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Original Research Article

CLINICOPATHOLOGICAL EVALUATION OF ACUTE LEUKEMIAS IN A TERTIARY CARE HOSPITAL

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ABSTRACT

Background: Acute leukemias (AL) are aggressive clonal hematologic malignancies that demand rapid, accurate classification to guide therapy. Indian data remain heterogeneous across regions and care levels. The objective (i) To estimate the prevalence and clinico-hematological profile of acute leukemia cases presenting to a tertiary center; (ii) To define their immunophenotypic distribution and classify per WHO 2022.

Materials and Methods: Prospective observational study of 69 newly diagnosed AL patients (January 2024–July 2025). Clinical data, complete blood counts, peripheral smear and bone marrow findings were recorded. Diagnosis and lineage assignment integrated morphology, cytochemistry (MPO/PAS), and flow-cytometric immunophenotyping (myeloid: CD13, CD33, MPO, CD117; B-lineage: CD19, CD10, CD22, CD79a, TdT; T-lineage: CD3, CD5, CD7, CD2) per WHO-2022. Descriptives were expressed as n (%); group comparisons used χ^2/Fisher's exact tests.

Results: Male: Female ratio was 1.5:1 (42/27). ALL constituted 56.5% (39/69) and AML 43.5% (30/69). Age distribution showed ALL predominance in 0–14 years (25/39; 64.1%), while AML clustered in adults (>30 years, 20/30; 66.7%). Common presentations were fever 85.5%, pallor 72.4%, hepatosplenomegaly 63.8%, lymphadenopathy 52.1%, bone pain 46.4%, and bleeding/gum symptoms 36.2%. Hematology revealed anemia 95.6%, thrombocytopenia 85.5%, leukocytosis 69.6%, leukopenic variants 10.1%; peripheral blasts were universal (100%). Immunophenotyping showed B-ALL 44.9% (31/69), T-ALL 11.6% (8/69), and AML (CD13/CD33/MPO±) 43.5% (30/69). The ALL: AML pattern, male excess, and age stratification aligned with contemporary Indian series.

Conclusion: In this tertiary cohort, ALL predominated overall—driven by pediatric burden—whereas AML was more frequent in adults. The clinical triad of fever, cytopenic symptoms, and organomegaly with near-universal anemia and thrombocytopenia underscores marrow failure at presentation. Flow-cytometry–anchored WHO-2022 classification is feasible and essential for uniform reporting and risk-adapted therapy. Expansion of regional immunophenotyping capacity and registry-based surveillance is warranted.

Keywords: Acute leukemia; ALL; AML; immunophenotyping; WHO 2022 classification; clinicopathological profile.

INTRODUCTION

Leukemias are malignant disorders of the hematopoietic system characterized by clonal proliferation of abnormal precursor cells that progressively infiltrate the bone marrow and frequently extend to peripheral blood, lymphoid organs, and other tissues.[1] This uncontrolled proliferation results in marrow failure, manifesting clinically as anemia, infections, and bleeding tendencies due to suppression of normal hematopoietic elements.[2] Depending on the lineage

involved, leukemias may arise from myeloid or lymphoid progenitor cells, and occasionally from multipotent stem cells capable of differentiating into both lineages.[1]

Leukemias are broadly classified into acute and chronic forms, based on the maturity of the neoplastic cells and the clinical course of the disease.[3] Acute leukemias (AL) are aggressive malignancies characterized by rapid accumulation of immature blasts with impaired differentiation, whereas chronic leukemias involve proliferation of more mature cells with preserved differentiation capacity and a relatively indolent course.[4] Acute leukemias are further subclassified into acute lymphoblastic leukemia (ALL) and acute myeloid leukemia (AML), based on lineage derivation; together, they constitute a major proportion of hematologic malignancies in both children and adults.[4,5]

Globally, leukemia ranks among the top ten cancers, accounting for approximately 3,51,000 new cases (2.8%) and 2,57,000 deaths (3.4%) annually.[10] The incidence varies significantly by geography, ethnicity, and socioeconomic status—being highest in Australia, New Zealand, and North America, and lowest in sub-Saharan Africa.[10] In India, leukemia represents one of the leading causes of childhood cancer mortality, and its incidence appears to be rising steadily due to improved diagnostic access and population aging.[5] Childhood leukemias constitute nearly 30 % of all pediatric malignancies, with ALL representing the majority.[5]

Acute lymphoblastic leukemia (ALL) is the most common leukemia in children and is characterized by proliferation of immature lymphoid precursors of either B-cell (pre-B) or T-cell (pre-T) lineage.[4,5] Approximately 85 % of ALL cases are of B-cell origin, typically manifesting as childhood acute leukemia, while the remaining 15 % are of T-cell origin, often presenting in adolescent males as mediastinal or thymic masses.[4] Cytogenetically, B-ALL frequently exhibits high hyperdiploidy or ETV6-RUNX1 fusion, both associated with a favorable prognosis, whereas T-ALL is more aggressive and commonly presents with higher leukocyte counts and extramedullary involvement.[5]

Acute myeloid leukemia (AML), on the other hand, is a clonal disorder of hematopoietic stem or progenitor cells resulting from acquired oncogenic mutations that arrest myeloid differentiation and promote uncontrolled proliferation of blasts.[3,4] The disease is clinically heterogeneous, with varying morphology, immunophenotype, cytogenetic profiles, and prognostic outcomes.[6] AML primarily affects adults, accounting for ~80 % of adult acute leukemias and ~20 % of childhood cases; incidence increases sharply with age.[5] Common cytogenetic abnormalities include t(8;21), inv,[16] and PML-RARA, each carrying specific therapeutic implications.[4,6]

In contrast to acute leukemias, the chronic leukemias—notably chronic myeloid leukemia (CML) and chronic lymphocytic leukemia (CLL)—are characterized by proliferation of more mature granulocytic or lymphoid cells.[1,3] CML arises from a pluripotent hematopoietic stem cell harboring the Philadelphia chromosome t(9;22)(q34;q11), resulting in the BCR-ABL1 fusion gene that confers constitutive tyrosine-kinase activity.[3] CLL, a neoplasm of mature B-lymphocytes co-expressing CD5 and CD23, is the most common adult leukemia in Western populations but relatively uncommon in Asia.[3]

The classification of leukemias has evolved considerably over the past five decades. The French–American–British (FAB) group first introduced a morphologic classification in 1976, which, though useful for diagnosis, lacked molecular and immunologic specificity.[6] To address these limitations, the World Health Organization (WHO) developed an integrated system in 1999 and revised it in 2001, 2008, 2016, and 2022.[7] The WHO framework incorporates morphologic, cytochemical, immunophenotypic, cytogenetic, and molecular features to ensure accurate lineage determination, prognostic grouping, and treatment selection.[7-9] This approach has revolutionized leukemia diagnosis and enabled targeted therapies such as ATRA for APL and tyrosine-kinase inhibitors for BCR-ABL1-positive leukemias.[7]

Despite these advances, India lacks a comprehensive national leukemia registry, and diagnostic facilities with access to flow cytometry and molecular testing are largely confined to tertiary urban centers.[11] Consequently, many cases are diagnosed late or misclassified. Regional studies remain vital to establish demographic and clinicopathological patterns, which can guide local diagnostic algorithms and resource allocation.[11,12]

The present study was undertaken to analyze the clinical, hematological, and immunophenotypic profiles of acute leukemia cases diagnosed in a tertiary-care hospital, and to classify them according to the WHO 2022 system of hematopoietic and lymphoid neoplasms.[7] By correlating demographic and hematologic features with immunophenotypic profiles, this study aims to identify prevalent leukemia subtypes and contribute to regional epidemiologic data. Such institution-based analyses are essential for refining diagnostic practices, improving early recognition, and optimizing management strategies tailored to the Indian population.[11,12]

AIM

To diagnose and classify cases of acute leukemia using clinico-hematological, morphological, and immunophenotypic parameters in accordance with WHO 2022 classification, and to analyze their demographic and clinical profiles in a tertiary care setting.

OBJECTIVES

1. To estimate the prevalence and clinico-hematological profile of patients diagnosed with acute leukemia.

2. To study the immunophenotypic profile of these patients using flow cytometry and classify the cases according to lineage and subtype.

MATERIALS AND METHODS

Study Design and Setting: The present study was a prospective observational study conducted in the Department of Pathology, Viswabharati Medical College and hospital, a tertiary care teaching hospital. The study period extended from January 2024 to July 2025, covering all newly diagnosed cases of acute leukemia confirmed by bone marrow and peripheral blood examination.

Study Population: A total of 69 patients clinically and hematologically diagnosed as acute leukemia (AL) were included in the study. Both pediatric and adult patients presenting with features suggestive of leukemia were considered. Patients already on chemotherapy or with relapsed disease were excluded to avoid bias due to therapy-related changes.

Ethical Considerations: Institutional Ethical Committee (IEC) approval was obtained before the commencement of the study. Written informed consent was obtained from all patients or guardians before sample collection and diagnostic procedures.

Clinical Evaluation: Detailed clinical history and examination findings were recorded for all patients, including age, gender, duration of illness, presenting symptoms (fever, pallor, bleeding, bone pain, etc.), and physical signs (hepatosplenomegaly, lymphadenopathy, gum hypertrophy, etc.). Relevant routine laboratory investigations such as complete blood count, peripheral smear, and bone marrow examination were performed for each case.

Sample Collection and Processing

- Peripheral blood samples were collected in EDTA vacutainers for hematological analysis.
- Bone marrow aspirate smears were prepared under aseptic conditions from the posterior superior iliac spine using a Salah or Klima needle.
- Bone marrow biopsy was performed in selected cases to assess cellularity and fibrosis when aspirate smears were inadequate.
- Air-dried smears were stained with Leishman–Giemsa stain, and additional cytochemical stains such as Myeloperoxidase (MPO) and Periodic Acid–Schiff (PAS) were applied wherever indicated.

Hematological Analysis: Complete blood counts were analyzed using an automated hematology analyzer (3-part/5-part cell counter). Peripheral smear evaluation was done manually under light microscopy to assess total and differential leukocyte counts, hemoglobin concentration, platelet count, and blast percentage.

Special attention was given to blast morphology, including nuclear shape, chromatin pattern, nucleoli, and cytoplasmic granularity or vacuolation.

Bone Marrow Examination: Bone marrow smears were examined for cellularity, blast morphology, erythroid–myeloid ratio, dysplasia, and maturation arrest. Diagnosis of acute leukemia was made when blast cells exceeded 20% of total nucleated cells, as per WHO 2022 criteria.

Smears were initially classified morphologically according to French–American–British (FAB) criteria (M0–M7 for AML; L1–L3 for ALL), followed by immunophenotypic confirmation.

Immunophenotyping: Flow cytometric immunophenotyping was performed on bone marrow or peripheral blood samples using a standard panel of monoclonal antibodies conjugated with fluorochromes.

Markers included:

- Myeloid lineage: CD13, CD33, MPO, CD117
- B-lymphoid lineage: CD19, CD10, CD22, CD79a, TdT
- T-lymphoid lineage: CD3, CD5, CD7, CD2

Data acquisition and analysis were done using a two- or three-color flow cytometer with appropriate gating strategies to identify blast populations. Diagnosis and lineage assignment were based on WHO 2022 classification integrating morphology, cytochemistry, and immunophenotyping.

Statistical Analysis: All collected data were tabulated and analyzed using Microsoft Excel and SPSS version 25.0 software. Results were expressed in frequency, percentage, mean, and standard deviation (SD). Comparative analysis between subgroups (ALL vs AML) was done using Chi-square or Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Gender-wise Distribution of Acute Leukemia Cases

Gender	Number of Cases	Percentage (%)
Male	42	60.9
Female	27	39.1
Total	69	100

Out of 69 acute leukemia cases, males were more commonly affected (60.9%) than females (39.1%), showing a male preponderance with a male-to-female ratio of approximately 1.5:1.

Table 2: Distribution of Acute Leukemia Subtypes

Type of Acute Leukemia	Number of Cases	Percentage (%)
Acute Lymphoblastic Leukemia (ALL)	39	56.5
Acute Myeloid Leukemia (AML)	30	43.5
Total	69	100

Among the total cases, ALL was the most frequent subtype (56.5%), followed by AML (43.5%). This indicates that ALL predominates in this cohort, especially in the pediatric and adolescent age group.

Table 3: Age-wise Distribution of Cases

Age Group (years)	ALL (n=39)	AML (n=30)	Total (%)
0–14	25	3	40.6
15–30	8	7	21.7
31–45	3	9	17.4
46–60	2	6	11.6
>60	1	5	8.7

ALL was predominantly seen in children aged 0–14 years, while AML was more frequent among adults (>30 years). This bimodal distribution aligns with the established epidemiological trend of age predilection.

Table 4: Clinical Presentations in Acute Leukemia

Clinical Feature	Number of Patients (n=69)	Percentage (%)
Fever	59	85.5
Pallor	50	72.4
Hepatosplenomegaly	44	63.8
Lymphadenopathy	36	52.1
Bone Pain	32	46.4
Gum Bleeding / Bruising	25	36.2
Fatigability / Weakness	40	58.0

The most common clinical feature was fever (85.5%), followed by pallor and organomegaly (hepatosplenomegaly). These features are consistent with marrow infiltration and cytopenia-related manifestations typical of acute leukemias.

Table 5: Hematological Findings

Hematological Parameter	ALL (n=39)	AML (n=30)	Total (%)
Anemia	37	29	95.6
Thrombocytopenia	33	26	85.5
Leukocytosis	27	21	69.6
Leukopenia	4	3	10.1
Blast Cells in Peripheral Smear	39	30	100

Anemia (95.6%) was the most common hematological abnormality, followed by thrombocytopenia (85.5%) and leukocytosis (69.6%). All patients demonstrated circulating blast cells, confirming the diagnosis of acute leukemia. These findings indicate marked marrow failure and blast proliferation.

Table 6: Immunophenotypic Profile of Acute Leukemias

Subtype	Marker Expression	Number of Cases	Percentage (%)
AML	CD13, CD33, MPO	30	43.5
ALL (B-cell type)	CD19, CD10, CD22, TdT	31	44.9
ALL (T-cell type)	CD3, CD7, CD5	8	11.6
Total		69	100

Table 7: Overall Frequency of Leukemia Types (India-wide Comparison)

Study Reference	ALL (%)	AML (%)
Present Study	56.5	43.5
Dores et al. (2012)	55	45
Rathee et al. (2014)	52	48
Kumar et al. (2017)	58	42
Preethi et al. (2014)	54	46

Among ALL cases, B-cell lineage (44.9%) predominated over T-cell (11.6%), with myeloid markers (CD13, CD33) defining the AML subset. This pattern reflects the typical immunophenotypic distribution seen in Indian tertiary care cohorts.

The current study's distribution pattern mirrors previous Indian studies, confirming that ALL remains the predominant acute leukemia subtype, particularly among pediatric patients, while AML predominates in adults.

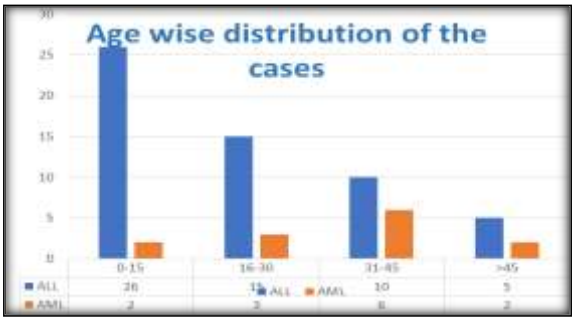

Figure 1: Age wise distribution of the cases

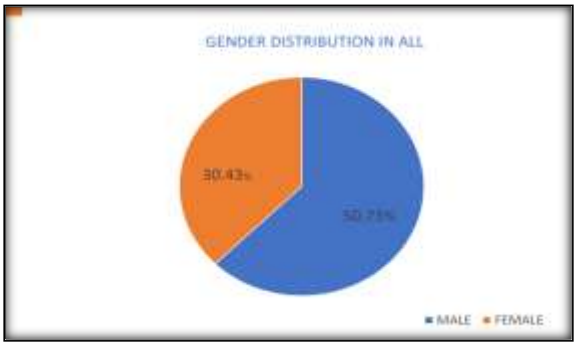

Figure 2: Gender Distribution in all

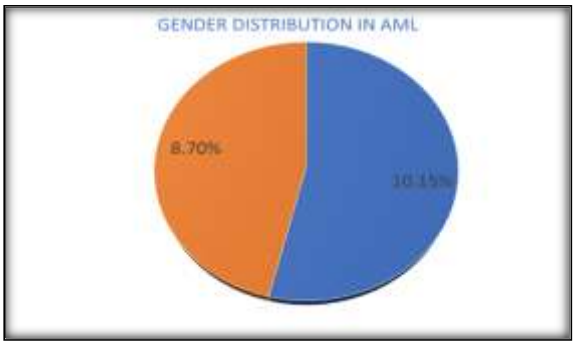

Figure 3: Gender Distribution in AML

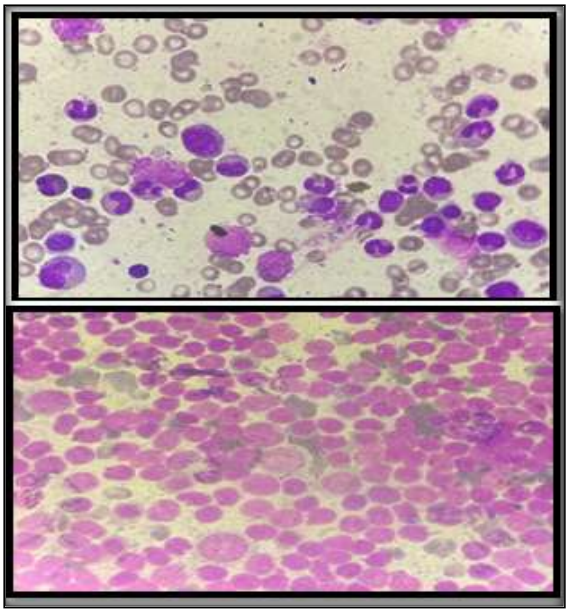

Figure 4: Histopathology in A) All B) AML

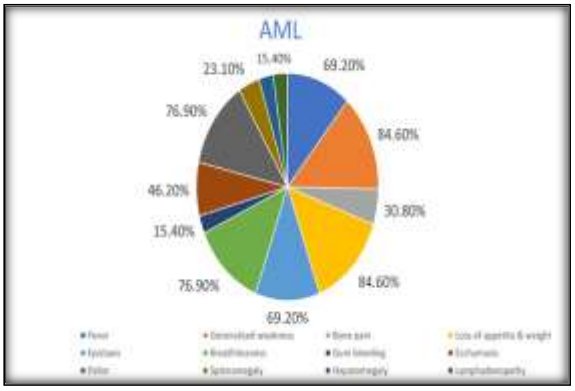

Figure 5: clinical features in AML

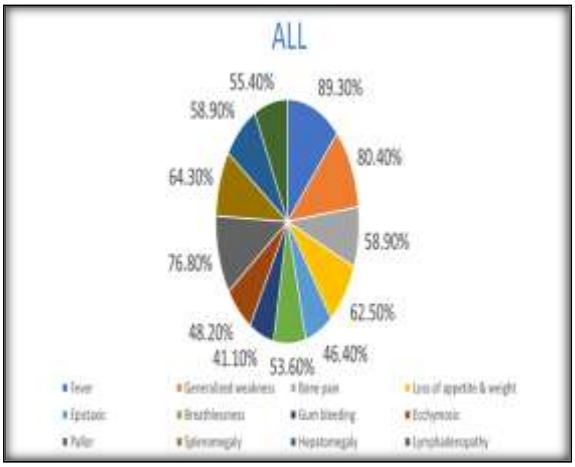

Figure 6: Clinical Features in all

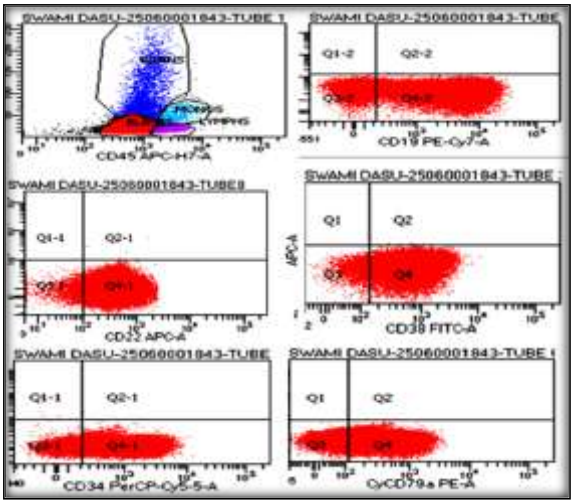

Figure 7: Immunophenotypic Findings in Acute Leukemias

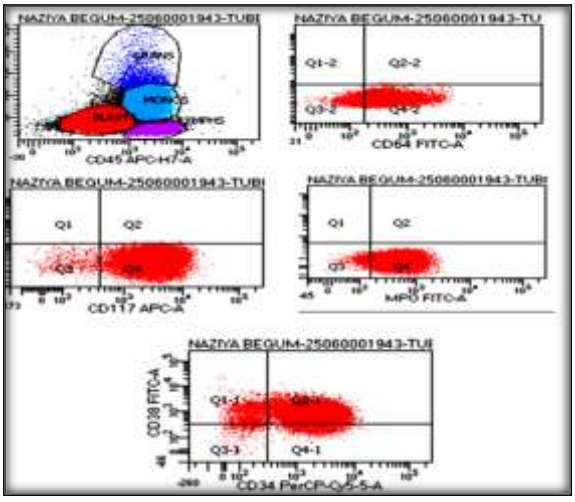

Figure 8: immunophenotypic findings in acute leukemias

DISCUSSION

Overview and Epidemiological Significance: Acute leukemias constitute one of the most aggressive and rapidly progressive hematological malignancies, accounting for a major share of cancer-

related morbidity in both developed and developing nations. Their clinical heterogeneity reflects underlying genetic and molecular diversity. The distribution of acute lymphoblastic leukemia (ALL) and acute myeloid leukemia (AML) is heavily influenced by demographic factors such as age, sex, and environmental exposures. Recent Indian data, including large cohort studies by Patel et al,[15] and Thakur et al,[16] confirm that the disease spectrum in South Asia parallels that observed globally, but the relative burden of ALL remains higher due to the younger population base.

In our study comprising 69 patients, ALL was more prevalent (56.5 %) than AML (43.5 %), with a male preponderance (M:F = 1.5:1). This pattern highlights both the pediatric predominance of ALL and possible gender-related risk factors. Socioeconomic and diagnostic disparities likely contribute to this distribution, with tertiary centers seeing more childhood and adolescent leukemia referrals, while adult AML cases may remain under-reported. These observations reinforce the need for improved registry-based reporting and diagnostic access, especially in rural and low-resource areas.

Gender Distribution: Males comprised 60.9 % of the cohort, producing a male-to-female ratio of 1.5:1. This aligns closely with Patel et al. (15) (1.7:1) and Thakur et al,[16] (1.7:1), confirming a persistent male predominance across both AML and ALL subtypes. Laishram et al,[17] also reported a ratio of 1.6:1, and Baviskar,[18] noted a similar trend (1.36:1). The consistency of this male bias across studies implies possible multifactorial influences, including occupational exposure to benzene and pesticides, hormonal modulation, and healthcare-seeking behavior differences favoring male patients in India.

Biological mechanisms may also contribute: androgen receptor signaling and differences in X-chromosomal inactivation patterns have been proposed to influence hematopoietic progenitor proliferation. Environmental-genetic interplay—especially exposure to ionizing radiation, industrial solvents, and infections—might amplify susceptibility in males. Hence, the observed sex disparity in our cohort is likely both biologically and socially driven.

Subtype Distribution (ALL vs AML): The predominance of ALL (56.5 %) over AML (43.5 %) in our study is consistent with the pediatric skew of our sample. Studies such as Kumar et al,[11] Rathee et al,[19] and Preethi et al,[14] reported similar findings (ALL 55–58 %). Conversely, Patel et al,[15] and Laishram et al,[17] observed AML predominance (63 % and 52 %, respectively), reflecting adult-oriented populations. This contrast highlights the impact of demographic composition on leukemia subtype frequencies.

Epidemiologically, India exhibits wide interregional variation in ALL:AML ratios due to environmental, nutritional, and genetic heterogeneity. The higher proportion of ALL in our series underscores the need for pediatric oncology strengthening at the district level. Moreover, WHO 2022's integration of genetic drivers (e.g., BCR-ABL1-like ALL, NPM1-mutated AML) allows re-classification of borderline or ambiguous cases, which may further refine subtype statistics in future multicentric studies.

Age Distribution: In our cohort, ALL was most common in children (0–14 years, 64 %), while AML predominated among adults (> 30 years, 67 %). This mirrors Dores et al,[5] who demonstrated that ALL peaks in early childhood and AML rises with age. Similar distributions were noted by Thakur et al,[16] (ALL < 20 years; AML 21–60 years) and Patel et al,[15] (mean ALL age 8 years; AML 48 years). The bimodal age distribution is a universal hallmark of acute leukemias.

The higher incidence of ALL in the pediatric group has been linked to genetic susceptibility (e.g., ETV6-RUNX1 fusions) and postnatal immune dysregulation. Adult AML predominance reflects age-related clonal hematopoiesis and mutational accumulation (DNMT3A, NPM1, FLT3). Thus, age stratification not only defines epidemiology but also dictates prognosis and therapy response.

Clinical Presentation: The major presenting symptoms in our study were fever (85.5 %), pallor (72.4 %), hepatosplenomegaly (63.8 %), and lymphadenopathy (52.1 %). These findings are comparable to Patel et al,[15] (fever 91.8 %, pallor 94.2 %) and Thakur et al,[16] (fever, weakness, and pallor universal). Similar symptom frequencies were reported by Ghosh et al,[13] and Kumar et al.[11] The predominance of systemic symptoms over localized findings emphasizes bone-marrow failure as the central pathophysiology.

Notably, lymphadenopathy was more frequent in ALL (52 %) than AML (30 %), while bleeding and gum hypertrophy occurred more often in AML, consistent with Thakur et al,[16] and Preethi et al.[14] The overall clinical spectrum observed reinforces that acute leukemias, though diverse, share a consistent triad—cytopenic symptoms, organomegaly, and systemic illness—necessitating comprehensive hematologic evaluation for timely differentiation.

Hematological Findings: Anemia (95.6 %), thrombocytopenia (85.5 %), and leukocytosis (69.6 %) were the predominant hematologic abnormalities in our patients. These trends closely align with Thakur et al,[16] (anemia 93–96 %, thrombocytopenia 80 %) and Patel et al,[15] (mean Hb 7.25 g/dL, mean platelets 39 912/µL). Similar cytopenic patterns have been observed by Rathee et al,[19] and Ghosh et al,[13] confirming marrow replacement as the key mechanism.

Our findings underscore anemia as a universal presenting feature, reflecting erythroid suppression by leukemic blasts. Thrombocytopenia accounted for bleeding manifestations, while leukocytosis signified high blast burden. Notably, leukopenic variants (10.1 %) were also identified, which may be misdiagnosed in peripheral setups due to absence of overt leukocytosis. This emphasizes the importance of

bone-marrow examination in every cytopenic patient with unexplained fever or pallor.

Immunophenotypic Profile: Flow cytometry revealed B-cell ALL (44.9 %) as the most frequent subtype, followed by T-cell ALL (11.6 %), and AML (43.5 %) showing myeloid marker positivity (CD13, CD33, MPO). Similar B-lineage predominance was reported by Thakur et al,[16] (100 % B-cell phenotype among ALL cases) and Patel et al,[15] where B-ALL-NOS surpassed T-ALL. The results also mirror observations by Siddiqui RP and Bachir F,[20] who documented B-ALL predominance across Asian and Mediterranean populations.

The WHO 2022 classification emphasizes immunophenotypic integration with genetics. Our study, though limited to phenotypic typing, supports this framework. The high frequency of B-ALL could reflect genetic subtypes like ETV6-RUNX1 and BCR-ABL1-like ALL, while AML cases with strong MPO positivity may correspond to t(8;21) or NPM1-mutated categories. Flow cytometry thus remains indispensable not only for diagnosis but also for prognostication and guiding targeted therapy.

Comparison with National & International Trends: When compared with national data, our ALL:AML ratio (1.3:1) matches findings from Rathee et al,[19] and Kumar et al,[11] and contrasts slightly with adult-centric studies such as Patel et al.[15] Regionally, AML predominance is often reported from western and northeastern India (Gujarat, Manipur; Laishram 2013),[17] while ALL dominance is common in southern and central India. Internationally, our pattern mirrors Dores et al,[5] and Siegel et al,[10] confirming consistency with global trends.

The persistence of high ALL incidence among Indian children may be associated with prenatal exposures, infectious triggers, or nutritional deficiencies. Improved access to immunophenotyping and public health surveillance will help delineate true incidence trends across states.

Clinical Implications: Our findings reinforce the essential role of morphology–flow cytometry integration for accurate classification and prognostic grouping. Early lineage identification enables personalized management, including ATRA in APL, imatinib in BCR-ABL1-positive ALL, and FLA-IDA or FLAG-IDA regimens for high-risk AML. The use of WHO-2022 genetic criteria ensures uniform reporting, which facilitates multi-center data pooling and outcome benchmarking.

Furthermore, the study underscores that most Indian centers can achieve diagnostic reliability using cost-effective panels of CD markers (CD13, CD33, CD19, CD10, CD3, MPO, TdT). Establishing regional flow cytometry hubs would greatly strengthen leukemia diagnosis outside metropolitan institutions.

Limitations

1. Single-center and retrospective design limits generalizability.
2. Cytogenetic and molecular studies were not performed for all cases, restricting prognostic correlation.
3. Short study duration and small sample size precluded survival analysis.
4. Referral bias toward pediatric cases may have influenced the ALL predominance.

Future multicentric prospective studies incorporating genomic profiling and treatment outcome tracking are recommended for comprehensive characterization of Indian leukemia patterns.

CONCLUSION

The present study highlights that acute lymphoblastic leukemia (ALL) is more common than acute myeloid leukemia (AML) in this regional cohort, particularly among male children. The most frequent clinical features were fever, pallor, and organomegaly, while anemia and thrombocytopenia were the key hematologic abnormalities. Immunophenotyping confirmed B-cell ALL as the predominant subtype.

These findings are in concordance with most Indian and international studies and underscore the need for early diagnosis, standardized classification, and wider use of flow cytometry. Incorporating WHO 2022 molecular subtyping will further enhance prognostication and therapeutic precision. Continued surveillance through multi-institutional registries will be vital to map leukemia trends and improve outcomes in the Indian population.

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