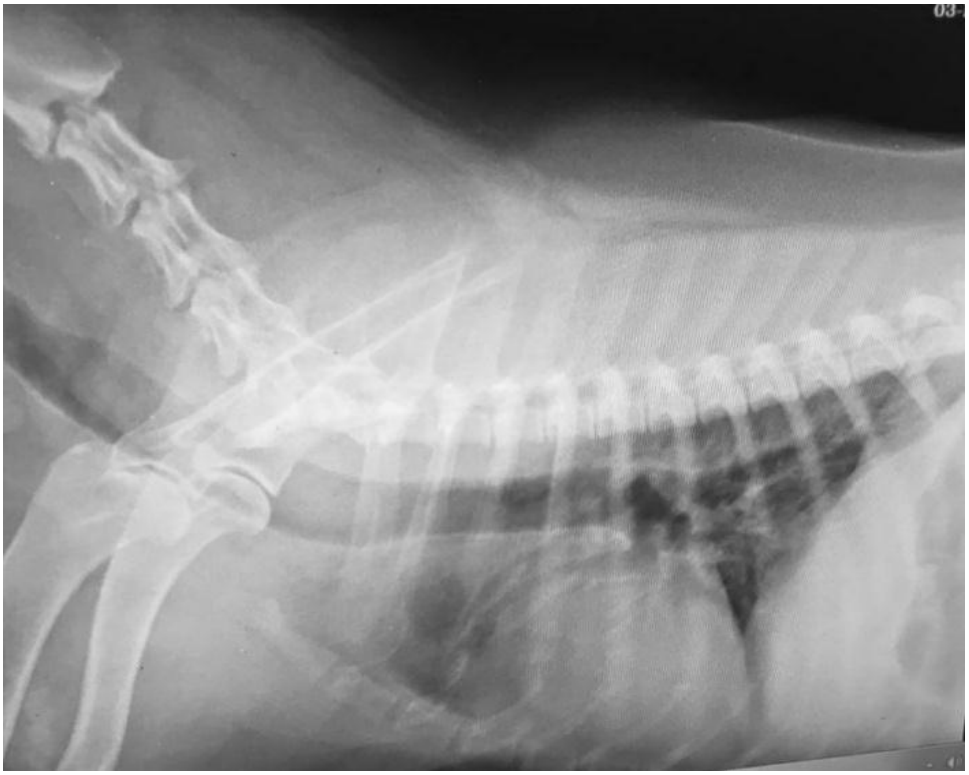


Fig. 43: Lateral radiograph of the chest revealing increased opacity in all the lung lobes indicative of pneumonia

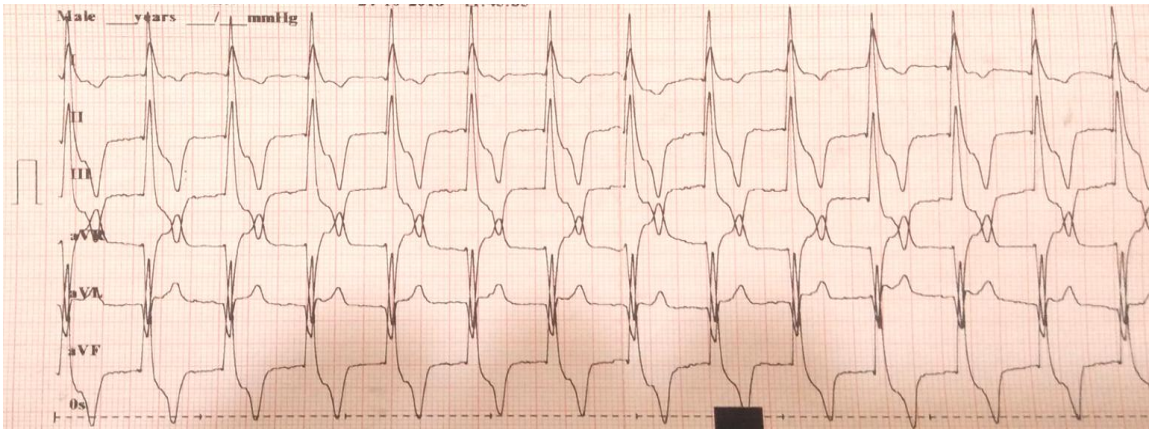


Fig. 44: Electrocardiograph (ecg) showing peaked QRS suggestive of left ventricle enlargement

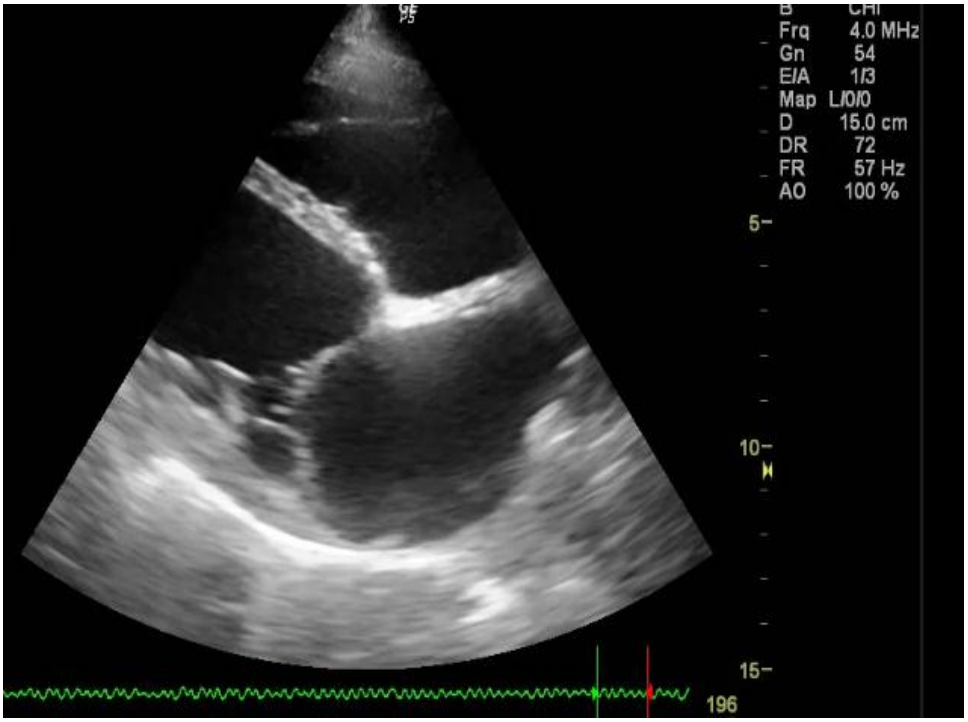


Fig. 45: Echocardiogram showing enlargement of left atrium and left ventricle

Special stains for lymphoma: May Grunwald Giemsa and Papanicolaou staining were also performed on cytological smears in lymphoma cases and of these Papanicolaou stain showed better nuclear details (Fig. 47 and 48) as compared to both Leishman and May Grunwald Giemsa stains (Fig. 49), whereas, the results of May Grunwald Giemsa stain were comparable with the Leishman stain. The results of Papanicolaou stain were in accordance with Bhattacharya *et al.* (2017) as they also reported better nuclear details with Papanicolaou stain in comparison to the other stains.

In one case, ultrasound guided FNAB from gastrointestinal tract (GIT), liver and peritoneal fluid was obtained. The cytological examination revealed numerous lymphoid cells showing pleomorphism suggesting GIT lymphoma (Fig. 50), along with pleomorphic lymphoid cells with numerous neutrophils in peritoneal fluid (Fig. 51) indicating malignant ascites and marked secondary suppurative inflammation, and neoplastic lymphoid cells and many neutrophils were also detected in the liver (Fig. 52 and 53), suggesting metastasis of lymphoma with severe suppurative inflammation. The case was diagnosed as end stage GIT Lymphoma with mesenteric lymph node involvement and liver metastasis.

FNAB was also obtained from lymph node and skin nodules in case of lymphocytic leukaemia which revealed large lymphoid cells infiltrating into the sites viz. lymph nodes (Fig. 54) and skin nodules (Fig. 55), suggesting metastasis of leukaemia into these sites. Clinical overlap of leukemia and lymphoma may arise if lymph nodes, liver or spleen become involved in leukemia, or if a lymphoma invades bone marrow and causes overspill of malignant cells into the blood (Leifer and Matus 1986).

Impression smears from the tumorous growth in the reproductive tract revealed presence of discrete round cells with single prominent nucleoli and vacuoles in cytoplasm (Fig. 56) suggesting transvenereal tumor (TVT) in 3 cases of dogs. The results of cytological examination of impression smears in cases of TVT were in accordance with Behera *et al* (2012).

Impression smear from a dog with oral growth (Fig. 57) revealed presence of pleomorphic cells with melanin pigment suggestive of melanoma (Fig. 58). The major criterion for diagnosis of melanoma has been melanin, reported in approximately 50-

80% of the cases. FNAB has proven to be a valuable tool for diagnosis of metastatic and primary melanoma (Kline and Kannan 1982).

Ascitic fluid was examined in 6 cases with history of abdominal enlargement of which 1 case revealed presence of round cells with eccentric nucleus and prominent cytoplasmic vacuolation (Fig. 59) which was suggestive of malignant histiocytosis. In other 5 cases, which had history of abdominal distension (Fig. 60) cytological examination of ascitic fluid revealed few inflammatory cells only along with few red blood cells (Fig. 61).

Impression smear obtained from skin lesions in 1 case (Fig. 62) revealed demodicosis with presence of massive suppurative inflammation at the local site (Fig. 63).

4.2.28 Correlation of pathological conditions with parasitological examination

Skin scrapings were examined in 9 cases which revealed *Demodex canis* (Fig. 64). Blood smear examination was performed for the diagnosis of hemoprotozoa which revealed *Ehrlichia canis* (Fig. 65) in 2 cases and *Hepatozoon canis* (Fig. 66) in 2 cases. Fecal sample examination was done in 2 cases which revealed hookworm infection (Fig.67). The findings of parasitological examination are summarized in Table 54.

Table 54: Correlation of pathological conditions with parasitological examination

Pathological condition	No. of cases parasitological examination done	Sample obtained	Findings
Demodicosis	9	Skin scrapings	*Demodex canis*
Ehrlichiosis	2	Blood	*Ehrlichia canis*
Hepatozoonosis	2	Blood	*Hepatozoon canis*
Hookworm infestation	2	Fecal sample	Hookworm infection

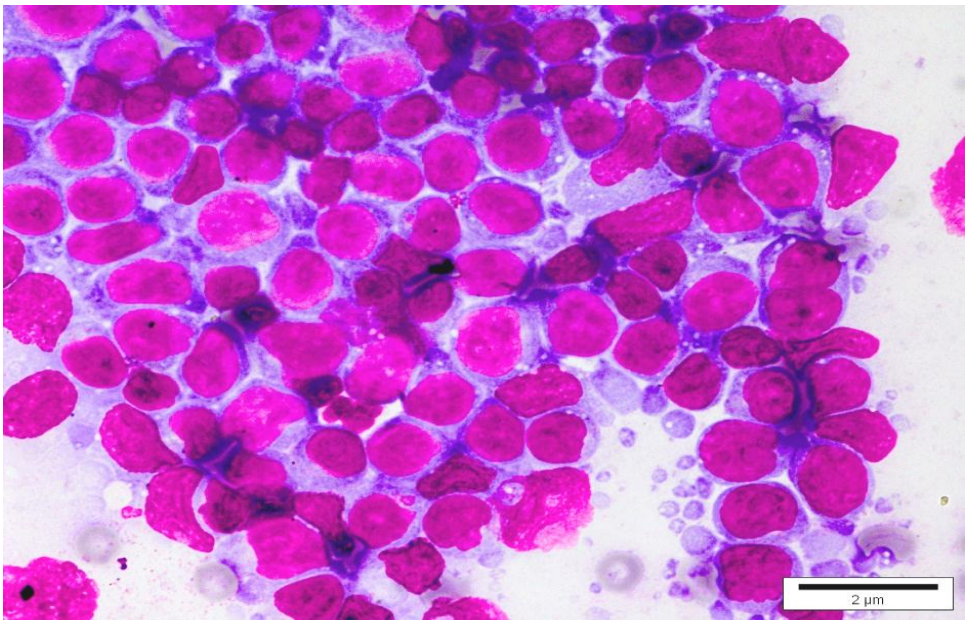


Fig. 46: FNAB of lymph node showing pleomorphic lymphoblastic cells with basophilic cytoplasm and lymphoglandular bodies suggestive of lymphoma. Leishman stain x 100X, Bar=2 µm

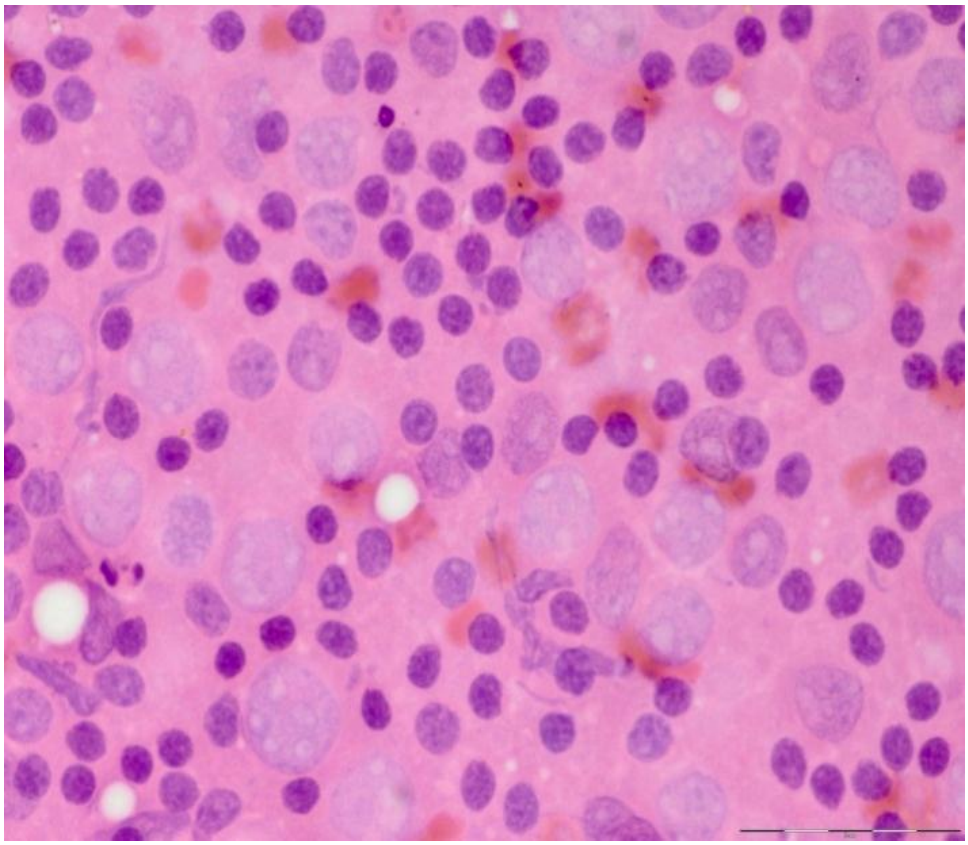


Fig. 47: Cytological examination of lymph node aspirate revealed lymphoma with pleomorphic lymphoblasts. PAP stain x 100X, Bar=2 µm

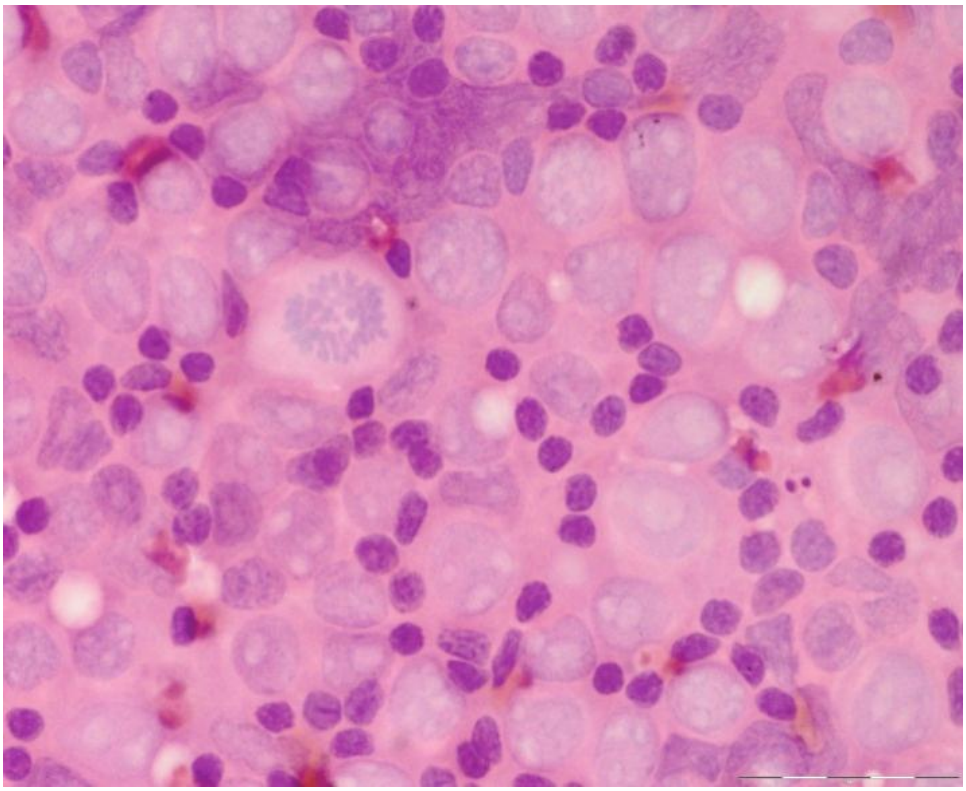


Fig. 48: Cytological examination of lymph node aspirate revealed lymphoma with pleomorphic lymphoblasts and a mitotic figure. PAP stain x 100X, Bar=2 µm

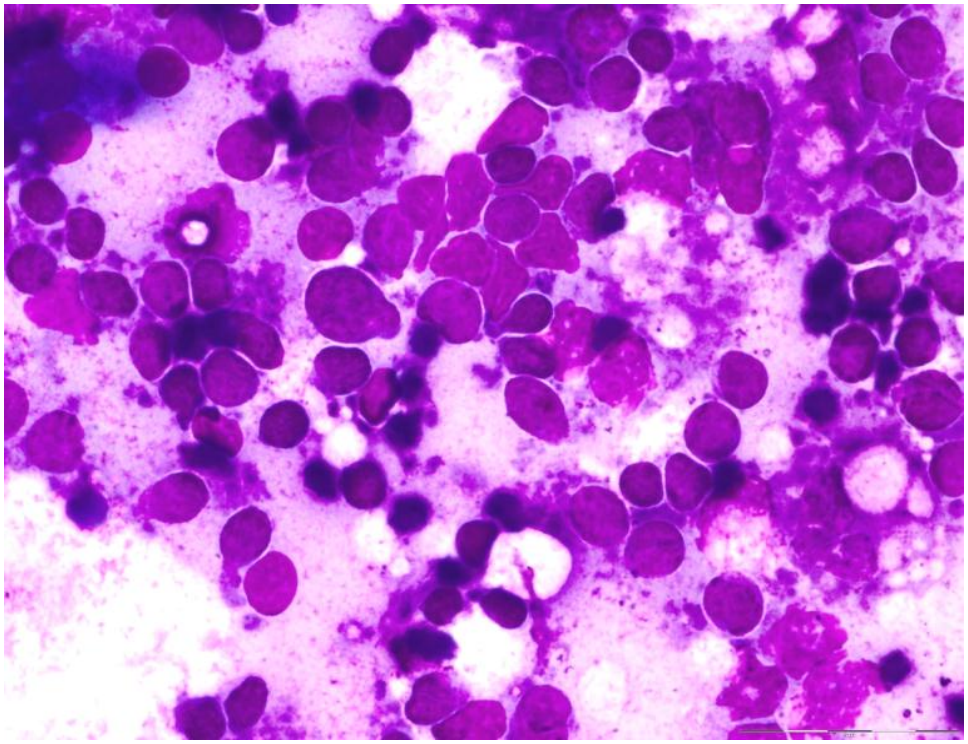


Fig. 49: Cytological examination of lymph node aspirate revealed lymphoma with pleomorphic lymphoblasts. May Grunwald Giemsa stain x 100X, Bar=2 µm

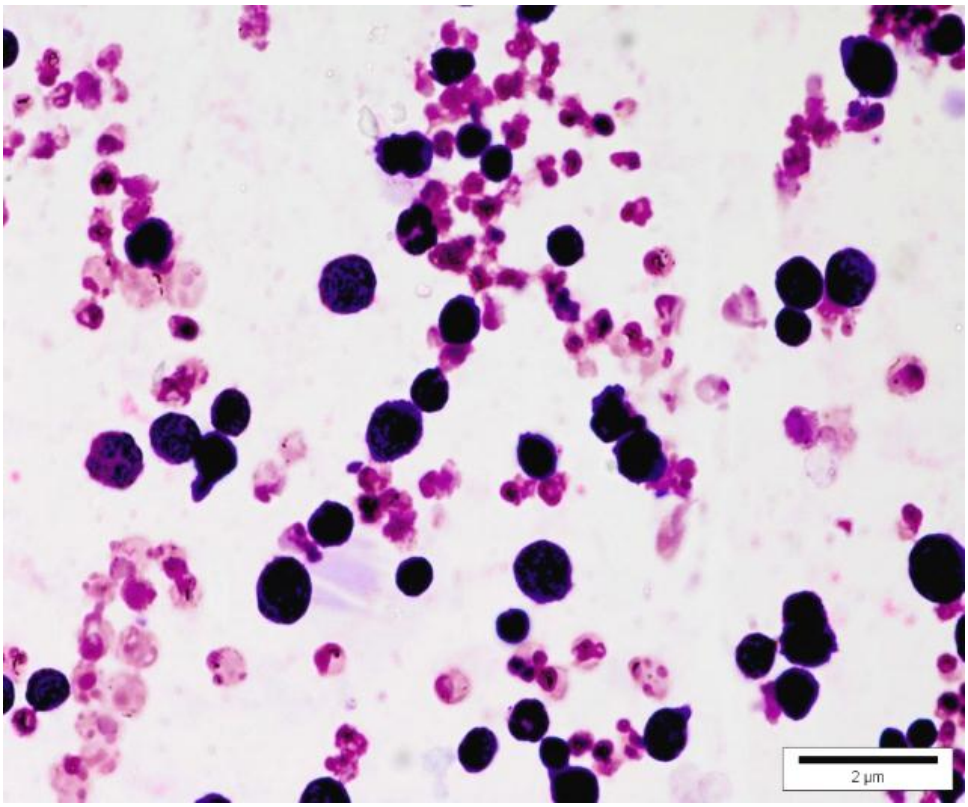


Fig. 50: FNAB from GIT showing numerous pleomorphic lymphoid cells indicative GIT lymphoma. Leishman stain x 100X, Bar=2 µm

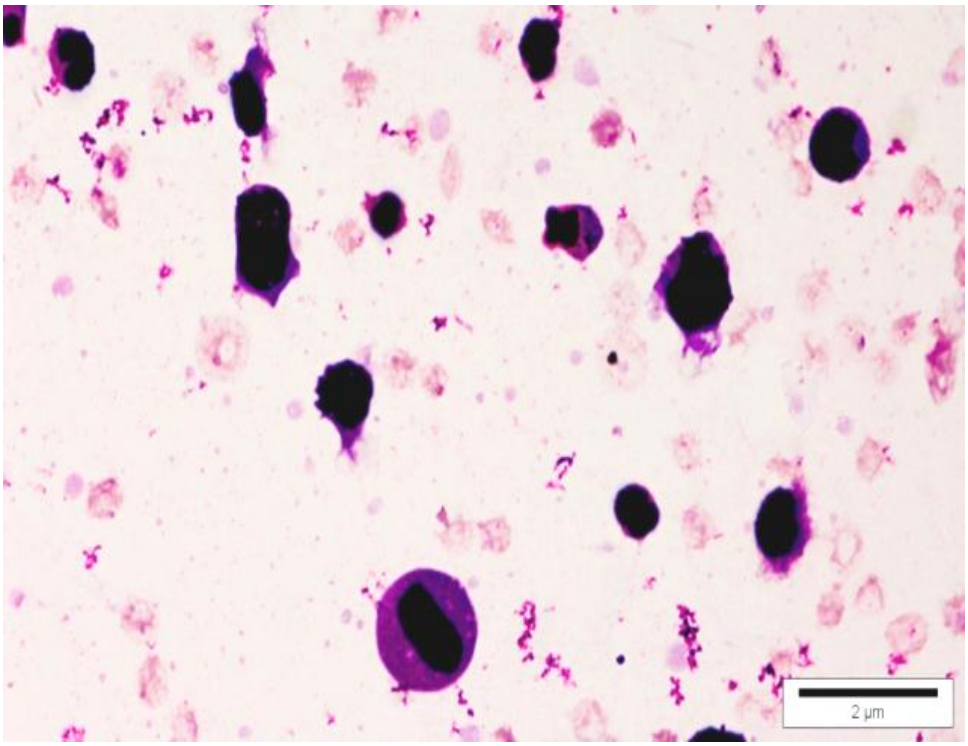


Fig. 51: Pleomorphic lymphoid cells with numerous neutrophils in peritoneal fluid in a case of GIT lymphoma. Leishman stain x 100X, Bar=2 µm

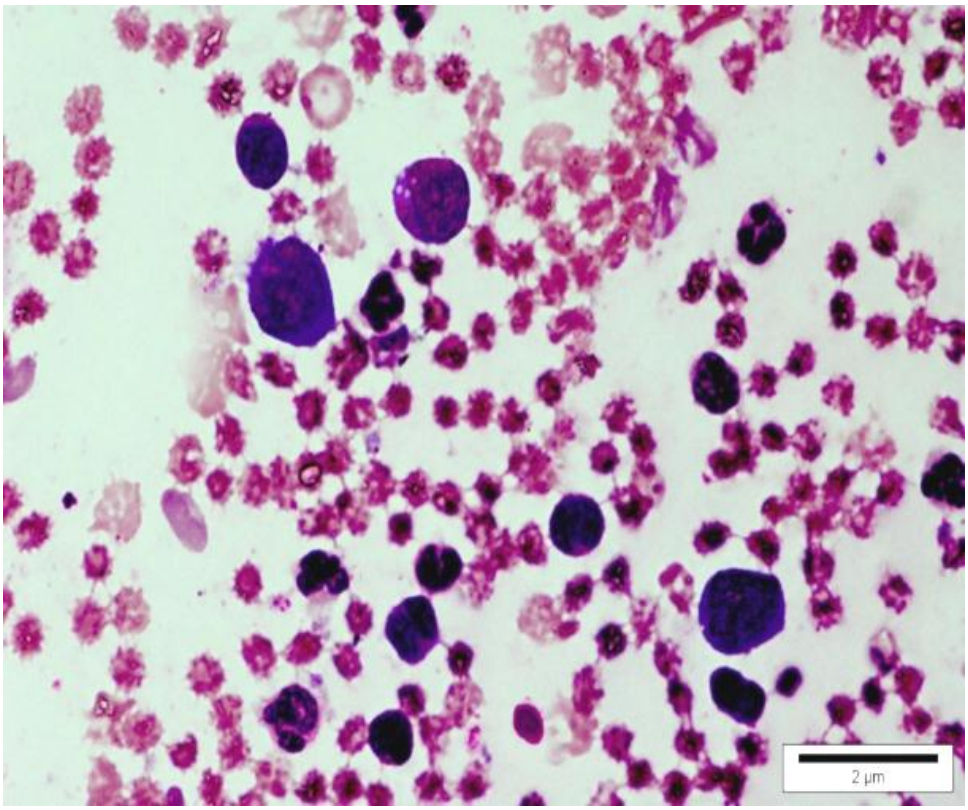


Fig. 52: FNAB of liver showing pleomorphic lymphoid cells along with many neutrophils in a case of GIT lymphoma. Leishman stain x 100X, Bar=2 µm

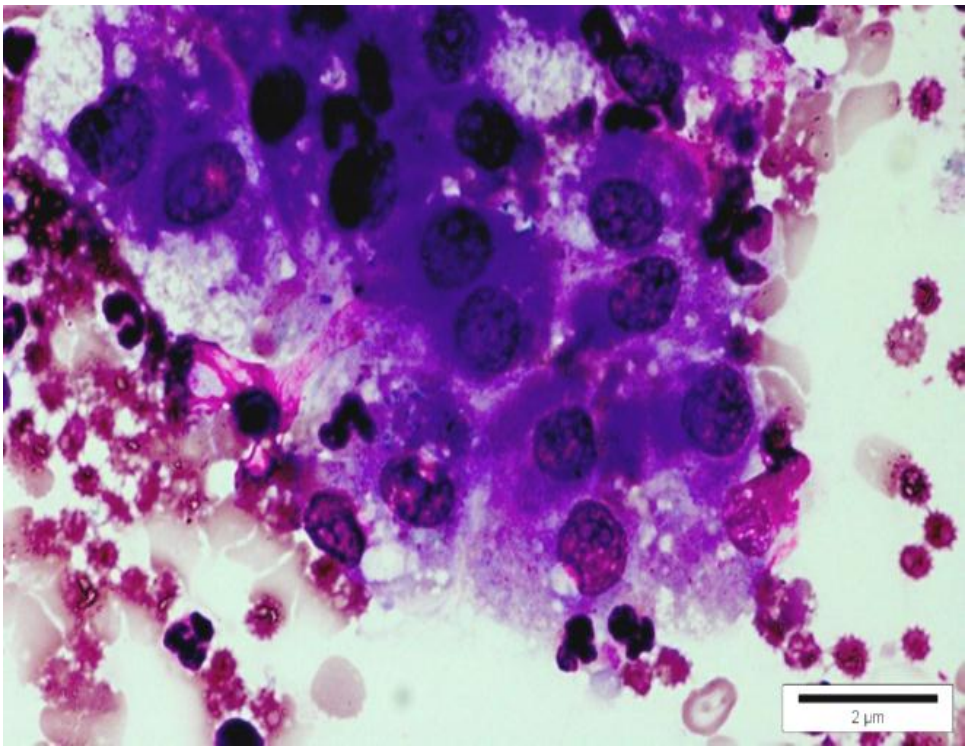


Fig. 53: FNAB of liver showing pleomorphic lymphoid cells along with many hepatocytes suggesting metastasis of lymphoma to the liver. Leishman stain x 100X, Bar=2 µm

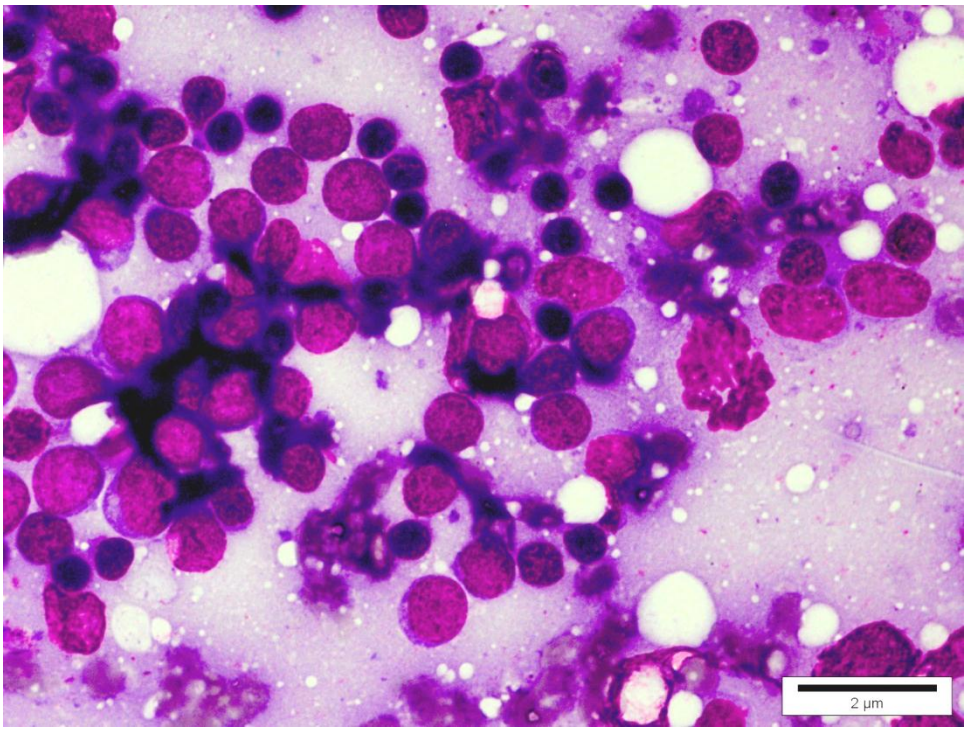


Fig. 54: FNAB of lymph node showing pleomorphic lymphocytes in case of lymphocytic leukemia. Leishman stain x 100X, Bar=2 µm

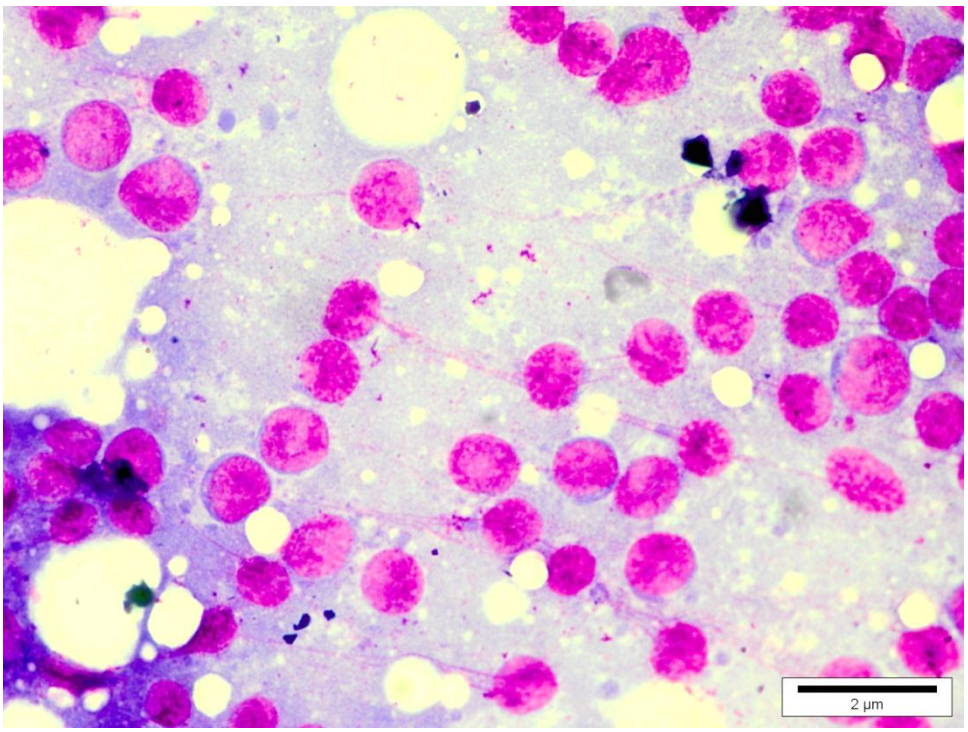


Fig. 55: FNAB from subcutaneous nodule showing pleomorphic lymphocytes in case of lymphocytic leukemia. Leishman stain x 100X, Bar=2 µm

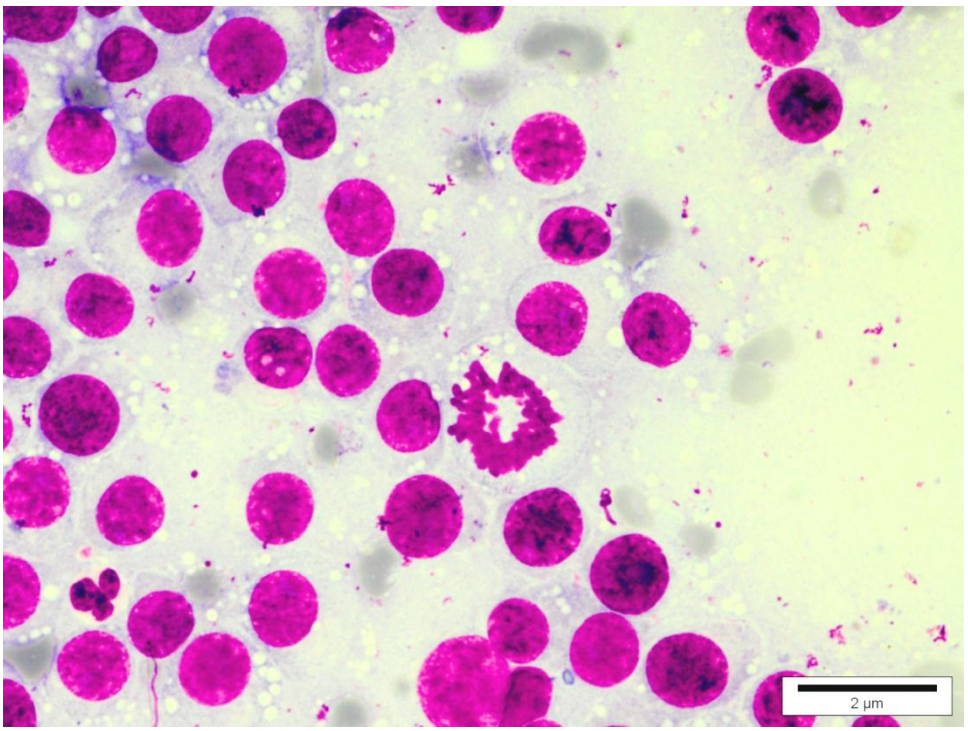


Fig. 56: Cytological examination of impression smear showing discrete round cells with vacuoles in cytoplasm and a mitotic figure suggestive of TVT. Leishman stain x 100X. Bar = 2 µm

Fig. 57: Dog showing black colored oral growth in a case suspected for melanoma

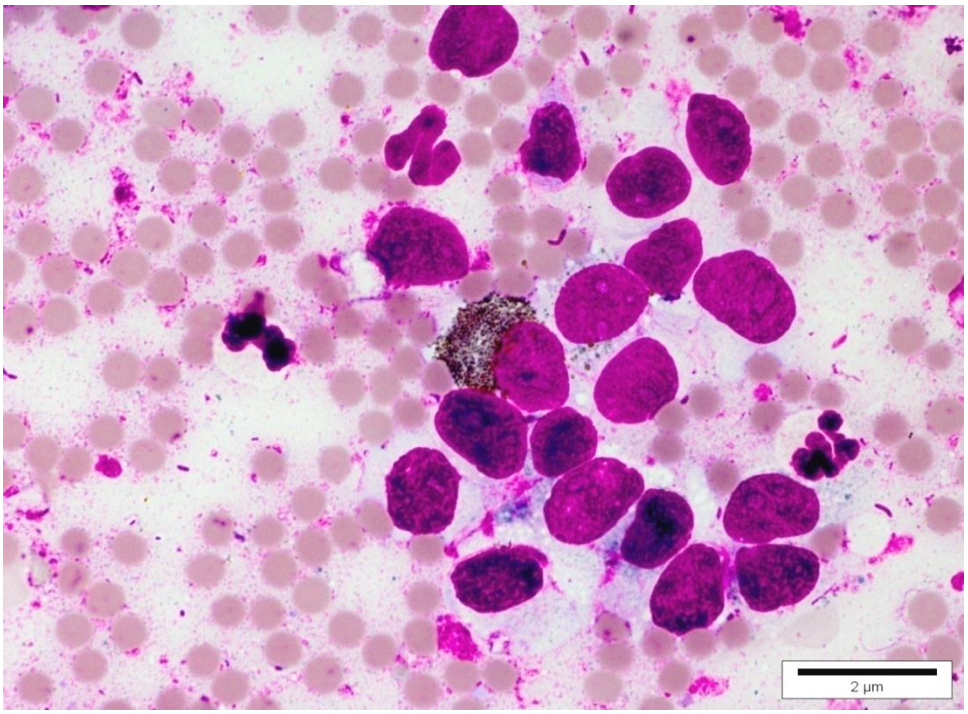


Fig. 58: Cytological examination of impression smear showing cells with melanin pigment suggestive of melanoma. Leishman stain x 100X. Bar = 2 µm

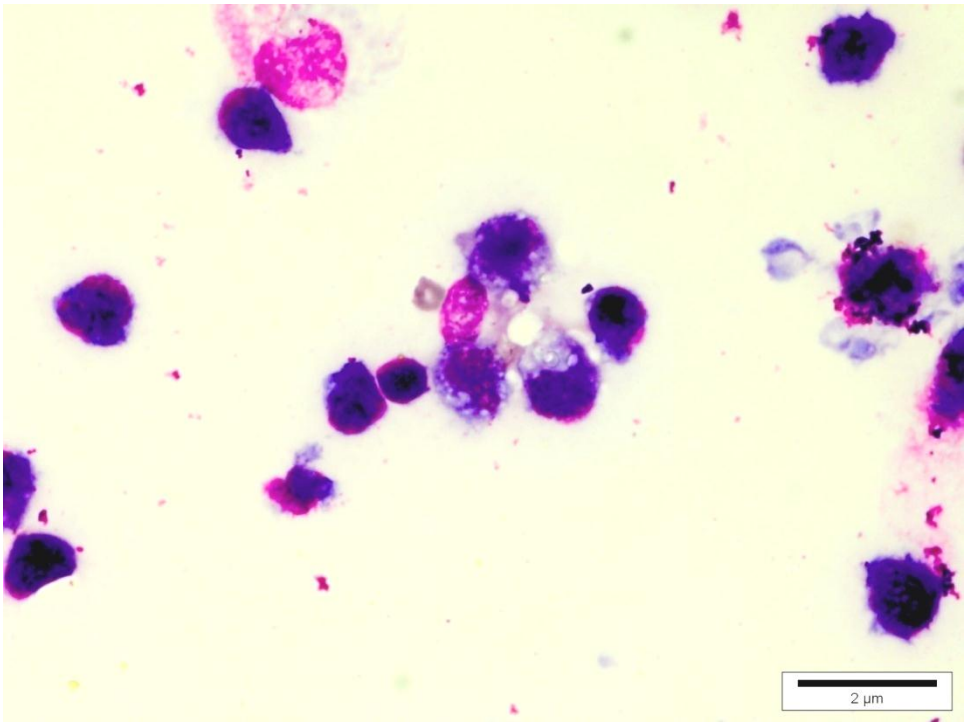


Fig. 59: Cytological examination of peritoneal fluid showing pleomorphic round cells with eccentric nucleus and vacuolated cytoplasm suggestive of malignant histiocytosis. Leishman stain x 100X. Bar = 2 µm

Fig. 60: Dog showing enlarged abdomen in a case suspected for ascites

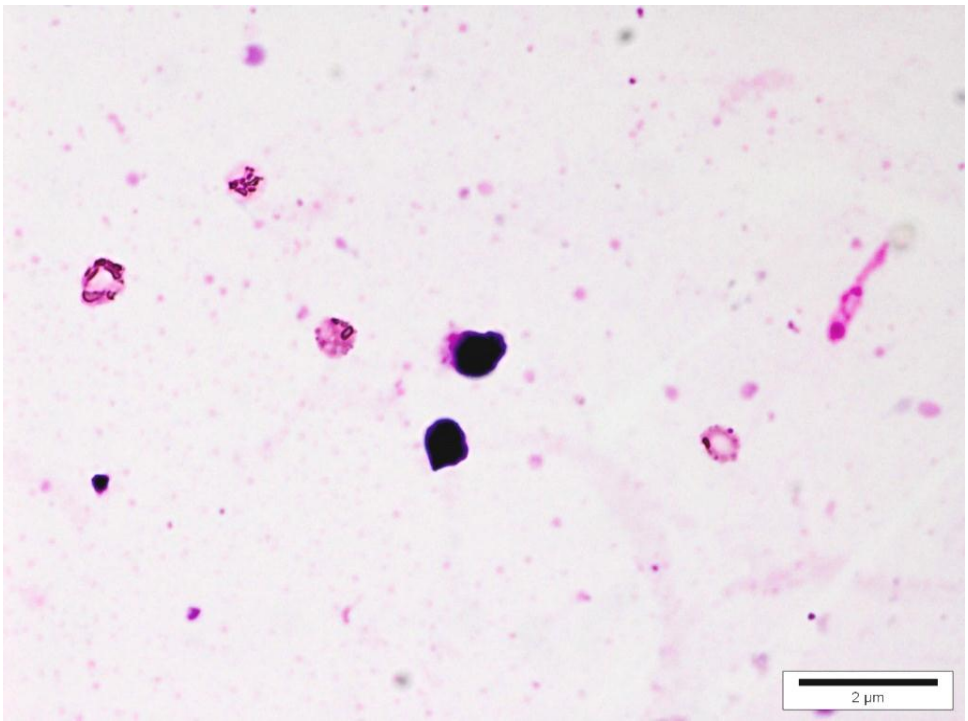


Fig. 61: Cytological examination of peritoneal fluid revealing few inflammatory cells along with RBC's in a case of ascites. Leishman stain x 100X. Bar = 2 µm

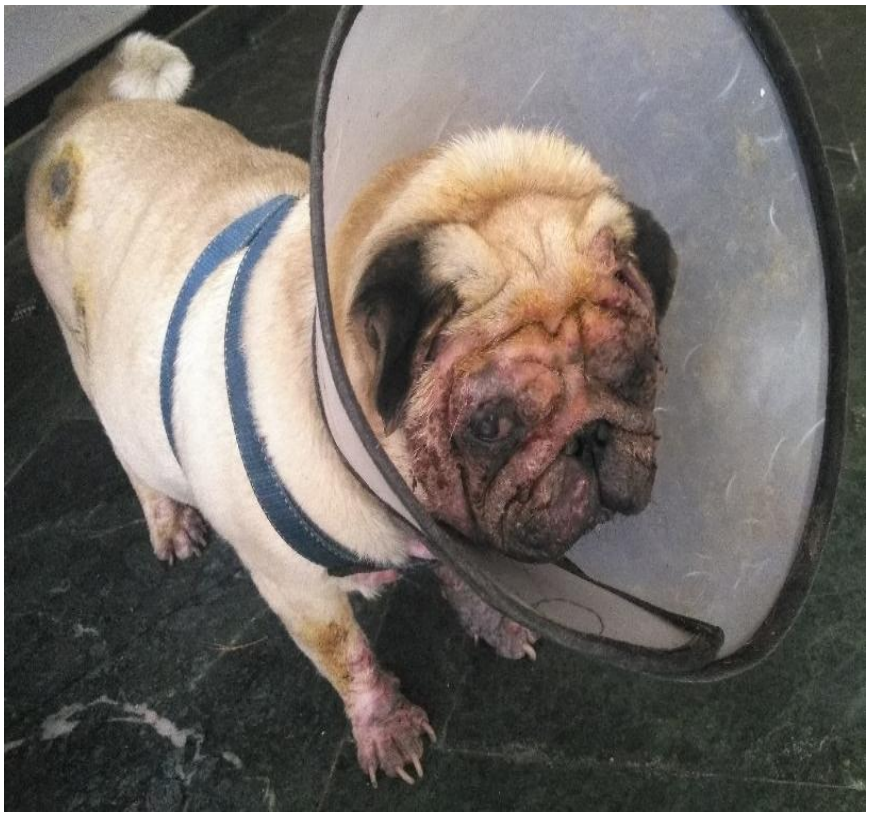


Fig. 62: Dog showing lesions on skin in a case suspected for demodicosis

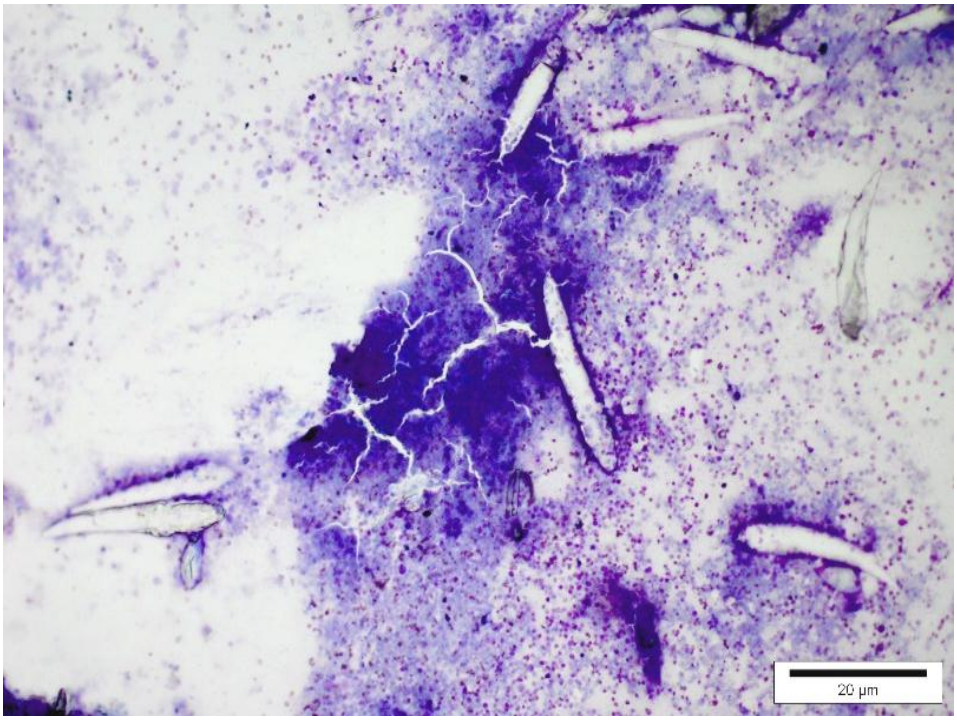


Fig. 63: Cytological examination of impression smear from skin revealed *Demodex canis.* Leishman stain x 10X. Bar = 20 µm

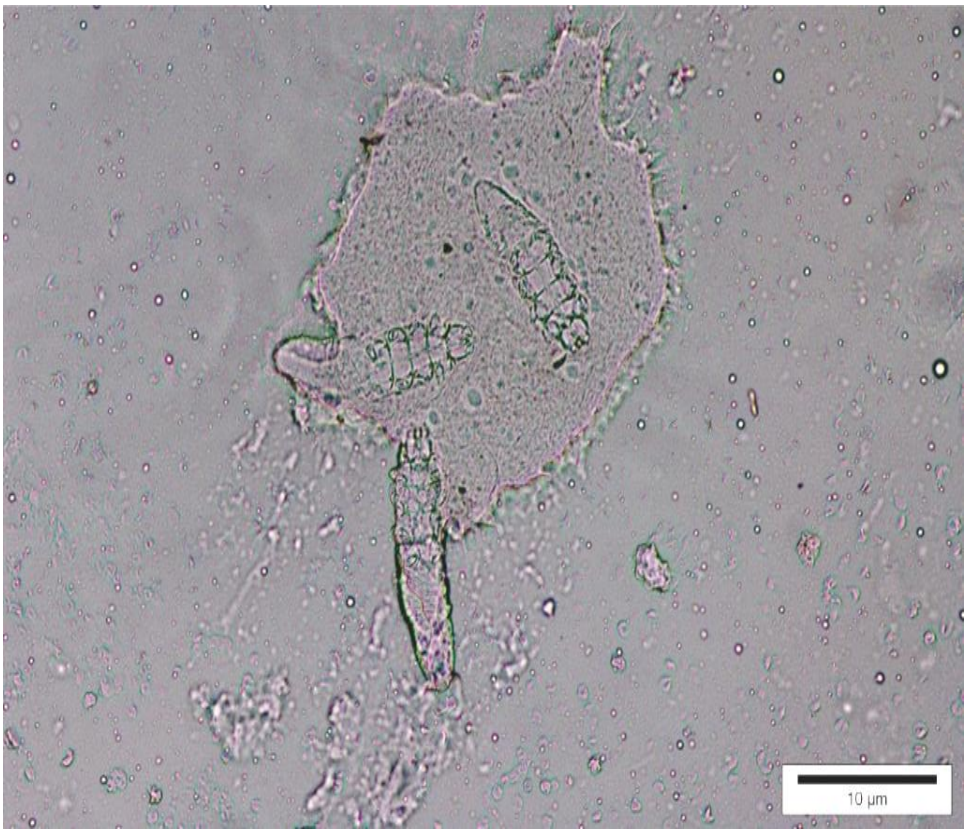


Fig. 64: *Demodex* canis revealed by examination of skin scrapings. 20x. Bar = 10 µm

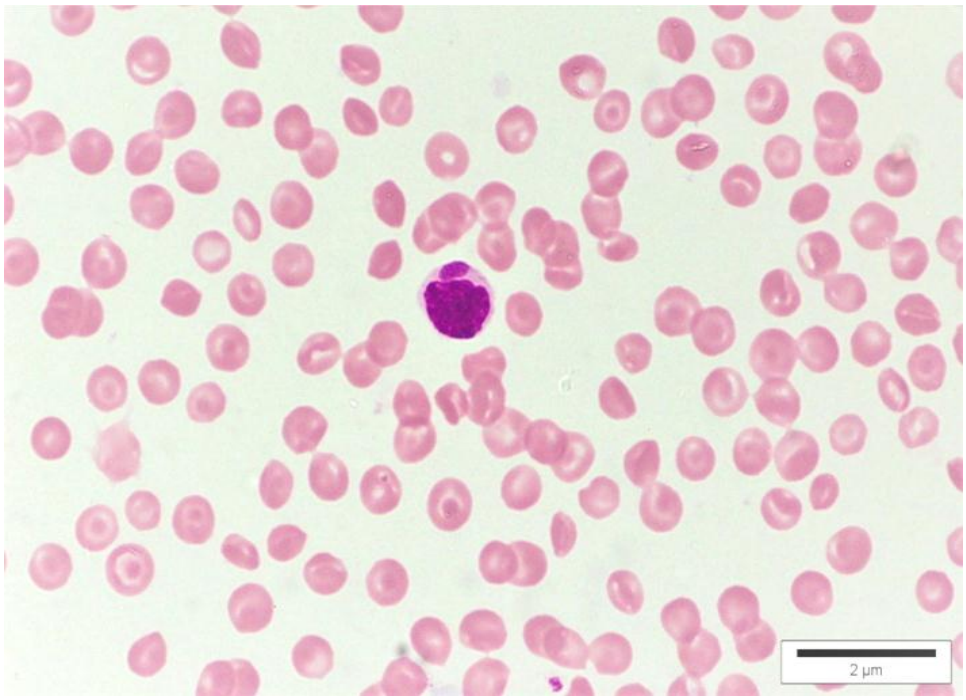


Fig. 65: Blood smear showing *Ehrlichia canis* morula and thrombocytopenia (TLC= 6600/µl, Hb= 11.8g/dl, Platelet= 70000/µl). Leishman stain x 100X. Bar = 2 µm

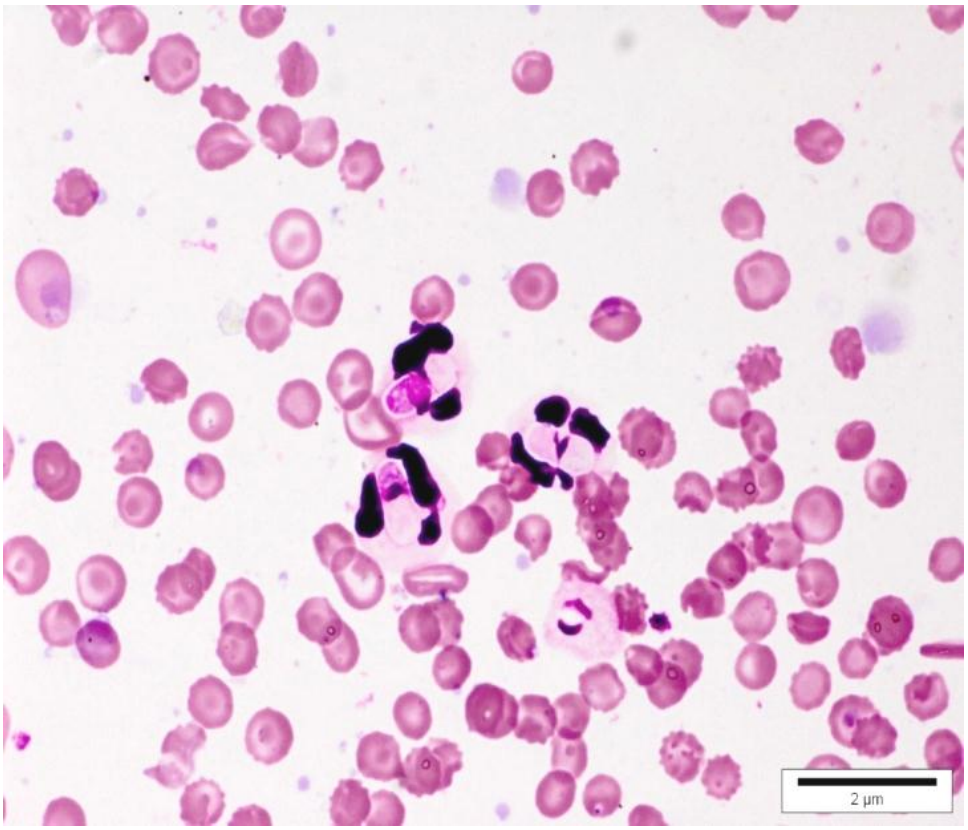


Fig. 66: Blood smear showing *Hepatozoon canis* (TLC= 37800/µl, Hb= 6.8 g/dl) Leishman stain x 100X. Bar = 2 µm

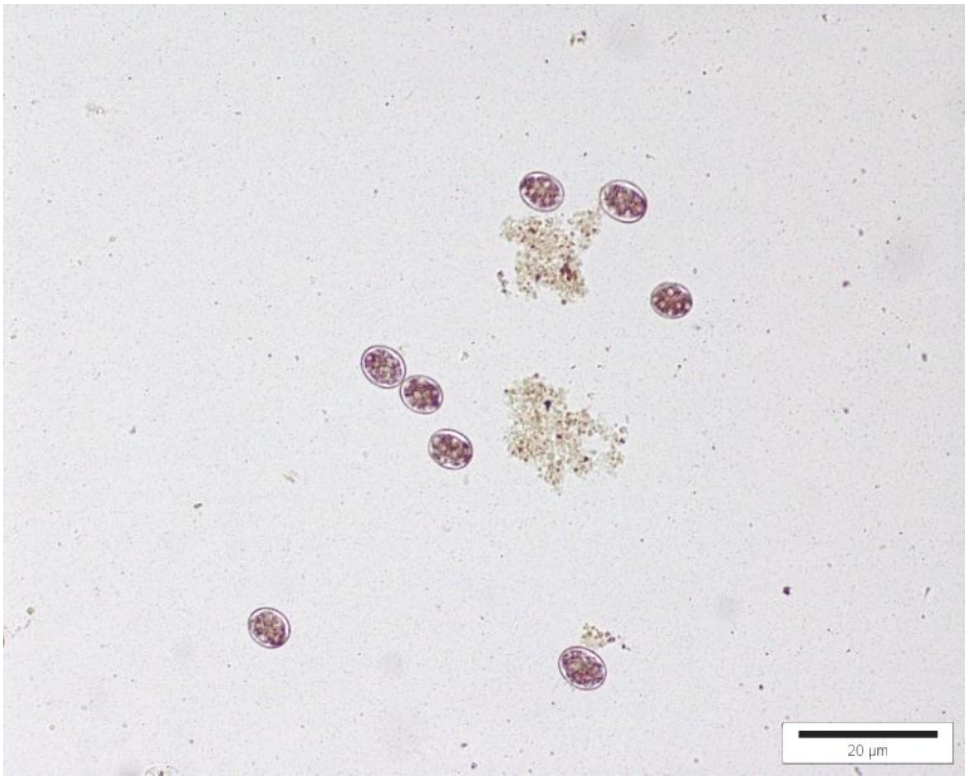


Fig. 67: Faecal sample examination showing hookworm eggs in a dog. 10x. Bar = 20 µm

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study was conducted with a view to evaluate the diagnostic and prognostic usefulness of leukocytic alterations in different pathological conditions of dogs and was split into two parts i.e. retrospective study and prospective study.

Retrospective data of two years (2016 and 2017) was analyzed to determine the incidence of various pathological conditions associated with leukocytic disorders in dogs. A total of 3374 cases of dogs were retrospectively analyzed.

Prospective study was conducted on a total of 300 blood samples from dogs which were subjected to estimation of hemoglobin, total leukocyte count and platelet count and these were further compared with 10 apparently healthy dog group. Blood smears were prepared and stained with Leishman stain for the analysis of differential leukocyte count which was performed by counting 200 cells manually and then absolute counts of various leukocytes were calculated. Blood smears were also analyzed for different types of morphological abnormalities in the cells including toxic changes in neutrophils and various types of lymphocytes viz. activated, granular and atypical lymphocytes and were scored.

Retrospective data analysis revealed the incidence of following diseases in decreasing frequency: renal dysfunction (606), hepatic dysfunction (542), gastrointestinal (GIT) disorders (251), urinary tract infections (UTI) (248), ascites (228), respiratory tract disorders (209), skin affections (201), pyometra (196), hepato-renal dysfunction (152), ehrlichiosis (129), Canine distemper (CD) (125), parvo virus infection (119), bone fracture (111), cardiac disorders (43), lymphoma (40), trans venereal tumor (TVT) (35), hookworm infestation (28), babesiosis (27), mammary tumor (26), brucellosis (19), demodicosis (18), hepatozoonosis (14) and lymphocytic leukaemia (7).

Analysis of leukogram findings in retrospective study with respect to reference values revealed the mean and median values of total leukocyte count (TLC) to be increased and among differential leukocyte count (DLC) neutrophils to be increased,

lymphocytes mean value was within reference range but median value was decreased, monocytes were decreased, eosinophils were within normal range.

Correlation of total leukocyte count (TLC) disorders with different pathological conditions of dogs revealed leukocytosis to be most common leukocytic disorder with maximum cases of renal dysfunction and hepatic dysfunction recorded followed by leukopenia with maximum cases of viral and bacterial diseases and leukemoid response with maximum cases of pyometra recorded.

Correlation of differential leukocyte count (DLC) disorders with different pathological conditions of dogs revealed relative neutrophilia to be most common leukocytic disorder followed by absolute neutrophilia with maximum cases of renal dysfunction recorded in both groups, absolute lymphocytosis with maximum cases of parasitic infections, relative lymphocytosis with maximum cases of viral and bacterial diseases, absolute eosinophilia with maximum cases of skin affections and relative eosinophilia with maximum cases of hepatic dysfunction recorded.

Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with pathological conditions revealed significant left shift in pyometra (p <0.01), renal dysfunction (p <0.05), viral diseases (P <0.05) and parasitic infections (P <0.05) whereas, significant toxic changes were associated only in viral diseases (P <0.05) and parasitic infections (P <0.05).

Prospective studies revealed the incidence of following diseases in decreasing frequency: hepatic dysfunction (57), renal dysfunction (42), hepato-renal dysfunction (33), pyometra (33), respiratory tract disorders (20), gastrointestinal (GIT) disorders (17), urinary tract infections (UTI) (14), lymphoma (11), ehrlichiosis (11), canine distemper (CD) (11), ascites (09), demodicosis (09), parvo virus infection (06), cardiac disorders (05), trans venereal tumor (TVT) (05), skin affections (04), lymphocytic leukaemia (04), mammary tumor (03), hookworm infestation (02) and hepatozoonosis (02), melanoma (01) and malignant histiocytosis (01).

Haematological parameters of dogs with different pathological conditions were compared with the reference values and apparently healthy dog group and the analysis revealed the mean and median values of TLC to be increased, hemoglobin to be decreased and platelets count to be well within the reference limits. Among DLC mean and median values of neutrophils and band cells were increased, monocytes and eosinophils were decreased, while lymphocytes mean value was within normal limit

with comparison to reference values but decreased in comparison to the apparently healthy dog group.

The hematology findings of different cases of hepatic dysfunction revealed mean values of hemoglobin ($p<0.05$), lymphocytes ($p<0.01$), and monocytes ($p<0.05$) to be significantly lower than the apparently healthy dog group, while neutrophils ($p<0.05$) were significantly higher but TLC (>0.05) was non-significantly higher than the apparently healthy dog group. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes. Mild (47) and moderate (8) toxic changes in neutrophils were also observed.

The hematology findings of different cases of renal dysfunction revealed mean values of hemoglobin ($p<0.01$), lymphocytes ($p<0.01$), and monocytes ($p<0.05$) to be significantly lower than the apparently healthy dog group, while TLC and neutrophils were higher than the apparently healthy dog group but values did not reach statistical significance ($p>0.05$). Mild to severe left shift was observed as indicated by band cells, metamyelocytes and myelocytes. Mild (34) and moderate (4) toxic changes in neutrophils were also observed.

The hematology findings of different cases of hepato-renal dysfunction revealed mean values of hemoglobin ($p<0.05$) and lymphocytes ($p<0.01$) to be significantly lower than the apparently healthy dog group, while neutrophils ($p<0.01$) were significantly higher but TLC (>0.05) was non-significantly higher than the apparently healthy dog group. N:L ratio was significantly higher than the apparently healthy dogs. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes. Mild (28) and moderate (3) toxic changes in neutrophils were also observed.

The hematology findings of different cases of pyometra revealed mean values of TLC and absolute count of neutrophils ($p<0.05$), band cells (%) and absolute count ($p<0.01$), absolute count of metamyelocyte and myelocyte ($p<0.05$) to be significantly higher than the apparently healthy dog group while lymphocytes ($p<0.01$) to be significantly lower than the apparently healthy dog group. Leukemoid response was observed in 2 cases of pyometra. Mild to severe left shift was observed as indicated by band cells, metamyelocytes and myelocytes. Mild (26) and moderate (6) toxic changes in neutrophils were also observed.

The hematology of the respiratory tract affections revealed increase in TLC and neutrophils but did not reach statistical significance (p >0.05) while significantly lower monocytes (p <0.05) when compared to apparently healthy dog group. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes. Mild (18) and moderate (1) toxic changes in neutrophils were also observed. Platelet count was increased in comparison to apparently healthy dog group but did not reach statistical significance (p >0.05).

The hematology of the GIT disorders revealed increased TLC and absolute count of neutrophils in comparison to the apparently dog group but did not reach statistical significance, whereas monocytes were significantly reduced (p<0.05) while platelets were reduced but not reach statistical significance in comparison to apparently healthy dog group. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes. Mild (17) toxic changes in neutrophils were also observed.

The hematology of the UTI cases revealed insignificant increase in TLC and neutrophils (p >0.05) whereas, significantly reduced lymphocytes (p <0.01) in comparison to the apparently healthy dog group. Mild to moderate left shift was observed as indicated by band cells and metamyelocytes. Mild (12) and moderate (1) toxic changes in neutrophils were also observed.

The hematology of the ascites cases revealed insignificantly increased TLC (p >0.05), significantly increased absolute count of neutrophils (p <0.05) and significantly reduced lymphocytes (p <0.05) and hemoglobin (p <0.05) in comparison to apparently healthy dog group. Mild left shift was observed as indicated by the presence of band cells. Mild (9) toxic changes in neutrophils were also observed.

The hematology of the cases with cardiac disorders revealed insignificant increase in TLC and neutrophils (p >0.05) and insignificant decrease in hemoglobin, lymphocytes and platelet count (p >0.05) in comparison to the apparently healthy dog group. Mild left shift was observed as indicated by band cells. Mild (5) toxic changes in neutrophils were also observed.

The hematology of different cases of skin affections revealed no significant changes between the two groups. TLC and neutrophil count were within normal range

but with mild left shift as indicated by band cells along with relative rise in lymphocytes, anaemia and thrombocytopenia (p >0.05) in comparison to the apparently healthy dog group. Mild (2) toxic changes in neutrophils were also observed.

The haematology of different cases of neoplasms revealed statistically significant increase in TLC (p <0.01), neutrophils (p <0.01), absolute count of lymphocytes (p <0.01) whereas statistically non-significant decrease in values of hemoglobin and platelet count (p >0.05) in comparison to apparently healthy dog group. Mild to moderate left shift was observed as indicated by presence of band cells and metamyelocytes. Mild (19) and moderate (2) toxic changes in neutrophils were also observed.

The hematology of different cases of parasitic infections revealed TLC and neutrophils within normal range but mild to severe left shift was observed as indicated by increase in band cells, metamyelocytes and myelocytes along with monocytopenia and anaemia in comparison to the apparently healthy dog group. The mean neutrophil count was higher than the apparently healthy dog group. Mild (20) and moderate (1) toxic changes in neutrophils were also observed.

The haematology of different cases of viral diseases revealed no significant changes in comparison to the apparently healthy dog group except significantly lower monocytes (p <0.05). Although, TLC was high, hemoglobin and lymphocytes were reduced but the values did not reach the statistical significance. Mild to moderate left shift was observed as indicated by presence of band cells and metamyelocytes. Mild (16) and moderate (1) toxic changes in neutrophils were also observed. Thrombocytosis was observed when compared with apparently healthy dog group but did not reach statistical significance.

Correlation of total leukocyte count (TLC) disorders with different pathological conditions of dogs revealed leukocytosis to be most common leukocytic disorder with maximum cases of hepatic dysfunction recorded followed by leukopenia with maximum cases of parasitic infections and leukemoid response with maximum cases of neoplasms recorded. Leukocytosis was significantly higher (p <0.05) in different pathological conditions of dogs viz. ascites, pyometra, parasitic infections and neoplasms. Leukopenia was significantly higher in parasitic infections (p <0.01)

and viral diseases (p <0.05). Leukemoid response was highly significant (p <0.01) in neoplasms.

Correlation of differential leukocyte count (DLC) disorders with different pathological conditions of dogs revealed relative neutrophilia to be most common leukocytic disorder with maximum cases of hepatic dysfunction and hepato-renal dysfunction recorded, followed by absolute neutrophilia with maximum cases of renal dysfunction recorded, relative lymphocytosis with maximum cases of parasitic infections recorded, absolute eosinophilia with maximum cases of GIT disorders recorded, absolute lymphocytosis with maximum cases of respiratory tract affections and GIT disorders recorded, and relative eosinophilia with a single case of viral disease recorded. Relative neutrophilia was highly significant (p <0.05) in hepato-renal dysfunction and pyometra. Absolute neutrophilia was highly significant (p <0.05) in cardiac disorders and respiratory tract affections. Relative lymphocytosis was highly significant (p <0.01) in skin affections, parasitic infections and viral diseases. Absolute lymphocytosis was highly significant (p <0.01) in neoplasms and GIT disorders (p <0.05). Relative eosinophilia was highly significant (p <0.01) in viral infections while absolute eosinophilia was highly significant in GIT disorders (p <0.01) and viral infections (p <0.05).

Correlation of leukocyte findings viz. left shift and toxic changes in neutrophils with pathological conditions revealed significant left shift in pyometra, renal dysfunction, hepatic dysfunction and hepato-renal dysfunction (p <0.05) whereas, significant toxic changes were associated only with skin affections and neoplasms (P <0.01).

The incidence of morphological changes in lymphocytes viz. activated, granular and atypical lymphocytes were more prominent in all the pathological conditions of dogs except in hepatic dysfunction and cardiac disorders when compared to apparently healthy dog group with maximum incidence in skin affections. Activated lymphocytes were not found to be associated with pathological disorders of dogs, although marginal significance was observed with hepato-renal dysfunction (P 0.0654), viral diseases (P 0.0845) and GIT disorders (P 0.0845). Granular lymphocytes were found to be significantly associated (P <0.05) with skin affections and neoplasms (P <0.01) whereas, atypical lymphocytes were significantly associated with hepatic dysfunction (P <0.05) and neoplasms (P <0.01).

Correlation of leukocyte findings viz. left shift, toxic changes in neutrophils, activated lymphocytes, granular lymphocytes and atypical lymphocytes with haematological findings was done. It was found that the dogs with left shift had significantly (p <0.05) higher mean TLC, absolute count of neutrophil, percentage and absolute count of band cell, metamyelocyte and myelocyte and absolute count of monocyte, as well as significantly (p <0.05) lower lymphocyte and eosinophil percentage counts when compared to those in which left shift was absent. The dogs with toxic changes in neutrophils had significantly (p <0.05) higher average band cell percentage, myelocyte percentage, and absolute counts of eosinophils and monocyte as well as significantly (p <0.05) higher average hemoglobin and platelet counts when compared to those dogs in which toxic changes were absent. The dogs with activated and granular lymphocytes had significantly (p<0.01) lower mean percentage and absolute count of neutrophil, as well as significantly (p<0.01) higher mean percentage of lymphocytes, percentage (p<0.01) and (p<0.05) absolute count of eosinophils. The dogs with granular lymphocytes had significantly higher (p<0.01) percentage count of toxic neutrophils and activated lymphocytes when compared to those where these were absent. The dogs with atypical lymphocytes had significantly (p <0.01) higher mean percentage and absolute count of lymphocytes, as well as significantly lower neutrophil percentage (p <0.05) and absolute count of eosinophil (p <0.01) when compared to those where atypical lymphocytes were absent.

Correlation of leukocyte findings viz. left shift, toxic changes in neutrophils, activated lymphocytes, granular lymphocytes and atypical lymphocytes was done with clinical symptoms in different pathological conditions. It was found that the chances of occurrence of left shift were more where vaginal discharge, hematuria, and abdominal distension was present. The chances of occurrence of toxic changes in neutrophils were more in the groups where vaginal discharge, melena, dyspnea and oral ulceration were present. The chances of occurrence of activated lymphocytes were more in the group where alopecia was present. The chances of occurrence of granular lymphocytes were more in the group where itching was present. The chances of occurrence of atypical lymphocytes were more in the group where vaginal discharge, stranguria, subcutaneous nodules were present and lymph nodes were swollen.

Correlation of leukocyte findings viz. left shift, toxic changes in neutrophils, activated lymphocytes, granular lymphocytes and atypical lymphocytes with leukocytic disorders was done. It was found that the chances of occurrence of left shift and toxic changes in neutrophils were more in the group where leukocytosis was present. The activated lymphocytes were not found to be associated with leukocytic disorder. The chances of occurrence of granular lymphocytes were more in the group where absolute eosinophilia was present. The chances of occurrence of atypical lymphocytes were more in the groups where leukemoid response, absolute neutrophilia and absolute lymphocytosis were present as compared to the groups where these were absent.

Correlation of leukocytic disorders with prognosis was done and analysis revealed absolute neutrophilia and absolute eosinophilia to be significantly (p <0.05) associated with good prognosis. Other leukocytic disorders were not significantly associated with prognosis (p >0.05).

Correlation of leukocyte findings viz. left shift, toxic changes in neutrophils, activated lymphocytes, granular lymphocytes and atypical lymphocytes with prognosis was done. Presence of left shift revealed maximum correlation with good prognosis (49.5% cases) followed by poor prognosis (36.5% cases) and fair prognosis (13.8% cases). Similarly, presence of toxic changes in neutrophils had maximum correlation with good prognosis (49.1% cases) followed by poor prognosis (36.5% cases) and fair prognosis (14.3% cases). Activated and granular lymphocytes had maximum correlation with good prognosis in 57.7% and 51.5% cases respectively, followed by poor prognosis in 28.4% and 31.01% cases respectively and poor prognosis in 13.7% and 17.4% cases respectively. The presence of atypical lymphocytes had maximum correlation with poor prognosis in 58.8% cases, followed by good prognosis in 29.4% cases and fair prognosis in 11.7% cases. It was found that there were no significant differences between the prognosis group with respect to left shift (p >0.05). Toxic changes in neutrophils were marginally significant in the poor prognosis group (p 0.0661). Activated lymphocytes were significantly associated with good and poor prognosis (p <0.01). Granular lymphocytes were found to be significantly associated with poor prognosis (p <0.05). Atypical lymphocytes were found to be marginally significant in the poor prognosis group (p 0.0661).

Correlation of leukocyte findings viz. left shift, toxic changes in neutrophils, activated lymphocytes, granular lymphocytes and atypical lymphocytes was done with serum biochemical changes in different pathological conditions wherever was possible. It was found that the dogs with left shift had significantly (p <0.01) higher total bilirubin, and significantly lower average levels of total protein (p <0.05), albumin (p <0.05), BUN (p <0.01), and creatinine (p <0.01) when compared to those in which left shift was absent. No significant changes in serum biochemicals were reported with respect to toxic changes in neutrophils. Significantly lower mean levels of SGOT (p <0.01) and (p <0.05) were reported in the dogs with activated and granular lymphocytes respectively in comparison to the group where these were absent. The dogs had significantly (p <0.01) lower average levels of total bilirubin, SGOT, SGPT, and GGT with atypical lymphocytes when compared to those where these were absent.

Correlation of leukocytic disorders with ultrasonography findings was done in the cases of hepatic dysfunction which revealed hyperechoic liver and free anechoic fluid in abdomen; renal dysfunction which revealed hyperechoi cortex and loss of corticomedullary differentiation; hepato-renal dysfunction which revealed renal cortex hyperechoic and free anechoic fluid in abdomen; ascites which revealed lots of anechoic fluid in abdomen; UTI which revealed distended urinary bladder with concretions and pyometra which revealed dilated uterine loops.

Correlation of leukocytic disorders with X-ray findings was done in the cases of respiratory affections which revealed pneumonia and pleural effusions; and in cardiac disorders heart enlargement was revealed.

Correlation of leukocytic disorders was done with electrocardiography findings (ECG) and echocardiography which revealed heart enlargement.

Correlation of leukocytic disorders with cytology was done wherever was possible. The cases of neoplasms viz. lymphoma, TVT, melanoma and malignant histiocytosis were diagnosed based on cytological examination of the lymph node aspirate (lymphoma), impression smears (TVT and melanoma) and ascitic/peritoneal fluid (malignant histiocytosis). Peritoneal fluid examination was also performed in cases of ascites and hepatic dysfunction. Impression smear was also utilized for the diagnosis of a case of demodicosis.

Correlation of leukocytic disorders with examination of blood smear for haemoprotozoa, skin scrapings and faecal sample was done in case of parasitic infections. Cases of ehrlichiosis, hepatozoonosis, demodicosis and hookworm infestation were diagnosed with these ancillary techniques.

Conclusions:

1. Leukocytosis appeared to be the most common total leukocyte count disorder and was significantly associated with ascites, pyometra, parasitic infections and neoplasms in dogs followed by leukopenia which was significantly associated with parasitic and viral diseases and leukemoid response which was significantly associated with neoplasms.
2. Relative neutrophilia appeared to be the most common differential leukocyte count disorder that was significantly associated with hepato-renal dysfunction and pyometra followed by absolute neutrophilia which was significantly associated with cardiac disorders and respiratory tract affections, relative lymphocytosis which was significantly associated with skin affections, parasitic infections and viral diseases, absolute eosinophilia which was significantly associated with GIT disorders and viral infections, absolute lymphocytosis which was significantly associated with neoplasms and GIT disorders, and relative eosinophilia which was significantly associated with viral infections.
3. N:L ratio was significantly increased in hepato-renal dysfunction.
4. Significant left shift was reported in pyometra, renal dysfunction, hepatic dysfunction, hepato-renal dysfunction, viral diseases and parasitic infections, whereas significant toxic changes were associated with skin affections, neoplasms, viral diseases and parasitic infections.
5. Significant association of granular lymphocytes with skin affections and atypical lymphocytes with neoplasms and hepatic dysfunction was a notable finding of the study.
6. Among different leukocytic disorders absolute neutrophilia and absolute eosinophilia appeared to be significantly associated with good prognosis.

7. Left shift was not at all found to be associated with prognosis and toxic changes in neutrophils appeared to be only marginally significant in the poor prognosis group.
8. Activated lymphocytes appeared to be significantly associated with both good and poor prognosis in dogs while, granular lymphocytes were found to be significantly associated with poor prognosis. Atypical lymphocytes were marginally significant in the poor prognosis group.
9. The toxic changes in neutrophils were significantly associated with left shift.
10. Granular lymphocytes were significantly associated with toxic changes in neutrophils.

Thus, leukocytic disorders and abnormalities in their morphology can be used to predict the diagnosis and prognosis of different pathological conditions in dogs. In addition to the toxic changes in neutrophils and left shift, changes in lymphocytes morphology can also be used to predict the prognosis in different pathological conditions of dogs.

REFERENCES

Abdel Haleem M M, Salib F A and Farag H S. 2015. Evaluation of haematological parameters, biochemical parameters and thyroxin level in dogs with generalized demodicosis. *Global Veterinaria* **15**(1): 133-36.

Adam F, Villiers E, Watson S, Coyne K and Blackwood1 L. 2009. Clinicalpathological and epidemiological assessment of morphologically and immunologically confirmed canine leukaemia. *Veterinary and Comparative Oncology* **7**(3): 181–95.

Adebayo O O, Ajadi R A, Omobowale T O, Omotainse S O, Dipeolu M A, Nottidge H O and Otesile E B. 2016. Reliability of clinical monitoring for the diagnosis of babesiosis in dogs in Nigeria. *Veterinary Medicine: Research and Reports* **7**: 85–90.

Ajadi A T, Ajadi R A, Makinde A F, Omobowale T O, Antia R E, Nottidge H O and Kasali O B. 2010. Radiographic assessment of canine transmissible venereal tumor metastases. *Communications in Theriogenology* **4**: Doc 1.

Albanese F, Salerni F L, Giordano S and Marconato L. 2006. Extragenital transmissible venereal tumour associated with circulating neoplastic cells in an immunologically compromised dog. *Veterinary and Comparative Oncology* 4 (1):57-62.

Amaravathi M, Kumar B, Reddy C and Devi J S. 2016. Clinico- Haematobiochemical changes in Canine Parvoviral infection. *International Journal of Advanced Multidisciplinary Research* **3(3)**: 31-33.

Andonova M, Urumova V, Petkova B, Slavov E, Dzhelebov P, Chaprazov T S, Roydev R and Borissov I. 2014. Haematological and biochemical parameters characterising the progression of experimental *Pseudomonas aeruginosa* skin infection in dogs. *Bulgarian Journal of Veterinary Medicine* **17(1)**: 32-41.

Andrea L, Vinodkumar K, Tresamol P V, Justin Davis K, Priya P M. 2017. Hematological changes in dogs with parvovirus enteritis in Thrissur district. *Imperial Journal of Interdisciplinary Research* **3(6)**: 1323-25.

Andrews J M, Cruser D L, Myers J B, Fernelius C A, Holm M T and Waldner D L. 2008. Using peripheral smear review, age and absolute lymphocyte count as predictors of abnormal peripheral blood lymphocytoses diagnosed by flow cytometry. *Leukemia & Lymphoma* **49:** 1731-37.

Apple M J G, Yates R A, Foley G L, Bernstein J J, Santinelli S, Spelman L H *et al.* 1994. Canine distemper epizootic in lions, tigers, and leopards in North America. Journal of *Veterinary Diagnostic Investigation* **6**:277-88.

Aroch I, Klement E and Segev G. 2005. Clinical, biochemical, and hematological characteristics, disease prevalence, and prognosis of dogs presenting with neutrophil cytoplasmic toxicity. *Journal* of *Veterinary Internal Medicine* **19**: 64-73.

Arora N, Vohra S, Singh S, Potliya S, Lather A, Gupta A, Arora D and Singh D. 2013. Therapeutic management of chronic generalized demodicosis in a pug. *Advances in Animal and Veterinary Sciences* **1**(2): 26-28.

Arora R, Tyagi A, Shekhar S, Rajora V S and Arora N. 2018. Haemato-biochemical alterations in gastroenteritis affected dogs. *Journal of Entomology and Zoology Studies* **6**(5): 972-74.

Babu M, Sahadev A, Nethra R and Rasmi S. 2018. Clinical studies on hemato-biochemical attributes in pyometra affected dogs. *International Journal of Science and Research* **7**(7): 902-04.

Banihashem A, Ghiassi T and Zabihyan S. 1996. Malignant histiocytosis: a case report and review of the literature. *Medical Journal of the Islamic Republic of Iran* **10**: 79-83.

Bastan I, Kurtdede A and Ozen D. 2013. Prognostic usefulness of some parameters in dogs with canine parvovirus. *Ankara Univ Vet Fak Derg* **60**: 53-58.

Behera S K, Kurade N P, Shongsir W M, Durga P D, Krishna K M and Ranjan K M. 2012. Clinico-pathological findings in a case of canine cutaneous metastatic transmissible venereal tumour. *Veterinarski Arhiv* **82(4)**: 401-10.

Berghoff N and Steiner J M. 2011. Laboratory tests for the diagnosis and management of chronic canine and feline enteropathies. *Veterinary Clinics of Small Animal* **41**: 311-28.

Bhadesiya C M and Raval S K. 2015. Hematobiochemical changes in ehrlichiosis in dogs of Anand region, Gujarat. *Veterinary World* **8**(6): 713-17.

Bhargavi M, Shobhamani B, Kumari K N and Srilatha C. 2017. Diagnostic Aspects and Haematobiochemical Changes Associated with Canine Parvoviral Enteritis in Dogs. *International Journal of Current Microbiology and Applied Sciences* **6**(11): 3357-64.

Bhat A A, Wadhwa D R, Singh S P and Singh I. 2013. Haematological and biochemical analysis in canine enteritis. *Veterinary World* **6**(7):380-83.

Bhattacharya M, Sonone R M, Shaikh S M, Rathi A, Sareen C and Yadav S. 2017. Comparison of efficacy and reliability of different histochemical stains in oral exfoliative cytology: a qualitative analysis. *International Journal of Oral Health and Medical Research* **4:** 26-30.

Bhojne G R, Dakshinkar N P and Kumar G P. 2001. Bilateral renal calculi in a dog. *Indian Veterinary Medicine Journal* **25**(12):411-12.

Bigliardi E, Parmigiani E, Cavirani S, Luppi A, Bonati L and Corradi A. 2004. Ultrasonography and Cyctic Hyperplasia-Pyometra Complex in the Bitch. *Reproduction in Domestic Animals* **39**: 136-140.

Bradea A, Codreanu M, Vlagioiu C and Simion V. 2013. Hematologic aspects in chronic kidney disease (CDK) in dogs. *Veterinary Medicine* **70**(2): 191-94.

Buragohain M, Goswami S and Kalita D J. 2017. Clinicopathological findings of canine distemper virus infection in dogs. *Journal of Entomology and Zoology Studies* **5**(6): 1817-19.

Burton A G, Harris L A, Owens S D and Jandrey K E. 2013. The prognostic utility of degenerative left shift. *Journal of Veterinary Internal Medicine* **27**(6): 1517-22.

Bush B M. 2002. *Interpretation of laboratory results for small animal clinics*. Pp 317-19. Blackwell Sciences Co, Iowa, USA.

Castaldi P A, Rosenberg M C and Stewart J H. 1966. The bleeding disorder of uremia: A qualitative platelet defect. *The Lancet* **288**(7454): 66-69.

Castro T X, Cubel N G, Gonçalves L P S, Costa E M, MarcelloGracy C G, Labarthe N V and Mendes-de-Almeida F. 2013. Clinical, hematological, and biochemical findings in puppies with coronavirus and parvovirus enteritis. *Canadian Veterinary Journal* **54**: 885-88.

Caswell M. 2011. Transitional cell carcinoma of the urinary bladder in a 14-year-old dog. *Canadian Veterinary Journal* **32**(6):673-75.

Center S. 1996. Diagnostic procedures for evaluation of hepatic disease. In: Grant Guilford W, Center S A, Strombeck D R, *et al* (eds.) Strombeck's small animal gastroenterology. 3rd Edn. Pp 136-43. Philadeiphia, Pa: WB Saunders Co.

Chikazawa S, Nakazawa T, Hori Y, Hoshi F, Kanai K, Ito N, Orino K, Watanabe K and Higuchi, S. 2013. Changes in serum ferritin concentration in experimentally induced anemia of chronic inflammation in dogs. *Journal Veterinary Medicine Science* **75**(11): 1419-26.

Choudhary S, Muralidhara A, Yathiraj S, D'Souza P E and Sengupta P P. 2015. Clinical, Hemato-Biochemical Alterations, Diagnosis and Management of Canine Ehrlichiosis. *Intas Polivet* **16**(2): 336-39.

Cizmeci S U, Kose A M, Aydin I, Dinc D A, Maden M and Kose S I. 2012. Clinical efficiency of Doxorubicin and Cisplatin in treatment of transmissible venereal tumour of bitches. *Revue de médecine vétérinaire* **163**(11): 516-21.

Cox J C and Joshua J O. 1979. Gential System. In: Startup W G, Sutton J B and Turenor W D (Eds.) Canine Medicine and Therapeutics. 1st Edn. Pp 351-61. Blackwell Scientific, London.

Crnogaj M, Petlevski R, Mrljak V, Kis I, Torti M, Kucer N. *et al.* 2010. Malondialdehyde levels in serum of dogs infected with *Babesia canis*. *Veterinary Medicine* **55**(4):163-171.

Dabhi D M., Dhami A J, Tank P H and Kelawala N H. 2007. Effect of Ovario-hysterectomy on serum enzymatic and hormonal profi le in bitches suffering from pyometra. *Indian Journal of Animal Reproduction* **28**(2): 1-6.

Das M R, Patra R C, Senapati S K and Rath P K. 2017. Haemato-biochemical alterations in the geriatric dogs with chronic kidney disease. *Indian Veterinary Journal* **94**(07): 21-23.

Dash S, Das M R, Sathapathy1 S, Patra R C, Senapati S K and Jena G R. 2017. Haematological, serum biochemical alterations and efficacy of different therapeutic regimens in haemorrhagic gastroenteritis with special reference to canine parvo virus infection. *Global Journal of bio-science and Biotechnology* **6**(2): 267-71.

Davies O, Szladovits B, Polton G, Garden O A, Leo A and Lara-Garcia C. 2018. Prognostic significance of clinical presentation, induction and rescue treatment in 42 cases of canine centroblastic diffuse large B-cell multicentric lymphoma in the United Kingdom. *Veterinary Comparitive Oncology* **16**:276–87.

Deb A R, Jha M K and Prasad K D. 2000. Clinical and haematological changes in dogs infected with *Demodex canis*. *Journal of Research Birsa Agricultural University* **12**(2): 281-83.

Deepti B R and Yathiraj S. 2015. hematological and biochemical variables in congestive heart failure in dogs. *International Journal of Science, Environment and Technology* **4**(3): 836-40

Devipriya K, Lavanya C, Selvaraj P and Ezakial Napolean R. 2018. Early diagnosis of renal insufficiency in dogs with haemato: Biochemical findings. *Journal of Entomology and Zoology Studies* **6**(5): 703-05.

Dharmadheeran J S, Kumar M and Shukla S K. 2003. Monitoring Haematobiochemical parameter in experimental canine parvovirus infection. *Indian Veterinary Journal* **23**(1): 9-11.

Dimri U, Sharma M C, Dwivedi P and Sharma B. 2006. Clinico-pathological changes in canine demodicosis with particular reference to Dectomax therapy. *Indian Journal of Veterinary Pathology* **30**(1): 13-15.

Eichenberger R M, Riond B, Willi B, Hofmann-Lehmann R and Deplazes P. 2016. Prognostic Markers in Acute Babesia canis Infections. *Journal of Veterinary International Medicine* **30**:174–82.

Elhiblu M A, Dua K, Mohindroo J, Mahajan S K, Sood N K and Dhaliwal P S. 2015. Clinico-haemato-biochemical profile of dogs with liver cirrhosis. *Veterinary World* **8**(4): 487-91.

Elliott J and Villiers E. 2018. Indolent, T-cell, large granular lymphocytic leukemia in a dog presenting with severe neutropenia and an absence of lymphocytosis. *Open Veterinary Journal* **8:** 118-24.

Ezeibe M C O and Udegbunam R I. 2008. Haematology of dogs infected with canine distemper virus. *Sokoto Journal of Veterinary Sciences* **7**(2): 31-33.

Farabaugh A E, Freeman L M, Rush J E and George K L. 2004. Lymphocyte subpopulations and hematologic variables in dogs with congestive heart failure. *Journal of Veterinary International Medicine* **18**: 505-09.

Ferrer R. 1998. Lymphadenopathy: Differential Diagnosis and Evaluation. *American Family Physician* **58**: 1313-20.

Fonseca J P, Bruhn F R P, Ribeiro M J M, Hirsch C, Rocha C M B, Guedes E and Guimarães A M. 2017. Hematological parameters and seroprevalence of *Ehrlichia canis* and *Babesia vogeli* in dogs. *Ciencia Animal Brasileira* **18**: 1-9.

Fransson B, Lagerstedtt A S, Hellmen E and Jonsson P. 1997. Bacteriological Findings, Blood Chemistry Profile and Plasma Endotoxin Levels in Bitches with Pyometra or other Uterine Diseases. *Journal of Veterinary and Medicine* **44**: 417-26.

Frezoulis P S, Angelidou E, Karnezi D, Oikonomidis I L, Kritsepi-Konstantinou M, Kasabalis D and Mylonakis M E. 2017. Canine pancytopoenia in a Mediterranean region: a retrospective study of 119 cases (2005 to 2013). *Journal of Small Animal Practice* **58**(7):395-402.

Gandini S, Ferrucci P F, Botteri E, Tosti G, Barberis M, Pala L, Battaglia A, Clerici1 A, Spadola G, Cocorocchio E and Martinol C. 2016. Prognostic significance of hematological profiles in melanoma patients. *International Journal of Cancer* **139:** 1618-25.

Garland M. 2011. Common morphological changes seen in canine and feline haematology – leukocytes. *Veterinary Nursing Journal* **26**: 85-87.

Gianopoulos A, Mylonakis M E, Theodorou K and Christopher M M. 2016. Quantitative and qualitative leukocyte abnormalities in dogs with experimental and naturally occurring acute canine monocytic ehrlichiosis. *Veterinary Clinical Pathology* **45:** 281-90.

Girmabirhan and Mersha C. 2015. A reveiw on canine transmissible venereal tumour from morphologic to biochemical and molecular diagnosis. *Academic Journal of Animal Diseases.* **3**:185-95.

Gonde S, Chhabra S, Singla L D and Randhawa C S. 2017. Clinico-haemato-biochemical changes in naturally occurring canine babesiosis in Punjab, India. *Malaysian Journal of Veterinary Research* **8**(1): 37-44.

Grigonis A, Macijauskas V and Zamokas G. 2002. Examination of liver functions in dogs with parvovirus enteritis. *Veterinarija Ir Zootechnika* **17**: 23-28.

Gupta S K, Bhardwaj R K, Singh R, Raina A K and Avinash K. 2002. Management of canine babesiosis - A case report. *Indian Journal of Veterinary Medicine* **22:**124.

Harvey J W. 2012. *Veterinary Hematology: A Diagnostic Guide and Color Atlas.* Pp 191-233. St. Louis, Mo, Elsevier/Saunders.

Herder J D and Prasse K W. 1972. Leukocyte Response in the Dog and Cat. *Iowa State University Veterinarian* **34**(2): 74-78.

Jacob E A. 2016. Complete Blood Cell Count and Peripheral Blood Film, Its Significant in Laboratory Medicine: A Review Study. *American Journal of Laboratory Medicine* **1**(3): 34-57.

Jain K J, Lakshmanan B, Syamala K, Praveena J E and Aravindakshan T. 2017. High prevalence of small *Babesia* species in canines of Kerala, South India. *Veterinary World* **10**(11): 1319-23.

Jain N C, Blue J T, Grindem C B, Harvey J W, Kociba G J, Krehbiel J D, Latimer K S, Raskin R E, Thrall M A and Zinkl J G. 1991. Proposed Criteria for Classification of Acute Myeloid Leukemia in Dogs and Cats. *Veterinary Clinical Pathology* **20**(3): 63-82.

Jain N C. 1986. The Dog: Normal Hematology with comments on Response to disease. In: *Schalms Veterinary Hematology*. 4th Edn. Pp 104. Lea and Febiger, Philadelphia.

Jan A, Wani S A, Ashraf T, Nisar M, Taifa S, Parray O R and Nabi S U. 2018. Studies on hemato-biochemical, radiological and echocardiographic changes in geriatric canine heart failure. *Journal of Pharmacognosy and Phytochemistry* **7**(2): 1197-1200.

Janus A, Tresamol P V, Mercey K A, Habeeb Biju P and Shameem H. 2014. A study on clinical and haematobiochemical parameters in canine demodicosis. *Indian Journal of Canine Practice* **6**(1): 92-94.

Jena B, Rao K S, Reddy K C S and Raghavender K B P. 2013. Physiological and haematological parameters of bitches affected with pyometra. *Veterinary World* **6**(7): 409-12.

Jitpean S, Strom-Holst B, Emanuelson U, Hoglund O V, Pettersson A, Alneryd-Bull C and Hagman R. 2014. Outcome of pyometra in female dogs and predictors of peritonitis and prolonged postoperative hospitalization in surgically treated cases. *BMC Veterinary Research* **10**: 1-12.

Kabuusu R M, Stroup D F and Fernandez C. 2010. Risk factors and characteristics of canine transmissible venereal tumours in Grenada, West Indies. *Veterinary and Comparative Oncology*. **8**(1): 50-55.

Kalli I, Leontides L S, Mylonakis M E, Moraitou K A, Rallis T and Koutinas A F. 2010. Factors affecting the occurrence, duration of hospitalization and final outcome in canine parvovirus infection. *Research in Veterinary Science* **89**: 174–78.

Kandula S and Karlapudi S K. 2015. Haemato-biochemical changes in dogs with renal insufficiency and its diagnostic significance. *Animal Science Reporter* **9**(4): 156-60.

Kaneko J J, Harvey J W and Bruss H L. 2008. *Clinical Biochemistry of Domestic animals*. 6th Edn. Elsevier Academic Press Publications, New York.

Kaneko J J, Harvey J W and Bruss M L. 1997. Clinical Biochemistry of Domestic Animals. 5th Edn. Academic Press, London.

Karunanithy M, Thakur N and Dey S. 2019. Prevalence of renal disorders in dogs of Bareilly area of Uttar Pradesh, India. *Biological Rhythm Research* :1-11.

Kayar A, Dokuzeylul B, Iskefli O, Bayrakal A, Saka S U, Yildirim F and Gurel A. 2018. Clinical features, haematologic parameters, blood serum biochemistry results and thymidine kinase activity of dogs affected by malignant lymphoma in Turkey. *Japanese Journal of Veterinary Research* **66:** 227-38.

Kebede A A and Getaneh F B. 2015. Patterns of ultrasound findings in abdominal lymphoma patients at tikur anbessa specialized hospital, addis ababa, Ethiopia. *Ethiopia Medicine Journal* **53:** 199-207.

Khomeriki S G and Morozov I A. 1998. Ultrastructural Changes of Neutrophilic Granulocytes in Dilated Cardiomyopathy and Their Dynamics after Blood Irradiation with Helium-Neon Laser in vitro. *Arkhiv Patologii* **60** (3): 28-31.

Kline T S and Kannan V. 1982. Aspiration Biopsy Cytology and Melanoma. *American Journal of Clinical Pathology* **77:** 597–601.

Kralova S, Lenka L and Toman M. 2010. Changes in lymphocyte function and subsets in dogs with naturally occurring chronic renal failure. *The Canadian Journal of Veterinary Research* **74**(2): 124-29.

Kramer J W and Hoffman W E. 1997. Clinical enzymology. In: Kaneko J, Harvey J and Bruss M (eds) Clinical Biochemistry of Domestic Animals. Pp 330. Academic Press London.

Kumar A, Das A K, Arya S K D, Sinha M, Kumar A and Kumar B. 2018. The study of various haematological and biochemical parameters in pre and post treated dogs affected with demodectic mange. *International Journal of Current Microbiology and Applied Sciences* **7**: 4222-31.

Kumar M. 2013. Studies on urinary tract disorders in dogs in Jammu. M.V.Sc. thesis submitted to Division of Veterinary Medicine, Faculty of Vety. Sc., SKUAST (J), R.S. Pura, Jammu.

Kumar P and Kumar A. 2018. Haemato-biochemical changes in dogs infected with *Babesiosis. International Journal of Chemical Studies* **4**: 25-28.

Kumar V V V A, Kumari K N, Kumar K S, Kumar V G and Lakshman M. 2017. Hemato-biochemical changes in transmissible venereal tumours (TVT) affected dogs. *The Pharma Innovation Journal* **6:** 313-15.

Kumar V V V A, Kumari K N, Kumar K S, Kumar V G and Lakshman M. 2018. Hemato-biochemical changes in mammary tumors affected dogs. *The Pharma Innovation Journal* **7**: 187-89.

Kuplulu S, Vural M R, Demirel A, Polat M and Akçay A. 2009. The comparative evaluation of serum biochemical, haematological, bacteriological and clinical findings of dead and recovered bitches with pyometra in the postoperative process. *Acta Veterinaria* **59(**23): 193-204.

Lakshmikanth T R, Murthy V C, Honnappa T G, Narayanaswamy H D, Rathnamma and Kantharaj S. 2016. Physiological and hematobiochemical changes in open and closed pyometra in female dogs. *International Journal of Applied and Pure Science and Agriculture* **2**(3): 95-97.

Lambert J L, Fernandez N J and Roy M F. 2016. Association of presence of band cells and toxic neutrophils with systemic inflammatory response syndrome and outcome in horses with acute disease. *Journal of Veterinary Internal Medicine* **16**(30): 1284-92.

Lamy T, Moignet A and Loughran T P Jr. 2017. LGL leukemia: from pathogenesis to treatment. *Blood* **129**: 1082-94.

Latimer K S and Rakich P M. 1989. Clinical interpretation of leukocyte responses. *Veterinary Clinics of North America: Small Animal Practice* **19**(4)**:** 637-68.

Latimer K S. 1995. Leukocytes in health and disease. In: Ettinger, S.J. and Feldman, E.C. (eds.) Text book of Veterinary Medicine. *Diseases of dog and cat*. Pp. 1057-63. W.B. Saunders Company, Philadelphia.

Lees G E, Brown S A, Elliot J, Grauer G F and Vaden S L. 2005. Assessment and management of proteinuria in dogs and cats: 2004 ACVIM forum consensus statement (small animal). *Journal of Veterinary International Medicine* **19**: 377–85.

Leifer C E and Matus R E. 1986. Canine Lymphoma: Clinical considerations. *Seminars in Veterinary Medicine and Surgery (Small Animal)* **1**: 43-50.

Lodh C and Das S. 2014. Diagnostic significance of haematobiochemical changes in canine dermatitis. *Indian Journal of Canine Practice* **6**(2): 99-102.

Ly J, Marticorena R and Donnelly S. 2004. Red blood cell survival in chronic renal failure. *American Journal of Kidney Diseases* **44**(4): 715-19.

Martin M W S, Stafford Johnson M J and Celona B. 2009. Canine dilated cardiomyopathy: a retrospective study of signalment, presentation and clinical findings in 369 cases. *Journal of Small Animal Practices* **50**: 23–29.

McCoach C E, Rogers J G, Dwyre D M and Jonas B A. 2015. Paraneoplastic Leukemoid Reaction as a Marker of Tumor Progression in Non-Small Cell Lung Cancer. *Cancer Treatment and Communications* **4**: 15–18.

McDonough S P and Moore P F. 2000. Clinical, hematologic, and immunophenotypic characterization of canine large granular lymphocytosis. *Veterinary Pathology* **37:** 637-46.

McManus M P and Craig L E. 2001. Correlation between leukocytosis and necropsy findings in dogs with immune-mediated hemolytic anemia: 34 cases (1994–1999). *Journal of the American Veterinary Medical Association* **218**:1308–13.

Mohapatra A K, Das D, Panda S K, Jena B and Singh J.2016. Spontaneous Canine Mammary Neoplasia: A Clinico Pathological Study. *Journal of Cell and tissue Research* **16**: 5661-66.

Mojzisova J, Valocky I and Maracek I. 2000. Monitoring of selected immunological parameters in bitches with glandular cystic hyperplasia pyometra complex before and after ovariohysterectomy. *Polish Veterinary Science* **3**:23-27.

Mondal D, Pramanik A K and Basak D K. 2004. Clinico-haematology and pathology of caprine mycoplasmal pneumonia in rain fed tropics of West Bengal. Small Ruminant Research **51**: 285-95.

Morgenstern L, Rosenberg J and Geller S A. 1985. Tumors of spleen. *World Journal of Surgery* **9:** 468-76.

Morris J S, Dunn J K and Dobson J M. 1993. Canine lymphoid leukemia and lymphoma with bone marrow involvement: A review of 24 cases. *Journal of Small Animal Practice* **34**: 72-79.

Mrudula V, George V T, Balachandran C and Manohar B M. 2005. Bacteriological and histopathological study of canine nephritis on clinical samples. *Journal of Animal and Veterinary Advances* **4**(12): 954-58.

Mundim A V, Aparecida de Morais I, Tavares M, Cury M C, Mundim M J S. 2008. Clinical and hematological signs associated with dogs naturally Infected by Hepatozoon sp. and with other hematozoa: A retrospective study in Uberlandia, Minas Gerais, Brazil. *Veterinary Parasitology* **153**:3-8.

Muris J J, Meijer C J, Cillessen S A, Vos W, Kummer J A, Bladergroen B A, Bogman M J, MacKenzie M A, Jiwa N M, Siegenbeek van Heukelom L H, Ossenkoppele G J and Oudejans J J. 2004. Prognostic significance of activated cytotoxic T lymphocytes in primary nodal diffuse large B cell lymphomas. *Leukemia* **18**: 589-96.

Mutz M, Boudreaux B, Kearney M, *et al*. 2013. Prognostic value of baseline absolute lymphocyte concentration and neutrophil/lymphocyte ratio in dogs with newly diagnosed multi-centric lymphoma. *Veterinary and Comparative Oncology* **13:** 337-47.

Nath K, Tiwari S K and Kalim O. 2009. Physiological and haematological changes in bitches with Pyometra. *Indian Veterinary Journal* **86**: 734-36.

Neuwald E B, Teixeira L V, Conrado F O, Da Silva M O, Hlavac N R C and Gonzalez F H D. 2014. Epidemiological, clinical and immunohistochemical aspects of canine lymphoma in the region of Porto Alegre, Brazil. Pesq. *Vet. Bras* **34**: 349-54.

Ning J, Shao X, Ma Y and Lv D. 2016. Valuable hematological indicators for the diagnosis and severity assessment of Chinese children with community-acquired pneumonia prealbumin. *Medicine* **95**: 1-7.

Nivy R, Itkin Y, Bdolah-Abram T, Segev G and Aroch I. 2013. Neutrophil Counts and Morphology in Cats: A Retrospective Case-Control Study of 517 Cases. *Israel Journal of Veterinary Medicine* **68**(3): 149-57.

Nobin H, Ayubi A W, Chowdhury Z, Mishra J and Komut O. 2015. Leukemoid reaction as a "prognostic marker" in breast cancer and review of literature. *International Archives of Integrated Medicine* **2:** 119-22.

Novacco M, Comazzi S, Marconato L, Cozzi M, Stefanello D, Aresu L and Martini V. 2015. Prognostic factors in canine acute leukaemias: a retrospective study. *Veterinary and Comparative Oncology* **14**(4): 409-16.

Nwufoh O C, Sadiq N A and Emikpe B O. 2019. Clinicopathological and mineral changes associated with dogs infested with *Sarcoptes scabiei* var. *canis. Comparative Clinical Pathology* **28**(4): 1037-44.

Omobowale T O, Emikpe B O, Alaka O O and Nottidge H O. 2017. Haematological changes and evidence of multiple organ involvement in natural *Babesiosis* in Nigerian dogs. *Animal Research International* **14**(1): 2604-10.

Osborne C A, Low D G and Finco D R. 1972. Canine and Feline Urology. W.B. Saunders company. *Philadelphia* **310**: 39-84.

Oscier D G, Matutes E, Copplestone A, Pickering R M, Chapman R, Gillingham R, Catovsky D and Hamblin T J. 1997. Atypical lymphocyte morphology: an adverse prognostic factor for disease progression in stage A CLL independent of trisomy 12. *British Journal of Haematology* **98:** 934-39.

Oudejans J J, Jiwa N M, Kummer J A, Ossenkoppele G J, Heerde P van, Baars J W, Kluin Ph M, Kluin-Nelemans J C, Diest P J van, Middeldorp J M and Meijer C J L M. 1997. Activated cytotoxic T cells as prognostic marker in Hodgkin's disease. *Blood* **89:** 1376-82.

Palmer L, Briggs C, Mcfadden S, Zini G, Burthem J, Rozenberg G, Proytcheva M, Machin S J. 2015. ICSH recommendations for the standardization of nomenclature and grading of peripheral blood cell morphological features. *International Journal of Laboratory Hematology* **37**: 287-303.

Panda C, Dehuri M, Panda M R, Panda S K. 2017. Clinico-haematological alterations in babesiosis infected dogs in and around Bhubaneswar, Odisha. *Global Journal of Bio-science and Biotechnology* **6**(3): 466-69.

Pandolfi F, Loughran T P Jr, Starkebaum G, Chisesi T. Barbui T, Chan W C, Brouet J C, *et al,* 1990. Clinical course and prognosis of the lymphoproliferative disease of granular lymphocytes. A multicenter study. *Cancer* **65**: 341-48.

Pankaj G, Raghunath M, Gupta A K, Ankur S and Kawardeep K. 2014. Clinical study for diagnosis and treatment of canine mammary Neoplasms (CMNs) using different modalities. *Indian Journal of Animal Research* **48**(1):45-49.

Pathak K M L and Bhatia B B. 1986. Haematobiochemical and pathological changes in a dog with generalized demodecosis. *Indian Journal of Veterinary Medicine* **6**(1): 26-28.

Petrov E A, Ulcar I, Celeska I, Ilievska K, Trenkovska P S, Novakov T, Krstevski K, Dovenski T and Stefanovska J. 2018. Effects of doxycycline treatment on hematological and blood biochemical parameters in dogs naturally infected with *Ehrlichia canis. Macedonian Veterinary Review* **41**(1): 99-105.

Polzin D J, Osborne C A, Jacob F and Ross S. 2000. Chronic renal failure. In: Ettinger, S J. And Feldman E C (Eds) Textbook of Veterinary Internal Medicine. W.B. pp 1277-92. Saunders Co., Philadelphia.

Porrata L F, Ristow K, Habermann T, and David J. 2010. Predicting survival for diffuse large B-cell lymphoma patients using baseline neutrophil/lymphocyte ratio. *American Journal of Hematology* **85**: 896–99.

Pradeep K, Byathiraj S, Cramesh P T, Dleena G and Enarayanswamy H D. 2017. Clinico-hemato-biochemical and ultrasonographic alterations in dogs with non infectious hepatic disorders associated with hypoalbuminemia. *International Journal of Advanced Biotechnology Research* **7**(3): 585-89.

Pradhan N R and Roy S. 2012. Chronic renal failure in dogs and its management. *Indian Journal of Canine Practice* **4**(2): 88-92.

Priyanka M, Dey S and Saxena M. 2019. Darbepoietin alpha ameliorates oxidative/nitrosative stress, decreases apoptosis, and improves clinical outcome in chronic canine monocytic ehrlichiosis. *Comparative Clinical Pathology* **28**: 215–24.

Punia M, Kumar A, Charaya G and Sindhu N. 2018. Haemato-Biochemical Alterations in Dogs Afflicted with Urinary Tract Infection. *Journal of Animal Research* **8**(5): 837-40.

Qurollo B A, Davenport A C, Sherbert B M, *et al*. 2013. Infection with Panola Mountain *Ehrlichia* sp. in a dog with atypical lymphocytes and clonal T-cell expansion. *Journal of Veterinary Internal Medicine* **27:** 1251-55.

Rai A, Nauriyal D C and Rajesh M. 1994. A note on haematological observations in canine parvo viral gastroenteritis. *Indian Veterinary Journal* **13**:99.

Rajathi S, Ramani C, Nagarrajan L, Kumar R, Suresh and Ameerjan K. 2006. Urolithiasis in dogs: clinical, biochemical and haematological evaluation. *Indian Journal of Veterinary Surgery* **27**(2):128.

Ramirez S, Douglass J P, Robertson I D. 2002. Ultrasonographic features of canine abdominal malignant histiocytosis. *Veterinary Radiology and Ultrasound* **43**: 167-70.

Ravishankar N, MurliManohar B, Balachandran C, Sumitra M, Manikandan P and Puvanakrishnan R. 2004. Haemato-biochemical alterations and pathological changes in canine pyometra. *Indian Journal of Veterinary Pathology* **28**(1): 14-17.

Reddy B S, Kumari K N and Sivajothi S. 2014. Thyroxin Levels and Haematological changes in Dogs with Sarcoptic Mange. *The Journal of Advances in Parasitology* **1**(2): 27-29.

Reddy B S, Kumari K N, Rao V V, Rayulu V C and Sivajothi S. 2016. Symptomatology and haemato-biochemical changes in dogs suffering recurrent pyoderma. Malaysian Journal of Veterinay Research **7**(2): 35-42.

Reece William O. 2004. *Dukes' Physiology of Domestic Animals*. 12th Edn. Pp 999. Cornell University Press, Ithaca.

Rejec A, Butinar J, Gawor J and Petelin M. 2017. Evaluation of Complete Blood Count Indices (NLR, PLR, MPV/PLT, and PLCRi) in Healthy Dogs, Dogs with Periodontitis, and Dogs with Oropharyngeal Tumors as Potential Biomarkers of Systemic Inflammatory Response. *Journal of Veterinary Dentistry* **7**(2): 1197-1200.

Richardson P, et al. 1996. Report of the 1995 World Health Organization/International Society and Federation of Cardiology Task Force on the Definition and Classification of Cardiomyopathies. Circulation **93** (5): 841-42.

Richter K P. 2003. Disease of the liver and hepato biliary system. In: Jam T R (Eds) Handbook of Small Animal Gastroenterology. 2nd edn. Pp. 379–81. St. Louish, Missouri.

Robinson W F, Shaw S E, Stanley B, Huxtable C R, Watson A D J, Friend S E and Mitten R. 1989. Chronic renal disease in Bull terriers. *Australian Veterinary Journal* **66**(7): 193-95.

Roble E S L, Ybañez R H D, Yandug R S and Ybañez A P. 2016. Canine parvovirus infection and pet owner's perception: a case study in Cebu, Philippines. *International Journal of Scientific and Research Publications* **6**(2): 77-84.

Rocha M N A, de Sousa Rocha M C, Kavasaki M L, Rodrigues J Y, de Souza W F and Mendonça A J. 2019. Thrombocytosis: a retrospective study of 573 dogs (2016-2017). *Ciência Animal Brasileira* **20**: 1-10.

Roland L, Drillich M and Iwersen M. 2014. Haematology as a diagnostic tool in bovine medicine. *Journal of Veterinary Diagnostic Investigation* **26**(5): 592-98.

Roopali B, Roy M and Roy S. 2018. Haemato-biochemical changes and therapeutic management of urinary tract infection in canines. *The Pharma Innovation Journal* **7**(6): 89-92

Ross S J, Osborne C A and Lekcharoensuk C. 2007. A case-control study of the effects of nephrolithiasis in cats with chronic kidney disease. *Journal American Veterinary Medicine Association* **230**: 1854-59.

Rothuizen J and Meyer H P. 2000. History, physical examination, and signs of liver disease. In: Ettinger, S.J. and Feldman, E.C. (Eds) Textbook of Veterinary Internal Medicine. 5th Edn, Vol. 2. Pp 1272-77. W. B. Saunders, Philadelphia.

Sahoo M, Panda S K, Sahoo N R, Mohapatra H K and Nath I. 2012. A clinico-pathological investigation on canine pyometra. *Indian Veterinary Journal* **89**(10): 21-22.

Sakina A, Mandial R K and Mudasir Q. 2012. Haematobiochemical Changes in Canine Demodecosis. *Vetscan* **7**(1): 75-78.

Salem N Y and Farag H S. 2014. Clinical, Hematologic, and Molecular Findings in Naturally Occurring Babesia canis vogeli in Egyptian Dogs. *Veterinary Medicine International* **2014**: 1-6.

Salem N Y. 2014. Canine viral diarrhoea: Clinical and biochemical alterations with particular reference to in-clinic rapid diagnosis. *Global Veterinaria* **13**(3): 302-07.

Samantha G, Sarath T, Monica G, Arunmozhi N, Sridevi P and Joseph C. 2018. Ultrasonographic and Haemato-biochemical Evaluation of Bitches Affected with Cystic Endometrial Hyperplasia-Pyometra Complex. *International Journal of Current Microbiology and Applied Sciences* **7**(6): 2327-38.

Sampaio M S, Martin P and Bunnapradist S. 2014. Renal dysfunction in end-stage liver disease and post-liver transplant. *Clinical Liver Disease* **18**(3): 543-60.

Sant'Anna M c, Giordano L G P, Flaiban K K M C, Muller E E and Martins M I M. 2014. Prognostic markers of canine pyometra. *Arq. Bras. Med. Vet. Zootec.* **66**(6): 1711-17.

Saravanan M, Mondal D B, Sarma K, Mahendran K, Vijayakumar H and Sasikala V. 2014. Comprehensive study of haemato-biochemical, ascitic fluid analysis and ultrasonography in the diagnosis of ascites due to hepatobiliary disorders in dog. *Indian Journal of Animal Sciences* **84**(5): 503–06.

Sarma B K and Kalita D. 2019. Changes of haematological and biochemical parameters of canine having urinary system disorders. *International Journal of Chemical Studies* **7**(1): 501-04.

Schepper De J, Vanderstock J and Capiau E. 1987. Anaemia and leukocytosis in one one hundred and twelve dogs with pyometra. *Journal of Small Animal Practice* **28**: 137-45.

Schultze A E. 2010. Interpretation of canine leukocyte responses. In: D J Weiss and K J Wardrop (Eds) Schalm's Veterinary Hematology. 6th Edn. Pp: 321-34. Wiley-Blackwell, Ames, Iowa, USA.

Sesh P S L, Venkatesh P, Jeyaraja K, Chandrasekar M and Pandiyan V. 2014. Haematological Profile of Dilated Cardiomyopathy Affected Dogs. *Indian Veterinary Journal* **91**(1): 77-78.

Sesh P S L, Venkatesh P, Jeyaraja K, Chandrasekar M and Pandiyan V. 2013. Blood biochemical, enzymatic and haematological status of dogs affected with dilated cardiomyopathy. *International Journal of Advanced Veterinary Science and Technology* **2**(1): 47-51.

Shah M A, Pande N, Shah I A, Chibber S and Agarwal R. 2016. Pre and Post-operative haemato-biochemical changes in pyometric bitches. *Journal of Animal Research* **6**(5): 911-13.

Shah S A, Sood N and Tumati S R. 2011. Haemato-biochemical changes in natural cases of canine babesiosis. *Asian Journal of Animal Science* **5**(6):387-92.

Shah S A, Sood N K, Wani B M, Rather M A, Beigh A B and Amin U. 2017. Haemato-biochemical studies in canine pyometra. *Journal of Pharmacognosy and Phytochemistry* **6**(4): 14-17.

Shah S A, Sood N K, Wani N, Gupta K and Singh A. 2013. Haemato-biochemical changes in canine parvoviral infection. *Indian Journal of Veterinary Pathology* **37**(2): 131-33.

Sharma A, Ahuja A, Srivastava M and Kachhawa J P. 2015. Haemato-biochemical changes in Dogs suffering from chronic renal failure. *Indian Journal of Canine Practice* **7**(2):102-07.

Sharma R, Hussain K, Chhibber S, Kumar M and Singh R. 2015. Clinico-haematological and biochemical studies in allergic dermatitis in dogs. *Indian Journal of Canine Practice* **7**(2): 124-29.

Sharma R, Kumar A, Goel P and Kumar R. 2008. Clinical hematology in canine haemorrhagic gastroenteritis. *Haryana Veterinarian* **47**: 35-38.

Shipov A, Klement E, Reuveni-Tager L, Waner T and Harrus S. 2008. Prognostic indicators for canine monocytic ehrlichiosis. *Veterinary Parasitology* **153**: 131–38.

Silverberg D S, Wexler D and Blum M. 2002. The correction of anemia in severe resistant heart failure with erythropoietin and intravenous iron prevents the progression of both the heart and the renal failure and markedly reduces hospitalization. *Clinical Nephrology*. **58**(1): 37-45.

Solter P F, Hoffman W E, Chambers M D, Schaeffer D J and Kakuhlenschmidt M S. 1994. Hepatic total 3–alpha-hydroxy bile acids concentration and enzyme activities in prednisone treated dogs. *American Journal of Veterinary Research* **55**(8): 1086-92.

Srivastava M, Gaikwad R V, Samad A, Chaudhary P R, Lal H P and Srivastava A. 2011. Haematobiochemical changes in dog suffering from remal failure. *Indian Journal Veterinary Medicine* **31**(1): 9-11.

Stockham S L and Scott M A. 2008. Leukocytes. In: Fundamentals of Veterinary Clinical Pathology. 2nd Edn. Pp 53-106. Blackwell Publishing, Ames, IA, USA.

Stockham S L, Keeton K S and Szladovits B. 2003. Clinical assessment of leukocytosis: distinguishing leukocytosis caused by inflammatory, glucocorticoid, physiologic, and leukemic disorders or conditions. *The Veterinary Clinic Small Animal Practice* **33**: 1335-57.

Sumit, Goel P, Kumar P, Gulia D, Jhambh R, Sindhu N and Chaudhary R N. 2018. Haematobiochemical and serum electrolytes alteration in dogs with chronic kidney disease. *The Pharma Innovation Journal* **7**(11): 302-06.

Tantary H A, Soodan J S, Chirag S and Ansari M M. 2014. Haematological and Biochemical Studies on Hepatic Disorders in Dogs. *International Journal of Veterinary Science* **3**(3): 135-38.

Tasca S, Carlil E, Caldin M, Menegazzo L, Furlanello T, Gallego L S. 2009. Hematologic abnormalities and flow cytometric immunophenotyping results in dogs with hematopoietic neoplasia: 210 cases (2002–2006). *Veterinary Clinical Pathology* **38:** 2–12.

Tejeswini V, Kande S, Premalatha P and Rayapa reddy T. 2012 Correlation of granularity index with toxic granulation of neutrophils by manual microscopy and C-reactive protein. *Journal of Dental and Medical Sciences* **3:** 35-39.

Tennant B C and Center S A. 2008. Hepatic function. In: Kaneko J J, Harvey J W and Bruss M L (eds) Clinical Biochemistry of Domestic Animals. 6th Edn, pp 379–412. Elsevier Publication.

Thakur M and Thakur R. 2017. Haemato-biochemical alterations in canine Parvo virus infection affected pups. *Himachal Journal of Agricultural Research* **43**(2): 131-34.

Thangapandiyan M, Balachandran C and MuraliManohar B. 2013. Incidence and haemato - biochemical changes in canine lymphoma. *Tamilnadu Journal of Veterinary & Animal Sciences* **9:** 29-31.

Thangapandiyan M, Balachandran C, Jeyaraja K, Raja A and Sridhar R. 2017. Study on haematological alterations in canine lymphoma. *The Pharma Innovation Journal* **6**(10): 116-18.

Thapa G and Sarkar S. 2018. Occurrence of Canine Skin Disorder and Its Haematobiochemical Alterations. *International Journal Current Microbiology Application Science* **7**(12): 184-95.

Thirunavukkarasu P S, Srinivasan S R, Vijayalakshmi P, Vijaykumar G, Nambi A P, Vairamuthu S and Prathaban S. 2010. Clinical evaluation of ceftriaxone and tazobactam in canine urinary tract infection. *Intas Polivet* **11**(1): 84-85.

Thirunavukkarasu P, Nagarajan B, Subapriya S and Nagarajan K. 2018. Haematological and serum biochemical variables in canine congestive heart failure. *International Journal of Chemical Studies* **6**(6): 2881-82.

Todorova G, Simeonova R, Simeonov and Dinev D. 2005. Efficacy and toxicity of doxorubicin and cyclophosphamide chemotherapy in dogs with spontaneous mammary tumours. *Trakia Journal of Sciences* **3**: 51-58.

Verma P, Mahindroo J, Singh S S and Singh C B. 2006. Sonographic findings in affections of urinary system in dogs. *Indian Journal of Veterinary Surgery* **27**(2):104-07.

Vijaykumar G, Nambi A P, Vasu K and Dhanapalan P. 1999. Ultrasonographic diagnosis of cystic calculi in a dog- a case report. *Indian Veterinary Journal* **76(**5):438-39.

Vishnurahav R B, Ajithkumar S, Pillai U N, Madhvan Unny N, John Martin K D Aravindakshan T V and Sunanda C 2017. Haemato-biochemical changes associated with dilated cardiomyopathy in dogs – a retrospective study. *International Journal of Science Environment and Technology* **6**(6): 3377-81.

Vojta L, Mrljak V and Beck R. 2012. Haematological and biochemical parameters of canine hepatozoonosis in Croatia. *Veterinarski Arhiv* **82**(4): 359-70.

Wadhwa D R, Pal B, Mandial R K, Kumar A and Agnihotri R K. 2011. Clinical, haemato biochemical and therapeutic studies of canine Babesiosis in Kangra valley of Himachal Pradesh. *Journal of Veterinary Parasitology* **25**(1):39-41.

Washabau R. 2010. Laboratory tests for liver disease. *Veterinary Focus* **20(3)**: 32–37.

Webster C R L. 2005. History, clinical signs and physical findings in hepatobiliary disease. In: Ettinger S J and Feldman E C (Eds) Textbook of Veterinary Internal Medicine, diseases of dog and cat. 6th Edn. Pp: 1422-34. Elsevier Saunders, USA.

Weltan S M, Leisewitz A L and Goddard A. 2008. A case-controlled retrospective study of the causes and implications of moderate to severe leukocytosis in dogs in South Africa. *Veterinary Clinical Pathology* **37**(2): 164–72.

Yogeshpriya S, Pillai U N, Ajithkumar S and Madhavan Unny. 2018. Clinico-Haemato-Biochemical Profile of Dogs with Urinary Tract Infection: A Retrospective Study of 32 Cases (2010-2012). *International Journal of Current Microbiology and Applied Sciences* **7**(9): 2797-2802.

APPENDIX I

Procedure of Leishman stain

1. Prepare a blood smear on clean, grease free slide and air dry.
2. Pour leishman stain on the slide and wait for 2 minutes.
3. Add double the quantity of buffered water over the slide and mix.
4. Allow to stain for 15 to 20 minutes.
5. Wash in water for 1 to 2 minutes.
6. Dry in air and examine under oil immersion lens of the microscope.

Procedure of May Grunwald Giemsa stain

1. Prepare blood film on a grease free slide and air dry.
2. Treat the dried blood film with methanol for 3 to 5 minutes.
3. Stain slides with May-Grunwald stain solution for 7 to 8 minutes.
4. Add equal amount of distilled water, mix and stain for 2 minutes.
5. Take off fluid and without washing pour fresh buffer diluted Giemsa (50:50 dilution) stain for 15 to 20 minutes.
6. Rinse with a quick ample jet of water.
7. Air dry the smear and examine under oil immersion lens of the microscope.

Procedure of Papanicolau stain

1. Fix the smears immediately in 95% alcohol for 5 to 15 minutes.
2. Rinse in 70% alcohol, 50% alcohol and distilled water.
3. Stain in Harris haematoxylin for 10 to 15 minutes.
4. Rinse in distilled water.
5. Rinse in acid alcohol (only dip).
6. Rinse thoroughly in water.
7. Leave for 1 minute in a weak solution of lithium carbonate (3 drops saturated aqueous solution / 100 ml water). Rinse thoroughly in water.
8. Rinse in distilled water, 50% alcohol, 70% alcohol, 80% alcohol and 95% alcohol.
9. Stain for 30 seconds to 1 minute in the Papanicolau Orange G-6 solution.
10. Rinse 5 to 10 times in each of two jars containing 95% alcohol.
11. Stain in Papanicolau EA36 for 10 to 15 minutes.
12. Rinse 5 to 10 times in each of three jars containing 95% alcohol (not the same alcohol that was used after orange G-6 solution).
13. Rinse in absolute alcohol and then in xylene.
14. Mount with DPX and observe under microscope.

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