

Less puncture, more precision: Immature reticulocyte fraction as an emerging diagnostic tool for pancytopenia

Madeeha Rehan¹, Sahrish Bari¹, Attika Khalid¹, Maihmoona Usman²

¹Fauji Foundation Hospital, Rawalpindi Pakistan

²Al-Khidmat Razi, Rawalpindi Pakistan

ABSTRACT

Objective: To evaluate the diagnostic utility of Immature reticulocyte fraction as an early indicator of bone marrow regenerating activity in pancytopenia.

Material and Methods: A retrospective observational study was conducted in Fauji Foundation Hospital Rawalpindi and AL-Khidmat Razi hospital from Jan 2022 to Jan 2025. Ethical approval was taken from the ethical review committee. Patients of all ages and both genders who were diagnosed with pancytopenia were included in the study. Diagnosed patients of malignancies already taking chemotherapy or radiotherapy were excluded from the study. All pancytopenia were verified on peripheral smear. Values of % of retics, Immature reticulocyte fraction (IRF), and absolute reticulocyte count were recorded. Results of other diagnostic workups done to identify the etiology of pancytopenia including malarial parasite (MP), biochemical profiles, bone marrow examination, radiological investigations and other ancillary investigations were recorded.

Results: The regenerative group showed the highest mean IRF (16.88 ± 10.28), followed by infiltrative cases (14.01 ± 9.12). The hypo-proliferative group had significantly lower values (2.42 ± 1.84). A one-way ANOVA confirmed these differences to be statistically significant ($p < 0.001$). ROC analysis demonstrated fair-to-good discriminative capacity ($AUC = 0.739$), and cut-off exploration highlighted that thresholds in the 6.5–7.0% range offer an optimal balance of sensitivity and specificity while maintaining high negative predictive value.

Conclusion: IRF is an effective early indicator of bone marrow erythropoietic activity. It should be a regular part of diagnostic work-up for pancytopenia to prevent invasive procedures for evaluation of pancytopenia.

Keywords: Bone marrow, Immature reticulocyte fraction, Pancytopenia

This article can be cited as: Rehan M, Bari S, Khalid A, Usman M. Less puncture, more precision: Immature reticulocyte fraction as an emerging diagnostic tool for pancytopenia. Pak J Pathol. 2025; 36(4): 294-299.

DOI: <https://doi.org/10.55629/pakipathol.v36i4.958>

INTRODUCTION

Pancytopenia is the most common clinical-hematological entity but not a disease itself. It is characterized by a decrease in red blood cells, white blood cells and platelets (Hb, 12gm/dL in females, <13gm/dl in males, TLC < $4 \times 10^9/L$ and plt < $100 \times 10^9/L$). Severity and variability in clinical manifestation depends upon the spectrum of underlying etiologies leading to pancytopenia [1]. Among various underlying causes of pancytopenia megaloblastic anemia, aplastic Anemia and infections are commonest. Certain drugs like methotrexate can result in megaloblastic anemia and pancytopenia [2]. The management and prognosis of pancytopenia depend on identifying and addressing the root cause. A systematic approach is essential to determine the etiology of pancytopenia [3]. Most cases of

pancytopenia are often referred to hematologists for detailed evaluation, as the range of potential diagnosis in patients with pancytopenia is challenging [4]. Bone marrow examination is widely accepted as a crucial diagnostic modality for identifying the underlying cause of pancytopenia [5]. According to Maria Shaikh *et al* reticulocyte indices can play a critical role in diagnosing numerous hematological disorders including pancytopenia [6]. Reticulocytes are immature red blood cells and changes in their count reflect the level of erythropoietic activity or potential dysfunction [7]. Reticulocyte indices are crucial in diagnosing numerous hematological conditions as these are non-invasive markers of underlying hematological activity or dysfunction [8]. Modern automated hematology analyzers can provide a cost-effective and efficient method for analyzing advanced reticulocyte indices with high accuracy. The basic mechanism in this automated analyzer is optical scatter or fluorescence to assess reticulocytes after reacting red blood cells with fluorescent dyes or nucleic acid stains to stain any remaining RNA in the reticulocytes. Advanced reticulocyte indices, such as the immature reticulocyte fraction (IRF), mean reticulocyte volume

Correspondence: Dr. Madeeha Rehan, Associate Professor of Pathology, Department of Pathology, Fauji Foundation Hospital, Rawalpindi Pakistan

Email: r.madeeha138@gmail.com

Receiving Date: 01 Oct 2025

Revision Date: 11 Dec 2025

Acceptance Date: 18 Dec 2025

Copyright © 2025. Madeeha Rehan, *et al*. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License, which permits unrestricted use, distribution & reproduction in any medium provided that original work is cited properly.



(MRV), and High fluorescence reticulocyte count (HFR), can also help in assessing causes of pancytopenia by providing valuable insights into the bone marrow's erythropoietic activity [9]. The term IRF indicates the least mature fraction of reticulocytes. It defines the ratio of immature reticulocytes to the total number of reticulocytes. It is an early and sensitive index of bone marrow erythropoietic activity. IRF helps in differentiating anemias based on erythropoietic response and typically falls within the range of 0.11-0.38 [14].

Pancytopenia is mostly due to treatable causes including infections and malnutrition. Their early identification and timely intervention can help lower mortality rates [10]. However, globally bone marrow examination is preferred diagnostic tool for evaluating the cause of pancytopenia. In the west, various studies have been conducted highlighting the significance of IRF as an initial tool for evaluating the cause of pancytopenia. But there is scarcity of literature in Pakistan in this context. Therefore, the rationale of our study is to contribute to the evidence regarding the use of IRF as an early and non-invasive diagnostic tool in identifying the underlying etiologies of pancytopenia. This data will help to prevent any unnecessary invasive investigations.

MATERIAL AND METHODS

This was a hospital based retrospective observational study. Ethical approval was taken from the institutional ethical review board (Ref No 1027/RC/FFH/RWP dated 14th December 2024). Total duration of study was three years i.e. from January 2022-2025. Patients of both genders and all ages which were evaluated for pancytopenia and referred from both inpatient and outpatient departments were included in the study. Patients who were already taking chemotherapy and radiotherapy were excluded from the study. Data extraction was done by exporting data of three years from Fully Automated Hematology Analyzer XN-1000. After extraction, data was processed in excel. All Complete Blood Counts (CBC), peripheral smear findings, biochemical profiles, serological tests results, radiological investigations including Ultrasound and CT-Scan, bone marrow examination reports and other ancillary laboratory investigations were retrieved and recorded. All CBC showing pancytopenia (hemoglobin <13 g/dL in males and 12gm/dl in females, a platelet counts of <100 × 10⁹/L and Total leucocyte count (TLC) <4.0×10⁹/l were verified on peripheral smears. Thorough details of Reticulocyte indices including Reticulocyte %,

absolute reticulocyte count, and Immature reticulocyte fraction (IRF) were recorded. Morphological findings and details regarding presence or absence of blasts, malarial parasites, any red cell or white cell inclusions and platelet clumping were reported. Sample Size and Sampling Method

This was a retrospective observational study including all eligible pancytopenia cases from January 2022 to January 2025 (N = 215). A priori sample-size calculation was not required for complete enumeration; however, the achieved sample exceeds $n \approx 196$ needed to detect a medium effect ($f = 0.25$) with 95% confidence and 80% power in one-way ANOVA (G*Power 3.1). The sampling technique was non-probability consecutive sampling of all eligible records. IBM SPSS version 26 was used for data analysis. Mean SD was calculated of all continuous variables (age, WBC, RBC, hemoglobin, platelet count, IRF %) and categorical variables (gender, morphological category, bone marrow status) as n (%). Shapiro–Wilk test and Q–Q plots, one-way ANOVA and Tukey post-hoc tests were used for statistical analysis. Receiver operating characteristic (ROC) analysis evaluated the ability of IRF to predict the need for bone marrow examination. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were computed from 2×2 contingency tables, taking bone marrow examination as the gold standard. A two-sided $p < 0.05$ was considered statistically significant.

RESULTS

All data was analyzed using IBM SPSS version 26. Continuous variables (age, WBC, RBC, hemoglobin, platelet count, IRF %) were summarized as Mean ± SD, and categorical variables (gender, morphological category, bone marrow status) as n (%). Normality of quantitative variables was assessed using the Shapiro–Wilk test and Q–Q plots ($p > 0.05$ = approximately normal). Because assumptions were satisfied, one-way ANOVA compared mean IRF across morphological categories, with Tukey post-hoc tests for pairwise differences. Receiver operating characteristic (ROC) analysis evaluated the ability of IRF to predict the need for bone marrow examination. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were computed from 2×2 contingency tables, taking bone marrow examination as the gold standard. A two-sided $p < 0.05$ was considered statistically significant.

A total of 215 patients with pancytopenia, fulfilling the study criteria, were included in the final analysis. The dataset was derived from a larger pool of 171,634 complete blood count (CBC) records obtained from hematology analyzers at Fauji Foundation Hospital and Al Razi hospitals. After applying pancytopenia criteria ($WBC < 4 \times 10^3/\mu L$, $Hb < 10 \text{ g/dL}$, $PLT < 100 \times 10^3/\mu L$), 552 potential cases were identified. Matching clinical and bone marrow procedure data retrieved from the institutional results portal yielded 296 cases, of which 217 were unique after removing duplicates. Following data cleaning for completeness, 215 cases with valid immature reticulocyte fraction (IRF) values were retained for detailed analysis. The subsequent results describe the demographic and hematological characteristics of this study population, followed by an evaluation of the diagnostic utility of IRF in predicting bone marrow examination requirements.

The mean age of the study population was 44.9 ± 22.3 years (range: 1–87 years). Hematological parameters showed marked cytopenias, with a mean WBC count of $2.41 \pm 1.02 \times 10^3/\mu L$, RBC count $2.54 \pm 0.79 \times 10^6/\mu L$, hemoglobin $7.30 \pm 1.83 \text{ g/dL}$, and platelet count $44.7 \pm 26.7 \times 10^3/\mu L$. The immature reticulocyte fraction (IRF) demonstrated a wide distribution, ranging from 0.0% to 53.9%, with a mean of $14.2 \pm 10.5\%$ (Table-I).

Based on morphological categorization, patients were grouped into the following three major diagnostic categories:

Hyper-regenerative (Peripheral Destruction / Recovery): IRF typically $>7.0\%$, suggesting preserved marrow response, commonly seen in cases of hemolysis, sepsis recovery, nutritional deficiency under treatment, or transient suppression.

Infiltrative Marrow Disorders: Intermediate or variable IRF ($\sim 10\text{--}15\%$), seen in conditions where the marrow is partially replaced or suppressed (e.g., malignancy, fibrosis, granulomatous infiltration).

Hypo-proliferative Marrow: IRF consistently $<5.0\%$, indicating impaired erythropoiesis, as in aplastic anemia, MDS, or drug-induced suppression or nutritional anemia.

The majority of cases ($n = 138$; 64.2%) were classified as Hyper-regenerative, followed by

Infiltrative ($n = 47$; 21.9%) and Hypo-proliferative ($n = 30$; 14.0%) (Table-III).

Out of total 215 patients, Bone marrow aspiration/ biopsy was performed in 77 cases (35.8%), while 138 patients (64.2%) did not undergo the procedure. IRF demonstrated marked variation across morphological groups (Table-IV). The Hyper-regenerative group showed the highest mean IRF (16.88 ± 10.28), followed by Infiltrative cases (14.01 ± 9.12), while the Hypo-proliferative group had significantly lower values (2.42 ± 1.84). A one-way ANOVA confirmed these differences to be statistically significant ($p < 0.001$). Normality for IRF was confirmed (Shapiro–Wilk $p = 0.072$), supporting the use of parametric ANOVA; the result ($F(2, 212) = 43.7$, $p < 0.001$) indicates that at least one group mean IRF differs significantly from the others.

The diagnostic accuracy of IRF in predicting the need for bone marrow examination was assessed using ROC analysis. The area under the curve (AUC) was 0.739 (95% CI: 0.665–0.813, SE = 0.038, $p < 0.001$), reflecting fair-to-good discriminative ability. The ROC curve is shown in Figure-I. Bone marrow examination status (performed = 1, not performed = 0) was taken as the gold standard for confirming hypo-proliferative marrow failure. We treated the test as positive when $IRF < 7\%$ (predicting need for bone marrow) and negative when $IRF \geq 7\%$. At the decision threshold $IRF \geq 7.0\%$, the contingency matrix was (Table IV) sensitivity = 85.5%, specificity = 50.6%, PPV = 49.1%, NPV = 86.2%, and accuracy = 63.1%. The high NPV indicates that patients with $IRF \geq 7\%$ are unlikely to have hypo-proliferative marrow failure and may not require immediate invasive bone marrow examination.

Selected cut-off values for IRF were examined to evaluate diagnostic accuracy (Table 5). At a threshold of $\geq 5.0\%$, sensitivity reached 100% with a negative predictive value (NPV) of 100%, though specificity was limited (46.8%). A cut-off around 6.5–7.0% provided a more balanced performance, with sensitivity maintained at 85–88% and specificity near 50%, while preserving high NPV (86–88%). At higher thresholds ($\geq 10.0\%$), specificity improved (58.4%) but sensitivity declined (73.9%), lowering overall accuracy.

Table-I. Descriptive statistics of baseline hematological parameters.

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	215	1	87	44.95	22.34
WBC ($\times 10^3/\mu L$)	215	0.01	3.98	2.41	1.02
RBC ($\times 10^6/\mu L$)	215	0.41	4.61	2.54	0.80
Hemoglobin (g/dL)	215	1.6	9.9	7.30	1.83
Platelets ($\times 10^3/\mu L$)	215	2	96	44.72	26.68
IRF (%)	215	0.0	53.9	14.24	10.49

Table-II: Distribution of study population by morphological category

Morphological Category	n	%
Infiltrative	47	21.9
Hypo proliferative	30	14.0
Hyper-regenerative (Peripheral Destruction / Recovery)	138	64.2
Total	215	100.0

Table III. Descriptive statistics of IRF across categories

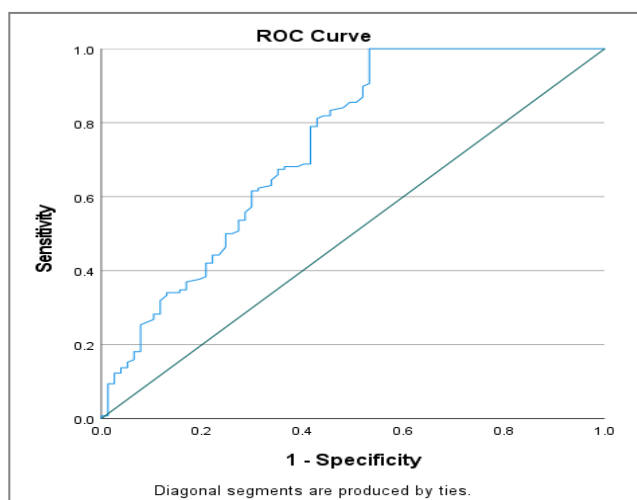
Morphological Category	Mean IRF (%)	Std. Deviation	n
Infiltrative	14.01	9.12	47
Hypo proliferative	2.42	1.84	30
Hyper-regenerative (Peripheral Destruction / Recovery)	16.88	10.28	138
Overall	14.24	10.49	215

Table: IV IRF and ROC Curve analysis

Outcome	Bone marrow performed (1)	Not performed (0)	Total
IRF < 7% (test +)	66	68	134
IRF ≥ 7% (test -)	11	70	81
Total	77	138	215

Table-V: Diagnostic accuracy of IRF at selected cut-off points.

IRF Cut-off (≥)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
5.0	100.0	46.8	51.2	100.0	65.9
6.5	88.4	48.1	48.7	88.1	62.5
7.0	85.5	50.6	49.1	86.2	63.1
10.0	73.9	58.4	49.8	80.0	64.0

**Figure-I: ROC Analysis results (SPSS).**

DISCUSSION

Bone marrow aspiration and trephine biopsy are commonly used as a primary diagnostic tool in evaluation and diagnosis of different causes of pancytopenia. IRF is an early and excellent indicator of bone marrow regenerative activity and differentiating various underlying etiologies of pancytopenia and often rises before the absolute reticulocyte count increases [11].

In our 215 patients, IRF clearly differed across morphological groups. Mean IRF was lowest in hypo proliferative marrow, intermediate in infiltrative disorders, and highest in hyper-

regenerative states. This difference was statistically significant by one-way ANOVA ($p < .001$). This pattern fits what IRF measures: IRF is a numerical indicator of RNA content of reticulocytes. The quantity of RNA in immature reticulocytes is more extensive than mature reticulocytes. Therefore, increased IRF implies early bone marrow reconstruction from response to treatment in anemias, chemotherapy, and conditioning regimens of stem cell transplantation. And usually increases before a boost in absolute reticulocyte count [12].

A study conducted by Ray *et al* revealed that value of IRF value was highest in hematological neoplastic conditions and cases with peripheral destruction of blood cells (acute blood loss and hypersplenism) as compared to aplastic anemia, nutritional anemia, and chronic diseases, and aplastic anemia¹³. Where's as in our study the regenerative group encompassing nutritional anemias, and response to therapy showed the highest mean IRF (16.88 ± 10.28), followed by infiltrative cases (14.01 ± 9.12), while the hypo proliferative group had significantly lower values (2.42 ± 1.84). The reason of differences in results might be the commonest cause of anemia in our setup is nutritional deficiency.

In a study conducted by Das J *et al* [14], a total of 154 cases of pancytopenia were obtained. Most common etiology detected was megaloblastic anemias in which IRF was 0.45. In this study highest IRF was seen in hematological neoplastic conditions and cases with peripheral destruction of blood cells (acute blood loss and hypersplenism) whereas low IRF value was found in chronic disorders, nutritional anemias and aplastic anemia [14].

Das *et al.* used reticulocyte indices (retic %, IRF, MRV) to separate specific anemia types and reported cut-offs for megaloblastic and iron-deficiency anemia. Our study did not evaluate MRV or retic % and focused instead on IRF for bone-marrow triage in pancytopenia, so direct numeric comparison is not appropriate.

Chakma K *et al* studied IRF value in patients with thalassemia trait and iron deficiency anemia. However, in our study all diagnosed cases of pancytopenia were evaluated. Moreover, they have evaluated the significance of all reticulocyte indices MFR, LFR & HFR. However, we have evaluated the significance of IRF in pancytopenia.

In their study the cut-off value of IRF for detecting Thalassemia trait was found to be 15.85-21.50%. IDA was >21.50% and for Thalassemia major it was < 15.85% [15]. IRF is also an effective diagnostic tool for differentiating different types of anemias [16,17]. Mehdi *et al* performed a comparative analysis of IRF significance between regenerative and a-regenerative anemias. It was concluded that IRF value for microcytic hypochromic anemia was found to be 19.06 ± 7.95 , in macrocytic anemias it was 12.24 ± 7.67 and in Normocytic normochromic anemia it was 14.87 ± 8.84 . The ROC curve analysis showed an optimal IRF cut-off of 15% which distinguishes regenerative from a-regenerative anemias, with a specificity of 61.8% and sensitivity of 94.4%. The area under the curve (AUC) was 0.840, indicating good diagnostic ability [18].

In our study IRF was evaluated as a triage tool for diagnosing underlying causes of pancytopenia and to opt for strategic diagnostic approach. Our ROC analysis for “bone marrow

performed” showed fair-to-good accuracy (AUC = 0.739; 95% CI [0.665, 0.813]; $p < .001$). At an IRF cut-off of $\geq 5.0\%$, sensitivity and negative predictive value (NPV) were 100%, but specificity was limited (46.8%). A threshold around 6.5–7.0% gave a better balance (sensitivity 85–88%, specificity ~50%), while keeping NPV high (86–88%). At $\geq 10.0\%$, specificity improved (58.4%) but sensitivity fell (73.9%). In clinical terms, using a threshold near 7% could help identify patients who are unlikely to have hypo proliferative marrow failure and who might not need immediate bone marrow especially those in the hyper-regenerative group. In our series, applying such IRF-guided triage could have avoided an estimated 30–35% of the 77 bone marrow procedures, with clinical follow-up maintained.

LIMITATION OF STUDY

This study was conducted in two different centers in the same region. Large data from various centers and regions can be used for further evaluation of results.

CONCLUSION

Immature reticulocyte fraction (IRF) is cost effective, simple, quick, reliable and reproducible tool. It is precise and sensitive indicator of bone marrow erythropoietic activity. It can be effectively used for differentiating different causes of pancytopenia. Thus, unnecessary invasive diagnostic procedures like bone marrow examination can be prevented.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

GRANT SUPPORT & FINANCIAL DISCLOSURE

Declared none

AUTHORS CONTRIBUTION

Madeeha Rehan: Conceptualization, Writing – original draft Conceptualization Designing Methodology, Writing –review & editing, final approval, accountable for all aspects of publication

Sahrish Bari: Acquisition, data analysis and interpretation, final approval, accountable for all aspects of publication

Attika Khalid: Acquisition, data analysis and interpretation, final approval, accountable for all aspects of publication

Maimoona Yasmeen: Drafting, Critical review for important intellectual content, final approval, accountable for all aspects of publication

REFERENCES

- Gajbhiye SS, Karwa AR, Dhok A, Jadhav SS. Clinical and etiological profiles of patients with pancytopenia in a tertiary care hospital. *Cureus*. 2022; 14(10): e30449. DOI: <https://doi.org/10.7759/cureus.30449>
- Thain A, Hart K, Ahmadi KR. Addressing the gaps in the vitamin B12 deficiency 2024 NICE guidelines: Highlighting the need for better recognition, diagnosis, and management of pernicious anemia. *Eur J Clin Nutr*. 2025; 79 (9): 607-10. DOI: <https://doi.org/10.1038/s41430-025-01583-4>
- Zulfiqar M, Ali BA, Jiskani SA, Waqar M, Saad M, Javed H. Evaluation of pancytopenia based on bone marrow examination in adults in a tertiary care hospital in Islamabad. *Prof Med J*. 2023; 30(9): 1152-6. DOI: <https://doi.org/10.29309/TPMJ/2023.30.09.7575>
- Jain A, Garg R, Kaur R, Nibhoria S, Chawla SP, Kaur S. Clinico-hematological profile of pancytopenic adult patients in a tertiary care teaching hospital. *Tzu Chi Med J*. 2022; 34(1): 95-101. DOI: https://doi.org/10.4103/tcmj.tcmj_17_21
- Saleem U, Tariq H, Alam S, Zafar AF, Tanveer U, Khan MH. Etiological spectrum of pancytopenia in adults based on hematological parameters and bone marrow studies. *Expert Rev Hematol*. 2024; 17(11): 861-9. DOI: <https://doi.org/10.1080/17474086.2024.2421374>
- Shaikh M, Shaikh H, Kalhor R, Javed S, George A, Memon K, *et al*. Significance of reticulocyte count in assessment of pancytopenia at tertiary care hospital. *Pak J Med Health Sci*. 2023; 17(6): 413. DOI: <https://doi.org/10.53350/pjmhs2023176413>
- Sah AK, Rao DS. Clinical significance of reticulocytes. *IntechOpen*. 2024; 29(16): 424. Available from: <https://www.intechopen.com/chapters/1187966>
- Almashjary MN, Barefah AS, Bahashwan S, Ashankyty I, El Fayoumi R, Alzahrani M, *et al*. Reticulocyte hemoglobin-equivalent potentially detects, diagnoses and discriminates between stages of Iron deficiency with high sensitivity and specificity. *J Clin Med*. 2022; 5675. DOI: <https://doi.org/10.3390/jcm11195675>
- Tariq H, Ujjan I, Shamsi TS. Evaluation of reticulocyte subpopulations and immature reticulocyte fractions in iron deficiency anemia. *J Popul Ther Clin Pharmacol*. 2024; 31(8): 1556-63. DOI: <https://doi.org/10.53555/94b80t76>
- Rodriguez V, Gonzales KM, Iqbal AM, Ramos NA, Wyatt KD, Lteif AN, *et al*. Pancytopenia secondary to autoimmune vitamin B12 deficiency in Graves' disease. *AACE Clin Case Rep*. 2020; 6(6): e282-5. DOI: <https://doi.org/10.4158/ACCR-2020-0055>
- Zhang X, Ren H, Tian J, Yang C, Luo H. Usefulness of baseline immature reticulocyte fraction to mature reticulocyte fraction ratio (IMR) as A prognostic predictor for patients with small cell lung cancer. *Heliyon*. 2023; 10(1): e23830 DOI: <https://doi.org/10.1016/j.heliyon.2023.e23830>
- Agrawala R, Kumar K, Kumar S, Choudhary V. The role of absolute reticulocyte counts in evaluation of pancytopenia: A cross-sectional study in Bihar, India. *SJHR Africa*. 2023; 4(12): 873. DOI: <https://doi.org/10.51168/sjhrafrica.v4i12.873>
- Ray S, Roy S, Das C, Sengupta M, Mridha S, *et al*. Clinico-hematological correlation of pancytopenia with special reference to the role of immature reticulocyte fraction by automated cell counter in a tertiary care hospital. *Int J Health Clin Res*. 2021; 4: 62-6. Available from: <https://ijhcr.com/index.php/ijhcr/article/view/1073>
- Das J, Khonglah Y, Tiewsoh I, Chowdhury Z, Barman H. Utility of reticulocyte indices in the diagnosis of pancytopenia. *J Family Med Prim Care*. 2022; 11: 1335-40. DOI: https://doi.org/10.4103/jfmpc.jfmpc_1121_21
- Chakma K, Kushwaha R, Yadav G, Singh US, Ali W, Kumar A, *et al*. Novel reticulocyte parameters in thalassemia and iron deficiency anemia. *IP J Diagn Pathol Oncol*. 2023; 8(1): 30-5. DOI: <https://doi.org/10.18231/j.idpo.2023.006>
- Abdrhman B. Reticulocyte indexes and their significance. *Med Discoveries*. 2024; 3(3): 1135. Available from: <https://meddiscoveries.org/pdf/1135.pdf>
- Takahashi Y, Kanai Y, Chishiki M, Goto A, Imamura T. Neonatal reticulocytes among preterm infants of small for gestational age. *Pediatr Neonatol*. 2022. DOI: <https://doi.org/10.18231/j.idp.o.2023.006>
- Mehdi A, Faraji Z, Malihi SE, Chakour PM, Raissi A. Pancytopenia with complex clinical presentation: A case report. *Sch J Med Case Rep*. 2025; 13(8): 1835-9. DOI: <https://doi.org/10.36347/sjmcr.2025.v13i08.020>