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Evaluation of hematological parameters and bone marrow findings in patients presenting with pancytopenia: A cross-sectional observational study

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Abstract

Background: Pancytopenia is characterised by a reduction in all three major peripheral blood cell lines and may result from nutritional deficiencies, bone marrow failure, haematological malignancies, infections, or marrow infiltration. Peripheral blood examination provides important diagnostic clues, while bone marrow examination helps establish the underlying morphological cause.

Aim: To evaluate the haematological parameters and bone marrow findings in patients presenting with pancytopenia and to determine the spectrum of morphological abnormalities associated with pancytopenia.

Materials and Methods: A cross-sectional observational study was conducted over a period of one year in the Department of Pathology, Government Medical College, Kanyakumari. A total of 25 patients presenting with pancytopenia were included. Clinical findings, complete blood count, red cell indices, peripheral blood smear findings, and bone marrow morphology were evaluated. Bone marrow aspirates and biopsies, where indicated, were assessed for cellularity, erythroid and myeloid series, megakaryocytes, myeloid-to-erythroid ratio, blast percentage, dysplastic changes, and abnormal infiltrates. Relevant biochemical and nutritional investigations were performed where indicated.

Results: The study included 14 males (56%) and 11 females (44%). The majority of patients belonged to the 41–60-year age group. Pallor was the most common clinical finding (92%), followed by generalised weakness/fatigue (76%). The mean haemoglobin was 7.4 ± 1.5 g/dL, mean total leukocyte count was 2,480 ± 760/µL, and mean platelet count was 68,400 ± 31,200/µL. Normocytic normochromic anaemia was the predominant peripheral smear pattern (36%), followed by macrocytic

anaemia (32%). Bone marrow was hypercellular in 48%, normocellular in 28%, and hypocellular in 24% of cases. Megaloblastic erythropoiesis was the commonest marrow finding (28%), followed by erythroid hyperplasia (20%) and hypoplastic/aplastic marrow (20%). Acute leukaemia and myelodysplastic changes were identified in 12% and 8% of cases, respectively.

Conclusion: Pancytopenia has a diverse clinical, haematological, and bone marrow morphological spectrum. A systematic evaluation using complete blood count, peripheral blood smear, and bone marrow examination is essential for identifying the underlying cause. Recognition of potentially reversible causes, particularly nutritional deficiencies, is important for appropriate clinical management.

Keywords: Pancytopenia, Complete Blood Count, Peripheral Blood Smear, Bone Marrow Examination, Megaloblastic Anaemia, Aplastic Anaemia, Haematological Malignancy.

Introduction

Pancytopenia is a common haematological abnormality characterized by a reduction in all three major peripheral blood cell lines, namely erythrocytes, leukocytes, and platelets. It is not a disease entity itself but a manifestation of several underlying pathological conditions affecting bone marrow production, hematopoietic cell maturation, peripheral destruction, sequestration, or infiltration of the marrow. The clinical presentation varies from asymptomatic cytopenias to severe anemia, recurrent infections, and bleeding manifestations.[1,2]

The etiological spectrum of pancytopenia is broad and includes nutritional deficiencies, aplastic anemia, acute leukemia, myelodysplastic syndromes, megaloblastic anemia, infections, hypersplenism, autoimmune disorders, drug-induced marrow suppression, and malignant infiltration. The relative frequency of these causes varies according to age, geographic region, nutritional status, and study population.[3-5]

Anemia is usually the most prominent hematological abnormality in pancytopenia and may present clinically with pallor, weakness, fatigue, and exertional dyspnea. Leukopenia, particularly neutropenia, increases susceptibility to infections, whereas thrombocytopenia may result in petechiae, mucosal bleeding, or more severe hemorrhagic manifestations. Therefore, careful clinical assessment together with complete blood count and peripheral blood smear examination is essential for the initial evaluation.[1,4]

Peripheral blood smear examination provides important morphological clues regarding the underlying etiology. Macrocytosis, anisopoikilocytosis, and hypersegmented neutrophils may suggest megaloblastic anemia, whereas blasts raise suspicion of acute leukemia. Similarly, marked hypoplasia or abnormal maturation patterns may indicate aplastic anemia or myelodysplastic syndromes. However, peripheral blood findings alone may not establish the definitive diagnosis in many patients.[2,5]

Bone marrow examination remains an important diagnostic investigation in patients with unexplained pancytopenia. Bone marrow aspiration allows assessment of cellularity, erythroid and myeloid maturation, megakaryocytes, blast percentage, dysplastic changes, and abnormal cellular infiltrates. Bone marrow biopsy provides additional information regarding marrow architecture, fibrosis, cellularity, and infiltrative lesions, particularly when aspiration is inadequate or a marrow failure/infiltrative disorder is suspected.[6,7]

Nutritional deficiencies, particularly vitamin B12 and folate deficiency, are important reversible causes of pancytopenia. Vitamin B12 deficiency can produce

ineffective hematopoiesis and characteristic megaloblastic changes in both peripheral blood and bone marrow. In contrast, aplastic anaemia is characterised by hypocellular marrow with marked reduction of hematopoietic precursors. Acute leukaemia and myelodysplastic syndromes require careful morphological assessment and appropriate ancillary investigations for confirmation.[3,8]

The present study was undertaken to evaluate the haematological profile and bone marrow morphological findings in patients presenting with pancytopenia at Government Medical College, Kanyakumari, over a period of one year. The study aimed to characterise the peripheral blood abnormalities, identify the spectrum of bone marrow findings, and assess the major morphological patterns associated with pancytopenia.

Materials And Methods

Study Design and Setting

A cross-sectional observational study was conducted over a period of one year in the Department of Pathology, Government Medical College, Kanyakumari, Tamil Nadu. The study included patients presenting with pancytopenia who were evaluated clinically and investigated hematologically, including bone marrow examination where indicated.

Study Population

A total of 25 patients fulfilling the diagnostic criteria for pancytopenia during the study period were included. Pancytopenia was defined as the simultaneous reduction of all three major peripheral blood cell lines, namely haemoglobin, total leukocyte count, and platelet count, below the laboratory reference ranges.

Inclusion Criteria

Patients of either sex and all age groups presenting with pancytopenia and undergoing evaluation at the study institution were included. Patients in whom adequate peripheral blood and bone marrow specimens were available for evaluation were considered for analysis.

Exclusion Criteria

Patients with inadequate or technically unsatisfactory bone marrow aspirates/biopsy specimens, patients who had received recent chemotherapy or radiotherapy, and those unwilling to undergo the required investigations were excluded from the study.

Clinical Evaluation

A detailed clinical history was obtained from each patient, including presenting symptoms, duration of illness, history of fever, fatigue, bleeding manifestations, recurrent infections, weight loss, drug exposure, nutritional status, and relevant past medical history. A thorough physical examination was performed, with particular attention to pallor, icterus, lymphadenopathy, hepatomegaly, splenomegaly, and other relevant clinical findings.

Hematological Investigations

Venous blood samples were collected under aseptic precautions in appropriate anticoagulant tubes. Complete blood counts were performed using an automated hematology analyzer. The following parameters were recorded:

- Hemoglobin concentration
- Total leukocyte count
- Red blood cell count
- Hematocrit/packed cell volume
- Mean corpuscular volume (MCV)
- Mean corpuscular hemoglobin (MCH)
- Mean corpuscular hemoglobin concentration (MCHC)
- Red cell distribution width (RDW)
- Platelet count

Peripheral blood smears were prepared and stained using standard Romanowsky staining techniques. The smears were examined for red cell morphology, leukocyte abnormalities, platelet morphology, abnormal cells, blasts, and other significant hematological findings.

Bone Marrow Examination

Bone marrow aspiration was performed under aseptic precautions from the posterior superior iliac spine using a standard bone marrow aspiration needle after obtaining informed consent. The aspirated material was used to prepare multiple smears, which were appropriately stained and examined microscopically.

Bone marrow smears were assessed for overall cellularity, erythroid and myeloid series, megakaryocytes, myeloid-to-erythroid ratio, maturation patterns, dysplastic changes, blast percentage, abnormal infiltrates, and other morphological abnormalities. Where clinically indicated and feasible, a bone marrow biopsy was performed for assessment of marrow architecture, cellularity, fibrosis, infiltration, and other pathological changes.

Etiological Evaluation

Based on clinical findings, peripheral smear and bone marrow morphology, additional investigations were performed where required to determine the underlying cause of pancytopenia. These included biochemical and nutritional investigations such as serum vitamin B12 and folate levels, liver and renal function tests, and other relevant investigations according to clinical indication.

Data Collection and Statistical Analysis

Relevant demographic, clinical, haematological, peripheral smear, and bone marrow findings were recorded in a structured data collection proforma. The data obtained from the 25 patients were entered into a spreadsheet and analysed using appropriate descriptive statistical methods. Continuous variables were expressed as mean ± standard deviation or median with range, as appropriate, while categorical variables were expressed as frequencies and percentages. The findings were analysed to determine the haematological profile and morphological spectrum of bone marrow findings among patients presenting with pancytopenia.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of Government Medical College, Kanyakumari. Written informed consent was obtained from participants or their legally authorised representatives before inclusion in the study. Patient confidentiality was maintained throughout the study, and the collected data were used solely for research purposes.

Results and Observations

A total of 25 patients presenting with pancytopenia were included in the present one-year cross-sectional observational study conducted at Government Medical College, Kanyakumari. The demographic characteristics, clinical findings, haematological parameters, peripheral smear findings, and bone marrow morphological findings were evaluated.

Table 1. Age-wise distribution of patients

Age group (years)	Number of patients	Percentage (%)
≤20	3	12.0
21–40	5	20.0
41–60	9	36.0
61–80	8	32.0
Total	25	100

The majority of patients belonged to the 41–60 years age group (36%), followed by the 61–80 years group (32%).

Table 2. Sex-wise distribution

Sex	Number of patients	Percentage (%)
Male	14	56.0
Female	11	44.0
Total	25	100

There was a slight male predominance, with 14 males (56%) and 11 females (44%).

Table 3: Presenting clinical features

Clinical feature	Number of patients	Percentage (%)
Generalized weakness/fatigue	19	76.0
Pallor	23	92.0
Fever	11	44.0
Bleeding manifestations	8	32.0
Recurrent infections	6	24.0
Hepatomegaly	4	16.0
Splenomegaly	7	28.0
Lymphadenopathy	3	12.0

Pallor (92%) was the most frequent clinical finding, followed by generalised weakness/fatigue (76%). Fever was present in 44% of patients.

Table 4: Hematological parameters

Parameter	Mean ± SD	Range
Haemoglobin (g/dL)	7.4 ± 1.5	4.2–10.2
RBC count (×10⁶/µL)	2.65 ± 0.54	1.70–3.60
Hematocrit (%)	22.9 ± 4.8	13.5–31.4
MCV (fL)	94.8 ± 15.7	65.0–128.0
MCH (pg)	30.1 ± 5.1	20.0–40.2
MCHC (g/dL)	31.8 ± 2.2	27.5–35.0
RDW (%)	18.7 ± 4.3	13.2–28.4
Total leukocyte count (/µL)	2,480 ± 760	1,100–3,900
Platelet count (/µL)	68,400 ± 31,200	18,000–128,000

All patients demonstrated reduction in haemoglobin, leukocyte count, and platelet count, consistent with pancytopenia. An increased RDW was observed in a considerable proportion of patients, indicating variation in red cell size.

Table 5: Morphological pattern of anaemia on peripheral smear

Peripheral smear finding	Number of patients	Percentage (%)
Normocytic normochromic	9	36.0
Macrocytic	8	32.0
Microcytic hypochromic	5	20.0
Dimorphic	3	12.0
Total	25	100

Normocytic normochromic anemia was the most common pattern (36%), followed by macrocytic anemia (32%).

Table 6: Peripheral leukocyte and platelet findings

Finding	Number of patients	Percentage (%)
Leukopenia with relative lymphocytosis	7	28.0
Neutropenia	15	60.0
Hypersegmented neutrophils	6	24.0
Abnormal/blast cells	3	12.0
Thrombocytopenia with reduced platelets	25	100
Platelet anisocytosis	5	20.0

Neutropenia was observed in 60% of patients. Hypersegmented neutrophils were identified in 24% of

cases, particularly among patients with macrocytic morphology.

Table 7: Bone marrow cellularity

Bone marrow cellularity	Number of patients	Percentage (%)
Hypercellular	12	48.0
Normocellular	7	28.0
Hypocellular	6	24.0
Total	25	100

Bone marrow was hypercellular in 48% of patients, while 28% showed normocellular and 24% showed hypocellular marrow.

Table 8: Bone marrow morphological findings

Bone marrow finding	Number of patients	Percentage (%)
Megaloblastic erythropoiesis	7	28.0
Erythroid hyperplasia	5	20.0
Hypoplastic/aplastic marrow	5	20.0
Acute leukemia	3	12.0
Myelodysplastic changes	2	8.0
Normal/nonspecific marrow findings	2	8.0
Other marrow infiltrative changes	1	4.0
Total	25	100

Megaloblastic erythropoiesis was the most frequent bone marrow finding (28%), followed by erythroid hyperplasia (20%) and hypoplastic/aplastic marrow (20%).

Table 9: Megakaryocytic findings in bone marrow

Megakaryocyte status	Number of patients	Percentage (%)
Increased	9	36.0
Normal	7	28.0
Reduced	7	28.0
Not adequately assessed	2	8.0
Total	25	100

Increased megakaryocytes were observed in 36% of cases, while reduced megakaryocytes were noted in 28%.

Table 10: Myeloid-to-erythroid (M) ratio

M ratio pattern	Number of patients	Percentage (%)
Reduced M ratio	11	44.0
Normal M ratio	8	32.0
Increased M ratio	4	16.0
Not assessable	2	8.0
Total	25	100

A reduced M ratio was the predominant finding (44%), mainly associated with erythroid hyperplasia and megaloblastic changes.

Table 11: Selected nutritional and biochemical investigations

Investigation	Patients tested (n)	Abnormal findings, n (%)
Serum vitamin B12	25	8 (32.0)
Serum folate	25	4 (16.0)
Liver function tests	25	5 (20.0)
Renal function tests	25	3 (12.0)

Vitamin B12 deficiency was identified in 32% of patients and was associated predominantly with macrocytic peripheral smear and megaloblastic bone marrow morphology.

Table 12: Correlation of peripheral smear with bone marrow findings

Peripheral smear pattern	Predominant bone marrow finding	Number of patients
Macrocytic anemia	Megaloblastic erythropoiesis	7
Normocytic normochromic anaemia	Erythroid hyperplasia	5
Microcytic hypochromic anaemia	Erythroid hyperplasia/other changes	5
Dimorphic anemia	Megaloblastic/dyserythropoietic changes	3
Other patterns	Hypoplastic, leukaemia or other findings	5
Total		25

The peripheral smear findings showed a clinically relevant association with bone marrow morphology. Macrocytic anaemia was predominantly associated with megaloblastic erythropoiesis, whereas hypoplastic marrow was associated with marked reduction in marrow cellularity and hematopoietic precursors.

Discussion

Pancytopenia represents a heterogeneous group of disorders and poses a diagnostic challenge because multiple etiological conditions can produce similar peripheral blood findings. In the present study, 25 patients presenting with pancytopenia were evaluated using clinical assessment, complete blood count, peripheral smear examination, and bone marrow evaluation. The findings demonstrated considerable variation in haematological and marrow morphology, emphasising the importance of systematic evaluation of these patients.

In the present study, there was a slight male predominance, with males accounting for 56% of cases and females for 44%. Similar variations in sex distribution have been reported in previous studies of pancytopenia, although the predominance differs between populations and may depend on the underlying etiological spectrum.[3,9] The highest proportion of patients in our study belonged to the 41–60-year age group. Pancytopenia can occur at any age, but its causes may vary considerably across different age groups.

Pallor was the most frequent clinical finding in our study, observed in 92% of patients, followed by generalized weakness or fatigue in 76%. These findings are expected because anaemia is one of the principal manifestations of pancytopenia. Fever was observed in 44% of cases and may be related to neutropenia and increased susceptibility to infection. Bleeding manifestations were present in 32% of patients and were likely associated with thrombocytopenia. Previous studies have similarly reported pallor, fever, weakness, and bleeding as common presenting features among patients with pancytopenia.[3,4]

The haematological profile in our study demonstrated significant reduction in all three cell lines. The mean haemoglobin concentration was 7.4 ± 1.5 g/dL, indicating predominantly moderate-to-severe anaemia. The mean total leukocyte count was 2,480/µL, while the mean platelet count was 68,400/µL. Neutropenia was observed in 60% of patients. These findings emphasise that the severity of individual cytopenias can vary considerably even though pancytopenia is present.

Peripheral smear examination provided important morphological information. Normocytic normochromic anaemia was the commonest pattern, observed in 36% of cases, followed by macrocytic anaemia in 32%. Dimorphic and microcytic hypochromic patterns were observed in smaller proportions. Macrocytosis and hypersegmented neutrophils are important clues toward megaloblastic hematopoiesis, particularly in patients with vitamin B12 or folate deficiency.[8,10]

Hypersegmented neutrophils were observed in 24% of patients in the present study. This finding, together with macrocytic morphology, was predominantly associated with megaloblastic changes in the bone marrow. Vitamin B12 deficiency was identified in 32% of the patients investigated. Vitamin B12 deficiency causes defective DNA synthesis and ineffective hematopoiesis, resulting in intramedullary destruction of abnormal precursor cells and consequent reduction of circulating erythrocytes, leukocytes, and platelets.[8,10]

Bone marrow examination demonstrated a heterogeneous spectrum of abnormalities. Hypercellular marrow was observed in 48% of patients, normocellular marrow in 28%, and hypocellular marrow in 24%. The predominance of hypercellular marrow in the present study suggests that ineffective hematopoiesis and abnormal maturation constituted important mechanisms underlying pancytopenia.

Megaloblastic erythropoiesis was the most frequent bone marrow finding, accounting for 28% of cases. This observation is consistent with the recognised importance of nutritional deficiency as a potentially reversible cause of pancytopenia. Megaloblastic marrow is characterised by erythroid hyperplasia, nuclear-cytoplasmic asynchrony, and abnormal maturation of hematopoietic precursors. Similar marrow findings have been reported in studies evaluating the etiological spectrum of pancytopenia.[3,,8,9]

Erythroid hyperplasia was observed in 20% of cases. An increased erythroid component can occur in conditions associated with ineffective erythropoiesis, including nutritional deficiency and other marrow disorders. In our study, a reduced myeloid-to-erythroid ratio was observed in 44% of patients, supporting the predominance of erythroid expansion in a significant proportion of cases.

Hypoplastic or aplastic marrow was identified in 20% of patients. Aplastic anaemia is characterised by hypocellular marrow with replacement of hematopoietic tissue by fat and absence of significant marrow infiltration or fibrosis. The presence of pancytopenia with hypocellular marrow should prompt consideration of aplastic anaemia after excluding other causes of marrow hypoplasia.[11]

Acute leukaemia was identified in 12% of patients, while myelodysplastic changes were observed in 8%. The detection of abnormal or blast cells on peripheral smear should raise suspicion of an underlying haematological malignancy and warrants bone marrow examination. Bone marrow morphology is particularly important in identifying increased blast populations, dysplasia, and abnormal cellular infiltrates.[6,9]

Increased megakaryocytes were observed in 36% of cases, whereas reduced megakaryocytes were observed in 28%. Increased megakaryocytes in the presence of thrombocytopenia may suggest preserved or compensatory platelet production, whereas reduced megakaryocytes may indicate impaired marrow production. Interpretation of megakaryocytic abnormalities should therefore be performed together with overall marrow cellularity and other hematopoietic lineages.

The present study also demonstrated an association between peripheral smear morphology and bone marrow findings. Patients with macrocytic anaemia frequently showed megaloblastic erythropoiesis, whereas patients with hypoplastic peripheral blood findings showed corresponding reduction in marrow cellularity. This emphasises the complementary role of peripheral smear and bone marrow examination in the diagnostic evaluation of pancytopenia.

The findings of the present study highlight that pancytopenia has a diverse morphological spectrum and that no single haematological parameter is sufficient to establish its underlying cause. A complete blood count provides the initial quantitative assessment, a peripheral smear provides valuable morphological clues, and a bone marrow examination helps establish the nature of the underlying marrow process. Early recognition of reversible causes, such as vitamin B12 and folate deficiencies, is particularly important because appropriate treatment can lead to haematological recovery.

Conclusion

The present study demonstrates that pancytopenia is associated with a broad spectrum of haematological and bone marrow abnormalities. Megaloblastic erythropoiesis, erythroid hyperplasia, hypoplastic/aplastic marrow, acute leukaemia, and myelodysplastic changes constituted important marrow findings. A systematic approach combining clinical evaluation, complete blood count, peripheral smear examination, and bone marrow assessment is essential for establishing the underlying cause and guiding appropriate management.

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