



Prevalence of Acute Myeloid Leukaemia among in Haematological malignancies and its Haematological Patterns at National Oncology Centre in Sana'a, Yemen

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ABSTRACT

Background and aims: Chromosomal abnormalities and an increase in primitive myeloid cells are hallmarks of acute myeloid leukemia (AML), a malignant condition of myeloid blood cells in the bone marrow. This study examined the prevalence, subtypes, and haematological characteristics of AML in patients at the National Oncology Center in Sana'a, Yemen, where information regarding this illness is still lacking.

Methods: This cross-sectional study included 487 patients with malignant hematological tumors, including 49 with acute myeloid leukemia. Data were collected using a standardized questionnaire, and a venous blood sample (3 mL) was drawn for evaluation. Complete blood counts were performed using an Advia 2120i hematology analyzer, and blood and bone marrow morphological examinations were conducted using Giemsa staining.

Results: The study included 487 patients, 269 (55.2%) men and 218 (44.8%) women, with a male-to-female ratio of 1.2:1 and ages ranging from 1 to 76 years. The most prevalent hematological malignancies were non-Hodgkin lymphoma (39.43%), leukemia (37.17%), and Hodgkin disease (17.04%). Acute leukemia was diagnosed in 20.94% of patients, whereas chronic leukemia accounted for 16.22%. Specific leukemia types included acute lymphoblastic leukemia (10.88%) and chronic lymphocytic leukemia (6.16%). AML had a prevalence of 10.06% among leukemia cases, with a mean age of 24.75 years. The FAB-M2 subtype was the most prevalent in acute myeloid leukemia at 34.7%, and other subtypes included M5 (22.4%), M0 (14.3%), M1 and M3 (10.2% each), and M4 (8.2%). Hematological changes in patients included anemia (100%), leukocytosis (63.3%), and thrombocytopenia (89.8%).

Conclusion: Leukemia was the most common malignant hematological tumor. The prevalence of acute myeloid leukemia (AML) is high, and it is the second most common type of leukemia. The AML-M2 subtype is the most frequent acute myeloid leukemia type. Anemia, leukocytosis, and thrombocytopenia are common hematological changes in patients with acute myeloid leukemia.

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1. INTRODUCTION

Leukemia is a group of malignant diseases characterized by the accumulation of malignant white blood cells in the bone marrow and peripheral blood [1]. The exact cause of leukemia is not yet fully understood; however, sev-

eral risk factors are associated with its development [2]. Acute myeloid leukemia (AML) is a malignant disorder that affects the myeloid cell lineage in the bone marrow. It is characterized by chromosomal changes that lead to the accumulation of primary myeloid cells in the bone

marrow and their infiltration into peripheral tissues [3–5]. AML has two peaks: one in young adults and the second in those aged 65 years and older [3–5]. It accounts for only a small proportion (10–15%) of childhood leukemia cases. The disease may arise spontaneously or as a result of a pre-existing malignant disease in the bone marrow [6–8]. In 2019, AML was responsible for 28.11% of leukemia-related deaths worldwide [9]. In 2017, AML represented 23.1% of all leukemia cases globally [10].

While the underlying cause remains unclear for most AML cases, prior exposure to DNA-damaging agents, such as those encountered in therapeutic, occupational, or environmental settings, has been implicated as a contributing factor in some patients [11]. The common symptoms of AML are fever, bone pain, lethargy, fatigue, shortness of breath, pale skin, frequent infections, easy bruising, and unusual bleeding [12].

In Yemen, a recent study found that the prevalence of AML is 23.43% at the National Oncology Center (NOC), with a prevalence of the FAB-M2 subtype [1, 3]. Other studies have found the prevalence of AML to range from 15.6% to 45.1% [1, 3, 7, 8, 13, 14].

A previous study with the same objective was conducted, but replication is crucial to address the local data gap, as a lack of cancer epidemiology data can lead to inadequate healthcare services and funding in the region. Therefore, conducting and replicating research at the National Cancer Center is essential to understand the specific burden borne by the local population. In addition, diagnosis under limited resources in areas such as Yemen, advanced genetic/molecular testing is often limited due to high costs and a lack of facilities. Therefore, validating practical and available methods (such as FAB classification and complete blood count) is critical for local clinical laboratories. Tracking demographic changes: Local prevalence rates, common FAB classification subtypes (such as M2 or M5), and median age at diagnosis may change over time. Updating these data allows local oncologists to improve triage, supportive treatments (such as transfusions), and diagnostic guidelines.

2. SUBJECTS AND METHODS

2.1. STUDY DESIGN:

A prospective study in which laboratory work was performed and data were collected by the first author as part of his master's project.

2.2. STUDY AREA:

This study was conducted at the National Oncology Center (NOC) in Sana'a city from August 1 to December 31, 2024.

2.3. STUDY POPULATION:

This study included 487 patients, including 269 men and 218 women. They attended the NOC and were diagnosed with Hematological Malignancies (HMs). Among them, there were 49 patients diagnosed with acute myeloid leukemia (AML), including 22 males and 27 females, aged between 1 and 76 years.

2.4. DATA COLLECTION:

Data were collected using a standard-designed questionnaire that included sociodemographic characteristics. It involves age, gender, diagnosis, and laboratory results. investigations.

2.5. SAMPLE COLLECTION:

Three milliliters (3 ml) of venous blood was collected from each patient and placed in an ethylene diamine tetraacetic acid (EDTA) tube. EDTA blood samples were used to estimate the complete blood count (CBC) using an automated hematology analyzer, morphological examination of blood/BM films, and immunophenotyping by flow cytometry.

2.6. LABORATORY INVESTIGATIONS:

Complete blood count (CBC): Estimation of complete blood count (CBC) was performed using the Advia 2120i hematology analyzer (Siemens, Germany). The tube was shaken gently to ensure that the blood was mixed well with EDTA in the vial to avoid clotting, and the blood sample was introduced to the hematology analyzer (CBC machine), and the results were read.

2.7. MORPHOLOGICAL EXAMINATION OF BLOOD/BM FILMS:

Morphological examination of blood/BM films was performed using Giemsa stain to study the morphology of cells.

2.8. IMMUNOPHENOTYPING BY FLOW CYTOMETRY:

Immunophenotyping was performed using flow cytometry (BD FACSLYRIC™, BD Company, USA) on peripheral blood or bone marrow aspiration. Immunophenotyping was used in certain cases to confirm the diagnosis because microscopic examination (morphology) alone is often insufficient to differentiate between various types of leukemia or lymphoma. Flow cytometry reveals specific protein markers on cells (such as immaturity markers like CD34 or lineage markers like CD19 for B cells or CD3 for T cells), allowing for accurate disease classification according to the World Health Organization guidelines.



Table[1]: The distribution and frequency of haematological malignancies by patient gender ($n = 487$).

Type of Malignancy	Male (N%)	Female (N%)	Total (N%)
Hodgkin disease	52 (19.3)	31 (14.2)	83 (17)
Non-Hodgkin lymphoma	102 (37.9)	90 (40.3)	192 (39.4)
Multiple myeloma	16 (5.9)	8 (3.7)	24 (4.9)
ALL	30 (11.2)	23 (10.6)	53 (10.9)
CLL	20 (7.4)	10 (4.6)	30 (6.2)
AML	22 (8.2)	27 (12.3)	49 (10.1)
CML	19 (7.1)	30 (13.8)	49 (10.1)
#Leukemia unspecified	1 (0.4)	1 (0.45)	2 (0.41)
Myelodysplastic syndromes	2 (0.8)	3 (1.4)	5 (1.03)
Total	269 (55.2)	218 (44.8)	487 (100)

#The diagnosis of leukemia has not been confirmed, but its exact type has not yet been determined (e.g., whether it is myeloid or lymphoid, acute or chronic).

2.9. STATISTICAL ANALYSIS:

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 29 (IBM Corporation, New York, USA). Descriptive statistics are presented as mean $\pm$ standard deviation (SD), frequency, and percentages. Pearson's correlation coefficients (R) were used to assess the association between variables, with a significance level set at $P < 0.05$.

2.10. ETHICAL CONSIDERATIONS:

All patients included in this study were informed about the study and approved it. Informed consent was obtained from all the patients. Ethical approval was obtained from the Faculty of Medicine and Health Sciences Committee on Postgraduate Studies and Scientific Research.

3. RESULTS

Table (1) shows the distribution and prevalence of hematological malignancies (HMs) in 487 patients. Among them, there were 269 (55.2%) males and 218 (44.8%) females, and the M:F ratio was 1.2:1. The prevalence of different types of HMs was as follows: **Non-Hodgkin lymphoma (NHL) (39.43%), leukemia (37.17%), Hodgkin disease (17.04%)**. Less common types of HMs included Multiple Myeloma (MM) (4.93%), myelodysplastic syndromes (MDS) (1.03%), and leukemia unspecified (0.41%). Among leukemia, acute leukemia (ALL and AML) was more common than chronic leukemia (CML and CLL). Acute leukemia was found in 102 (20.94%) patients and chronic leukemia in 79 (16.22%) patients. The relative frequencies of leukemia types were as follows: Acute Lymphoblastic Leukemia (ALL) (10.88%), Acute Myeloid Leukemia (AML) (10.06%), Chronic Myeloid Leukemia (CML) (10.06%), and Chronic Lymphocytic Leukemia (CLL) (6.16%). The prevalence of AML was 10.06% among HMs and 27.07%

among leukemia types. AML was found in 22 (4.52%) males and 27 (5.54%) females, with an M:F ratio of 0.8:1.

Table (2) illustrates the patterns of AML subtypes among the 49 AML patients. There were 22 males (44.9%) and 27 females (55.1%), aged 1–76 years, with a mean $\pm$ SD of 35.73 ± 24.75 years. FAB-M2 was detected in 17 (34.7%) patients; among them, there were 8 (16.3%) males and 9 (18.4%) females, the M:F ratio was 0.9:1, and the mean $\pm$ SD age was 40.29 ± 24.12 years. FAB-M5 was found in 11 (22.4%) patients, followed by FAB-M0 (14.3%), FAB-M1, FAB-M3 (10.2% each), and FAB-M4 (8.2%). FAB-M6 and M7 were not observed in our study.

The haematological trends in patients with AML ($n=49$) are shown in Table (3). It contained platelets, white blood cells (WBC), and hemoglobin (Hb). The mean $\pm$ SDs of Hb, WBC, and platelets were 8.39 ± 1.57 , 48.72 ± 73.59 , and 57.49 ± 73.04 , respectively. Hb readings ranged from 4.6 to 12.6, WBC values from 0.72 to 343, and platelet counts from 4 to 366.

The pattern of alterations in fundamental haematological markers in AML patients ($n=49$) is shown in Table (4). Thrombocytopenia, leukocytosis, and anemia were observed in 44 (89.8%), 31 (63.3%), and 49 (100%) patients, respectively.

The haematological trends in patients with AML subtypes ($n=49$) are shown in Table (5). The mean $\pm$ SD of Hb for FAB-M2 was 8.74 ± 1.85 , with minimum and maximum values of 5.3 and 12.6, respectively; the mean $\pm$ SD of WBC was 37.74 ± 55.47 , with minimum and maximum values of 0.72 and 210, respectively; and the mean $\pm$ SD of platelets was 92.23 ± 95.55 , with minimum and maximum values of 11 and 366, respectively. The mean $\pm$ SD of Hb for FAB-M5 was 7.68 ± 1.83 , the mean $\pm$ SD of WBC was 65.87 ± 96.35 , and the mean $\pm$ SD of the

Table[2]: AML subtype distribution by patient age and sex ($n = 49$).

FAB subtype of AML	n (%)	Sex		Age			
		Male n%	Femal n%	Mean $\pm$ SD	Range	Min.	Max.
AML-M0	7 (14.3)	4 (8.2)	3 (6.1)	28.71 (25.111)	64	1	65
AML-M1	5 (10.2)	2 (4.1)	3 (6.1)	44.20 (26.678)	67	2	69
AML-M2	17 (34.7)	8 (16.3)	9 (18.4)	40.29 (24.119)	73	3	76
AML-M3	5 (10.2)	3 (6.1)	2 (4.1)	33.60 (32.230)	69	1	70
AML-M4	4 (8.2)	2 (4.1)	2 (4.1)	27.75 (11.786)	27	15	42
AML-M5	11 (22.4)	3 (6.1)	8 (16.3)	33.18 (27.342)	69	1	70
Total	49 (100%)	22 (44.9)	27 (55.1)	35.73 (24.745)	75	1	76

Table[3]: AML patients' haematological patterns ($n = 49$).

Hematological parameter	Mean $\pm$ SD	Range	Min.	Max.
Hb (g/dL)	8.39 (1.57)	8	4.6	12.6
WBC ($\times 10^9/L$)	48.72 (73.59)	343	0.72	343
Platelets ($\times 10^9/L$)	57.49 (73.04)	362	4	366

platelet count was 26.28 ± 17.33 . Table (3,5) displays the data for FAB-M0, M1, M3, and M4.

The correlations between factors among patients with AML ($n=49$) are shown in Table (6). Age, Hb level, WBC count, and platelets were not significantly correlated ($p>0.05$).

4. DISCUSSION

As one of the main causes of illness and mortality in Yemen, cancer is generally a serious public health concern; Nevertheless, there aren't many published studies on this subject, such as: "Association of Epstein-Barr virus with breast cancer: a case-control study" [15], "Prevalence of risk factors associated with hepatitis B virus infection among cancer patients" [16], "Clinical and histological analysis of biopsy specimens from oral and maxillofacial lesions" [17], "Prevalence and histological identification of central nervous system tumours in patients who have undergone surgery" [18], "Duration of recovery of peripheral blood counts during induction therapy for acute lymphoblastic leukaemia in children" [7], Bladder cancer: differentiation between types, age, sex distribution, and variations associated with grading" [19], "Hepatitis C virus and leukemia patients [8], cytomegalovirus infection among children with leukemia" [20], "Kidney lesions: differentiation between malignant and benign tumors, sex and age distribution, and variations associated with renal cell carcinoma" [21], and the major types of leukemia of childhood, their signs and clinical outcomes [13]. "Bladder cancer: differ between types, age, sex distribution, and variations associated with grading" [19], "Hepatitis C virus and leukemia patients [8], cytomegalovirus infection among children with leukemia" [20], "Kidney lesions: differentiation between

malignant and benign tumors, age and sex distribute, and variations associate with renal cell carcinoma" [21], and the major types of leukemia in childhood, their symptoms, signs, and outcomes [13].

The distribution by sex generally aligned with our study criteria; typically, male patients comprised 55% to 67% of cases, while female patients comprised 33% to 45%. This results in a male-to-female ratio of 1.2:1 to 2:1, which is slightly higher than the global average. The age range of patients is broad (from one year old to the late 70s/80s), with the average age of onset often falling in the mid-30s to 50s [1, 7, 8].

The current study's acute myeloid leukemia (AML) rate of 10.06% is within the range of other reports from Yemen, where the prevalence of AML among adults ranged from 15.6% to 45.1% of leukemia [1, 7, 8, 13]. Additionally, a recent study at the National Oncology Center (NOC) in Sana'a City revealed that the FAB-M2 subtype of AML was frequent, with a prevalence of 23.43% [1]. According to Alhadi et al. (2021), 15.6% of children with leukemia had AML.

Males had a slightly higher prevalence of haematological malignancies (HMs) in the current study (55.24%) than females (44.76%), with an M:F ratio of 1.2:1 for all HM types, except for acute myeloid leukemia (AML), chronic myeloid leukemia (CML), and myelodysplastic syndromes (MDS). Leukemia (37.17%), Hodgkin disease (17.04%), and non-Hodgkin lymphoma (NHL) (39.43%) were the most common HMs types. Leukemia unspecified (0.41%), myelodysplastic syndromes (MDS) (1.03%), and multiple myeloma (MM) (4.93%) were less frequent forms of HMs. Similar results regarding the higher distribution and prevalence of haematological malignancies in Yemen have been previously documented [1, 3, 14, 21–23].



Table[4]: Haematological parameter alterations in AML patients ($n = 49$).

Hematological parameter	Low		Normal		High	
	N	%	N	%	n	%
Hb	49	100.0	0	0.0	0	0.0
WBC	12	24.5	6	12.2	31	63.3
Platelets	44	89.8	5	10.2	0	0.0

Table[5]: Haematological findings in 49 patients with subtypes of AML.

AML Subtypes	Hb				WBC				Platelets			
	Mean $\pm$ SD	Range	Min.	Max.	Mean $\pm$ SD	Range	Min.	Max.	Mean $\pm$ SD	Range	Min.	Max.
AML M0	8.41 (1.06)	3.1	7.6	10.7	31.98 (40.56)	115.49	1.20	116.60	85.14 (82.56)	222	10	232
AML M1	8.70 (1.43)	3.8	6.9	10.7	97.81 (141.70)	341.68	2.20	343.80	13.00 (3.16)	8	10	18
AML M2	8.74 (1.85)	7.3	5.3	12.6	37.74 (55.47)	210.18	0.72	210.90	92.23 (95.55)	355	11	366
AML M3	8.94 (0.50)	1.2	8.5	9.7	35.94 (31.44)	67.48	5.92	73.40	19.60 (16.65)	41	4	45
AML M4	7.75 (1.16)	2.8	6.5	9.3	32.14 (29.04)	58.90	1.10	60.00	50.28 (60.86)	129.9	10.1	140
AML M5	7.68 (1.83)	6.9	4.6	11.5	65.87 (96.35)	325.57	3.46	329.30	26.28 (17.33)	62.9	11.1	74
Total	8.39 (1.58)	8	4.6	12.6	48.72 (73.59)	343.16	0.72	343.88	57.49 (73.04)	362	4	366

Table[6]: AML patients' correlations between factors ($n = 49$).

Variable	Age		Hb		WBC		Platelet	
	R	P value	R	P value	R	P value	r	P value
Age	1	0.000	0.132	0.367	-0.096	0.512	0.062	0.673
Hb	0.132	0.367	1	0.000	0.160	0.271	0.230	0.113
WBC	-0.096	0.512	0.160	0.271	1	0.000	-0.059	0.686
Platelet	0.062	0.673	0.230	0.113	-0.059	0.686	1	0.000

Pearson correlation, correlation is significant at the 0.05 level (2-tailed)

Leukemia was the second most prevalent type of HMs in the current study, with a prevalence of 37.17%. Acute leukemia was more common (20.94%) than chronic leukemia (16.22%). The leukemia types with the highest relative frequencies were acute lymphoblastic leukemia (ALL) (10.88%), acute myeloid leukemia (AML) (10.06%), chronic myeloid leukemia (CML) (10.06%), and chronic lymphocytic leukemia (CLL) (6.16%). Yemen has been found to have a higher prevalence of leukemia and its subtypes [1, 14, 22, 23].

According to the current study, the prevalence of AML was 27.07% among leukemia types and 10.06% among HMs. With an M:F ratio of 0.8:1, AML was more frequent in females (5.54%) than in males (4.52%). With a prevalence of 34.7%, we discovered that the most prevalent subtype of AML was FAB-M2, which was more prevalent in females (18.4%) than in males (16.3%). M5 (22.4%), M0 (14.3), M1 and M3 (10.2% each), and M4 (8.2%) came after FAB-M2. FAB-M6 and M7 were not observed

in our investigation. Our results are consistent with those of prior research that found M2 to be the most prevalent subtype [1, 3, 24–26]. While M2 and M4 have a favorable prognosis, FAB subtypes M0, M5, M6, and M7 are linked to the worst prognoses. Among all AML subtypes, AML-M3 has the best prognosis [27].

anemia (100%), leukocytosis (63.3%), and thrombocytopenia (89.8%) were the patterns of changes in basic haematological parameters in AML patients in the current study. WBC was 48.72 ± 73.59 , platelets were 57.49 ± 73.04 , and Hb was 8.39 ± 1.58 . Other investigations have observed similar patterns of alterations in haematological markers [1, 3, 24–27]. According to a recent study by Al-Nuzaili et al. [3], haematological findings included decreased hemoglobin (Hb), increased white blood cells (WBC), and decreased platelets in 97.5%, 82.3%, and 96.2% of patients, respectively.

Al-Nuzaili et al.'s 2022 investigation revealed an increase in total leukocyte count (mean $97.6 \pm 89.4 \times 10^9/L$) and

a decrease in hemoglobin and platelet counts (mean 8.0 ± 1.6 g/dl and $41.7 \pm 21.2 \times 10^9/L$, respectively) [1]. In a different study [27], Sultan et al. found that while the total leukocyte count was greater (mean $43 \pm 6.8 \times 10^9/L$), the hemoglobin and platelet counts were lower (mean 8.2 ± 2 g/dl and $62 \pm 7.8 \times 10^9/L$, respectively).

5. CONCLUSION

In conclusion, leukemia was found to be the most common hematological malignancy. Acute myeloid leukemia (AML) is the second most common type of leukemia. AML-M2 was the most common AML subtype. Common hematological changes, including anemia, leukocytosis, and thrombocytopenia, were also observed in patients with AML. The pattern of alterations in fundamental haematological markers in our AML patients reflects classic bone marrow failure in acute myeloid leukemia (AML). In AML, the uncontrolled proliferation of immature myeloid cells in the bone marrow disrupts normal hematopoiesis, resulting in a characteristic peripheral blood cell deficiency.

We recommend further studies in different regions of Yemen to determine the prevalence and types of hematological malignancies and leukemias in the country. This will help understand the reasons for the high incidence of leukemia and contribute to appropriate diagnosis and treatment.

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