Vol.19, No.3, Page 210- 215, 2025 https://doi.org/10.59628/jchm.v19.i3.1597 ISSN 2958-7476 JCHM

Sana'a University Journal of Medical and Health Sciences

Prevalence of Pancytopenia among HIV Patients Attended to HIV Center in Sana'a City

Ibrahim Ahmed Ali Al-Babeli[1], Mohammed Ahmed Hajar[1], Ahmed Kaid Salem[2] and Hassan Abdulwahab Al-Shamahy[1,3,4]

[1]**Department of Internal Medicine, Faculty of Medicine and Health Sciences, Sana'a University, Yemen,**
[2]**Department of Hematology, Faculty of Medicine and Health Sciences, Sana'a University, Yemen ,**
[3]**Department of Basic Sciences, Faculty of Dentistry, Sana'a University, Republic of Yemen,**
[4]**Medical Microbiology and Clinical Immunology Department, Faculty of Medicine and Health Sciences, Sana'a University, Republic of Yemen.**

*Corresponding author:e-mail: shmahe@yemen.net.ye, / h.shmahe15@su.edu.ye

Abstract

Background: Pancytopenia, a decrease in all three major blood cell types (white blood cells, platelets, and red blood cells), is a common disorder among individuals living with HIV. It is caused by multiple factors, including direct effects of the virus, opportunistic infections, nutritional deficiencies, and antiretroviral therapies. The prevalence and severity of pancytopenia vary among different populations, but there are limited data regarding its incidence among HIV patients in Yemen. This study aimed to determine the prevalence of pancytopenia and its associated factors among HIV-infected individuals attending the HIV Center for Treatment at the Al-Jumhuri Teaching Hospital Authority in Sana'a, Yemen.

Materials and Methods: The time frame for this cross-sectional study was July 2024–January 2025. There were 238 HIV-positive individuals, both males and females. Structured questionnaires were used to gather demographic information, and a Sysmex XN-550 hematological analyzer was used to examine blood samples. SPSS version 26 was used for the statistical analysis, and $P < 0.05$ was chosen as the significance threshold.

Results: The median age of the patients was 35 years, with males comprising 71.8% of the study population. Anemia was the most prevalent hematological abnormality, affecting 52.1% of patients, while leukopenia and thrombocytopenia were observed in 35.3% and 10.5% of cases, respectively. Pancytopenia was the least common, occurring in 4.2% of the patients. Anemia was more frequent in males (55%) than females (44.8%), but the difference was not statistically significant ($P = 0.157$). However, leukopenia was significantly more prevalent in females (49.3%) than in males (29.8%) ($P = 0.005$). Thrombocytopenia was observed in 12.3% of males and 6% of females; however, there was no statistically significant change ($P = 0.153$).

Conclusion: In Yemen, pancytopenia, especially anemia, is common among people with HIV, with a significant association between female sex and leukopenia. These findings highlight the importance of routine hematological monitoring and early intervention in the management of cytopenia in patients with HIV. Further studies are needed to explore the underlying mechanisms and the impact of antiretroviral therapy on hematological abnormalities in this population.

Article Info

Keywords:
Hematological abnormality, HIV-patients, Pancytopenia, prevalence, Sana'a, Yemen.

Article History:
Received:25-February-2025 ,
Revised:14-June-2025 ,
Accepted:22-June-2025 ,
Available online:30-June-2025

1. INTRODUCTION

HIV, a positive-sense single-stranded RNA virus, belongs to the Retroviridae family. This is at odds with two main types: HIV-1 and HIV-2. In addition, HIV-1 is advanced into multiple groups and subtypes that are spread across various regions, whereas HIV-2 tends to have slower progression and is generally less aggressive than its counterpart [1]. The virus remains a significant global health challenge; as of the end of 2018, approximately 37.9

million individuals were reported to be existing with HIV, and there were 1.7 million new infections documented worldwide [2]. In Yemen, HIV prevalence is relatively low, estimated at 4,000 cases (ranging from 2,000 to 11,000) per 100,000 individuals [3]. However, a recent study conducted in Al-Hodeidah investigated the prevalence of HIV infection among high-risk patients with tuberculosis. The findings revealed that 10% of patients with TB were co-infected with HIV [4]. In Yemen, many factors, including HIV, affect the hematopoietic system of these individuals, leading to anemia and cytopenias [5, 6], and also affect the immune system, resulting in a gradual decline in immune function [7]. Disruptions in the hematopoietic system are frequently observed in individuals living with HIV [8], and typically manifest as cytopenia, which refers to a decreased number of blood cells [9]. Patients with HIV frequently experience hematologic complications, particularly cytopenia, such as anemia, leukopenia, and thrombocytopenia [10]. These conditions may arise due to the virus's direct impact on the bone marrow, inhibition of bone marrow function resulting from consequent infections or malignancies, nutritional deficiencies, or adverse effects of antiretroviral medications [11]. The most prevalent hematological issue in HIV-positive individuals is cytopenia, which can affect any of the main blood cell lineages and result in diseases such as leukopenia, thrombocytopenia, and anemia [12]. These cytopenias have a variety of complicated causes, such as co-infections with hepatitis B and C viruses, opportunistic infections, direct results of HIV, and side consequences of medical treatments [13]. The underlying processes of cytopenia can be broadly categorized into two groups: increased loss or damage of blood cells in the bloodstream and decreased bone marrow synthesis of blood cells [14]. The incidence and severity of these cytopenias tend to increase as HIV infection worsens and CD4 count declines. This can impact the effectiveness of highly active antiretroviral therapy (HAART), possibly leading to increased rates of morbidity and mortality as well as a negative impact on overall quality of life [15]. Anemia is the most commonly observed hematologic disorder in individuals with HIV, affecting approximately 30% of those who are asymptomatic and between 75% and 80% of those diagnosed with clinically acquired immunodeficiency syndrome (AIDS). It is more prevalent than thrombocytopenia and leukopenia in AIDS patients. The association of anemia with progression to AIDS, shorter survival rates, and poor prognosis for HIV-positive individuals is significant, regardless of their CD4 cell counts [16]. Anemia in HIV-positive individuals can be caused by a number of factors, such as opportunistic infections, chronic illnesses, dietary deficiencies, and drug side effects. Notably, increasing anemia in HIV/AIDS patients has been associated with several antiretroviral medications, including zidovudine (AZT) and stavudine (d4T) [17]. Leukopenia is a common hematological disorder found in individuals with HIV, resulting from various factors including the direct effects of the HIV virus, autoimmune diseases, cancers, antiretroviral therapy (ART), and opportunistic infections. Its prevalence among patients can reach as high as 26.8%, and it is associated with adverse outcomes related to HIV, including increased mortality and morbidity associated with AIDS [18]. Research has indicated that worsening HIV conditions, such as advancing clinical stages and lower CD4+ cell counts, are linked to a greater risk of developing leukopenia, particularly in individuals who have not yet begun antiretroviral treatment [19]. The most prevalent type of leukopenia is neutropenia, which affects up to 70% of people with severe AIDS and 5% to 30% of those with early symptomatic HIV infection [13]. Numerous reasons, such as the direct effects of the HIV virus, autoimmune diseases, opportunistic infections, malignancies, and drugs used to treat HIV and associated illnesses, can induce neutropenia in people with HIV. These include cotrimoxazole and other medications that can inhibit bone marrow function, as well as antiretroviral treatments, especially those that include AZT [20]. Thrombocytopenia is a prevalent hematological condition that affects 4%–40% of people with HIV at every stage of the illness. This condition arises from either reduced platelet production or increased destruction of platelets, with immune thrombocytopenic purpura being the leading cause [5]. The immune system's role in the shortened lifespan of platelets involves more than just the elimination of platelets marked by antibodies in the reticuloendothelial system; it also includes impaired T-cell responses, activation of the complement cascade, and clearance of platelets that are coated with immunoglobulins [21]. A significant decrease in CD4+ cell counts, worse quality of life, and higher rates of morbidity and death are associated with thrombocytopenia. Thrombocytopenia in untreated HIV patients is significantly associated with immunosuppression and advanced clinical stages [17]. Despite the existing research on the prevalence of pancytopenia in HIV-infected populations, there is a lack of studies examining this issue among individuals living with HIV in Yemen. Therefore, this study aimed to determine the prevalence of pancytopenia in HIV-infected individuals.

2. SUBJECTS AND METHODS

2.1. Study Design

This is a cross-sectional study conducted at the HIV center at the Republican Teaching Hospital Authority in Sana'a City from July 2024 to January 2025.

2.2. Sample Size

The sample consisted of 238 participants, including both males and females. It was determined using the Open

Epi program (version 2.3.1) with a 95% confidence level. The expected prevalence of HIV was 19.1%, based on the study by Fan et al.[9], along with a design effect of 1 and study power of 80%.

2.3. Data Collection

Demographic information such as age, sex, and marital status was obtained from each individual using a questionnaire.

2.4. Sample Collection

Blood samples were obtained by venipuncture using 3 ml sterile disposable syringes and needles. The blood was then dispensed into Ethylene Diamine Tetraacetic acid (EDTA) tubes, which were used for complete blood count (CBC) analysis using the Sysmex XN-550.

2.5. Statistical Analysis

The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26 (LEAD Technologies, Inc., USA). Quantitative data are expressed as median (minimum(min)-maximum(max)) , while qualitative data are expressed as percentages.

2.6. Ethics Statements

Before providing written consent, all individuals who participated in this study received a consent form and provided details regarding the experimental protocols. Approval for this study was obtained from the Committee of Postgraduate Studies and Scientific Research of the Faculty of Medicine and Health Science.

3. RESULTS

The median age of the HIV-infected patients in our study was 35 years (interquartile range= 1-65 years). The majority belonged to the age group of 30-39 years (34%), followed by those aged 40-49 years (24.8%) and 18-29 years (24.4%). Patients aged ≥50 years accounted for 12.6%, whereas those aged <18 years were the least frequent (4.2%). Most HIV-infected patients were male (71.8%), while females constituted 28.2% of the study population. Regarding marital status, the majority were married (66.4%), followed by single individuals (30.3%), whereas divorced patients were the least common (3.4%) (Table 1).

The median hemoglobin level among HIV-infected patients was 12.4 g/dL. The median RBC count was 4.7 $\times 10^{12}$/L, while the WBC count 4.8 $\times 10^{9}$/L. Regarding differential white blood cell counts, the median neutrophil count was 2.2 $\times 10^{9}$/L, lymphocytes were 1.6 $\times 10^{9}$/L, monocytes were 0.4 $\times 10^{9}$/L, eosinophils were 0.1 $\times 10^{9}$/L, and basophils were the least frequent at 0.0 $\times 10^{9}$/L. The median platelet count was 269.5 $\times 10^{9}$/L (Table 2).

Table 1. Demographic characteristic of study population

Age (years) median (min-max)	35 (1-65)
Age group n(%)	
<18	10(4.2%)
18-29	58(24.4%)
30-39	81(34%)
40-49	59(24.8%)
≥50	30(12.6%)
Gender n(%)	
Male	171(71.8%)
Female	67(28.2%)
Marital Status n(%)	
Single	72(30.3%)
Married	158(66.4%)
Divorced	8(3.4%)

Table 2. Hematological parameter in HIV infected individual

Variable	Median(min-max)
Hemoglobin (g/dl)	12.4 (4.7-211)
RBCS ($\times 10^{12}/L$)	4.7 (1.7-8.75)
WBC ($\times 10^{9}/L$)	4.8 (1.2-24.1)
Absolute Neutrophil count ($\times 10^{9}/L$)	2.2 (0.65-23.86)
Absolute Lymphocyte count ($\times 10^{9}/L$)	1.6 (0.15-10.18)
Absolute Monocyte count ($\times 10^{9}/L$)	0.4 (0.0-2.75)
Absolute Eosinophil count ($\times 10^{9}/L$)	0.1 (0.0-3.69)
Absolute Basophil count ($\times 10^{9}/L$)	0.0 (0.0-0.13)
PLT COUNT ($\times 10^{9}/L$)	269.5 (22-801)

Among HIV-infected patients, anemia was the most prevalent hematological abnormality, affecting 52.1% of cases, while 47.9% had normal hemoglobin levels. Leukopenia was observed in 35.3% of patients, whereas 64.7% had normal white blood cell counts. Thrombocytopenia was present in 10.5% of patients, while the majority (89.5%) had normal platelet counts. Pancytopenia, characterized by the simultaneous presence of anemia, leukopenia, and thrombocytopenia, was the least common, affecting only 4.2% of patients, while 95.8% did not exhibit pancytopenia (Table 3).

Among HIV-infected patients, anemia was more common in males (55%) than in females (44.8%), though the difference was not statistically significant (p=0.157). Leucopenia was significantly more prevalent in females (49.3%) compared to males (29.8%), with a p-value of 0.005, indicating a statistically significant difference. Thrombocytopenia was observed in 12.3% of males and 6% of females, but this difference was not statistically significant (p=0.153) (Table 4).

Table 3. Prevalence of hematological abnormalities among HIV infected individuals

Variable	Yes	No
Anemia	124 (52.1%)	114 (47.9%)
Leucopenia	84 (35.3%)	154 (64.7%)
Thrombocytopenia	25 (10.5%)	213 (89.5%)
Pancytopenia	10 (4.2%)	228 (95.8%)

Table 4. Sex distribution of hematological abnormalities among HIV infected individuals

Parameters	Male	Female	p-value
Anemia			
Yes	94 (55%)	30 (44.8%)	0.157
No	77 (45%)	37 (55.2%)	
Leucopenia			
Yes	51 (29.8%)	33 (49.3%)	0.005
No	120 (70.2)	34 (50.7%)	
Thrombocytopenia			
Yes	21 (12.3%)	4 (6%)	0.153
No	150 (87.7%)	63 (94%)	

4. DISCUSSION

Cytopenia, whether isolated or involving multiple lineages resulting from ineffective hematopoiesis or heightened peripheral destruction, are prevalent hematological abnormalities observed in individuals living with HIV [11]. This study examined the prevalence of pancytopenia among antiretroviral-naïve adult HIV-positive individuals receiving care at the HIV center of the Republican Teaching Hospital Authority in Sana'a City. The findings revealed that anemia affected 51.1% of patients, while thrombocytopenia and leukopenia were observed in 35.3% and 10.5% of patients, respectively. Additionally, more than half of the participants (67.6%) exhibited at least one form of cytopenia, including anemia, thrombocytopenia, or leukopenia. These findings align with the results of a study by Fiseha and Ebrahim [17]. Anemia emerged as the most common cytopenia in this study, affecting 51.1% of antiretroviral-naive HIV patients at the start of antiretroviral therapy. Previous studies have documented anemia in > 60% of patients [22, 23]. Comparatively lower anemia prevalence rates have been observed in other studies, including 22% in India [24], 35% in Ethiopia [25], 47.8% in Uganda [26], and 57.5% in Nigeria [27]. However, this study reported a lower prevalence than several investigations of anemia among ART-naive patients. For example, a 2011 study by Johannessen et al. in rural Tanzania revealed a prevalence of 77.4% among ART-naive HIV-positive individuals [28], while a study by Dikshit et al. in India revealed anemia in 65.5% of the participants [22]. Furthermore, among ART-naïve HIV-positive individuals in Ethiopia, Daka et al. reported an even greater incidence of 86.5% [29]. The antiretroviral-naive HIV patients in this study had a leukopenia prevalence of 35.3%, which is in line with findings from other studies [30]. Estimates of the prevalence of leucopenia in ART-naive patients range from 10% to 44% [31, 32]. According to a study conducted in northern Ethiopia, 9.0% of ART-naive patients had thrombocytopenia and 16.6% had leukopenia [33]. Similarly, a study conducted in Uganda discovered that 8.3% of patients had thrombocytopenia and 24.3% had leukopenia [25]. Leukopenia and thrombocytopenia were observed in 26.8% and 16.1% of ART-naive patients, respectively, in a Nigerian population in a 2010 study by Akinsegun et al. [34]. In this study, leukopenia was independently predicted by the female sex. Approximately 10.5% of patients presented with thrombocytopenia at the start of ART. This observation aligns with studies conducted in Uganda, which reported a rate of thrombocytopenia in HIV-infected patients who had not previously received ART of 8.5%. [25]. Nonetheless, this figure was lower than the 18.7% prevalence documented in Northeast Ethiopia [18], as well as in studies from Tanzania [35], India [36], and China [29]. In contrast, it was higher than the 5.9% prevalence found in Northwest Ethiopia [37]. These variations may be attributed to differences in study populations, sample sizes, research methodologies, and criteria used to define thrombocytopenia.

5. CONCLUSION

This study highlights the considerable prevalence of hematological abnormalities among HIV-infected individuals attending the HIV Center at the Republican Teaching Hospital Authority in Sana'a, Yemen. Anemia was the most common abnormality, affecting more than half of the participants, followed by leukopenia and thrombocytopenia. Although less frequent, pancytopenia was still present in a notable proportion of patients. These findings indicate a significant association between female sex and leukopenia, suggesting potential sex-specific vulnerabilities to hematological complications. These results underscore the importance of routine hematological monitoring in HIV-positive individuals to facilitate early detection and management of cytopenia. Further research is needed to explore the underlying mechanisms that contribute to these hematological abnormalities, particularly the impact of antiretroviral therapy and opportunistic infections. Implementation of proactive screening and intervention strategies could improve the overall health outcomes and quality of life of people living with HIV in Yemen.

REFERENCES

[1] Barbara M Nastri et al. "HIV and Drug-Resistant Subtypes". In: *Microorganisms* 11.1 (2023), p. 221. DOI: 10.3390/microorganisms11010221.

[2] Tesfaye Teklu et al. "Assessment of Prevalence of Malnutrition and Its Associated Factors among AIDS Patients from Asella, Oromia, Ethiopia". In: *BioMed Res. Int.* 2020 (2020), p. 7360190. DOI: 10.1155/2020/7360190.

[3] Basheer Al-Rowaishan Attal et al. "HIV stigma in the teaching hospitals in Sana'a, Yemen: a conflict and low-resource setting". In: *BMC Public Health* 21.1 (2021), p. 1793. DOI: 10.1186/s12889-021-11845-y.

[4] K. Alselwi and M. A. Suhail. "Tracing HIV infection among high-risk tuberculosis patients in Hodiedah Referral Center, Yemen". In: *J. Community Health Manag.* 18.3 (2024), pp. 33–37.

[5] S. Ahmed Ali Al-Jarrmozi et al. "Prevalence and risk factors for anemia during pregnancy in Sana'a city". In: *Sana'a Univ. J. Med. Health Sci.* 18.5 (2024), pp. 107–113. DOI:

10.59628/jchm.v19i4.1380. URL: https://doi.org/10.59628/jchm.v19i4.1380.

[6] Selam Getawa et al. “The global prevalence of thrombocytopenia among HIV-infected adults: A systematic review and meta-analysis”. In: *Int. J. Infect. Dis.* 105 (2021), pp. 495–504. DOI: 10.1016/j.ijid.2021.02.118.

[7] Sandra Renelt et al. “HIV-1 Infection of Long-Lived Hematopoietic Precursors In Vitro and In Vivo”. In: *Cells* 11.19 (2022), p. 2968. DOI: 10.3390/cells11192968.

[8] Takashi Tsukamoto. “Hematopoietic Stem/Progenitor Cells and the Pathogenesis of HIV/AIDS”. In: *Front. Cell. Infect. Microbiol.* 10 (2020), p. 60. DOI: 10.3389/fcimb.2020.00060.

[9] Abdullahi Usman et al. “Prevalence of Cytopenia and its Correlation with Immunosuppression in Naïve HIV-1 Infected Patients Initiating First-Line Antiretroviral Therapy: A Pilot Study”. In: *Infect. & Chemother.* 55.4 (2023), pp. 479–489. DOI: 10.3947/ic.2023.0080.

[10] Li Fan, Chunmei Li, and Hongxin Zhao. “Prevalence and Risk Factors of Cytopenia in HIV-Infected Patients before and after the Initiation of HAART”. In: *BioMed Res. Int.* 2020 (2020), p. 3132589. DOI: 10.1155/2020/3132589.

[11] Habtamu Bisetegn and Hussen Ebrahim. “The prevalence of thrombocytopenia and leucopenia among people living with HIV/AIDS in Ethiopia: A systematic review and meta-analysis”. In: *PLoS One* 16.9 (2021), e0257630. DOI: 10.1371/journal.pone.0257630.

[12] Bewuketu Bayleyegn et al. “Magnitude and associated factors of peripheral cytopenia among HIV-infected children attending at University of Gondar Specialized Referral Hospital, Northwest Ethiopia”. In: *PLoS One* 16.3 (2021), e0247878. DOI: 10.1371/journal.pone.0247878.

[13] Chrisna Durandt et al. “HIV and haematopoiesis”. In: *South Afr. Med. J.* 109.8b (2019), pp. 40–45. DOI: 10.7196/SAMJ.2019.v109i8b.13829.

[14] Aster Gebreweld et al. “Prevalence of cytopenia and its associated factors among HIV infected adults on highly active antiretroviral therapy at Mehal Meda Hospital, North Shewa Zone, Ethiopia”. In: *PLoS One* 15.9 (2020), e0239215. DOI: 10.1371/journal.pone.0239215.

[15] Li Huang et al. “Prediction of the risk of cytopenia in hospitalized HIV/AIDS patients using machine learning methods based on electronic medical records”. In: *Front. Public Health* 11 (2023), p. 1184831. DOI: 10.3389/fpubh.2023.1184831.

[16] Teklie E Fekene et al. “Prevalence of cytopenias in both HAART and HAART naïve HIV infected adult patients in Ethiopia: a cross sectional study”. In: *BMC Hematol.* 18.1 (2018), p. 8. DOI: 10.1186/s12878-018-0102-7.

[17] Temesgen A Ageru et al. “Anemia and its associated factors among adult people living with human immunodeficiency virus at Wolaita Sodo University teaching referral hospital”. In: *PLoS One* 14.10 (2019), e0221853. DOI: 10.1371/journal.pone.0221853.

[18] Temesgen Fiseha and Hussen Ebrahim. “Prevalence and Predictors of Cytopenias in HIV-Infected Adults at Initiation of Antiretroviral Therapy in Mehal Meda Hospital, Central Ethiopia”. In: *J. Blood Med.* 13 (2022), pp. 201–211. DOI: 10.2147/JBM.S355966.

[19] Zelalem Tamir, Abdurahaman Seid, and Hailay Haileslassie. “Magnitude and associated factors of cytopenias among antiretroviral therapy naïve Human Immunodeficiency Virus infected adults in Dessie, Northeast Ethiopia”. In: *PLoS One* 14.2 (2019), e0211708. DOI: 10.1371/journal.pone.0211708.

[20] Mutsa Madzime et al. “Interactions of HIV and Antiretroviral Therapy With Neutrophils and Platelets”. In: *Front. Immunol.* 12 (2021), p. 634386. DOI: 10.3389/fimmu.2021.634386.

[21] Roberto Castelli et al. “Complement activation in patients with immune thrombocytopenic purpura according to phases of disease course”. In: *Clin. Exp. Immunol.* 201.3 (2020), pp. 258–265. DOI: 10.1111/cei.13475.

[22] Pamela S Belperio and David C Rhew. “Prevalence and outcomes of anemia in individuals with human immunodeficiency virus: a systematic review of the literature”. In: *The Am. J. Med.* 116.7A (2004), 27S–43S. DOI: 10.1016/j.amjmed.2003.12.010.

[23] Biswojit Dikshit et al. “Profile of hematological abnormalities of Indian HIV infected individuals”. In: *BMC Blood Disord.* 9.1 (2009), p. 5. DOI: 10.1186/1471-2326-9-5.

[24] Fernanda G Nascimento and Patricia Y Tanaka. “Thrombocytopenia in HIV-Infected Patients”. In: *Indian J. Hematol. Blood Transfus.* 28.2 (2012), pp. 109–111. DOI: 10.1007/s12288-011-0124-9.

[25] Getachew Ferede and Yitayih Wondimeneh. “Prevalence and related factors of anemia in HAART-naive HIV positive patients at Gondar University Hospital, Northwest Ethiopia”. In: *BMC Hematol.* 13.1 (2013), p. 8. DOI: 10.1186/2052-1839-13-8.

[26] Rachel Kyeyune et al. “Prevalence and correlates of cytopenias in HIV-infected adults initiating highly active antiretroviral therapy in Uganda”. In: *BMC Infect. Dis.* 14.1 (2014), p. 496. DOI: 10.1186/1471-2334-14-496.

[27] Ballah A Denue et al. “Prevalence of Anemia and Immunological Markers in HIV-Infected Patients on Highly Active Antiretroviral Therapy in Northeastern Nigeria”. In: *Infect. Dis. Res. Treat.* 6 (2013), pp. 25–33. DOI: 10.4137/IDRT.S10477.

[28] Asgeir Johannessen et al. “Antiretroviral treatment reverses HIV-associated anemia in rural Tanzania”. In: *BMC Infect. Dis.* 11.1 (2011), p. 190. DOI: 10.1186/1471-2334-11-190.

[29] Desta Daka, Daniel Lelissa, and Aklilu Amsalu. “Prevalence of anaemia before and after the initiation of antiretroviral therapy at the ART centre of Hawassa University Referral Hospital, Hawassa, South Ethiopia”. In: *Sch. J. Med.* 3.1 (2013), pp. 1–6.

[30] Yinzhong Shen et al. “A cross-sectional study of leukopenia and thrombocytopenia among Chinese adults with newly diagnosed HIV/AIDS”. In: *Biosci. Trends* 9.2 (2015), pp. 91–96. DOI: 10.5582/bst.2015.01024.

[31] M F Murphy et al. “Incidence and mechanism of neutropenia and thrombocytopenia in patients with human immunodeficiency virus infection”. In: *Br. J. Haematol.* 66.3 (1987), pp. 337–340. DOI: 10.1111/j.1365-2141.1987.tb06920.x.

[32] Richard A Kaslow et al. “Infection with the human immunodeficiency virus: clinical manifestations and their relationship to immune deficiency”. In: *Ann. Intern. Med.* 107.4 (1987), pp. 474–480. DOI: 10.7326/0003-4819-107-4-474.

[33] Bamlaku Enawgaw et al. “Determination of hematological and immunological parameters among HIV positive patients taking highly active antiretroviral treatment and treatment naïve in the antiretroviral therapy clinic of Gondar University Hospital, Gondar, Northwest Ethiopia: a comparative cross-sectional study”. In: *BMC Hematol.* 14.1 (2014), p. 8. DOI: 10.1186/2052-1839-14-8.

[34] Akinsegun Akinsegun. “Hematologic abnormalities in treatment-naive HIV patients”. In: *Infect. Dis. Res. Treat.* 3 (2010), pp. 45–49.

[35] Daniel W Gunda et al. “Cytopenias among ART-naive patients with advanced HIV disease on enrolment to care and treatment services at a tertiary hospital in Tanzania: A cross-sectional study”. In: *Malawi Med. J.* 29.1 (2017), pp. 43–52. DOI: 10.4314/mmj.v29i1.9.

[36] Smita Bhardwaj et al. "Hematologic derangements in HIV/AIDS patients and their relationship with the CD4 counts: a cross-sectional study". In: *Int. J. Clin. Exp. Pathol.* 13.4 (2020), pp. 756–763.

[37] Yitayih Wondimeneh, Dagnachew Muluye, and Getachew Ferede. "Prevalence and associated factors of thrombocytopenia among HAART-naive HIV-positive patients at Gondar University Hospital, northwest Ethiopia". In: *BMC Res. Notes* 7.1 (2014), p. 5. DOI: 10.1186/1756-0500-7-5.