Ethiopian International Journal of Multidisciplinary Research

pISSN:2349-5707 Volume:12,Issue 10,October-2025 eISSN:2349-5715

HISTOLOGICAL AND CYTOMORPHOLOGICAL CHARACTERISTICS OF LEUKEMIC CELLS IN DIFFERENT TYPES OF LEUKEMIA

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Annotation: Leukemia represents a heterogeneous group of malignant disorders characterized by uncontrolled proliferation of abnormal hematopoietic cells within the bone marrow and peripheral blood. The histological and cytomorphological characteristics of leukemic cells serve as the foundation for classification, diagnosis, and prognosis of the disease. Each leukemia subtype—acute or chronic, myeloid or lymphoid—exhibits distinctive microscopic features that reflect the stage of cellular differentiation and the nature of malignant transformation. This article provides an overview of the histological organization of leukemic tissues and the cytomorphological variations of leukemic cells, emphasizing their diagnostic relevance in differentiating leukemia types and assessing disease progression.

Key words: leukemia, bone marrow, histology, cytomorphology, blasts, hematopoiesis, acute leukemia, chronic leukemia

Introduction

Leukemia is a malignant neoplastic disorder of the hematopoietic system that originates in the bone marrow and often infiltrates the peripheral blood and other organs. It is broadly classified into acute and chronic forms based on the maturity of proliferating cells, and further into myeloid and lymphoid lineages according to the affected hematopoietic lineage. The cytomorphological characteristics of leukemic cells provide crucial diagnostic information that correlates with the underlying molecular and cytogenetic abnormalities.

Histological and cytomorphological evaluation remains a cornerstone of leukemia diagnosis, even in the era of molecular medicine. Examination of peripheral blood smears, bone marrow aspirates, and trephine biopsies allows the visualization of blast morphology, maturation stages, nuclear features, and cytoplasmic granularity, which are essential for classification according to the World Health Organization (WHO) and French–American–British (FAB) systems.

1. General Cytomorphological Features of Leukemic Cells

Leukemic cells are characterized by uncontrolled proliferation, loss of differentiation, and abnormal morphology. Common cytological features include increased nuclear-to-cytoplasmic ratio, fine chromatin pattern, prominent nucleoli, and basophilic cytoplasm. Depending on the lineage and stage of maturation, additional features such as cytoplasmic granules, vacuoles, or Auer rods may be observed.

- Blast cells represent the hallmark of acute leukemias. They are typically large, with round to irregular nuclei, fine chromatin, and one or more prominent nucleoli. The cytoplasm is scant and basophilic.
- Mature leukemic cells, as seen in chronic leukemias, display well-differentiated morphology but abnormal accumulation due to defective apoptosis or proliferative signaling.

pISSN:2349-5707 Volume:12,Issue 10,October-2025 eISSN:2349-5715

2. Histological Features of Bone Marrow in Leukemia

In normal bone marrow, hematopoietic elements are distributed in an orderly fashion, with a balance between myeloid, erythroid, and megakaryocytic cells. In leukemia, this architecture becomes disrupted.

- Acute leukemias demonstrate a hypercellular bone marrow almost completely replaced by immature blast cells. Normal hematopoietic precursors are markedly suppressed, and adipose tissue is reduced. Blasts may form dense clusters, and mitotic figures are frequent, indicating rapid proliferation.
- Chronic leukemias exhibit increased cellularity with predominance of more mature forms of myeloid or lymphoid cells, depending on the subtype. The marrow sinusoids may be dilated, and infiltration often extends into the bone trabeculae and surrounding connective tissue.

Histochemical and immunohistochemical staining further enhances diagnostic accuracy. For instance, myeloperoxidase (MPO) positivity supports myeloid differentiation, while periodic acid–Schiff (PAS) positivity is typical for lymphoid blasts.

3. Cytomorphology of Major Leukemia Types

Acute Myeloid Leukemia (AML):

AML is characterized by the proliferation of immature myeloid precursors (myeloblasts). Morphologically, these cells have abundant basophilic cytoplasm with fine azurophilic granules and sometimes contain Auer rods—needle-like crystalline inclusions pathognomonic of myeloid differentiation. The nucleus is large with delicate chromatin and prominent nucleoli. Bone marrow smears reveal a high blast count (>20%), with suppression of erythroid and megakaryocytic series.

Acute Lymphoblastic Leukemia (ALL):

In ALL, the malignant cells are lymphoblasts that appear smaller than myeloblasts, with scant cytoplasm, high nuclear-to-cytoplasmic ratio, and dense chromatin. Cytoplasmic granules are absent. Based on immunophenotype, ALL is divided into B-cell and T-cell variants. Bone marrow shows diffuse infiltration by lymphoblasts, with effacement of normal marrow architecture.

Chronic Myeloid Leukemia (CML):

CML is marked by excessive proliferation of mature and maturing myeloid cells. Peripheral blood shows leukocytosis with all stages of granulocytic maturation, including myelocytes, metamyelocytes, and segmented neutrophils. The bone marrow is markedly hypercellular, with expansion of the myeloid series and megakaryocytic hyperplasia. Cytogenetically, the Philadelphia chromosome (t(9;22)(q34;q11)) is a defining feature.

Chronic Lymphocytic Leukemia (CLL):

CLL involves the accumulation of small, mature-appearing lymphocytes with dense chromatin and scant cytoplasm. Smudge cells—ruptured lymphocytes—are a characteristic finding in blood smears. Bone marrow infiltration is diffuse or nodular, often accompanied by splenic and nodal

pISSN:2349-5707 Volume:12,Issue 10,October-2025 eISSN:2349-5715

enlargement. Immunophenotyping confirms the presence of monoclonal B cells expressing CD5 and CD23.

4. Cytomorphological Variants and Diagnostic Significance

The morphological spectrum of leukemic cells varies not only between types but also within the same disease depending on differentiation and genetic background. For instance, acute promyelocytic leukemia (APL), a subtype of AML, shows abnormal promyelocytes with numerous granules and bundles of Auer rods (faggot cells), while hairy cell leukemia exhibits lymphocytes with irregular cytoplasmic projections.

Modern diagnostics integrates morphology with immunophenotyping, cytogenetics, and molecular studies to achieve precise classification. However, cytomorphological evaluation remains indispensable for rapid diagnosis, treatment initiation, and monitoring response to therapy.

Conclusion

The histological and cytomorphological examination of leukemic cells remains a cornerstone in the diagnosis and classification of leukemia. Despite the advances in molecular and genetic testing, microscopic evaluation provides the initial and often decisive step in identifying disease type and progression. The morphology of leukemic cells reflects the stage of differentiation arrest, lineage involvement, and proliferative activity within the bone marrow.

Each leukemia type displays unique structural features that aid in diagnosis: myeloblasts with Auer rods in acute myeloid leukemia, small lymphoblasts with condensed chromatin in acute lymphoblastic leukemia, mature granulocytic proliferation in chronic myeloid leukemia, and small mature lymphocytes in chronic lymphocytic leukemia. Recognition of these features allows for differentiation between acute and chronic, myeloid and lymphoid forms—an essential step in treatment planning and prognostication.

In addition, histopathological assessment of bone marrow architecture provides insights into disease burden, infiltration pattern, and hematopoietic suppression. When combined with cytochemical and immunohistochemical markers, histological and cytomorphological analysis offers a comprehensive understanding of leukemogenesis. As diagnostic technologies evolve, morphological evaluation remains the visual foundation upon which molecular discoveries are interpreted, reinforcing its irreplaceable role in modern hematopathology.

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pISSN:2349-5707 Volume:12,Issue 10,October-2025 eISSN:2349-5715

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