



Original Article

Diagnostic Concordance Between Bone Marrow Aspirate, Touch Imprint Cytology and Trephine Biopsy in Haematological Disorders: An Observational Study from a Tertiary Care Centre in North East India

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ABSTRACT

Background: Bone marrow examination is a cornerstone in the diagnosis of haematological disorders. Bone marrow aspirate (BMA), touch imprint cytology (TIC), and trephine biopsy (BMB) each provide unique diagnostic insights, but their concordance varies across disease categories.

Objective: To evaluate diagnostic concordance between BMA, TIC, and BMB in haematological disorders and to identify conditions where biopsy and TIC provide additional diagnostic value.

Methods: This hospital based observational study was conducted at Agartala Government Medical College, Tripura, from April 2024 to March 2026. A total of 120 consecutive patients undergoing bone marrow evaluation were included. Clinical details, complete blood counts, peripheral smears, aspirates, TIC, and biopsies were assessed. Concordance and additional diagnostic utility were analysed.

Results: Overall concordance between BMA and BMB was 75%. Trephine biopsy provided additional diagnostic value in 38.3% of cases, particularly in aplastic anaemia, granulomatous lesions, lymphomas, and metastatic deposits. TIC showed 88% concordance with biopsy among evaluable cases, supporting its role as a rapid adjunct. Diagnosis wise concordance was highest in reactive marrow, CML/MPN, ITP, and hemophagocytosis (100%), while lowest in aplastic marrow (16.7%), granulomatous lesions (16.7%), lymphoma (25%), and metastatic deposits (25%).

Conclusion: While aspirates remain reliable for cytological diagnosis of disorders such as megaloblastic anaemia and acute leukaemia, trephine biopsy is indispensable for hypocellular, infiltrative, and focal lesions. TIC bridges cytology and architecture, enhancing diagnostic yield when aspirates are inadequate.

Keywords: Bone marrow aspirate, Touch imprint cytology, Trephine biopsy, Diagnostic concordance, Haematological disorders.

INTRODUCTION

Bone marrow examination is a fundamental tool in the diagnosis and monitoring of haematological and certain non-haematological disorders. As the primary site of hematopoiesis, the marrow provides essential information about cellular morphology, maturation, and disease processes. Clinical conditions such as leukaemia, lymphoma, plasma cell neoplasms, aplastic anaemia, and myelodysplastic syndromes often require direct marrow evaluation when peripheral blood findings are inconclusive.¹

Bone marrow aspiration (BMA) is a relatively simple and rapid procedure that yields detailed cytological information. It allows assessment of hematopoietic cell morphology, lineage maturation, and differential counts, and is indispensable for ancillary studies such as cytogenetics, molecular diagnostics, and flow cytometry.² However, aspirates may be hemodiluted, aparticle, or result in a “dry tap” in cases of marrow fibrosis or hypercellularity, limiting their diagnostic utility. Furthermore, aspirates are less sensitive in detecting focal lesions such as lymphoma infiltration or metastatic deposits.³

Bone marrow biopsy (BMB) or Trephine biopsy complements aspiration by providing architectural and structural information. It enables evaluation of overall marrow cellularity, distribution of hematopoietic elements, and detection of focal or diffuse infiltrative processes.⁴ BMB is particularly superior in diagnosing aplastic anaemia, myelofibrosis, granulomatous lesions, and metastatic tumours, where aspirates often fail.⁵ In addition, biopsy sections allow assessment of stromal components, trabecular bone, and vascular structures, which are critical in staging and prognostication of haematological malignancies.⁶

Touch imprint cytology (TIC) serves as an intermediate modality, bridging cytological and architectural evaluation. Prepared from trephine cores, TIC provides rapid morphological assessment, especially in cases of dry tap or inadequate aspirates.⁷ Studies have demonstrated high concordance between TIC and biopsy findings, making it a valuable adjunct for immediate evaluation while awaiting histopathology. TIC enhances diagnostic yield in plasma cell neoplasms and lymphomas by providing cytological clarity alongside architectural features on biopsy.⁸

Several studies have highlighted the complementary roles of BMA, TIC, and BMB. While BMA excels in cytology and ancillary testing, BMB provides indispensable architectural detail, and TIC bridges both approaches. Concordance between BMA and BMB is high in conditions such as megaloblastic anaemia and acute leukaemia, but significantly lower in aplastic anaemia, granulomatous lesions, and lymphomas, where biopsy proves superior.⁹ Thus, simultaneous evaluation using all three modalities enhances diagnostic accuracy and reduces uncertainty in haematological practice.¹⁰

Despite extensive literature, regional variations in disease prevalence and diagnostic challenges necessitate local studies. Data on the comparative utility of BMA, TIC and BMB from North East India remain limited. Regional patterns of nutritional anaemia, infections, haemoglobinopathies and haematological malignancies may influence the spectrum of marrow findings encountered in routine practice. The present study was therefore undertaken to evaluate the diagnostic concordance between bone marrow aspirate, TIC and trephine biopsy in patients undergoing marrow examination at a tertiary care centre in North East India, and to identify situations in which biopsy and TIC provide additional diagnostic value.

MATERIALS AND METHODS

Study Design and Setting

This was a hospital-based observational study conducted in the Department of Pathology at Agartala Government Medical College, Agartala, Tripura, over a period of two years, from April 2024 to March 2026. The study included patients referred for bone marrow evaluation for suspected or established haematological disorders and selected non-haematological conditions with suspected bone marrow involvement.

Sample Size

A total of 120 consecutive bone marrow cases received during the study period were included.

Inclusion Criteria

All patients of any age and sex who underwent bone marrow aspiration and trephine biopsy for diagnostic evaluation were included. TIC was performed wherever adequate trephine biopsy cores were available before fixation. Cases with available clinical details, complete blood count, peripheral blood smear findings and sufficient material for morphological correlation were included.

Exclusion Criteria

Cases with inadequate clinical details, poorly preserved smears, unsatisfactory biopsy cores, poorly processed biopsy sections or insufficient material for final diagnostic correlation were excluded. Haemodiluted aspirates, aparticle aspirates and dry tap cases were not excluded if trephine biopsy was adequate, as these cases were specifically evaluated for the additional diagnostic value of biopsy.

Clinical and Peripheral Blood Evaluation

Relevant clinical details and indications for bone marrow examination were recorded. Complete blood count parameters including haemoglobin concentration, total leukocyte count, differential leukocyte count, platelet count and red cell indices were documented. Peripheral blood smears were reviewed for anaemia pattern, leukocyte abnormalities, thrombocytopenia or thrombocytosis, blasts, immature cells, dysplastic changes, rouleaux formation, haemoparasites and abnormal circulating cells.

Bone Marrow Aspiration and Trephine Biopsy Procedure

Bone marrow procedures were performed under aseptic precautions. The posterior superior iliac spine was the preferred site in adults and children, while the proximal tibia was used in infants when indicated. Bone marrow aspirate smears were prepared immediately after collection, air-dried and stained with Leishman stain. Trephine biopsy cores were obtained from the same site, fixed in 10% neutral-buffered formalin, decalcified where required, routinely processed, paraffin-embedded, and stained with haematoxylin and eosin.

Touch Imprint Cytology

Touch imprint smears were prepared by gently touching or rolling the fresh trephine biopsy core on clean glass slides before fixation. The smears were air-dried and stained with Leishman stain. Smears showing adequate cellular material and marrow elements were considered satisfactory. Unavailable, poorly cellular or unsatisfactory touch imprint smears were recorded as not applicable or inconclusive.

Adequacy Criteria

Bone marrow aspirates were considered adequate when marrow particles and sufficient nucleated cells were present for cytological assessment. Aspirates were categorised as adequate, haemodiluted, aparticle or dry tap. Trephine biopsy cores were considered adequate when sufficient marrow space was available for assessment of cellularity, architecture and focal lesions. Touch imprint smears were considered adequate when representative marrow cells were present for cytomorphological evaluation.

Diagnostic Evaluation and Concordance

Bone marrow aspirate smears were evaluated for cellularity, myeloid and erythroid maturation, megakaryocytes, blasts, plasma cells, dysplastic changes, haemophagocytosis, granulomas, parasites and abnormal cells. Touch imprint smears were assessed for cytomorphological details similar to aspirate smears. Trephine biopsy sections were evaluated for marrow cellularity, architecture, distribution of haematopoietic elements, fibrosis, granulomas, lymphoid aggregates, plasma cell infiltration, metastatic deposits and other focal or diffuse lesions.

The final diagnosis was established through an integrated assessment of clinical details, complete blood count, peripheral blood smear, BMA, TIC, and BMB findings.

Cases were classified as concordant when bone marrow aspirate and trephine biopsy showed the same final diagnostic category. Cases were classified as discordant when one modality was non-diagnostic or inadequate, or when it showed findings that differed from the final integrated diagnosis. Trephine biopsy was considered to have additional diagnostic value when it established or clarified the diagnosis in haemodiluted, aparticle or dry-tap aspirates, or when it provided additional information regarding marrow cellularity, architecture, fibrosis, granulomas, lymphoma involvement, plasma cell infiltration, metastatic deposits or focal lesions.

Statistical Analysis

Data were compiled and analysed using SPSS software version 25. Categorical variables were expressed as frequencies and percentages. Overall concordance, diagnosis-wise concordance, touch imprint-biopsy concordance and the additional diagnostic value of trephine biopsy were calculated.

Ethical clearance and consent

The study protocol was reviewed and approved by the Institutional Ethics Committee of Agartala Government Medical College & Govind Ballabh Pant Hospital (AGMC & GBPH), Agartala, Tripura, prior to commencement. Written informed consent was obtained from all participants before enrollment. Consent forms were provided in the local languages (Bengali or Kokborok) or in English, depending on the respondent's preference, and duly signed. Confidentiality of participant information was strictly maintained throughout the study.

RESULTS

The study included 120 participants. The largest age group was 41–50 years (29 cases, 24.2%), followed closely by 51–60 years (25 cases, 20.8%) and those aged 60 years and above (25 cases, 20.8%). Together, these three groups account for 65.8% of the study population, showing that the majority of participants were middle-aged and older adults. Younger groups were less represented, with only 1 case (0.8%) in 0–10 years, 11 cases (9.2%) in 11–20 years, and 12 cases (10%) in 21–30 years. Out of the 120 participants, 68 were male (56.7%) and 52 were female (43.3%). This indicates a male predominance in the study population (Table 1)

Table 1. Demographic characteristics of the study population

Parameter	Category	Number of cases	Percentage
Age group	0-10 years	1	0.8%
	11-20 years	11	9.2%

	21-30 years	12	10.0%
	31-40 years	17	14.2%
	41-50 years	29	24.2%
	51-60 years	25	20.8%
	>60 years	25	20.8%
	Total	120	100.0%
Sex	Male	68	56.7%
	Female	52	43.3%
Total		120	100.0%

Table 2 shows that the most frequent broad clinical indication for bone marrow examination was cytopenia, accounting for 73 cases (60.8%), which included presentations such as pancytopenia, bicytopenia, isolated anaemia, thrombocytopenia, persistent cytopenia, pyrexia of unknown origin (PUO) with cytopenia, and B symptoms with cytopenia. The next major group was leukocytosis and suspected acute leukaemia, with 16 cases (13.3%), followed by plasma cell disorder-related indications, such as lytic bone lesions and anaemia with rouleaux formation, in 10 cases (8.3%). Other less common indications included lymphoma staging or suspected marrow metastasis (7 cases, 5.8%), splenomegaly with suspected myeloproliferative neoplasms or chronic myeloid leukaemia (7 cases, 5.8%), and PUO with suspected tuberculosis (5 cases, 4.2%). The least frequent indication was bleeding manifestations, observed in only 2 cases (1.7%).

Table 2. Broad clinical indications for bone marrow examination

Broad indication	Included indications	Number of cases	Percentage
Cytopenias	Pancytopenia, bicytopenia, anaemia, thrombocytopenia, isolated thrombocytopenia, persistent cytopenia, PUO with cytopenia and B symptoms with cytopenia	73	60.8%
Leukocytosis / suspected acute leukaemia	Leukocytosis, leukocytosis with blasts and suspected acute leukaemia	16	13.3%
Plasma cell disorder-related indications	Lytic bone lesion, anaemia with rouleaux and suspected plasma cell disorder	10	8.3%
Lymphoma / metastatic marrow evaluation	Lymphoma staging, suspected marrow metastasis and leukoerythroblastic blood picture	7	5.8%
Splenomegaly / suspected MPN or CML	Splenomegaly and suspected MPN/CML	7	5.8%
PUO / suspected tuberculosis	PUO and suspected tuberculosis	5	4.2%
Bleeding manifestation	Bleeding manifestation	2	1.7%
Total		120	100.0%

On complete blood count analysis, the most frequent haematological patterns observed were bicytopenia (33 cases, 27.5%) and pancytopenia (32 cases, 26.7%), together accounting for more than half of the study population. Leukocytosis and leukocytosis with blasts were each noted in 11 cases (9.2%), reflecting a significant subset with proliferative disorders. Other patterns included anaemia alone (9 cases, 7.5%), isolated thrombocytopenia (6 cases, 5.0%), and anaemia with leukocytosis (4 cases, 3.3%). Less frequent findings comprised normal/reactive patterns (4 cases, 3.3%), thrombocytosis (4 cases, 3.3%), persistent cytopenia (3 cases, 2.5%), and anaemia with rouleaux formation (3 cases, 2.5%). Overall, the data indicate that cytopenic presentations were the predominant haematological abnormality, while proliferative and plasma cell disorder-related features were observed at lower frequencies, underscoring the diverse clinical spectrum that necessitates bone marrow evaluation (Table 3).

Table 3. Haematological pattern on complete blood count

CBC pattern	Number of cases	Percentage
Bicytopenia	33	27.5%
Pancytopenia	32	26.7%
Leukocytosis	11	9.2%
Leukocytosis with blasts	11	9.2%
Anemia	9	7.5%
Isolated thrombocytopenia	6	5.0%
Anaemia with leukocytosis	4	3.3%
Normal/reactive pattern	4	3.3%
Thrombocytosis	4	3.3%
Persistent cytopenia	3	2.5%

Anaemia with rouleaux	3	2.5%
Total	120	100.0%

In terms of aspirate adequacy, 90 bone marrow aspirates (75.0%) were adequate, ensuring reliable cytological evaluation. However, 15 cases (12.5%) were reported as hemodiluted, which can compromise diagnostic yield due to dilution with peripheral blood. Aparticle aspirates were noted in 12 cases (10.0%), reflecting insufficient marrow particles for assessment. Additionally, 3 cases (2.5%) resulted in a dry tap, often associated with underlying marrow pathology such as fibrosis or hypercellularity (Table 4).

Table 4. Adequacy of bone marrow aspirate

Aspirate adequacy	Number of cases	Percentage
Adequate aspirate	90	75.0%
Hemodiluted aspirate	15	12.5%
Aparticle aspirate	12	10.0%
Dry tap	3	2.5%
Total	120	100.0%

In Table 5, the final integrated diagnoses revealed a diverse spectrum of haematological and marrow disorders. Megaloblastic anaemia was the most common finding, observed in 20 cases (16.7%), followed closely by acute leukaemia in 18 cases (15.0%). Other frequent diagnoses included reactive marrow changes (14 cases, 11.7%), aplastic/hypoplastic marrow (12 cases, 10.0%), and chronic myeloid leukaemia or other myeloproliferative neoplasms (12 cases, 10.0%). Plasma cell neoplasms accounted for 10 cases (8.3%), while marrow involvement by lymphoma was seen in 8 cases (6.7%). Less common but clinically significant diagnoses included myelodysplastic syndrome (6 cases, 5.0%), granulomatous lesions (6 cases, 5.0%), immune thrombocytopenic purpura (ITP) pattern/megakaryocytic hyperplasia (6 cases, 5.0%), metastatic tumour deposits (4 cases, 3.3%), and hemophagocytosis (4 cases, 3.3%).

Table 5. Final integrated diagnosis

Final integrated diagnosis	Number of cases	Percentage
Megaloblastic anemia	20	16.7%
Acute leukemia	18	15.0%
Reactive marrow	14	11.7%
Aplastic/hypoplastic marrow	12	10.0%
CML / myeloproliferative neoplasm	12	10.0%
Plasma cell neoplasm	10	8.3%
Lymphoma marrow involvement	8	6.7%
Myelodysplastic syndrome	6	5.0%
Granulomatous lesion	6	5.0%
ITP pattern / megakaryocytic hyperplasia	6	5.0%
Metastatic tumor deposit	4	3.3%
Hemophagocytosis	4	3.3%
Total	120	100.0%

Table 6 indicates that the final diagnoses, when grouped into broad pathological categories, showed that nutritional and benign erythroid disorders (megaloblastic anaemia) were the most common, accounting for 20 cases (16.7%). Acute leukaemia was the next major category, with 18 cases (15.0%), while myeloid neoplasms, including chronic myeloid leukaemia, other myeloproliferative neoplasms, and myelodysplastic syndromes, also comprised 18 cases (15.0%). Reactive or non-neoplastic marrow changes were noted in 14 cases (11.7%), and hypocellular marrow disorders such as aplastic or hypoplastic marrow were seen in 12 cases (10.0%). Among neoplastic conditions, plasma cell neoplasms (10 cases, 8.3%) and lymphoid neoplasms involving marrow (8 cases, 6.7%) were significant contributors. Less frequent but important categories included granulomatous lesions (6 cases, 5.0%), megakaryocytic disorders/ITP pattern (6 cases, 5.0%), metastatic tumour deposits (4 cases, 3.3%), and hemophagocytic patterns (4 cases, 3.3%).

Table 6. Final diagnosis grouped into broad pathological categories

Broad pathological category	Included diagnoses	Number of cases	Percentage
Nutritional / benign erythroid disorder	Megaloblastic anemia	20	16.7%
Acute leukemia	Acute leukemia	18	15.0%
Reactive / non-neoplastic marrow	Reactive marrow	14	11.7%
Hypocellular marrow disorder	Aplastic / hypoplastic marrow	12	10.0%

Myeloid neoplasm	CML / myeloproliferative neoplasm and myelodysplastic syndrome	18	15.0%
Plasma cell neoplasm	Plasma cell neoplasm	10	8.3%
Lymphoid neoplasm involving marrow	Lymphoma marrow involvement	8	6.7%
Granulomatous lesion	Granulomatous lesion	6	5.0%
Megakaryocytic disorder / ITP pattern	ITP pattern / megakaryocytic hyperplasia	6	5.0%
Metastatic tumor deposit	Metastatic tumor deposit	4	3.3%
Hemophagocytic pattern	Hemophagocytosis	4	3.3%
Total		120	100.0%

The analysis of diagnostic concordance between bone marrow aspirate (BMA) and trephine biopsy (BMB) revealed that in the majority of cases, the findings were concordant (90 cases, 75.0%), indicating strong agreement between the two modalities. In 29 cases (24.2%), however, the aspirate findings were either inconclusive or misleading, and the trephine biopsy was necessary to establish or clarify the final diagnosis, underscoring its added diagnostic value in certain conditions such as aplastic anaemia, granulomatous lesions, or focal infiltrative disorders. Only 1 case (0.8%) showed a truly discordant diagnosis between the two techniques (Table 7).

Table 7. Diagnostic concordance between bone marrow aspirate and trephine biopsy

BMA-BMB concordance category	Number of cases	Percentage
Concordant diagnosis	90	75.0%
Discordant, but trephine biopsy established or clarified the final diagnosis	29	24.2%
Truly discordant diagnosis	1	0.8%
Total	120	100.0%

The diagnostic utility of trephine biopsy showed that in 74 of 120 cases (61.7%), it did not provide any additional diagnostic information beyond that obtained from the bone marrow aspirate. However, in a significant proportion of cases (46; 38.3%), the trephine biopsy provided additional diagnostic value, either by clarifying inconclusive aspirate findings or by detecting pathology not evident on aspirate alone, such as focal lesions, marrow fibrosis, or infiltrative disorders (Table 8).

Table 8. Diagnostic utility of trephine biopsy

Diagnostic contribution of trephine biopsy	Number of cases	Percentage
No additional diagnostic value over aspirating	74	61.7%
Additional diagnostic value present	46	38.3%
Total	120	100.0%

Trephine biopsy established or clarified the final diagnosis in 29 cases (24.2%) in which the aspirate was inconclusive, inadequate or non-representative. Overall, trephine biopsy provided additional diagnostic value in 46 cases (38.3%). This included 29 diagnostically decisive cases and 17 additional cases in which biopsy contributed supplementary architectural or quantitative information, such as assessment of marrow cellularity, fibrosis, focal infiltration, granulomatous lesions, plasma cell burden or metastatic deposits, without necessarily changing the broad aspirate diagnosis.

The analysis of the utility of trephine biopsy according to aspirate adequacy revealed a striking difference between the two groups. Among cases with an adequate aspirate (90 cases), trephine biopsy provided additional diagnostic value in 16 cases (17.8%), showing that while aspirates are generally reliable, biopsy can still uncover important findings in a subset. In contrast, for cases with hemodiluted, aparticle aspirates, or dry taps (30 cases), trephine biopsy contributed additional diagnostic value in all 30 cases (100%), underscoring its indispensable role when aspirate quality is poor or non-representative (Table 9).

Table 9. Additional diagnostic value of trephine biopsy according to the adequacy of the aspirate

Aspirate category	Total cases	Cases where trephine biopsy added diagnostic value	Percentage within category
Adequate aspirate	90	16	17.8%
Hemodiluted / aparticle aspirate / dry tap	30	30	100.0%
Total	120	46	38.3%

The concordance analysis between TIC and trephine biopsy showed that in the majority of cases (81, 67.5%), the findings were concordant, reflecting good agreement between the two diagnostic modalities. Discordant or inconclusive results were observed in 11 cases (9.2%), where trephine biopsy provided clarification or a more definitive diagnosis. In 28 cases (23.3%), TIC was not applicable or not evaluable, often due to technical limitations or inadequate samples. When considering only the 92 evaluable cases, the concordance rate between touch imprint and trephine biopsy was notably high at 88.0% (Table 10).

Table 10. Touch imprint cytology and trephine biopsy concordance

Touch imprint-BMB concordance category	Number of cases	Percentage among total cases
Concordant	81	67.5%
Discordant/inconclusive	11	9.2%
Not applicable / not evaluable	28	23.3%
Total	120	100.0%
Concordance among evaluable touch imprint cases	81/92	88.0%

The diagnosis-wise concordance between BMA and BMB varied across disease categories. Reactive marrow, CML/myeloproliferative neoplasms, ITP pattern/megakaryocytic hyperplasia, and hemophagocytosis demonstrated complete concordance (100%), indicating that aspirate alone was sufficient for diagnosis in these conditions. High concordance was also observed in megaloblastic anaemia (95.0%), acute leukaemia (88.9%), and myelodysplastic syndrome (83.3%), though trephine biopsy clarified a small proportion of cases. In contrast, lower concordance was noted in plasma cell neoplasms (80.0%), where biopsy added value in detecting marrow infiltration, and particularly poor concordance was seen in lymphoma marrow involvement (25.0%), metastatic tumour deposits (25.0%), aplastic/hypoplastic marrow (16.7%), and granulomatous lesions (16.7%), where biopsy was essential to establish the diagnosis. Overall, out of 120 cases, 90 (75.0%) were concordant, while 30 (25.0%) required biopsy for definitive diagnosis (Table 11).

Table 11. Diagnosis-wise concordance between bone marrow aspirate and trephine biopsy

Final diagnosis	Total cases	Concordant cases	Discordant / biopsy diagnostic cases	Concordance percentage
Reactive marrow	14	14	0	100.0%
CML / myeloproliferative neoplasm	12	12	0	100.0%
ITP pattern / megakaryocytic hyperplasia	6	6	0	100.0%
Hemophagocytosis	4	4	0	100.0%
Megaloblastic anemia	20	19	1	95.0%
Acute leukemia	18	16	2	88.9%
Myelodysplastic syndrome	6	5	1	83.3%
Plasma cell neoplasm	10	8	2	80.0%
Lymphoma marrow involvement	8	2	6	25.0%
Metastatic tumor deposit	4	1	3	25.0%
Aplastic / hypoplastic marrow	12	2	10	16.7%
Granulomatous lesion	6	1	5	16.7%
Total	120	90	30	75.0%

The diagnostic categories in which trephine biopsy proved superior highlight its unique ability to provide architectural and cellular insights that aspirates often miss. In aplastic or hypoplastic marrow, biopsy was essential for assessing overall marrow cellularity and fat spaces, which cannot be reliably judged on aspirates. For lymphoma marrow involvement, biopsy enabled detection of focal, paratrabecular, interstitial, or diffuse infiltrates that are frequently missed in aspirates. Similarly, granulomatous lesions were identified through biopsy by visualising focal granulomas and architectural changes. In cases of metastatic tumour deposits, biopsy revealed focal tumour infiltration and marrow replacement, which aspirates may fail to capture. For plasma cell neoplasms, biopsy provided a superior assessment of the pattern and extent of plasma cell infiltration. Moreover, in situations of dry tap or aparticulate aspirates, biopsy supplied diagnostic tissue when aspirates were non-diagnostic, and in hemodiluted aspirates, it prevented false-negative interpretations caused by peripheral blood dilution (Table 12).

Table 12. Diagnostic categories in which the trephine biopsy was superior

Diagnostic category	Reason for the superiority of the trephine biopsy
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Aplastic/hypoplastic marrow	Assessment of overall marrow cellularity and fat spaces
Lymphoma marrow involvement	Detection of focal, paratrabecular, interstitial or diffuse marrow infiltration
Granulomatous lesion	Identification of focal granulomas and architectural lesions
Metastatic tumor deposit	Detection of focal tumour deposits and marrow replacement
Plasma cell neoplasm	Assessment of pattern and extent of plasma cell infiltration
Dry tap/aparticulate aspirate	Provided diagnostic tissue when the aspirate was non-diagnostic
Hemodiluted aspirate	Helped avoid false-negative interpretation due to peripheral blood dilution

The summary of key study findings (Table 13) highlights the overall demographic, clinical, and diagnostic profile of the 120 cases evaluated. The most common age group was 41–50 years, with a male-to-female ratio of 1.3:1, indicating a slight male predominance. Clinically, cytopenias were the leading broad indication (73 cases, 60.8%), with pancytopenia being the most frequent specific indication (30 cases, 25.0%). On complete blood count, bicytopenia (33 cases, 27.5%) was the most common pattern. In terms of aspirate adequacy, 90 cases (75.0%) were adequate, while 30 cases (25.0%) were hemodiluted, aparticulate, or dry taps, necessitating reliance on trephine biopsy.

The final integrated diagnosis most frequently identified megaloblastic anaemia (20 cases, 16.7%), followed by acute leukaemia (18 cases, 15.0%). Overall, BMA–BMB concordance was achieved in 90 cases (75.0%), while 29 cases (24.2%) required biopsy to establish or clarify the diagnosis, and trephine biopsy provided additional diagnostic value in 46 cases (38.3%). TIC showed 67.5% concordance among all cases, but when restricted to evaluable cases, concordance rose to 88.0%, confirming its supportive role. Importantly, diagnostic categories with low BMA–BMB concordance included aplastic/hypoplastic marrow, granulomatous lesions, lymphoma marrow involvement, and metastatic tumour deposits, underscoring the indispensable role of trephine biopsy in these conditions (Table 13).

Table 13. Summary of key study findings

Parameter	Finding
Total number of cases	120
Most common age group	41-50 years
Male:female ratio	1.3:1
Most common broad clinical indication	Cytopenias: 73 cases (60.8%)
Most common specific clinical indication	Pancytopenia: 30 cases (25.0%)
Most common CBC pattern	Bicytopenia: 33 cases (27.5%)
Adequate bone marrow aspirate	90 cases (75.0%)
Hemodiluted/aparticulate aspirate / dry tap	30 cases (25.0%)
Most common final integrated diagnosis	Megaloblastic anaemia: 20 cases (16.7%)
The second most common final integrated diagnosis	Acute leukaemia: 18 cases (15.0%)
Overall BMA-BMB concordance	90 cases (75.0%)
Cases where trephine biopsy established or clarified the diagnosis	29 cases (24.2%)
Overall, the additional diagnostic value of trephine biopsy	46 cases (38.3%)
Touch imprint-BMB concordance among total cases	81 cases (67.5%)
Touch imprint-BMB concordance among evaluable cases	81/92 cases (88.0%)
Diagnoses with low BMA-BMB concordance	Aplastic/hypoplastic marrow, granulomatous lesion, lymphoma marrow involvement and metastatic tumour deposit

The kappa analysis of diagnostic concordance between BMA and BMB showed 75.0% agreement, with 90 of 120 cases concordant. The calculated Cohen's kappa value was 0.725, which falls within the range of substantial agreement according to standard interpretation guidelines (Table 14).

Table 14. Kappa analysis of diagnostic concordance between bone marrow aspirate and trephine biopsy

Comparison	Total cases	Concordant cases	Percentage agreement	Cohen's kappa value	Strength of agreement
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Bone marrow aspirate cytology vs trephine biopsy	120	90	75.0%	0.725	Substantial agreement
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Note: BMA and BMB showed 75.0% overall diagnostic concordance. Cohen's kappa value of 0.725 indicates substantial agreement. Trephine biopsy provided additional information particularly in hemodiluted aspirate, aparticulate aspirate, dry tap, hypocellular marrow disorders and focal or architectural marrow lesions.

The comparison between TIC and trephine biopsy demonstrated a high level of diagnostic agreement. Out of 120 total cases, 92 were evaluable, and among these, 81 cases (88.0%) showed concordance between touch imprint and biopsy findings (Table 15).

Table 15. Diagnostic agreement between touch imprint cytology and trephine biopsy

Comparison	Total cases	Evaluable cases	Concordant cases among evaluable cases	Percentage agreement among evaluable cases
Touch imprint cytology vs trephine biopsy	120	92	81	88.0%

Images

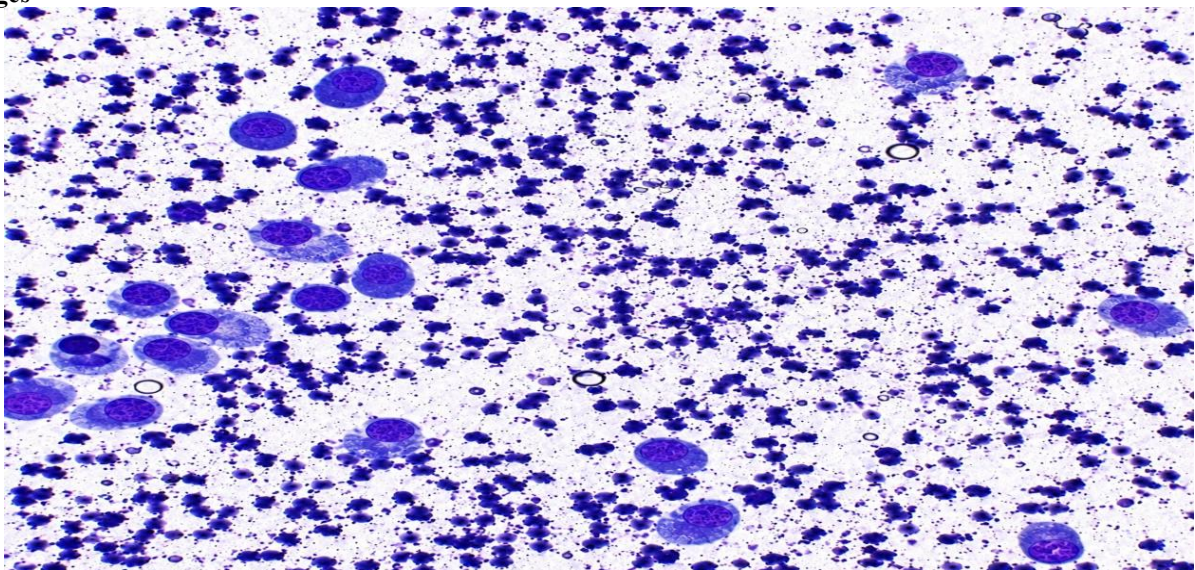


Image 1: Bone marrow aspirate smear showing abnormal plasma cells in multiple myeloma. Leishman stain, 40x.

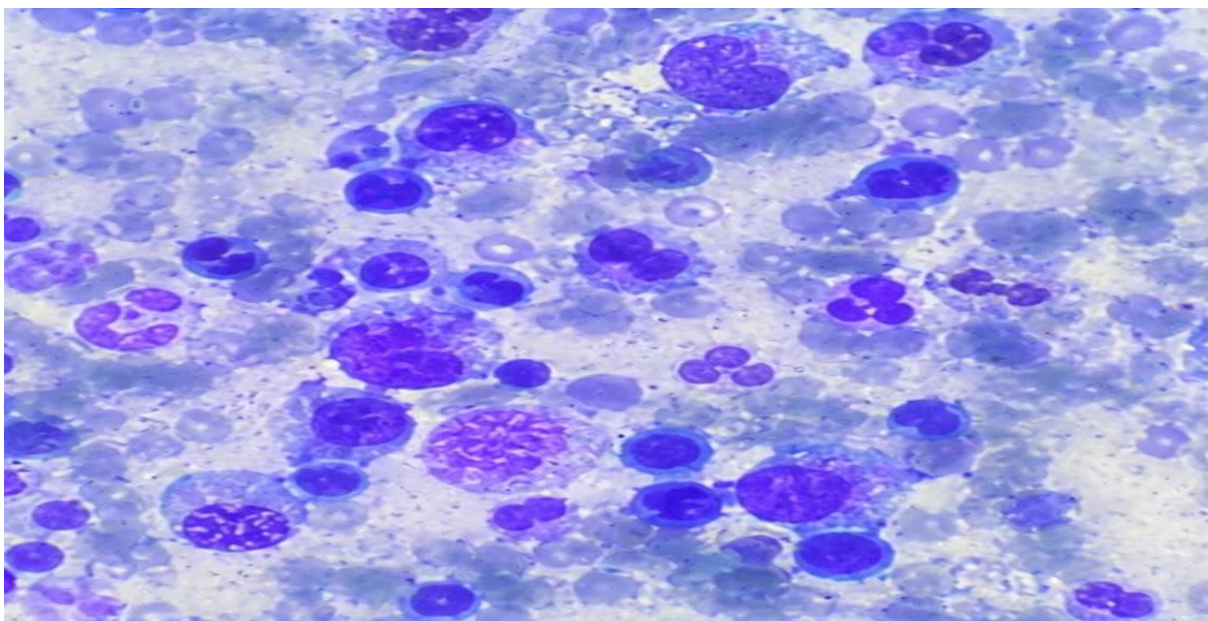


Image 2: Bone marrow aspirate smear showing giant metamyelocytes and megaloblasts in megaloblastic anaemia. Leishman stain, 100x.

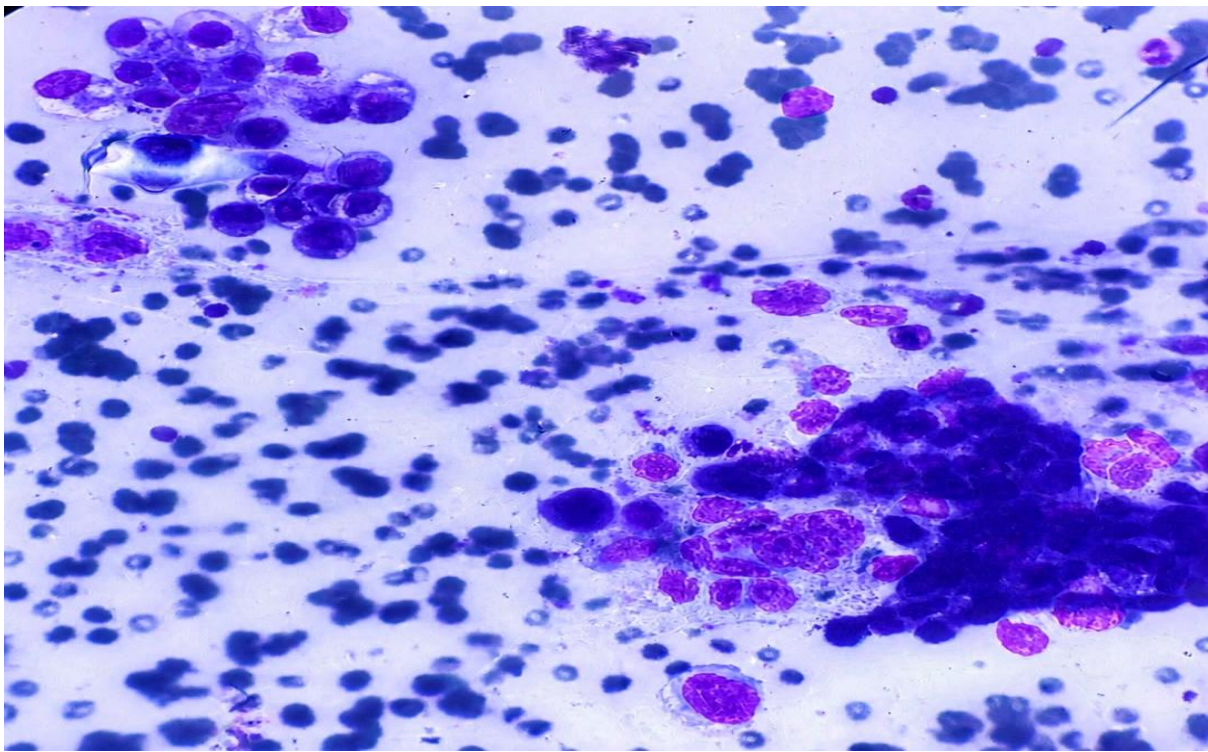


Image 3: Bone marrow touch imprint showing clusters of atypical epithelial cells consistent with metastatic adenocarcinoma. Leishman stain, high-power view.

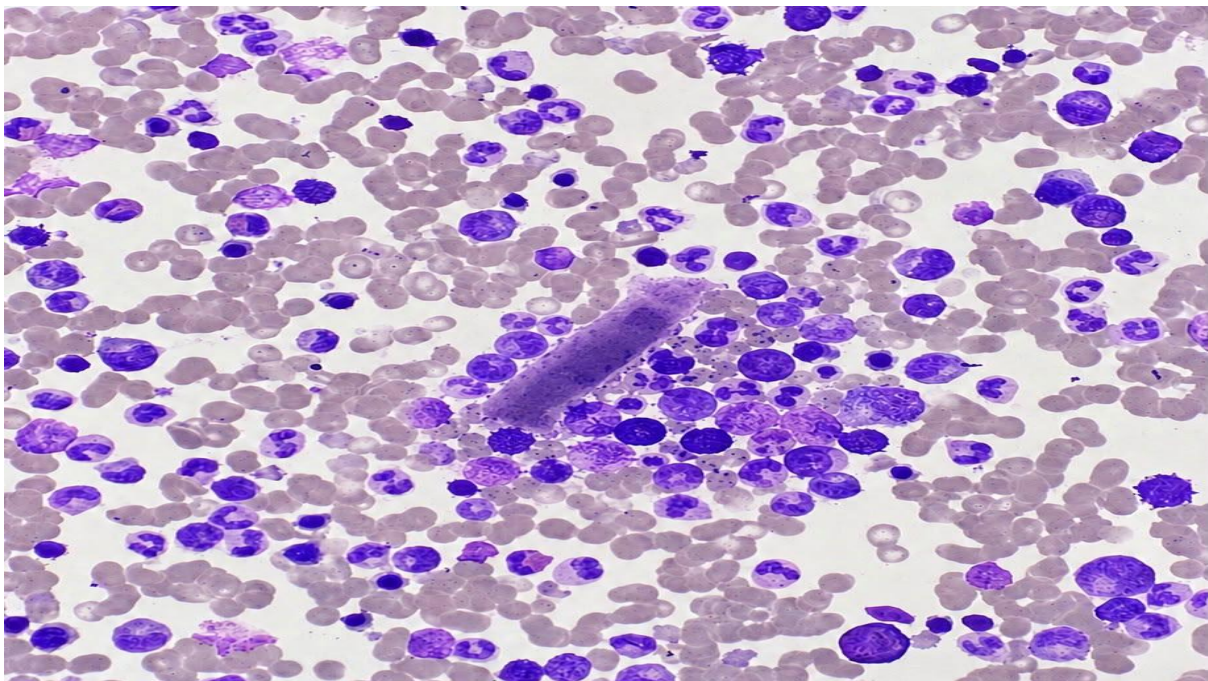


Image 4: Bone marrow touch imprint smear from a dry tap case showing bone marrow elements. Leishman stain, 40x.

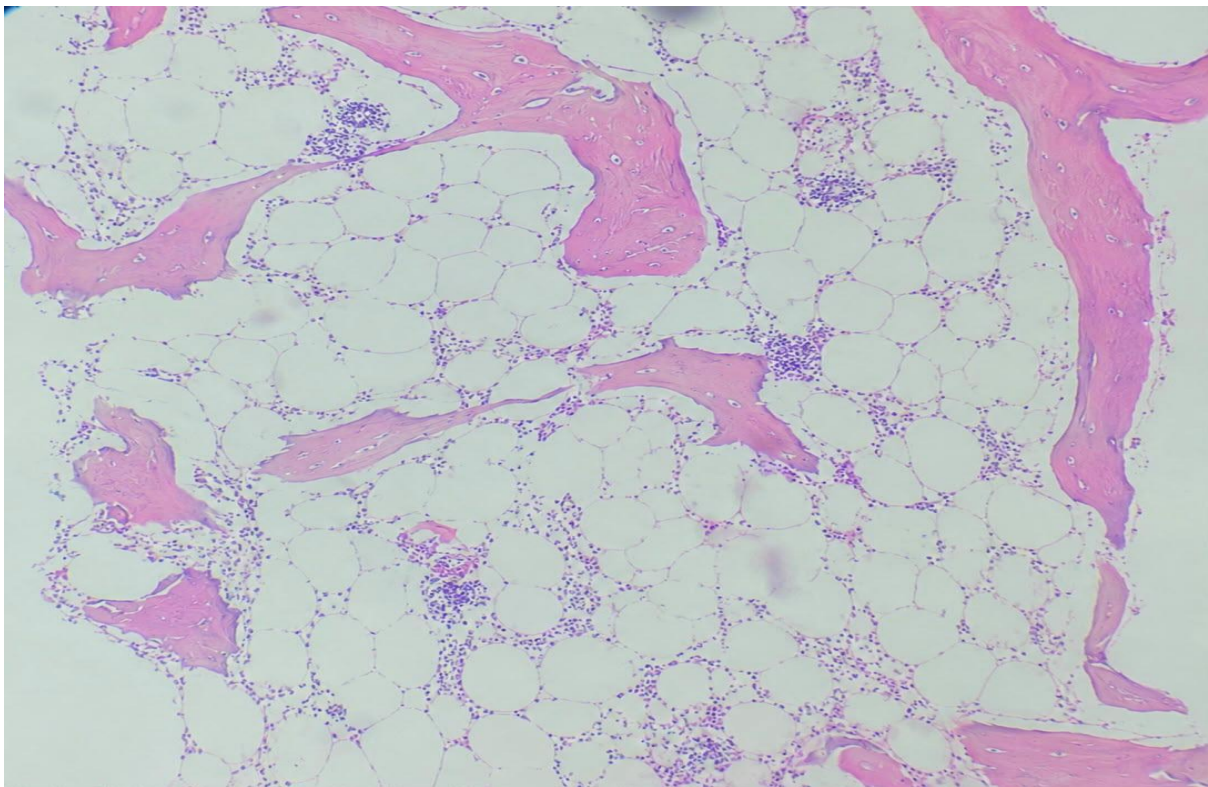


Image 5: Bone marrow biopsy showing hypocellular marrow in aplastic anaemia. H&E stain, low-power view.

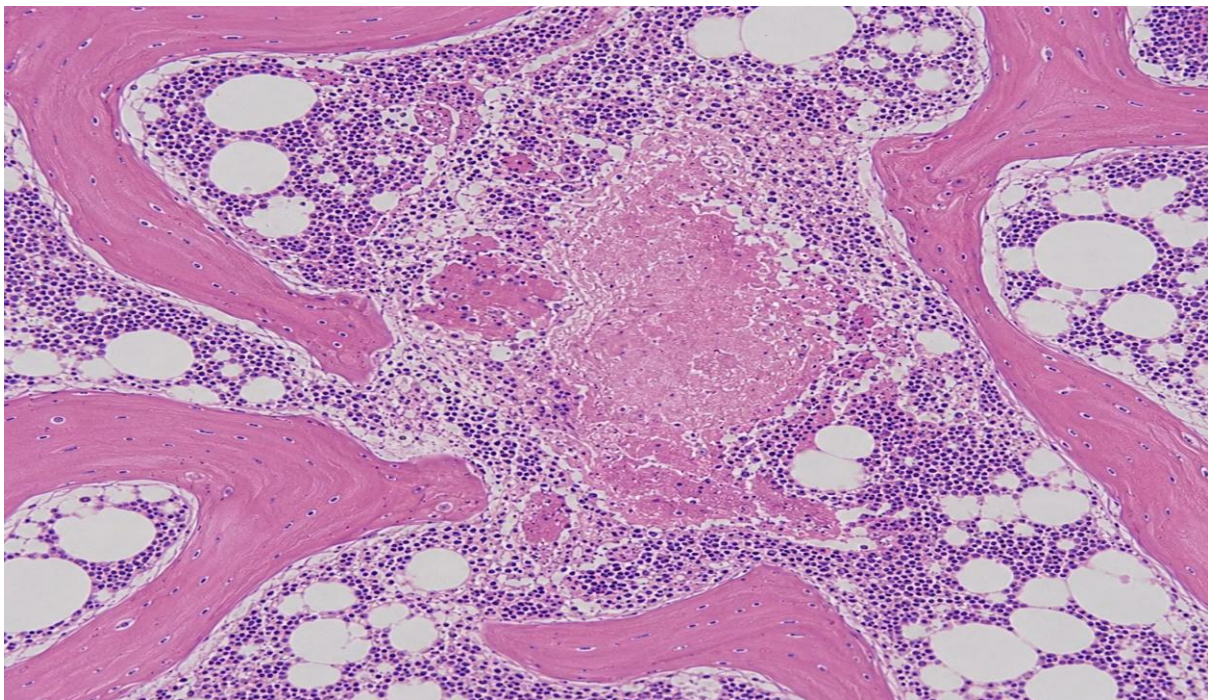


Image 6: Bone marrow trephine biopsy showing granulomatous inflammation. H&E stain, low-power view.

DISCUSSION

The present study highlights the complementary roles of BMA, TIC, and BMB in the evaluation of haematological disorders. Overall concordance between BMA and BMB was high (75%), consistent with earlier reports that aspirates are generally reliable for conditions such as megaloblastic anaemia and acute leukaemia.^{11,12} In our cohort, megaloblastic anaemia showed 95% concordance, reaffirming that aspirates provide sufficient cytological detail for nutritional anaemias. Similarly, acute leukaemia showed 88.9% concordance, reflecting aspirates' ability to capture blast morphology and lineage differentiation.¹³

However, trephine biopsy proved indispensable in specific diagnostic categories. In aplastic or hypoplastic marrow, concordance was only 16.7%, underscoring the biopsy's superiority in assessing overall cellularity and fat spaces, which aspirates cannot reliably evaluate.¹⁴ Likewise, marrow involvement by lymphoma and metastatic deposits showed poor concordance (25%), highlighting the biopsy's role in detecting focal, paratrabeular, or diffuse infiltrates that are often missed on aspirates.^{15,16} Granulomatous lesions also required biopsy confirmation, with concordance limited to 16.7%, as architectural visualisation of granulomas is essential for diagnosis.¹⁷

TIC demonstrated strong agreement with biopsy in evaluable cases (88%), supporting its utility as a rapid adjunct, particularly when aspirates are inadequate. This finding aligns with prior studies that emphasised TIC's role in plasma cell neoplasms and lymphomas, where it provides immediate cytological clarity while biopsy offers architectural context.^{18,19} In our study, plasma cell neoplasms showed 80% concordance between aspirate and biopsy, with biopsy adding value in quantifying infiltration patterns.

The diagnostic utility of trephine biopsy was most evident in cases with poor aspirate adequacy. Among hemodiluted, aparticulate, or dry tap aspirates, biopsy contributed additional diagnostic value in 100% of cases, confirming its indispensable role when aspirates are non-representative. Even with adequate aspirates, biopsy added value in 17.8% of cases, revealing fibrosis, focal infiltration, or quantitative details not apparent on cytology.

These findings emphasise that while aspirates remain the cornerstone for cytomorphology and ancillary studies, trephine biopsy is critical for architectural assessment, especially in hypocellular, infiltrative, or focal lesions. TIC bridges both modalities, enhancing diagnostic yield and providing rapid preliminary insights. Together, the three techniques form a synergistic triad that maximises diagnostic accuracy in haematological practice.

Regional relevance is also noteworthy. The predominance of megaloblastic anaemia and acute leukaemia in our cohort reflects nutritional deficiencies and the burden of haematological malignancies in North East India. The relatively frequent detection of granulomatous lesions underscores the endemicity of tuberculosis in this region, further validating the need for biopsy in local diagnostic practice.²⁰

CONCLUSION

This study demonstrates that integrated evaluation using BMA, TIC, and BMB significantly improves diagnostic accuracy in haematological practice. Aspirates are sufficient for many cytological conditions, including megaloblastic anaemia and acute leukaemia, but biopsy remains crucial in aplastic anaemia, granulomatous lesions, lymphomas, and metastatic deposits where architectural assessment is indispensable. TIC serves as a valuable rapid adjunct, particularly in cases of dry tap or inadequate aspirates, and shows high concordance with biopsy in plasma cell neoplasms and lymphomas. Together, these modalities form a complementary triad that reduces diagnostic uncertainty and ensures comprehensive evaluation of marrow pathology.

Study limitations

- The study was conducted in a single tertiary care centre, which may limit generalisability to other regions.
- The sample size, though adequate, may not capture the full spectrum of rare marrow disorders.
- TIC was not evaluable in 23.3% of cases due to technical limitations, which may underestimate its potential utility.
- Ancillary techniques such as immunohistochemistry, cytogenetics, and molecular studies were not systematically integrated, which could have further refined diagnostic accuracy.

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