

**A study of spectrum of Hematological Disorders Diagnosed by Bone Marrow Examination in a Tertiary Care Centre of a Tribal Region: A Cross-Sectional Study**

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Abstract

Background: Bone marrow examination remains an important diagnostic investigation for patients with unexplained cytopenias, abnormal peripheral blood morphology and suspected hematological malignancy. Data describing the marrow-diagnosed spectrum from tertiary centres serving tribal populations are limited. This study evaluated the pattern of hematological disorders identified on bone marrow examination in a tertiary health-care centre in a tribal region.

Methods: A cross-sectional observational study was conducted in the Department of Pathology over 24 months (July 2023–July 2025). One hundred patients of

all ages and genders for whom bone marrow examination was advised by clinicians and who fulfilled the study criteria were included. Clinical data, complete blood count, peripheral smear, bone marrow aspiration and biopsy findings were integrated to establish the final marrow diagnosis. Data were analyzed using descriptive statistics and appropriate tests of association.

Results: The study included 100 patients aged 1–72 years (mean 37.5±21.4 years; median 39 years), with a male predominance (63%; male:female 1.7:1). Patients older than 60 years constituted the largest age group (32%). Megaloblastic anemia (25%) and mixed deficiency anemia (23%) were the two most frequent

marrow diagnoses, together accounting for 48% of cases. Myelodysplastic syndrome (9%), hypersplenism (8%), acute lymphoblastic leukemia (6%), immune thrombocytopenia (5%) and chronic myeloid leukemia (4%) were other frequent diagnoses. Overall, nutritional/deficiency diagnoses accounted for 50% of the cohort, while the diagnoses classified as hematological malignancies in the dissertation accounted for 24%.

Conclusion: Nutritional and deficiency-related disorders formed a substantial component of the marrow-diagnosed disease spectrum in this tertiary centre serving a tribal region, while malignant disorders also represented an important proportion. The findings support the continued diagnostic role of bone marrow examination and highlight the need to strengthen both preventive nutritional health measures and diagnostic capacity for hematological malignancies.

Keywords: Bone Marrow Examination, Hematological Disorders, Megaloblastic Anemia, Mixed Deficiency Anemia, Myelodysplastic Syndrome, Tribal Region, India.

Introduction

Bone marrow is the principal site of hematopoiesis and plays a central role in the diagnosis, classification and assessment of a wide range of hematological disorders. Although careful clinical examination, complete blood count (CBC) and peripheral blood smear examination frequently provide an initial diagnostic direction, bone marrow aspiration and biopsy may be indispensable when cytopenias remain unexplained, when abnormal or immature cells are identified in peripheral blood, or when a marrow-based malignancy, marrow failure syndrome, storage disorder or infiltrative process is suspected.^{1,2}

Bone marrow examination provides direct assessment of cellularity, maturation of erythroid, myeloid and megakaryocytic lineages, abnormal infiltrates and dysplastic changes. It can therefore distinguish between disorders that may present with similar peripheral blood abnormalities. In addition to morphology, marrow material can facilitate immunophenotyping, cytogenetics and molecular testing, which are increasingly important for precise classification and prognostic stratification of hematological neoplasms.^{1,5}

The spectrum of diseases encountered on bone marrow examination varies considerably between populations and institutions. Age structure, nutritional status, genetic background, environmental factors, referral practices and availability of diagnostic facilities can all influence the pattern observed. Published Indian and South Asian series have demonstrated substantial representation of nutritional anemias, aplastic anemia, immune thrombocytopenia, hypersplenism and acute or chronic leukemias among patients undergoing marrow evaluation.²⁻⁴ Consequently, local studies remain relevant, particularly from regions where marrow examination has only recently become established as a routine diagnostic service.

In developing and resource-constrained settings, nutritional deficiencies remain important contributors to hematological morbidity. The original dissertation literature review notes that iron deficiency and other nutritional disorders continue to contribute substantially to the hematological disease burden, while advanced diagnostic facilities are more concentrated in urban centres. This creates a need for strengthening diagnostic services in peripheral and tribal regions, where delayed referral and limited access to specialized

hematopathology may influence the stage at which patients are investigated.^{3,4}

Previous marrow-based studies have reported considerable variation in the relative frequency of individual disorders. Atchyuta et al. reported erythroid hyperplasia as the most frequent finding, followed by megaloblastic anemia, while chronic and acute leukemias constituted important malignant categories.² Other Indian series, including studies from central India and other tertiary centres, have similarly demonstrated nutritional anemia as an important non-malignant diagnosis, although the proportions of megaloblastic anemia, iron deficiency anemia, aplastic anemia and leukemia have differed between cohorts^{3,4,6,7}. These variations emphasize that marrow findings should be interpreted in the context of the population studied and the clinical indications for performing the procedure.

The present study was undertaken at a tertiary health-care centre serving a tribal region, where systematic bone marrow examination was newly introduced. The study therefore provides an opportunity to describe the local diagnostic spectrum and to examine the clinical and hematological patterns accompanying marrow diagnoses. Such information may be useful for understanding referral patterns, planning laboratory services and identifying areas where additional diagnostic modalities are required.

Against this background, the present study aimed to evaluate the spectrum of hematological disorders diagnosed by bone marrow examination and to correlate marrow findings with clinical features, CBC and peripheral smear findings. The study also sought to describe the prevalence and broad etiological classification of marrow-diagnosed disorders and to

identify situations in which morphology alone was insufficient for definitive classification.

Aim and Objectives

The study aimed to evaluate bone marrow examination findings in patients with hematological disorders for whom marrow examination was indicated, and to describe the associated clinical and hematological profile. Specific objectives included assessment of the prevalence and etiological spectrum of marrow-diagnosed disorders and correlation with clinical and routine hematological findings.

Materials and Methods

Study design and setting: Cross-sectional observational study conducted in the Department of Pathology of a tertiary health-care centre in a tribal region over 24 months from July 2023 to July 2025.

Study population and sample size: The dissertation reported a sample size of 100, calculated using the single-proportion formula with an expected prevalence of 10.4%, 1.96 as the standard normal deviate and 6% allowable error. Simple random sampling was reported.

Eligibility: Patients of all ages and genders for whom bone marrow examination was advised by clinicians and who provided written informed consent were eligible. Patients unwilling to participate, those with inadequate samples showing no hematopoietic cells, previously diagnosed marrow disorders and severe bleeding disorders with spontaneous or impending bleeding were excluded.

Laboratory methods: Clinical history included fever, bleeding tendencies, pallor, lymphadenopathy, hepatomegaly, splenomegaly and other relevant history. CBC was performed using automated hematology analyzers. Peripheral blood and bone marrow aspirate smears were stained with Leishman/Romanowsky stain,

and biopsy sections were stained with hematoxylin and eosin. The final marrow diagnosis was established by integrating aspiration and biopsy findings.

Results

Table 1: Age and sex-wise distribution of patients undergoing bone marrow examination (n=100).

Age group	Male, n (%)	Female, n (%)	Total, n (%)	Male:Female
1–15 years	11 (11)	7 (7)	18 (18)	1.57:1
15–30 years	18 (18)	2 (2)	20 (20)	9:1
31–60 years	22 (22)	8 (8)	30 (30)	2.75:1
>60 years	12 (12)	20 (20)	32 (32)	0.6:1
Total	63 (63)	37 (37)	100 (100)	1.7:1

The age range was 1–72 years, with mean age 37.5 ± 21.4 years and median 39 years. The association between age group and sex was statistically significant ($\chi^2=16.58$,

Statistics: Data were compiled and analyzed using STATA version 12 as described in the dissertation. A p-value <0.05 was considered statistically significant.

df=3, $p=0.00086$). The >60-year group was the largest, while female predominance was observed in this age group.

Table 2: Distribution of bone marrow diagnoses (n=100).

Bone marrow diagnosis	n	%
Megaloblastic anemia	25	25
Mixed deficiency anemia	23	23
Myelodysplastic syndrome	9	9
Hypersplenism	8	8
Acute lymphoblastic leukemia	6	6
Immune thrombocytopenia	5	5
Chronic myeloid leukemia	4	4
Erythroid hyperplasia	4	4
Aplastic anemia	2	2
Anemia of chronic disease	2	2
AML-M5	2	2
Iron deficiency anemia	2	2
Other individual diagnoses	8	8

The detailed dissertation table recorded 20 diagnostic categories. The eight diagnoses occurring once each were myeloid hyperplasia with dysmyelopoiesis, acute leukemia, CML in blast crisis, Gaucher disease, AML-

M2, myeloid hyperplasia, normocellular marrow and reactive plasmacytosis. The most frequent diagnoses were megaloblastic anemia and mixed deficiency anemia.

Table 3: Broad etiological grouping derived from the detailed diagnostic frequencies.

Etiological grouping derived from individual diagnoses	Included diagnoses	n	% of 100
Nutritional/deficiency	Megaloblastic anemia, mixed deficiency anemia, iron deficiency anemia	50	50
Hematological malignancies	MDS, ALL, CML, AML-M5, acute leukemia, CML-blast crisis, AML-M2	24	24
Autoimmune	ITP	5	5
Hematopoietic failure	Aplastic anemia	2	2
Other marrow/reactive/storage diagnoses	Remaining diagnoses in detailed spectrum	19	19

The broad grouping in Table 3 is calculated directly from the individual frequencies reported in the dissertation. It is presented here to avoid reproducing an internal denominator inconsistency in the dissertation's

separate etiological-classification table, which reports n=88 although the individual diagnostic frequencies in the prevalence table sum to 100.

Table 4: Frequency of major clinical features among the study participants (n=100).

Clinical feature	Frequency, n	Percentage
Pallor	98	98
Fever	39	39
Hepatomegaly	23	23
Splenomegaly	23	23
Bleeding manifestations	8	8
Lymphadenopathy	3	3
Other significant history	4	4

Discussion

The present study of 100 patients demonstrates a broad spectrum of hematological disorders diagnosed on bone marrow examination, with nutritional/deficiency disorders forming the largest etiological group. Megaloblastic anemia (25%) and mixed deficiency anemia (23%) together accounted for 48% of the cohort, while the broad nutritional/deficiency grouping accounted for 50% when iron deficiency anemia was included. The dissertation's detailed prevalence table

showed a statistically non-uniform distribution of diagnoses ($\chi^2=183.2$, $p<0.001$), indicating that the marrow diagnoses were concentrated in a limited number of common categories.

The predominance of nutritional disorders is consistent with the broader pattern reported in Indian marrow series, although the relative proportions vary. In the present study, megaloblastic anemia was 25%, comparable to the 24.29% reported by Hussain et al. and lower than the 27.8% reported by Zeeshan et al. [8,9].

Mixed deficiency anemia was notably frequent in the present series (23%), exceeding the proportions reported in several comparative studies cited in the dissertation. The dissertation attributes such differences to variation in patient selection and diagnostic criteria. Iron deficiency anemia constituted only 2%, lower than several published series, which may reflect the clinical indications leading to bone marrow examination in the present tertiary-care cohort.

Hematological malignancies represented an important component of the spectrum. The broad etiological classification in the dissertation recorded 24% as hematological malignancies, including myelodysplastic syndrome, acute leukemias and chronic myeloid leukemia. MDS was the most frequent individual malignant/clonal diagnosis (9%), followed by ALL (6%), CML (4%) and AML subtypes (3%), with additional cases of acute leukemia and CML in blast crisis. The relative frequencies of CML, ALL and AML differ substantially among published series, reflecting differences in age composition, referral patterns and study populations.⁴

Hypersplenism was diagnosed in 8% of the present cohort. This finding is within the range reported in published marrow series, although frequencies vary according to the referral population and diagnostic criteria⁵⁻⁷. Immune thrombocytopenia occurred in 5%, while erythroid hyperplasia was seen in 4%. The single case of Gaucher disease (1%) illustrates that uncommon storage disorders may also be encountered during marrow evaluation. These findings reinforce that rare storage, reactive and immune disorders may be identified even when they represent only a small proportion of the total workload.

Clinical findings provided important context for interpreting the marrow diagnoses. Pallor was the most frequent clinical feature, occurring in 98% of patients, and was seen across nutritional anemias, leukemias, marrow failure syndromes and infiltrative disorders. Fever occurred in 39% and was particularly represented among acute leukemias and megaloblastic or mixed deficiency anemia. Hepatomegaly and splenomegaly each occurred in 23% and were associated with leukemias, hypersplenism and Gaucher disease in the present cohort. Bleeding manifestations were less frequent (8%) and were confined mainly to aplastic anemia and ITP. The dissertation found a statistically significant association between clinical features and marrow diagnosis ($\chi^2=297.19$, $df=114$, $p=2.8 \times 10^{-18}$).

The disease-specific clinical observations provide additional context to the marrow diagnoses. Splenomegaly was present in all eight patients with hypersplenism, while hepatomegaly was observed in a proportion of patients with MDS. Among the combined acute leukemia cases, fever, splenomegaly and hepatomegaly were frequent. These observations illustrate the value of integrating clinical examination with marrow morphology rather than interpreting an isolated laboratory finding.

The CBC profile further demonstrated the diagnostic heterogeneity underlying apparently similar clinical syndromes. Pancytopenia was present in 60%, followed by bicytopenia (23%), anemia (16%) and normal counts (1%). Pancytopenia was most frequently associated with megaloblastic anemia, mixed deficiency anemia and MDS. Compared with the central Indian study by Nigam et al., the present frequency of pancytopenia was higher, whereas bicytopenia and anemia were lower.⁴ Such differences are expected in referral-based cohorts

because the indication for marrow examination determines the case mix.

Leukocytosis occurred in 14% of patients, predominantly in CML and acute leukemias, while thrombocytosis was identified in 5%, most frequently in iron deficiency anemia. The statistically significant association between CBC patterns and marrow diagnoses ($\chi^2=212.7$, $df=57$, $p<0.001$) supports the clinical value of CBC as a trigger for marrow evaluation. Nevertheless, the same CBC pattern may arise from multiple diseases, explaining why CBC should be interpreted together with peripheral smear, clinical findings and marrow morphology.

Taken together, these findings are consistent with the central role of bone marrow examination described in the literature. Bashawri emphasized the diagnostic indications and value of marrow examination, while the broader Indian literature demonstrates substantial variation in marrow-diagnosed disease patterns across tertiary-care populations⁵⁻⁷.

An important practical finding was the limitation of marrow morphology in 27% of cases. Six percent demonstrated non-specific or reactive marrow changes, while 21% required ancillary investigations. Most of the latter group comprised MDS and acute leukemias, together with selected leukemia subtypes and reactive plasmacytosis. This finding is particularly relevant to contemporary hematopathology because morphology alone may not provide the genetic or immunophenotypic information required for definitive classification.

Overall, the present findings support the continued utility of bone marrow examination in a tertiary centre serving a tribal region, while also emphasizing that the diagnostic process is increasingly multimodal. The high frequency of nutritional/deficiency disorders highlights

the continuing clinical importance of preventable nutritional deficiencies, whereas the substantial malignant component underscores the need for timely recognition and access to flow cytometry, cytogenetics and molecular testing. Because the study is cross-sectional and single-centre, the observed proportions should be interpreted as the diagnostic spectrum of this selected cohort rather than as population prevalence.

Strengths and Limitations

A strength of the study was systematic integration of clinical information, CBC, peripheral smear, marrow aspiration and biopsy findings in a tertiary centre serving a tribal region. Limitations included the single-centre design, modest sample size, referral bias, limited access to ancillary tests such as flow cytometry/cytogenetics/molecular studies, absence of follow-up, and resource constraints. Therefore, the diagnostic spectrum should not be generalized directly to the wider tribal or Indian population.

Conclusion

The marrow-diagnosed spectrum in this tertiary centre was characterized by a high frequency of nutritional/deficiency anemias, particularly megaloblastic and mixed deficiency anemia, alongside a meaningful burden of hematological malignancy. Bone marrow examination provided an important diagnostic framework, but complete characterization of selected malignant and indeterminate cases requires ancillary investigations. The findings support strengthening nutritional prevention and improving access to advanced hematopathology diagnostics in resource-limited settings.

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