



Hematological and Immunophenotypic Characteristics of Acute Myeloid Leukemia in Yemeni Patients

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ABSTRACT

Background: Acute myeloid leukemia (AML) is a heterogeneous hematologic malignancy characterized by clonal proliferation of immature myeloid cells, resulting in impaired normal hematopoiesis. Data on the hematological and immunophenotypic characteristics of AML in Yemeni patients remain limited.

Objectives: This study aimed to describe the demographic, hematological, morphological subtypes, and immunophenotypic features of newly diagnosed AML among Yemeni patients.

Methods: A descriptive cross-sectional study was conducted on 50 newly diagnosed AML patients recruited from three oncology centers in Sana'a and Ibb, Yemen, between Aug. 2024 and Dec. 2025. Demographic and laboratory data were collected at diagnosis. Complete blood count, peripheral blood smear examination, bone marrow aspiration wherever available and flow cytometric immunophenotyping were performed. AML subtypes were classified according to the French-American-British (FAB) system. Statistical analysis was carried out using SPSS version 26, with sig. at $p < 0.05$.

Results: The mean age of patients was 37.22 ± 17.48 years, with a slight male predominance (56%). At presentation, the mean hemoglobin level was 8.62 ± 1.62 g/dL, white blood cell count (WBCs) was $80.34 \pm 39.94 \times 10^9/L$, platelet count was $77.28 \pm 35.00 \times 10^9/L$, and peripheral blast percentage was $60.44 \pm 21.05\%$. Anemia, leukocytosis, and thrombocytopenia were observed in 94%, 98%, and 96% of patients, respectively. FAB classification showed that AML-M2 was the most frequent subtype (28.0%). Immunophenotypic analysis demonstrated high expression of CD33 (96%), CD13 (86%), and CD117 (82%), while aberrant lymphoid marker expression was infrequent. A significant negative correlation was observed between hemoglobin and WBC count ($r = -0.289$, $p = 0.042$), and a significant positive correlation between hemoglobin and platelet count ($r = 0.306$, $p = 0.031$). Bone marrow and peripheral blood blast percentage differed significantly among FAB subtypes ($p < 0.001$).

Conclusion: Yemeni patients with AML have a high leukemic blast percentage and present at a younger age. The most common subtype is AML-M2, and CD33, CD13, and CD117 were the predominant immunophenotypic markers. These findings highlight the diagnostic value of flow cytometry and the need for broader molecular and cytogenetic characterization of AML in Yemen.

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1. INTRODUCTION

AML is a genetically and clinically heterogeneous hematological malignancy, which is defined by the clonal expansion and accumulation of immature myeloid precursors (blasts) in the bone marrow and peripheral blood [1, 2]. The clonal proliferation of myeloid blasts results in the suppression of normal blood cell production (hematopoiesis) which leads to critical and life-



endangering blood disorders which may include the following: severe anemia, and varied degrees of either WBCs overproduction (leukocytosis) or underproduction (leukopenia), and marked low platelet production (thrombocytopenia) [3].

Considering age and geographical location, the clinical manifestation of AML and more importantly, the blood count status (anemia, leukopenia, or leukocytosis, thrombocytopenia) may widely vary. AML shows age-related variation in incidence, and its demographic pattern differs across populations; recently, it has been reported that AML has been reported among a younger population in Middle Eastern countries, particularly Yemen [4, 5].

For accurate diagnosis and categorization of AML, there is a need for a combination of microscopic examination (morphology) and another specialized laboratory examination called flow cytometric immunophenotyping. This examination assists in the detection of specific proteins expressed on the surface of malignant cells, referred to as cluster of differentiation (CD) antigens. The detection of CD33 and CD13 antigens is very important for the identification of the myeloid lineage of leukemia and also for the identification of the treatment approach [6].

In Yemen, the conflict and socioeconomic problems have had a significant impact on the healthcare system, leading to patients seeking late diagnosis and an unfavorable disease state. There is a significant scarcity of literature available on the hematological characteristics and immunophenotypic properties of Yemeni patients with AML [5]. Hence, the purpose of this study was to assess the demographic features, initial hematological findings, morphological subtypes, and immunophenotypic properties of AML in Yemeni patients.

2. MATERIALS AND METHODS

STUDY DESIGN AND POPULATION

This descriptive cross-sectional study was conducted on a total of 50 patients with newly diagnosed AML from three participating oncology centers in Ibb and Sana'a, Yemen. National Cancer Control Foundation-Ibb (10 cases), Prof. Dr. Saeed Thabit Nasher Center-Ibb (13 cases), and National Oncology Center-Sanaa, Yemen (27 cases), from August 1, 2024, to Dec 31, 2025.

DATA AND SPECIMEN COLLECTION

Demographic data, such as age and sex, were collected from the patients prospectively at diagnosis. From each patient, five mL of venous blood and bone marrow aspirate samples (wherever available) were aseptically collected into separate EDTA vacuum tubes.

AML DIAGNOSIS AND FAB CLASSIFICATION

AML diagnosis was established according to the routine diagnostic protocols of the participating centers based on clinical assessment, peripheral blood morphology, bone marrow aspiration, and flow cytometric immunophenotyping. In six cases, bone marrow aspiration was not feasible because of clinical or procedural constraints; therefore, diagnosis and classification relied on the best available morphologic and immunophenotypic data in accordance with local institutional practice. AML cases were classified according to the FAB classification system based primarily on blast percentage and available morphological features in bone marrow as well as peripheral blood, as cytochemical stains were not routinely available for all patients. Immunophenotyping was used as a supportive tool for lineage confirmation and not as part of the FAB classification.

HEMATOLOGICAL AND IMMUNOPHENOTYPING ANALYSIS

A complete blood count (CBC) was performed using an automated hematology analyzer (Mindray BC-5000; Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). Preparation of blood smears and B.M aspiration with Giemsa staining were used equally to evaluate morphology and the percentage of blasts for AML diagnosis and classification.

Flow cytometric immunophenotyping was performed within 48 hours of sample collection using a FACSCalibur flow cytometer (Becton Dickinson Immunocytometry Systems, USA), at the National Oncology Center-Sanaa, Yemen. A standardized panel of monoclonal antibodies targeting myeloid markers (CD33, CD13, CD117, CD14, CD64), stem cell markers (CD34, HLA-DR), and lymphoid markers (CD7, CD19, CD3, CD10) was used. The analysis was conducted to confirm lineage assignment and to identify aberrant antigen expression patterns. Blasts were gated based on low side scatter and dim CD45 expression. Instrument calibration and quality control were performed according to the manufacturer's recommendations.

STATISTICAL ANALYSIS

Data analysis was performed using IBM SPSS Statistics version 26.0. Continuous data were presented as mean $\pm$ standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Pearson's correlation coefficient (r) was used to evaluate the relationships between clinical and hematological parameters. To compare hematological parameters across AML subtypes, one-way ANOVA was conducted. A p -value < 0.05 was considered statistically significant.

3. RESULTS

DEMOGRAPHIC DATA OF THE STUDY POPULATION

The study cohort comprised 50 Yemeni patients with a recent diagnosis of AML made up the study cohort. The demographic analysis in Table ?? showed that the mean age at presentation was 37.22 ± 17.48 years. The disease was most common in young to middle-aged adults, according to the distribution across age strata; in particular, the 21–40 age group made up the largest portion of the population, accounting for 40% ($n=20$) of all cases. The pediatric and adolescent groups (≤ 20 years) came next, making up 24% ($n=12$) of the cohort. A 20% of patients were between the ages of 41 and 60, and 16% were more than 60 years. There was a slight male predominance in terms of sex distribution, with 28 males (56%) and 22 females (44%), resulting in a male-to-female ratio of 1.27:1.

Table 1. Demographic characteristics of AML patients ($n = 50$).

Variable	Category	No.	%
Age (years)	Mean $\pm$ SD	37.22 ± 17.48	-
Age groups	≤ 20	12	24
	21–40	20	40
	41–60	10	20
	> 60	8	16
Gender	Male	28	56
	Female	22	44

BASELINE HEMATOLOGICAL FINDINGS

Table 2 summarizes the hematological parameters of Yemeni patients with AML at diagnosis. Most patients presented with anemia, leukocytosis, and thrombocytopenia. The mean hemoglobin level was 8.62 ± 1.62 g/dL, the mean WBC count was $80.34 \pm 39.94 \times 10^9/L$, the mean platelet count was $77.28 \pm 35.00 \times 10^9/L$, the mean peripheral blood blast percentage was $60.44 \pm 21.05\%$, and the mean bone marrow (B.M) blast percentage was $64.77 \pm 18.66\%$, indicating substantial disease burden at diagnosis.

CORRELATION ANALYSIS OF HEMATOLOGICAL PARAMETERS

Table 3 presents the Pearson correlation coefficients and p-values for the hematological variables among the 50 AML patients. The analysis revealed two statistically significant correlations. A significant weak negative cor-

Table 2. Hematological parameters in AML patients at diagnosis.

Parameter	No.	Min.	Max.	Mean $\pm$ SD
Hb (g/dL)	50	5.8	12.5	8.62 ± 1.62
WBC ($\times 10^9/L$)	50	9.5	181.3	80.34 ± 39.94
Plts ($\times 10^9/L$)	50	24.0	166.0	77.28 ± 35.00
P.B blasts (%)	50	22	96	60.44 ± 21.05
B.M blasts (%)	44	33	97	64.77 ± 18.66

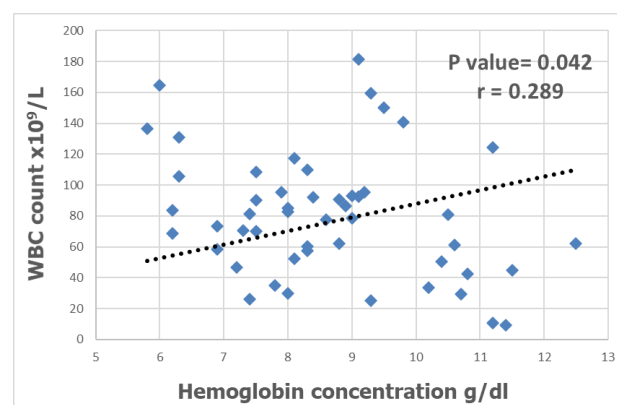


Figure 1. Scatter plot of correlation between WBC count and Hb concentration in AML.

relation was observed between hemoglobin (Hb) and white blood cell (WBC) counts ($r = -0.289$, $p = 0.042$), as visually demonstrated by the downward trend regression line in the scatter plot in Figure 1.

Additionally, a significant weak positive correlation was identified between Hb and platelet counts (PLTS) ($r = 0.306$, $p = 0.031$), which is illustrated by the upward-sloping regression line in the scatter plot in Figure 2. No significant correlations were found between age and any hematological parameters, including Hb ($r = -0.045$, $p = 0.754$), WBC ($r = 0.016$, $p = 0.913$), PLTS ($r = -0.062$, $p = 0.667$), or peripheral blast cell percentage ($r = -0.251$, $p = 0.078$). Additionally, the peripheral blast cell percentage showed no significant association with any of the measured hematological parameters.

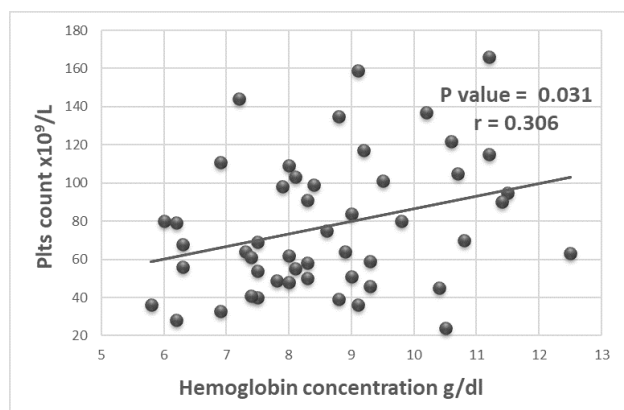
AML SUBTYPES ACCORDING TO FAB CLASSIFICATION

FAB morphological criteria were used to classify each of the 50 patients (Table 4). According to the distribution, the most common subtype was AML-M2, which was found in 28% ($n=14$) of the cases. The monocytic lineage subtype, M5, which comprised 22% ($n=11$), was the next most common. At 20% ($n=10$), the M1 subtype came in second. With 18% ($n=9$) and 12% ($n=6$) of the entire study population, respectively, the M3 and M4 subtypes

**Table 3.** Pearson correlation of hematological variables in AML patients ($n = 50$).

Variable	Age		Hb		WBC		PLTS		Blast	
	r	P value	r	P value	r	P value	r	P value	r	P value
Age	1									
Hb	-0.045	0.754	1							
WBC	0.016	0.913	-0.289*	0.042	1					
PLTS	-0.062	0.667	0.306*	0.031	-0.032	0.827	1			
P.B Blast	-0.217	0.130	-0.064	0.660	0.165	0.253	0.117	0.417	1	

*Correlation is significant at the 0.05 level (2-tailed).

**Figure 2.** Scatter plot of correlation between Plts count and Hb concentration in AML

were less prevalent. The M0, M6, and M7 subtypes were not observed in the study cases.

Table 4. Distribution of AML subtypes according to FAB classification.

AML Subtypes (no. 50)	Number	(%)
M1	10	20.0
M2	14	28.0
M3	9	18.0
M4	6	12.0
M5	11	22.0

FREQUENCY OF HEMATOLOGICAL ABNORMALITIES

A high frequency of abnormal hematological indices was observed in 94% ($n=47$) of the patients; anemia was almost universal. Similarly, none of the patients had leukocytopenia, but 98% ($n=49$) of the cohort had leukocytosis. A total of 96% ($n=48$) of the participants had thrombocytopenia (low platelet count). The severity of the disease at diagnosis was demonstrated by the fact

that normal hemoglobin, WBC, and platelet values were only found in 6%, 2%, and 4% of cases, respectively (Table 5).

Table 5. Frequency distribution of hematological abnormalities ($n = 50$).

Parameter	Decreased n (%)	Normal n (%)	Increased n (%)
Hb	47 (94)	3 (6)	0 (0)
WBC	0 (0)	1 (2)	49 (98)
Plts	48 (96)	2 (4)	0 (0)

IMMUNOPHENOTYPIC CHARACTERIZATION

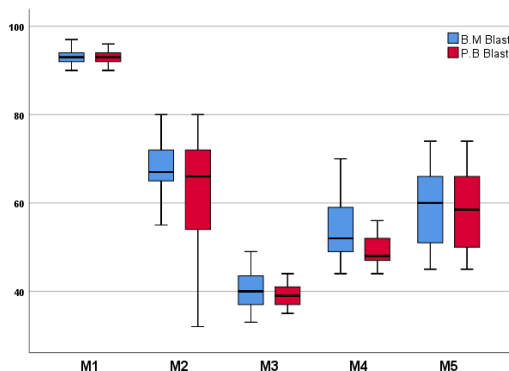
Different immunophenotypic patterns were found when CD marker expression in AML blasts from 50 Yemeni patients was examined using flow cytometry (Table 6). At 96% (48/50) and 86% (44/50), respectively, the myeloid-associated antigens CD33 and CD13 displayed the highest positivity rates. Also, 82% (41/50) of cases, CD117 was expressed. The hematopoietic progenitor cell markers CD34 and HLA-DR were detected in 62% (31/50) and 64% (32/50) of the cases, respectively. In 28% (14/50) and 34% (17/50) of the cases, respectively, monocytic differentiation markers CD14 and CD64 were positive. A small percentage of cases had abnormal lymphoid marker expression, as evidenced by aberrant antigen expression, and the overall immunophenotypic profile remained compatible with myeloid leukemia: 10% (5/50) had positive CD7, 8% (4/50) had positive CD19, and only 2% (1/50) had weak positive CD3.

HEMATOLOGICAL PARAMETERS IN AML SUBTYPES

Table ?? summarizes the distribution of hematological parameters across the different AML subtypes (M1–M5). The statistical analysis revealed no significant differences among the subtypes regarding Hb levels ($p=0.833$), WBC counts ($p=0.186$), or PLTs counts ($p=0.920$). However, a

Table 6. Profile of CD markers expression in AML blasts.

CD markers	Positive		Negative	
	No.	%	No.	%
CD 34	31	62	19	38
HLA DR	32	64	18	36
CD 19	4	8	46	92
CD 13	44	86	6	12
CD 33	48	96	2	4
CD 117	41	82	9	18
CD 14	14	28	36	72
CD 64	17	34	33	66
CD 7	5	10	45	90
CD 3	1	2	49	98
CD 10	0	0	50	100

**Figure 3.** Boxplot of B.M and P.B blast percentage in AML subtypes.Boxplot of B.M and P.B blast percentage in AML subtypes.

highly significant difference was observed in the blast cell percentage in peripheral blood and bone marrow among the FAB classifications ($p < 0.001$). As illustrated in the boxplot (Figure ??), the M1 subtype exhibited the highest blast percentage in peripheral blood and bone marrow (~93%), whereas the M3 subtype showed the lowest mean percentages at 40.43% (B.M) and 38.33% (P.B). The M2 subtype also demonstrated a notably higher blast percentage compared to M3, M4, and M5.

4. DISCUSSION

AML is a heterogeneous group of neoplasms arising from the clonal proliferation of immature myeloid progenitors [6]. This study aimed to describe the hematological and immunophenotypic features of AML in Yemeni patients, who make up a cohort that has mostly been ignored by the world cancer literature.

Our findings are consistent with reports from Yemen

and the wider region showing a relatively younger age at diagnosis with a mean age of 37.22 ± 17.48 years compared with many western cohorts. Al-Adhami et al. and Al-Nuzaili et al. report an average age of 35 years and 28.9 years at the National Oncology Center (NOC) in Sana'a, respectively [5, 7]. Al-Ghazali et al. reported a mean age 40 years among patients with AML at the Al-Jomhori Teaching Hospital in Sana'a [8].

These findings are consistent with regional and international reports at the median age of approximately 35 years, which coincides with our observations [9–14]. In addition, these populations showing such low ages of AML appear to share either novel or different genetic structures or environments from the populations exhibiting older ages of AML, which needs to be investigated.

In contrast, the median age at diagnosis of AML in the United States and Europe ranges between 68 and 72 years, highlighting a clear epidemiological difference between our population and Western cohorts [15, 16].

The male-to-female ratio of 1.27:1 in our study is in accordance with the global prevalence of a slight male dominance, reported to be 56% versus 44%. This gender ratio has been reported from Colombia (1.4:1) [17], and Iraq (1.2:1) [12], as well as from previous Yemeni cohorts that have reported ratios of 1.2:1 to 1.3:1 [5, 8].

Our findings from the Yemeni AML cohort revealed the presence of moderate to severe anemia, with a mean hemoglobin level of 8.62 g/dL, which was constant to the study conducted in NOC Sana'a, Yemen, where the hemoglobin concentration was 8.0 g/dL [5]. Other local studies have observed that over 97% of patients had anemia, confirming that it is a significant early finding in Yemeni AML patients [18]. This is likely due to extensive infiltration of the marrow by leukemic blasts and ineffective erythropoiesis, which have been described as a consistent pattern of AML diagnosis worldwide [19].

Leukocytosis was marked in this cohort, with a mean WBC count of $80.34 \times 10^9/L$, which is similar to the findings of another Yemeni study, in which the WBC count was $97.6 \times 10^9/L$ [5]. Also, this is similar to the findings from the National Oncology Center, Sana'a, where the mean total WBC count was also high ($89.84 \times 10^9/L$) and leukocytosis was noted in over 80% of the cases [19]. Likewise, other international studies have also described leukocytosis [20, 21]. The high WBC count could have been due to delayed diagnosis in Yemen due to the lack of healthcare facilities.

Thrombocytopenia was also prominent in our patients with a mean of $77.28 \times 10^9/L$, in apathetic hematopoiesis and the resulting marrow failure [22]. Other research conducted in Sana'a, Yemen supports our study argument that thrombocytopenia is highly prevalent among patients with AML, reporting that 96.9% of patients have thrombocytopenia with an average platelet count of $48.58 \times 10^9/L$ [19].

With a mean of 64.77%, 60.44%, bone marrow and

**Table 7.** Hematological parameters in AML subtypes.

Parameter	M1 (n=10)	M2 (n=14)	M3 (n=9)	M4 (n=6)	M5 (n=11)	p-value
Hb (g/dL)	9.11 ± 1.2	8.57 ± 1.5	8.49 ± 1.8	8.13 ± 1.9	8.61 ± 1.9	0.833
WBC ($\times 10^9/L$)	78.69 ± 33.2	73.45 ± 33.8	61.19 ± 35.7	86.44 ± 56.4	102.96 ± 41.8	0.186
PLTs ($\times 10^9/L$)	73.52 ± 39.2	76.43 ± 32.4	73.56 ± 39.9	74.67 ± 36.0	86.27 ± 34.9	0.920
P.B Blast cells (%)	93.30 ± 2.06	59.29 ± 15.8	38.33 ± 3.3	47.67 ± 12.7	57.09 ± 10.9	< 0.001*
B.M Blast cells (%)	M1 (n=9)	M2 (n=13)	M3 (n=7)	M4 (n=5)	M5 (n=10)	< 0.001*
	93.33 ± 2.24	66.15 ± 9.81	40.43 ± 5.53	54.80 ± 10.09	59.30 ± 9.84	

* Sig. P value < 0.05

peripheral blast percentages respectively, were found to be high. This further supports the results of a descriptive study conducted in Sana'a, Yemen, which discovered that blast counts frequently exceeded diagnostic thresholds, and this has been confirmed to reinforce the fact that a high blast count is typical in AML patients at the time of diagnosis in Yemen [4]. This has also been supported by other global studies [21, 23].

In this cohort of Yemeni patients with AML, most correlations among clinical and hematological variables were weak and statistically non-significant, reflecting the biological heterogeneity of AML. However, hemoglobin levels were significantly negatively correlated with WBC count and significantly positively correlated with platelet count. These findings suggest that an increased leukemic burden may be associated with the progressive suppression of normal hematopoiesis, leading to anemia and thrombocytopenia. This pattern is consistent with the established pathobiology of AML, in which leukemic expansion in the bone marrow impairs erythroid and megakaryocytic production [24, 25].

No significant correlation was found between age and hematological indices or between blast percentage and peripheral counts. This may indicate that peripheral blood parameters in AML are influenced not only by blast burden but also by subtype-specific biology, marrow reserve, and disease kinetics. Similar variability has been emphasized in modern AML classifications, where morphology alone is insufficient to explain clinical and hematologic diversity [26].

FAB subtypes showed AML-M2 to be the most common type in terms of morphology at 28.0%, followed by M5 at 22.0%, M1 at 20.0%, M3 at 18.0%, and M4 at 12.0%. This has been supported by other Yemeni studies conducted recently. Harize and Hamid reported that the most common type in Yemeni patients was M2 at 40% [27]. This finding is supported by another local study, which reported M2 in 48.57% of patients [5]. Also, our findings hold true to reports from Saudi Arabia and Pakistan [28, 29]. However, unlike other reports, which show that M1 and M5 were the most predominant subtype categories in Saudi Arabia and Jordan, respectively [30, 31].

This variation may be attributed to differences in population genetics, environmental factors, age distribution, and diagnostic practices.

Comparison across FAB subtypes showed no significant differences in hemoglobin, WBC count, or platelet count, whereas bone marrow and peripheral blast percentage differed significantly ($p < 0.001$). The lack of variation in routine hematological parameters suggests that anemia, leukocytosis, and thrombocytopenia are common features across FAB categories and may not reliably distinguish morphological subtypes. In contrast, the significant difference in blast percentage in bone marrow and peripheral blood is biologically plausible, as the FAB classification is primarily based on the degree of cellular maturation and blast predominance [32].

These findings support the view that while FAB classification retains descriptive value, especially in low-resource settings, its ability to stratify AML biologically is limited compared with contemporary WHO and ICC frameworks that incorporate cytogenetic and molecular abnormalities [26, 32]. Therefore, the significant variation in blast percentage across FAB groups in this study likely reflects morphological differences rather than broader hematologic divergence.

Yemeni AML patients exhibit distinctive myeloid antigen expression patterns in their immunophenotypic profile, with some significant regional variances. Their diagnostic value as pan-myeloid markers in AML is confirmed by the high frequency of CD13 (86%) and the nearly universal expression of CD33 (96%). These results are in line with reports from around the world that show that most AML cases, regardless of genetic subtype, express CD33 and CD13 [24]. Interestingly, our results are higher than the frequencies recorded at Nanakaly Hospital in Erbil, Iraq (CD13:75%; CD33:70%) [21]. These discrepancies could result from variations in the genetic backgrounds, flow cytometry sensitivities, or patient demographics.

Additionally, a preponderance of immature myeloid phenotypes was indicated by CD117 positivity (82%), which is in line with international data (70–90%) [33]. The HLA-DR (64%) and CD34 (62%) expression rates

were within the recognized global ranges of 57.6% to 75.9% [34]. Notably, 36% of the cases lacked HLA-DR, which may indicate high-risk immunophenotypes, such as the RAM phenotype (CD56-bright/HLA-DR-negative), which is associated with poor outcomes [33, 35].

A small percentage of cases had abnormal lymphoid marker expression, which was interpreted as aberrant antigen expression rather than evidence of T-lineage differentiation, as the overall immunophenotypic profile remained compatible with myeloid leukemia. Only 10% of the cases expressed CD7, the most prevalent aberrant marker, which is similar to the findings of other studies [36, 37], and significantly less than the 15%–30% reported in other studies [38–40]. Similarly, 8% of the cases expressed CD19, which is consistent with the findings of Arshad et al., 2024 and Raza et al., 2022 [36, 38]. In contrast, Akrabi & Hamid, 2024 found that CD19 was expressed in 30% of their cases [41]. The rarity of CD3 (2%) remains consistent with global and Yemeni trends [41–43].

Although the WHO classification represents the current standard for AML diagnosis, its application requires comprehensive bone marrow, cytogenetic, and molecular data, which were not uniformly available in this study. Therefore, the FAB classification was adopted as a pragmatic and consistent approach applicable to all cases. This approach reflects real-world diagnostic constraints in resource-limited settings and ensures methodological uniformity.

This study has several limitations. First, the sample size was small in this study. Second, the study design was descriptive and observational in nature. Third, bone marrow aspiration was not performed in all patients, which limited the full morphological confirmation in some cases. Fourth, MPO, cytochemistry, cytogenetics, and molecular analyses were not routinely performed in the study. Finally, the study reflects the diagnostic resources of the participating centers and may not be generalizable to the entire AML population in Yemen.

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, Yemeni patients with newly diagnosed AML frequently present at a relatively young age with marked anemia, leukocytosis, thrombocytopenia, and high peripheral blast burden. AML-M2 was the most common FAB subtype, and CD33, CD13, and CD117 were the most frequently expressed myeloid markers. These findings support the value of flow cytometry in AML diagnosis in resource-limited settings and highlight the need for future studies incorporating bone marrow morphology, MPO, cytogenetics, and molecular profiling to improve classification and risk stratification.

ABBREVIATIONS

AML: Acute Myeloid Leukemia, B.M: Bone Marrow, CBC: Complete Blood Count, CD: Cluster of Differentiation, EDTA: Ethylenediaminetetraacetic Acid, FAB: French-American-British Classification, Hb: Hemoglobin, HLA-DR: Human Leukocyte Antigen – DR isotype, M1–M5: FAB Morphological Subtypes of AML, NCCF: National Cancer Control Foundation, MPO: Myeloperoxidase, NOC: National Oncology Center, SD: Standard Deviation, SPSS: Statistical Package for the Social Sciences and WBC: White Blood Cells.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Committee on Postgraduate Studies and Scientific Research gave its approval to the study, Faculty of Medicine and Health Sciences, Sana'a University. Informed consent in writing was collected before being included in the study from each participant or their legal guardian. The patient data privacy and confidentiality were rigorously maintained during the entire research process. All collected data were anonymized and used solely for scientific purposes.

COMPETING INTEREST

The authors affirm that no competing interests, either financial or non-financial, could have affected the research's design, data collection, analysis, interpretation, or publication.

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