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HEMATOLOGICAL ABNORMALITIES AND THEIR ASSOCIATION WITH CD4 COUNT AMONG PEOPLE LIVING WITH HIV/AIDS: A CROSS-SECTIONAL STUDY

Shubhangi V. Swami[1], Pravin R. Bhagat[2], Sharad B. Sonawane[3]

[1]*Associate Professor, Department of Pathology, Government Medical College, Dharashiv, Maharashtra, India.*
[2]*Assistant Professor, Department of General Medicine, MIMSR Medical College, Latur, Maharashtra, India.*
[3]*Assistant Professor, Department of General Medicine, MIMSR Medical College, Latur, Maharashtra, India.*

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Corresponding Author:
Dr. Shubhangi V. Swami,
Associate Professor, Department of Pathology, Government Medical College, Dharashiv, Maharashtra, India.
Email: svswami86@gmail.com

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ABSTRACT

Background: Human immunodeficiency virus (HIV) infection is associated with a wide spectrum of hematological abnormalities, which may become more prominent with progressive immunosuppression. Although CD4 lymphocyte count remains an important indicator of immune status, routine hematological investigations may provide useful supplementary information regarding disease severity. This study was undertaken to evaluate the hematological profile of people living with HIV/AIDS (PLHA) and determine its association with CD4 lymphocyte count.

Materials and Methods: A hospital-based observational cross-sectional study was conducted in the Department of Pathology in collaboration with the ART Centre of a tertiary care hospital. A total of 100 consecutive HIV-positive patients aged >12 years, of either sex, were included irrespective of antiretroviral treatment status. Patients with previously diagnosed hematological disorders, pregnant women, those unwilling to participate, and those with inadequate samples were excluded. Complete hemogram, peripheral blood smear examination and CD4 lymphocyte estimation by flow cytometry were performed. Hematological parameters were expressed as frequencies and percentages or mean ± standard deviation. Associations between hematological abnormalities and CD4 categories were assessed using Chi-square/Fisher's exact test, with $p<0.05$ considered statistically significant.

Results: Among the 100 participants, 80 (80%) were males and 20 (20%) were females, with a mean age of 33.8 years. The majority belonged to the 31–40-year age group (44%), followed by 21–30 years (30%). The mean hemoglobin level was 10.02 g/dL; 35% had hemoglobin >6–≤9 g/dL and 12% had hemoglobin ≤6 g/dL. Leukopenia (TLC <4000/µL) was present in 40% of participants, while platelet count ≤1.5 lakh/µL was observed in 31%. The mean CD4 count was 135.14 cells/µL, and 82% had CD4 counts ≤200 cells/µL. Leukopenia was significantly more frequent among patients with CD4 ≤200 cells/µL than those with CD4 >200 cells/µL (45% vs. 20%; p=0.041). Lymphocyte percentage ≤20% was also significantly more common in the lower CD4 group (50% vs. 15%; p=0.03). Hemoglobin category (p=0.119), neutrophil percentage (p=0.618) and platelet count (p=0.102) were not significantly associated with CD4 category. Morphological type of anemia showed a significant association with CD4 count (p=0.0358).

Conclusion: Hematological abnormalities were common among PLHA, particularly in those with lower CD4 counts. Leukopenia and reduced peripheral lymphocyte percentage showed significant associations with advanced immunosuppression, while other hematological parameters demonstrated variable relationships. Routine hematological evaluation may provide useful

supportive information regarding immunological status, although it cannot replace direct CD4 estimation.
Keywords: Human immunodeficiency virus; HIV/AIDS; Hematological abnormalities; CD4 lymphocyte count; Anemia; Leukopenia; Lymphopenia; Thrombocytopenia; Peripheral blood smear; Immunosuppression.

INTRODUCTION

Human immunodeficiency virus (HIV) infection remains an important global public health problem and is characterized by progressive impairment of the immune system, predominantly through depletion and dysfunction of CD4-positive T lymphocytes. The CD4 cell count is an important marker of immune status and disease progression in people living with HIV/AIDS (PLHA). Progressive decline in CD4 count increases the susceptibility to opportunistic infections, malignancies and other HIV-associated complications. Although viral load is currently the principal laboratory marker for monitoring response to antiretroviral therapy (ART), CD4 cell count continues to provide important information regarding the degree of immunosuppression, particularly in individuals with advanced HIV disease.[1]

HIV infection is associated with a wide spectrum of hematological abnormalities involving erythroid, myeloid and megakaryocytic cell lines. Anemia, leukopenia, lymphopenia, neutropenia and thrombocytopenia are among the commonly reported abnormalities. These abnormalities may occur because of direct effects of HIV on hematopoietic tissues, immune-mediated destruction of blood cells, impaired hematopoiesis, nutritional deficiencies, chronic inflammation, opportunistic infections, malignancies and adverse effects of medications used in HIV management.[2] Hematological abnormalities tend to become more prominent with advanced immunosuppression and may therefore provide useful clinical information regarding the underlying disease status.[3]

Anemia is considered the most frequent hematological abnormality among PLHA. Its severity has been associated with progression of HIV infection and reduced CD4 cell counts. The mechanisms are multifactorial and include anemia of chronic inflammation, iron deficiency, nutritional deficiencies, opportunistic infections, renal dysfunction, bone marrow suppression and drug-related effects. In an Indian study of 200 HIV-infected individuals, anemia was observed in 65.5% of patients, with evidence of both iron deficiency and anemia of chronic disease. A strong negative correlation between hemoglobin levels and CD4 count was also reported, suggesting that worsening anemia may accompany increasing immunosuppression.[4]

Leukocyte abnormalities are also frequently encountered in HIV infection. Leukopenia and neutropenia may result from HIV-associated marrow dysfunction, immune-mediated mechanisms, opportunistic infections and myelosuppressive medications. Lymphopenia is particularly relevant because HIV selectively affects CD4-positive T lymphocytes, although absolute lymphocyte counts may not always accurately reflect the CD4 cell population. Previous studies have demonstrated that abnormalities in leukocyte and lymphocyte parameters become more frequent as immunosuppression progresses.[5]

Thrombocytopenia is another recognized hematological manifestation of HIV infection. It may occur through immune-mediated platelet destruction, increased platelet consumption and impaired platelet production. The prevalence and severity of thrombocytopenia vary according to the stage of HIV infection, associated infections and treatment status. A review of the literature reported thrombocytopenia in approximately 4.5–26.2% of PLHA and noted that its occurrence was more pronounced in individuals with CD4 counts below 200 cells/µL, higher viral loads and concomitant infections.[6]

Several studies have specifically investigated the association between hematological parameters and CD4 cell count. Parinitha and Kulkarni, in a study of 250 HIV-positive patients, reported anemia in 84%, lymphopenia in 65.2% and thrombocytopenia in 18% of patients. Among individuals with CD4 counts below 200 cells/µL, anemia, leukopenia and lymphopenia were particularly frequent. The authors observed increasing hematological abnormalities with disease progression and reported a significant association between absolute lymphocyte count and CD4 count.[5]

More recently, Bhardwaj et al. evaluated hematological abnormalities and their relationship with CD4 counts in HIV/AIDS patients in Jammu, India. Anemia was found in 72.5% of participants, while leukopenia, lymphopenia and thrombocytopenia were observed in 18.33%, 49.17% and 15.83%, respectively. Significant associations were identified between CD4 count and anemia, absolute lymphocyte count and thrombocytopenia, whereas total leukocyte count and absolute neutrophil count did not demonstrate significant relationships with CD4 count.[7]

The relationship between hematological abnormalities and immune status is not entirely consistent across different populations. For example, studies from India and other settings have reported significant associations between declining CD4 counts and anemia or thrombocytopenia, while other studies have not demonstrated a significant relationship for particular hematological parameters.[4,5,8] Such differences may be explained by variations in nutritional status, ART exposure, duration of HIV infection, opportunistic infections, comorbidities, geographical characteristics and

differences in study populations. Therefore, evaluation of hematological parameters together with CD4 count may provide a more comprehensive assessment of the clinical and immunological status of PLHA.[8]

Routine hematological investigations are relatively inexpensive, widely available and can be performed even in resource-constrained healthcare settings. Complete blood count parameters such as hemoglobin, total leukocyte count, differential leukocyte count, absolute lymphocyte count and platelet count may therefore provide useful supplementary information about disease status. Although hematological parameters cannot replace CD4 estimation or viral-load testing, identification of cytopenias may facilitate early recognition of patients requiring further evaluation for nutritional deficiencies, opportunistic infections, drug toxicity or other complications. Current HIV management guidance also emphasizes laboratory monitoring for both immunological status and treatment-related hematological abnormalities.[9]

Despite advances in ART and improved survival among PLHA, hematological abnormalities continue to contribute to morbidity and may adversely affect quality of life.[6] Understanding their relationship with CD4 cell count is particularly relevant in clinical settings where resource limitations may affect the frequency or availability of sophisticated investigations. Hence, the present study was undertaken to evaluate the **hematological parameters among people living with HIV/AIDS and to determine their association with CD4 cell count**, with the aim of identifying hematological changes that may reflect the degree of underlying immunosuppression.

Objectives of the Study

Primary Objective

1. To study the hematological profile of people living with HIV/AIDS (PLHA) and determine its association with CD4 lymphocyte count.

Secondary Objectives

1. **To determine the prevalence and pattern of hematological abnormalities, including anemia, leukopenia, lymphopenia, neutropenia and thrombocytopenia, among PLHA.**
2. To compare the hematological parameters among PLHA with different CD4 count categories.
3. To assess the relationship between hemoglobin, total leukocyte count, absolute lymphocyte count, platelet count and CD4 lymphocyte count.
4. To identify the hematological abnormalities associated with advanced immunosuppression (CD4 count <200 cells/µL).
5. To study the peripheral blood smear findings among PLHA and correlate abnormal findings with CD4 count.

MATERIALS AND METHODS

Study design and study setting

The present study was a **hospital-based observational cross-sectional study** conducted in the Department of Pathology in collaboration with the ART Centre of a tertiary care hospital and referral centre. The study was undertaken after obtaining permission from the Institutional Ethics Committee and the concerned authorities of the ART Centre/NACO.

The study included **100 consecutive HIV-positive patients** attending the ART Centre during the study period. The study was designed to evaluate the hematological profile of people living with HIV/AIDS (PLHA) and to determine the association between various hematological parameters and CD4 lymphocyte count.

Study population

The study population consisted of HIV-positive patients aged **more than 12 years**, of either sex, attending the ART Centre during the study period. Patients were included irrespective of their antiretroviral treatment status. This approach was adopted to assess hematological abnormalities across the spectrum of HIV infection and immunological status. The source document similarly included HIV-positive patients aged >12 years of either sex irrespective of ART status.

Sample size

A total of **100 consecutive HIV-positive patients** fulfilling the predefined inclusion and exclusion criteria were enrolled in the study.

Sampling technique

Patients were recruited using a **consecutive sampling technique**. Every eligible HIV-positive patient attending the ART Centre during the study period was considered for inclusion until the required sample size was achieved.

Inclusion Criteria

The following patients were included:

1. HIV-positive patients aged **>12 years**.
2. Patients of either sex.
3. Patients attending the ART Centre of the tertiary care hospital.
4. Patients diagnosed as HIV-positive according to the prevailing WHO/NACO diagnostic criteria.
5. Patients irrespective of their antiretroviral treatment status.
6. Patients who provided informed consent to participate in the study.

These criteria were based on the methodology of the provided document.

Exclusion Criteria

Patients fulfilling any of the following criteria were excluded:

1. Patients with a **previously diagnosed hematological disorder**.
2. Pregnant females.
3. Patients who did not provide consent for participation.

4. Patients in whom adequate blood samples could not be obtained for hematological investigations and CD4 estimation.

The first two exclusion criteria were specifically included in the source document.

Ethical considerations

The study was conducted after obtaining approval from the **Institutional Ethics Committee** and necessary permission from the concerned ART Centre/NACO authorities. The purpose and procedures of the study were explained to each participant in a language that was easily understood. Written informed consent was obtained before enrolment. Confidentiality of patient information was maintained throughout the study, and each participant was assigned a study identification number.

Data collection

Data were collected using a **pre-tested, structured proforma** prepared according to the objectives of the study. The source document also specifies the use of a pre-tested proforma for data collection.

The following information was recorded:

- Age
- Sex
- Relevant sociodemographic details
- Duration of HIV infection, wherever available
- Antiretroviral treatment status
- Relevant clinical history
- History of opportunistic infections
- Relevant treatment history
- Hematological investigation findings
- CD4 lymphocyte count

A detailed history was obtained from each participant, including relevant risk factors and clinical complaints. A thorough physical examination was subsequently performed. Appropriate laboratory investigations were carried out according to the study protocol.

Hematological investigations

Venous blood samples were collected under aseptic precautions from all enrolled participants.

A **complete hemogram** was performed, which included assessment of:

- Hemoglobin concentration
- Total leukocyte count
- Differential leukocyte count
- Red blood cell indices, wherever available
- Platelet count

A peripheral blood smear examination was also performed to assess red cell morphology, leukocyte morphology and platelet adequacy and to identify any abnormal hematological findings. Complete hemogram with peripheral smear examination was included in the original study methodology.

Hematological abnormalities were classified according to standard laboratory reference ranges. Anemia, leukopenia, neutropenia, lymphopenia and thrombocytopenia were documented wherever present.

Bone marrow examination

Bone marrow aspiration/biopsy was performed whenever clinically indicated, particularly in patients with unexplained or severe cytopenias or suspected marrow pathology. This was also included as an investigation in the source methodology.

CD4 lymphocyte count

CD4-positive T-lymphocyte counts were estimated using flow cytometry by standard technique. In the source study, CD4 lymphocyte estimation was performed using a Becton-Dickinson FACScan flow cytometer.

The CD4 count was recorded as cells/µL and was subsequently used to assess the relationship between the degree of immunosuppression and individual hematological parameters.

For analysis, participants may be categorized according to CD4 count into clinically relevant immunological categories, such as:

- **<200 cells/µL**
- **200–499 cells/µL**
- **≥500 cells/µL**

This categorization permits comparison of the prevalence and severity of hematological abnormalities across different levels of immunosuppression.

Study variables

The principal independent variable was **CD4 lymphocyte count**. The dependent variables included hematological parameters such as:

1. Hemoglobin
2. Total leukocyte count
3. Absolute lymphocyte count
4. Absolute neutrophil count
5. Platelet count
6. Peripheral smear findings
7. Presence or absence of anemia
8. Presence or absence of leukopenia
9. Presence or absence of thrombocytopenia

Additional demographic and clinical variables were considered for descriptive analysis and assessment of potential associations.

Statistical Analysis

The collected data were entered into a computerized database and analysed using appropriate statistical software.

Categorical variables were expressed as **frequency and percentage**, whereas continuous variables were expressed as **mean ± standard deviation (SD)**.

The association between categorical hematological abnormalities and CD4-count categories was assessed using the **Chi-square test** or **Fisher's exact test**, wherever appropriate. For comparison of continuous variables between two groups, an **unpaired Student's t-test** was used when the data satisfied the assumptions of parametric testing. Where appropriate, correlation analysis was performed to determine the relationship between CD4 count and individual hematological parameters.

The original methodology similarly used percentages, mean, standard deviation, standard error, unpaired *t* test, Chi-square test and proportion

testing, with proportions compared using the Chi-square test. methods

A **p-value <0.05 was considered statistically significant**, while a *p*-value <0.001 was considered highly statistically significant.

RESULTS

Table 1: Age and sex distribution of study participants

Age group (years)	Male, n (%)	Female, n (%)	Total, n (%)
<20	0 (0.0)	2 (10.0)	2 (2.0)
21–30	20 (25.0)	10 (50.0)	30 (30.0)
31–40	40 (50.0)	4 (20.0)	44 (44.0)
41–50	10 (12.5)	2 (10.0)	12 (12.0)
51–60	7 (8.75)	2 (10.0)	9 (9.0)
>60	3 (3.75)	0 (0.0)	3 (3.0)
Total	**80 (100)**	**20 (100)**	**100 (100)**

The study included 100 HIV-positive patients, of whom 80 (80%) were males and 20 (20%) were females, giving a male-to-female ratio of 4:1. The majority of participants belonged to the 31–40 years age group (44%), followed by 21–30 years (30%). Overall, 74% of participants were between 21 and 40 years of age. Among males, the 31–40 years age group predominated (50%), whereas among females, the 21–30 years age group was most frequent (50%). The mean age of the study population was 33.8 years.

Table 2: Distribution of hematological parameters among study participants

Hematological parameter	Category	n	%
Hemoglobin (g/dL)	≤6	12	12
	>6–≤9	35	35
	>9–≤13	46	46
	>13	7	7
Total leukocyte count (/µL)	<4000	40	40
	4000–11000	56	56
	>11000	4	4
Neutrophils (%)	≤50	7	7
	50–70	78	78
	>70	15	15
Lymphocytes (%)	≤20	38	38
	20–40	52	52
	>40	10	10
Platelet count (lakh/µL)	≤1.5	31	31
	1.5–4.0	64	64
	>4.0	5	5

The hematological profile showed that 46% of patients had hemoglobin levels between >9 and ≤13 g/dL, while 35% had hemoglobin between >6 and ≤9 g/dL and 12% had severe anemia with hemoglobin ≤6 g/dL. The mean hemoglobin level was 10.02 g/dL. Regarding total leukocyte count, 40% had leukopenia with TLC <4000/µL, whereas 56% had TLC between 4000 and 11000/µL. Neutrophil percentage was between 50–70% in the majority (78%), while 7% had neutrophils ≤50%. Lymphocyte percentage was ≤20% in 38% of patients. Platelet count was ≤1.5 lakh/µL in 31% of patients, indicating thrombocytopenia according to the study criteria.

Table 3: Distribution of CD4 lymphocyte count among study participants

CD4 count (cells/µL)	Male, n (%)	Female, n (%)	Total, n (%)
≤200	66 (82.5)	16 (80.0)	82 (82.0)
>200	14 (17.5)	4 (20.0)	18 (18.0)
Total	**80 (100)**	**20 (100)**	**100 (100)**

The CD4 lymphocyte count showed considerable variation, ranging from 1.51 to 1041 cells/µL, with a mean CD4 count of 135.14 cells/µL. The majority of patients, 82 (82%), had a CD4 count ≤200 cells/µL, while only 18 (18%) had a CD4 count >200 cells/µL. Among males, 82.5% had CD4 counts ≤200 cells/µL, compared with 80% of females. Thus, the study population predominantly consisted of patients with low CD4 counts.

Table 4: Association between hemoglobin level and CD4 count

Hemoglobin (g/dL)	CD4 ≤200, n (%)	CD4 >200, n (%)	Total, n (%)
≤6	5 (6.25)	3 (15.0)	8 (8)
>6–≤9	30 (37.5)	3 (15.0)	33 (33)
>9–≤13	38 (47.5)	10 (50.0)	48 (48)

>13	7 (8.75)	4 (20.0)	11 (11)
Total	**80 (100)**	**20 (100)**	**100 (100)**
p-value			**0.119**

Among the 80 patients with CD4 count ≤200 cells/µL, 30 (37.5%) had hemoglobin >6–≤9 g/dL, while 38 (47.5%) had hemoglobin >9–≤13 g/dL. Five patients (6.25%) had hemoglobin ≤6 g/dL. In comparison, among patients with CD4 >200 cells/µL, 10 (50%) had hemoglobin >9–≤13 g/dL. Overall, the findings suggested a tendency toward greater anemia among patients with lower CD4 counts; however, the association between hemoglobin category and CD4 count was not statistically significant (p=0.119).

Table 5: Association between total leukocyte count and CD4 count

Total leukocyte count (/µL)	CD4 ≤200, n (%)	CD4 >200, n (%)	Total, n (%)
<4000	36 (45.0)	4 (20.0)	40 (40)
4000–11000	43 (53.75)	13 (65.0)	56 (56)
>11000	2 (1.25)	3 (15.0)	4 (4)
Total	**80 (100)**	**20 (100)**	**100 (100)**
p-value			**0.041**

Among patients with CD4 ≤200 cells/µL, 36 (45%) had a TLC <4000/µL, compared with 4 (20%) among those with CD4 >200 cells/µL. A normal TLC of 4000–11000/µL was observed in 43 (53.75%) patients with CD4 ≤200 cells/µL and 13 (65%) patients with CD4 >200 cells/µL. The association between TLC and CD4 category was statistically significant (p<0.041), indicating that leukopenia was more frequently observed among patients with lower CD4 counts.

Table 6: Association between neutrophil percentage and CD4 count

Neutrophils (%)	CD4 ≤200, n (%)	CD4 >200, n (%)	Total, n (%)
≤50	6 (7.5)	1 (5.0)	7 (7)
50–70	62 (77.5)	16 (80.0)	78 (78)
>70	12 (15.0)	3 (15.0)	15 (15)
Total	**80 (100)**	**20 (100)**	**100 (100)**
p-value			**0.618**

The majority of patients in both CD4 groups had a neutrophil percentage between 50–70%. Among patients with CD4 ≤200 cells/µL, 6 (7.5%) had neutrophil percentages ≤50%, whereas 62 (77.5%) had values between 50–70%. Among patients with CD4 >200 cells/µL, 1 (5%) had neutrophils ≤50%. The difference between the two CD4 groups was not statistically significant (p=0.618), suggesting no significant association between neutrophil percentage and CD4 category in this study.

Table 7: Association between lymphocyte percentage and CD4 count

Lymphocytes (%)	CD4 ≤200, n (%)	CD4 >200, n (%)	Total, n (%)
≤20	40 (50.0)	3 (15.0)	43 (43)
20–40	24 (30.0)	14 (70.0)	38 (38)
>40	16 (20.0)	3 (15.0)	19 (19)
Total	**80 (100)**	**20 (100)**	**100 (100)**
p-value			**0.03**

A lymphocyte percentage of ≤20% was observed in 40 (50%) patients with CD4 ≤200 cells/µL, compared with only 3 (15%) patients with CD4 >200 cells/µL. Conversely, lymphocyte percentages between 20–40% were more frequent among patients with CD4 >200 cells/µL (70%) than among those with CD4 ≤200 cells/µL (30%). The association between lymphocyte percentage and CD4 category was statistically significant (p<0.03). These findings indicate that a lower peripheral lymphocyte percentage was more frequently associated with reduced CD4 counts.

Table 8: Association between platelet count and type of anemia with CD4 count

Parameter	Category	CD4 ≤200, n (%)	CD4 >200, n (%)	Total, n (%)	p-value
Platelet count (lakh/µL)	≤1.5	27 (33.75)	3 (15.0)	30 (30)	0.102
	1.5–4.0	50 (62.5)	16 (80.0)	66 (66)	
	>4.0	3 (3.75)	1 (5.0)	4 (4)	
Type of anemia	Normocytic normochromic	44 (55.0)	5 (25.0)	49 (49)	**0.0358**
	Microcytic hypochromic	31 (38.75)	14 (70.0)	45 (45)	
	Dimorphic	2 (2.5)	1 (5.0)	3 (3)	
	Pernicious	3 (3.75)	0 (0)	3 (3)	

Among patients with CD4 ≤200 cells/µL, 27 (33.75%) had platelet counts ≤1.5 lakh/µL, compared with 3 (15%) patients with CD4 >200 cells/µL. Although thrombocytopenia was more frequent in the lower CD4 group, the association was not statistically significant (p=0.102). Regarding morphological type of anemia, normocytic normochromic anemia was the most common pattern among patients with CD4 ≤200 cells/µL, occurring in 44 (55%) cases, followed by microcytic hypochromic anemia in 31 (38.75%) cases. Among patients with CD4 >200 cells/µL, microcytic hypochromic anemia was predominant (70%). The association between type of anemia and CD4 category was statistically significant (p<0.0358).

DISCUSSION

The present study evaluated the hematological profile of 100 people living with HIV/AIDS (PLHA) and assessed its association with CD4 lymphocyte count. The study population consisted predominantly of males (80%), with most participants belonging to the 21–40-year age group. A substantial proportion of participants had advanced immunosuppression, as 82% had CD4 counts ≤200 cells/µL, with a mean CD4 count of 135.14 cells/µL.

Age and sex distribution

In the present study, males constituted 80% of the study population, with a male-to-female ratio of 4:1. The majority of participants were between 21 and 40 years of age. Similar demographic patterns have been reported in Indian studies of HIV-associated hematological abnormalities, although the exact male-to-female distribution varies according to the study setting and population. Parinitha and Kulkarni evaluated 250 HIV-positive patients and also demonstrated that hematological abnormalities were common among patients with HIV, with a large proportion having CD4 counts below 200 cells/µL.[10] Bhardwaj et al., in a cross-sectional study from Jammu, similarly evaluated HIV-positive individuals across different clinical and immunological categories.[11]

The predominance of younger adults in the present study is clinically relevant because HIV infection affects individuals during economically productive years. However, differences in the sex distribution between studies may reflect differences in healthcare-seeking behaviour, referral patterns and the demographic characteristics of the study population rather than a biological difference in hematological manifestations.

Hematological profile

Anemia was one of the major hematological abnormalities observed in the present study. The mean hemoglobin concentration was 10.02 g/dL, and 47% of participants had hemoglobin ≤9 g/dL. This finding is consistent with previous Indian studies, which have consistently identified anemia as one of the most frequent hematological abnormalities in HIV infection.

Dikshit et al. studied 200 HIV-infected individuals and reported anemia in 65.5% of patients. They also demonstrated a strong negative correlation between anemia and CD4 count, with anemia being particularly frequent among individuals with CD4 counts <200 cells/µL.[12] Similarly, Parinitha and Kulkarni reported anemia in 84% of 250 HIV-positive patients, with normocytic normochromic anemia being the most common morphological pattern.[10] In their study, anemia was present in 91.4% of patients with CD4 counts <200 cells/µL. These findings are broadly comparable with the high frequency of reduced hemoglobin observed in our study.

However, the present study did not demonstrate a statistically significant association between hemoglobin category and CD4 category (p=0.119). This differs from the findings of Dikshit et al., Parinitha and Kulkarni, and Suja et al., who reported significant associations between declining CD4 counts and anemia.[10,12,13] Suja et al., in a study of 100 HIV-infected patients, found that CD4 count decreased significantly as hemoglobin levels decreased (p=0.004). 13 The difference may be related to sample size, distribution of CD4 categories, nutritional status, ART exposure, opportunistic infections and other causes of anemia.

Total leukocyte count

In the present study, 40% of participants had leukopenia, defined as TLC <4000/µL. Leukopenia was more frequent among patients with CD4 ≤200 cells/µL (45%) than among those with CD4 >200 cells/µL (20%). Importantly, this association was statistically significant (p<0.041).

Our findings are in agreement with observations by Parinitha and Kulkarni, who reported leukopenia in 26.8% of patients with CD4 counts <200 cells/µL. 10 They observed that hematological abnormalities became more frequent with increasing immunosuppression. Similarly, Dikshit et al. described hematological abnormalities as increasingly prominent with advancing HIV disease.[12]

However, our results differ from those of Bhardwaj et al., who reported leukopenia in 18.33% of patients and found that total leukocyte count was not significantly associated with CD4 count.[11] This discrepancy may be due to differences in the definition of leukopenia, treatment status, disease stage and study population. The relatively high prevalence of leukopenia in our cohort may also be related to the large proportion of participants with CD4 counts ≤200 cells/µL.

Neutrophil percentage

The majority of participants in our study had a neutrophil percentage between 50% and 70%. Although the proportion with neutrophils ≤50% was slightly higher in the CD4 ≤200 group than in the CD4 >200 group, the difference was not statistically significant (p=0.618).

This observation is consistent with the findings of Bhardwaj et al., who found no significant relationship between absolute neutrophil count and CD4 count.[11] In contrast, the Varanasi cohort reported by Attili et al. demonstrated significantly lower CD4 counts among patients with severe anemia and neutropenia, suggesting an association between advanced immunosuppression and neutropenia. 14 Differences between these studies may reflect the use of neutrophil percentage in the present study rather than absolute neutrophil count, as well as differences in disease severity and concomitant infections or medications.

Lymphocyte percentage

A significant association was observed between peripheral lymphocyte percentage and CD4 count in our study. Half of the patients with CD4 ≤200 cells/µL had lymphocyte percentages ≤20%, compared with only 15% of patients with CD4 >200 cells/µL ($p<0.03$).

This finding is biologically plausible because progressive HIV infection results in depletion of CD4-positive T lymphocytes and increasing immune dysfunction. Our observation is supported by Parinitha and Kulkarni, who reported lymphopenia in 65.2% of their study population and found that lymphopenia was particularly frequent among patients with CD4 counts <200 cells/µL.[10] In their cohort, lymphopenia was present in approximately 80% of patients with CD4 counts below 200 cells/µL. Bhardwaj et al. also found a statistically significant association between absolute lymphocyte count and CD4 count ($p=0.018$).[11] Thus, the present finding strengthens the evidence that peripheral lymphocyte abnormalities may accompany advanced immunosuppression. Nevertheless, peripheral lymphocyte percentage should not be considered a substitute for direct CD4 estimation because the two measurements are not interchangeable.

Platelet count and thrombocytopenia

Thrombocytopenia was observed in approximately one-third of patients according to the study's platelet-count criterion. It was more common among patients with CD4 ≤200 cells/µL (33.75%) than among those with CD4 >200 cells/µL (15%), but the association was not statistically significant ($p=0.102$).

This finding is comparable with Dikshit et al., who reported thrombocytopenia in 7% of their 200 patients and found no significant correlation between thrombocytopenia and CD4 count.[12] Parinitha and Kulkarni similarly reported thrombocytopenia in 18% of patients and found that, although it was more frequent in patients with lower CD4 counts, the increase was not statistically significant.[10]

In contrast, Bhardwaj et al. reported a significant relationship between thrombocytopenia and CD4 count ($p=0.044$).[11] Therefore, the relationship between platelet abnormalities and CD4 count appears less consistent than that observed for anemia and lymphocyte abnormalities. HIV-associated thrombocytopenia may have multiple mechanisms, including immune-mediated platelet destruction, impaired platelet production, opportunistic infections and treatment-related effects, which could partly explain the variable association with CD4 counts across studies.

Morphological pattern of anemia

In our study, normocytic normochromic anemia was the predominant morphological pattern among patients with CD4 ≤200 cells/µL, accounting for 55% of cases, whereas microcytic hypochromic anemia was more frequent among patients with CD4 >200 cells/µL. The association between the morphological type of anemia and CD4 category was statistically significant ($p<0.0358$).

The predominance of normocytic normochromic anemia in patients with advanced immunosuppression is consistent with previous observations. Parinitha and Kulkarni reported normocytic normochromic anemia as the most common morphological type, accounting for 40.4% of their cases. 10 Suja et al. also reported a predominance of normocytic normochromic and anemia-of-chronic-disease patterns among HIV-infected patients.[13]

Dikshit et al. demonstrated that both iron deficiency and anemia of chronic disease contributed substantially to anemia among HIV-infected individuals.[12] Thus, the morphological pattern observed in our study may reflect the multifactorial nature of HIV-associated anemia, including chronic inflammation, nutritional deficiencies, opportunistic infections and altered hematopoiesis.

CONCLUSION

The present study demonstrated that hematological abnormalities were common among people living with HIV/AIDS (PLHA), particularly among those with lower CD4 lymphocyte counts. The study population was predominantly male and consisted mainly of young and middle-aged adults. A substantial proportion of participants had advanced immunosuppression, with 82% having CD4 counts ≤200 cells/µL.

Anemia was a frequent hematological abnormality, with nearly half of the participants having hemoglobin levels ≤9 g/dL. Leukopenia and reduced lymphocyte percentages were also common, and both showed a statistically significant association with CD4 count. In contrast, the associations of hemoglobin level, neutrophil percentage and platelet count with CD4 category were not statistically significant. Normocytic normochromic anemia was the predominant morphological pattern among patients with lower CD4 counts, and the type of anemia showed a significant association with CD4 category.

Overall, the findings indicate that routine hematological investigations, particularly hemoglobin, total leukocyte count, differential leukocyte count and platelet count, can provide useful supportive information regarding the

hematological status of PLHA. However, hematological parameters should not be considered substitutes for CD4 estimation. Regular hematological evaluation along with appropriate immunological assessment may facilitate early recognition of cytopenias and identification of patients requiring further clinical evaluation.

Thus, the study highlights the close relationship between HIV-associated hematological abnormalities and the degree of immunosuppression, with leukocyte and lymphocyte abnormalities showing particularly important associations with CD4 count.

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