Practical Approach to the Interpretation of Complete Blood Count Reports and Histograms

SONALI DIXIT,[1] TANVI JHA,[1] RICHA GUPTA,[1] DHEERAJ SHAH,[2] NITIN DAYAL,[3] MRINALINI KOTRU[1]

From Departments of [1]Pathology and [2]Pediatrics, University College of Medical Sciences and GTB Hospital, Delhi; [3]Department of Hematology, Max Super Speciality Hospital, Saket, New Delhi.

Correspondence to: Dr Mrinalini Kotru, Department of Pathology, University College of Medical Sciences and GTB Hospital, Dilshad Garden, Delhi 110095. mrinalini.kotru@gmail.com

Improvement in technology and inclusion of new parameters in automated hematology analyzers allows for better and faster detection of anemias. These parameters along with histograms provide details and clues that help to diagnose the etiology of anemia and help bridge the time lag in detection and treatment. Timely and expert interpretation of complete blood counts should not be limited to the pathologist but should also interest the clinician to allow for efficient patient care.

Keywords: *Anemias, Platelet indices, Red cell distribution width, Reticulocyte indices.*

Automated hematology analyzer is a cost-effective strategy in resource-limited settings for diagnosis of common blood disorders [5]. Moreover, given the difficulty of blood sampling in the pediatric age group, extracting the maximum possible information from each investigation is essential. Modern-day automated hematology analyzers, with their constantly expanding assessment parameters provide a good, quick overview of the patients' blood picture [6]. We, herein, provide a framework to better interpret complete blood count (CBC) parameters and histograms, which can serve as an invaluable tool towards diagnosing childhood anemias.

INTERPRETATION OF CBC PARAMETERS

CBC is the first investigation routinely performed in both in-patient and out-patient settings. Most automated hematology analyzers generate: numerical and graphical data. Numerical data is in the form of measurement of various WBC, RBC and platelet parameters. The automated analyzers also provide RBC, WBC, and platelet histograms derived by plotting each cell's size on the *X*-axis and their relative number on the *Y*-axis. Interpretation of these CBC parameters and histograms together helps us assess the presentation and etiology of anemia without requiring other expensive investigations.

RBC Parameters

Automated hematology analyzers provide information on RBC parameters like hemoglobin, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), RBC count and hematocrit (HCT), that are used to assess the type of anemia, the treatment response and long-term follow-up of patients (**Table I**) [7,8]. Anemias are classified based on MCV and morphology as normocytic, microcytic and macrocytic.

All macrocytic anemias are evaluated and treated for vitamin B12 and folate deficiency. Non-megaloblastic macrocytic anemia requires further evaluation of reticulocyte count, features of hemolysis and interpretation of bone marrow aspirate smears. Reticulocyte count is necessary for the evaluation of normocytic normochromic anemias. When this is <3%, megaloblastic anemia, liver disease and hypothyroidism, must be ruled out. However, when >3%, further evaluation of WBC and platelet parameters followed by bone marrow evaluation may be required [8]. Further, RDW informs us regarding RBC anisocytosis and helps differentiate between pure micro/normocytic and mixed red cell populations. Recently reticulocyte indices have been introduced in many high-end counters. Newer reticulocyte indices (**Table I**) provide information regarding treatment-response in conditions such as nutritional anemia [9]. They also have a role in diagnosis and monitoring of aplastic anemia [10,11]. Newer parameters, additionally, provide information that has made the detection of type and cause of anemias easier and may, over time, reduce the dependence on peripheral blood smear examination for all cases [12]. They also help distinguish between the various etiologies of anemia such as iron deficiency anemia (IDA), anemia of chronic disease (ACD), anemia of inflammation (AI) and anemias due to

Table I Newer RBC and Reticulocyte Parameters on Automated Analyzer

RBC parameter	*Significance in anemia*
RBC hemoglobin equivalent (RBC-He): Hemoglobin content of all mature RBCs	Along with RET-He helps in detecting onset of anemia and also improvement in erythropoiesis
Fragmented red cell count (FRC): Fragmented RBCs	In detection of microangiopathies, DIC, infections, sepsis, immune disorders, etc.
Red cell size factor (RSf): Cellular hemoglobin content of RBCs and reticulocytes	• Low in IDA • Can be used for IDA screening in pediatric population
Percentage hypochromic cells (%HC) or equivalent low hemoglobin density (LHD%): hypochromic RBCs (%)	• Low in IDA • Can be used for IDA screening in pediatric population • Iron restricted erythropoiesis marker
Percentage unghosted cells: Target cells in peripheral blood	Screening of thalassemia
RBC-Y: Size and contents of the RBCs	Can help distinguish between hemoglobinopathies and IDA.
Reticulocyte hemoglobin equivalent (Ret-He) or Mean Reticulocyte Hemoglobin Content (CHr): Mean content of hemoglobin within reticulocytes	• Differentiate between IDA and FID • Iron restricted erythropoiesis marker
Low fluorescence reticulocyte (LFR), Medium fluorescence reticulocyte (MFR), High fluorescence reticulocyte (HFR): Maturity stages of reticulocytes	• Differentiate between IDA and FID • Iron restricted erythropoiesis marker
Immature reticulocyte fraction (IRF): Sum of HFR and MFR	• Assesses effectiveness of erythropoiesis • Assessment of response to iron or vitamin-B12/folate supplementation in nutritional anemias • Monitoring EPO therapy response
Reticulocyte-Y (RET-Y): Size and contents of the reticulocyte	• Low in IDA and AI

ACD: anemia of chronic disease, AI: anemia of inflammation, DIC: disseminated intravascular coagulation, EPO: erythropoietin, FID: functional iron deficiency, IDA: iron deficiency anemia. All normal values are taken as standard reference values as mentioned in Nathan and Oski's Hematology and Oncology of Infancy and Childhood, 8th Ed [8].

inherited conditions such as thalassemia (**Table I**) [7,8,10,13-17].

The conventional parameters are generated in all automated cell counters, while the newer parameters discussed in **Table I** are available in specific counters and need to be customized to be generated as printouts. Additionally, there are a number of indicators that can be derived from the parameters reported in the automated analyzers such as the Mentzer index (MCV/RBC) that can also help differentiate between IDA and β-thalassemia.

In RBC histograms, the cell-counters count RBCs between 25 and 250 femtoliter (fL). The histograms have two flexible discriminators that help differentiate RBC curves from others: RBC lower discriminator (RL) that fluctuates between 25 and 75 fL and RBC upper discriminator (RU) that fluctuates between 200 and 250 fL. When the cell population is homogeneous, the curve shows a symmetrical bell-shaped or Gaussian distribution. The area of the histogram's peak (60 to 125 fL) helps to calculate MCV and RDW (**Fig. 1**).

In a normal RBC histogram, RBCs are located between 55-125 fL. MCV is calculated using a perpendicular line between the base of the curve and its peak. RDW helps calculate the variation in RBC size and can be of 2 forms: RDW-SD and RDW-CV. RDW-SD is the standard deviation expressed as fL obtained by drawing a line of 20% on the y-axis. Its normal range is between 35-45 fL. RDW-CV is the coefficient of variation percentage and lies within the range of 11.5% to 14.5%. It is calculated as: RDW-CV = SD/MCV ×100 (**Fig. 2**).

To avoid interference of aperture artifacts, giant platelets, RBC agglutinates, the information <20% of the scale on the histogram is excluded. When RBCs are smaller than normal in size, as in microcytic anemia, the curve shifts to the left and when larger than normal, as in macrocytic anemia, the curve shifts to the right. The extension of the lower end of the scale helps in the detection of RBC fragments, WBC fragments and platelets (**Fig. 1**).

RBC Histograms Flags in Childhood Anemia

Flags are signals that occur when automated hematology analyzers detect an abnormal result (**Fig. 2**). Any abnormal flag should always be correlated with the peripheral smear findings.

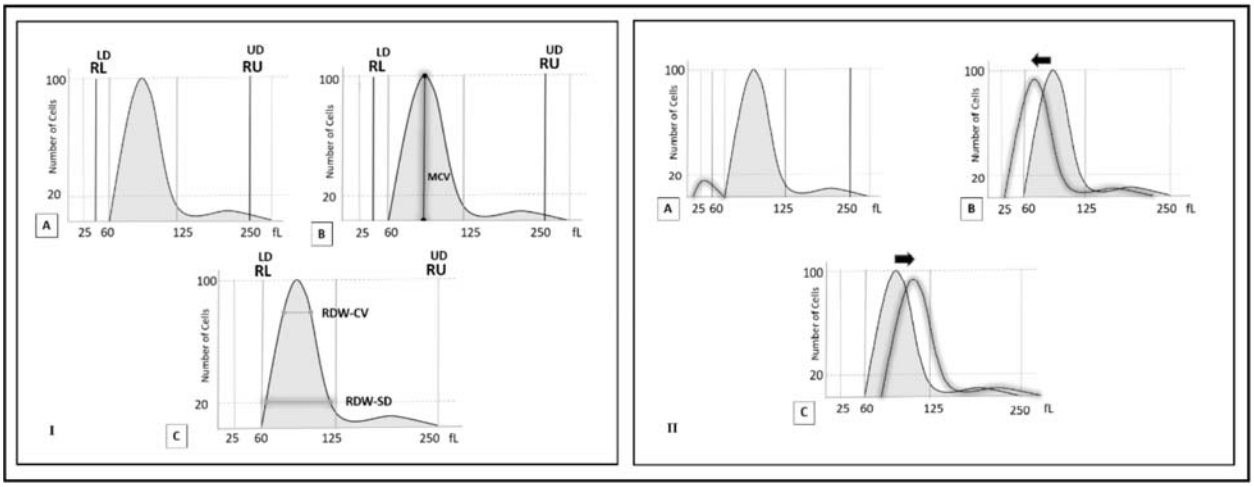

Fig. 1 Interpretation of RBC Histograms (I): normal RBC curve (A), calculation of MCV (B) and RDW (C). Shift in the curve of RBC Histogram (II): extension of lower end of curve as seen in case of normal MCV with flagging (A), leftward shift of curve as seen in the presence of microcytic RBCs (B), and rightward shift of curve as seen in the presence of macrocytic RBCs (C).

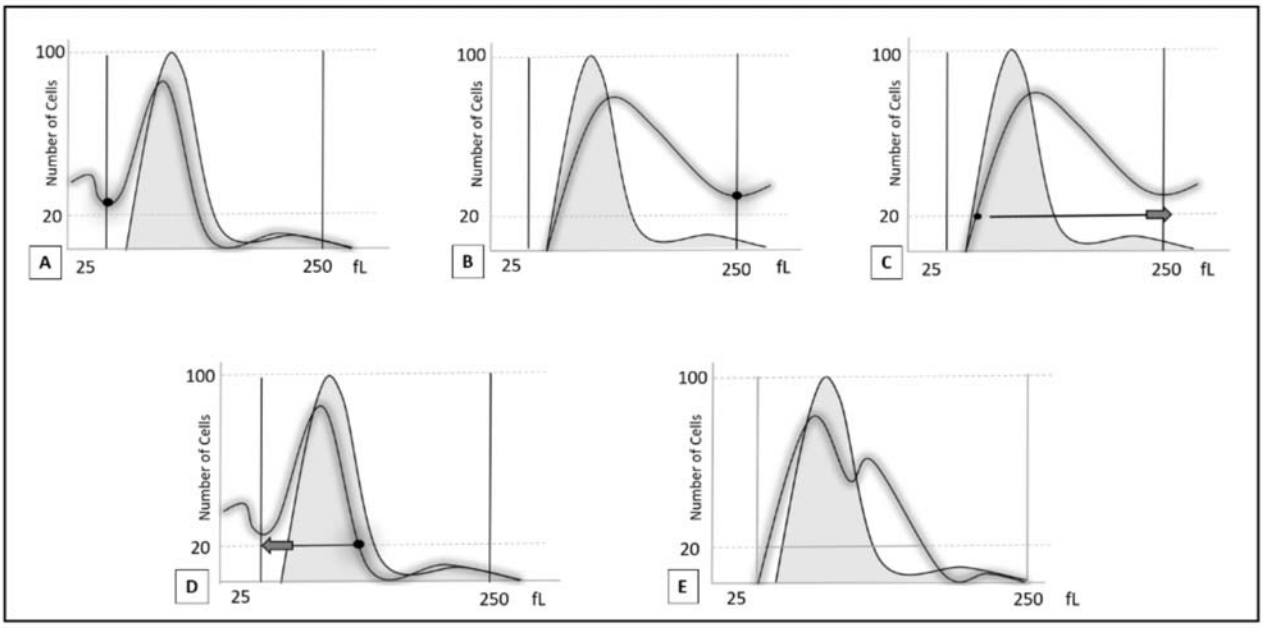

Fig. 2 Flags encountered in RBC histograms: RL Flag (A), RU Flag (B), RDW Flags (C and D) and MP Flag (D).

RL Flag: This occurs due to abnormal height at lower discriminator when it exceeds the preset height by >10%. This is seen in the presence of platelet clumps, RBC fragments, extreme micro-erythrocytosis, giant platelets, micro-RBCs and noise.

RU Flag: This is represented by abnormal height at upper discriminator when it exceeds the preset height by >5%. It can be seen in the presence of nucleated RBCs, RBC agglutination, cold agglutinins and chronic lymphocytic leukemia (CLL) when the small lymphoid cells are present in very high numbers. In the presence of cold agglutinins, the flag disappears when the sample is incubated at 37ºC.

RDW Flag: This occurs in the presence of abnormal RDW and is seen when the curve does not match the 20% line twice. The possible causes of this may include those of RL and RU flags.

MP Flag: Here multiple peaks are seen in the presence of increased anisocytosis, i.e., raised RDW. This is also known as bimodal flag. Causes include post-transfusion blood samples, iron-deficiency anemia in recovery and

dimorphic anemias (both iron and vitamin B12/folate deficiency).

Platelet Parameters

Platelets may be abnormal in size or number in various anemias and may help determine the etiology of anemia. Details of newer platelet indices are summarized in **Table II**.

Platelets are counted and represented between 2 and 20 fL in platelet histograms. At 20 fL, there may be interference in counting due to RBC and WBC fragments, while at 2 fL, interference may be due to air, EDTA particles and air bubbles. Here, two flexible discriminators: lower discriminator (LD) or platelet lower discriminator (PL), upper discriminator (UD) or platelet upper discriminator (PU), and a fixed discriminator at 12 fL are used. The platelet histogram curve should lie between LD and UD and it starts and ends at the baseline. The platelet curve is normally left skewed. In thrombocytosis, the curve shifts upwards, while it shifts downwards in thrombocytopenia.

Platelet histogram is used to calculate mean platelet volume (MPV), platelet distribution width (PDW) and platelet large cell ratio (P-LCR) (**Fig. 3**). MPV, which is analogous to the MCV of RBCs, represents the average volume of the counted platelets. It lies between 8 and 12 fL normally. MPV (fL) = Plateletcrit (%) / platelet count (x 103/ μL)

MPV, i.e., the range of platelet size, varies with platelet count. In physiological conditions, MPV is inversely related to platelet count and is raised in thrombocytopenia [18,19]. Additionally, MPV is used to discriminate between reactive (MPV normal) and malignant thrombocytosis (MPV raised). MPV is raised in conditions such as splenectomy, chronic myeloid leukemia (CML), myelofibrosis, Bernard Soulier syndrome and immune thrombocytopenic purpura (ITP) [19]. It is decreased in hypersplenism, aplastic anemia, megaloblastic anemia, Wiskott Aldrich syndrome and chemotherapy.

PDW is a measure of the variation of platelet size. It is a coefficient of variation calculated as SD / MPV×100 and has a reference range of 9 to 14%. It is expressed in the histogram by drawing an arbitrary line at the height of 20%. PDW is high in aplastic anemia, megaloblastic anemia, chronic myelogenous leukemia (CML), chemotherapy, etc. and is falsely elevated in the presence of platelet clumps, microcytic RBCs and fragments.

P-LCR is the percentage of platelets that exceed the normal value of platelet volume of 12 fL in the total platelet count. It is calculated as platelet cell concentration (P-LCC)/platelet count, where P-LCC refers to the platelets in the volume range of 12 to 30 fL. The normal range of P-LCR is 15 to 35% and it is raised in the presence of platelet clumps, giant platelets and microcytic RBCs.

Platelet Histogram Flags in Childhood Anemia

LD Flag (PL Flag): This occurs when LD exceeds preset height by 10%. This can occur due to the presence of a high blank value, platelet aggregation, cell fragments, contaminated reagents and high numbers of bacteria.

Table II Platelet Parameters on Automated Analyzer

Platelet parameters	*Significance in Anemia*
Platelet volume distribution width (PDW): Variation in platelet size	Raised when platelet anisocytosis present.
Mean platelet volume (MPV): Thrombocyte volume	Act as acute phase reactant;High in anemias associated with myeloproliferative neoplasms and chronic disease, e.g., type I diabetes mellitus; Predictor of higher risk of stroke or myocardial infarction particularly in children with type I diabetes mellitus.
Plateletcrit (Pct): Volume of circulating platelets in unit volume of blood	High in active stages of certain chronic diseases (e.g., Crohn disease)
[a]Reticulated platelets or immature platelet fraction (IPF): Immature platelets	Recovery of thrombopoiesis (dengue);Peripheral destruction of platelets (autoimmune conditions, malaria)
Platelet large cell ratio (P-LCR): Large circulating platelets	Reactive thrombocytosis (IDA, viral infections); Peripheral destruction of platelets (DHF)
Platelet component distribution width (PCDW)	Raised when variation in platelet shape is present (e.g., giant platelets in reactive thrombocytosis)
Mean platelet mass (MPM) or mean platelet component (MPC)	Raised in reactive thrombocytosis (IDA, thalassemia)

IDA: iron deficiency anemia, DHF: dengue hemorrhagic fever. [a]Similar parameters calculated differently in different types of automated cell counters. All normal values are taken as standard reference values as mentioned in Nathan and Oski's Hematology and Oncology of Infancy and Childhood, 8th Ed [8].

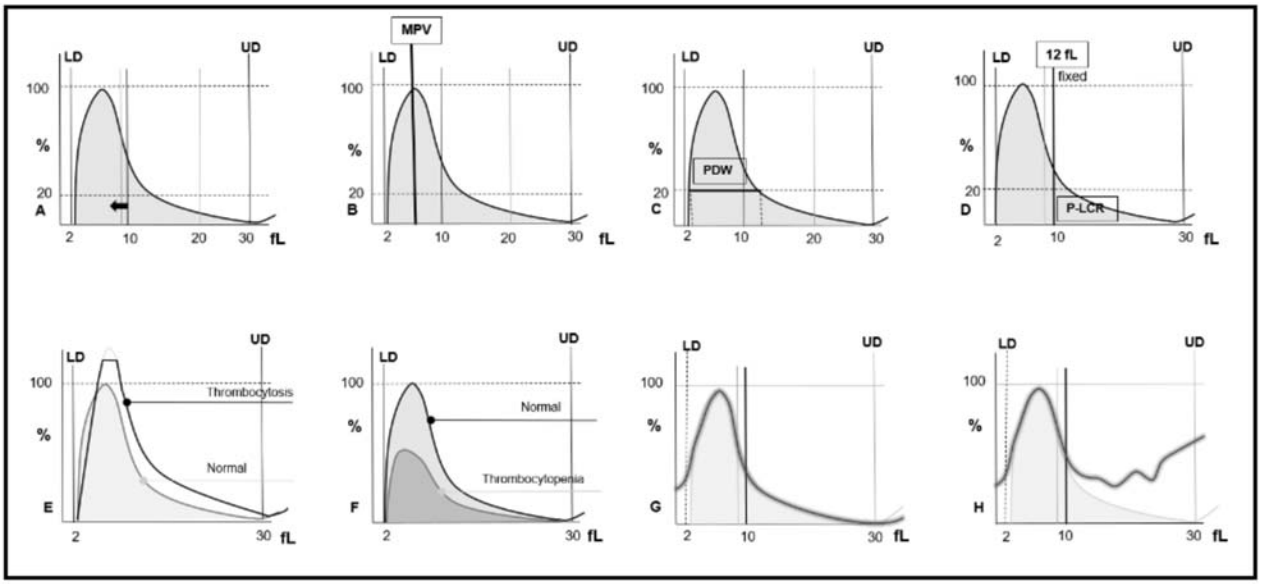

Fig. 3. Interpretation of normal platelet histogram: Normal platelet histogram is left skewed (arrow, A), MPV calculation (B), PDW calculation (C), thrombocytosis vs normal curve (D), thrombocytopenia vs normal curve (E), PL flag (F) and PU flag (G).

UD Flag (PU Flag): This occurs when there is abnormal height at UD and it exceeds the preset height by >40 %. It can be seen in the presence of platelet clumps (clotted sample or EDTA incompatibility), giant platelets and microcytic RBCs.

MP Flag: This occurs when there are multiple peaks present. It can be seen in cases of platelet transfusion, recovery from chemotherapy and platelet aggregation.

WBC Parameters

WBC differential indicates the chronicity of the disease and very high counts may indicate severe infections and malignancies. Further, the presence of leucopenia along with anemia, can point towards more specific etiologies (**Table III**).

WBC histograms generated by automated hemato-logy analyzers plot the size of cells (in fL) on the *X*-axis and the frequency of the cells on *Y*-axis. The counter here also sets a lower discriminator (LD or WL) that fluctuates between 30 and 60 fL and an upper discriminator (UD or WU) that is fixed at 300 fL. The number of cells between these two discriminators is the total WBC count. A normal WBC histogram curve should be within the discri-minators and start and end at the baseline. WBC histograms consist of two troughs or valleys; T1 lies between 78 and 114 fL and T2 <150 fL. These 2 troughs are detected by 2 inner discriminators that separate the WBC populations into 3 groups, based on the size of cells. The peak between LD and T1 represents a small cell popu-lation, i.e., lymphocytes with their volume ranging from 35 to 90 fL. The peak between T1and T2 represents medium cell population comprising of eosinophils, basophils, monocytes, promyelocytes and blasts with their volume ranging between 90 and 160 fL. The peak between T2 and UD denotes neutrophils with their size ranging from 160 to 300 fL. (**Fig. 4**)

Table III White Blood Cell Parameters on Automated Analyzer

WBC parameters	*Significance in anemia*
Immature granulocyte count (IMG): Immature myeloid cells	Systemic inflammation, sepsis, hematological disorders (MPN, AML, bone marrow infiltrative disorder).
High fluorescent lymphocytes (HFL) or Atypical lymphocytes, ALY% or Large unstained cells, %LUC	Reactive lymphocytes, lymphoma cells, blasts; Helps in sepsis monitoring.
Neutrophil granulation (NEUT-X/NEUT-Y): Granularity/nucleic acid and protein content	Raised in sepsis; Low in MDS or MDS/MPN.
Malaria factor (Mf)	More than 3.7 in the absence of a WBC peak in malaria.

AML: acute myeloid leukemia, MDS: myelodysplastic syndrome, MDS/MPN: myelodysplastic syndrome/myeloproliferative neoplasm. All normal values are taken as standard reference values as mentioned in Nathan and Oski's Hematology and Oncology of Infancy and Childhood [8].

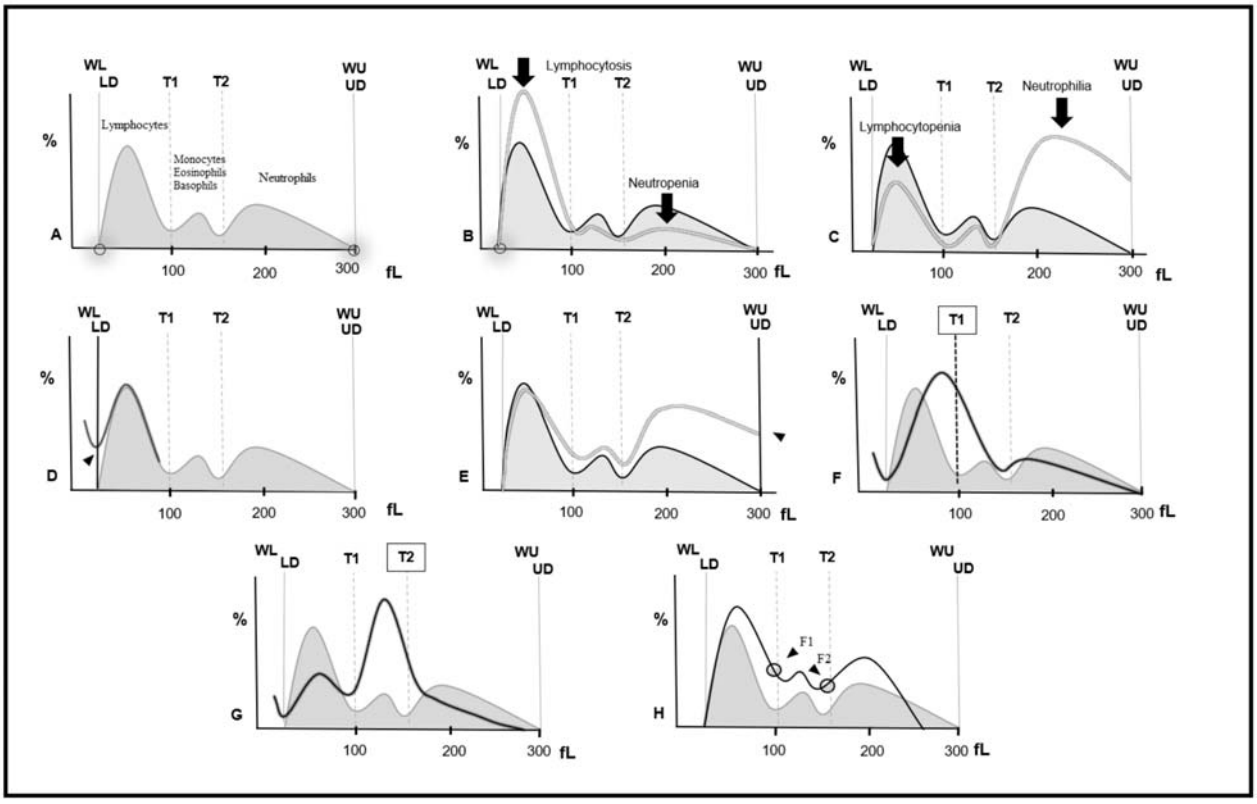

Fig. 4 Interpretation of WBC Histograms: Normal Histogram (A), histograms showing normal distribution of neutrophils and lymphocytes and their distribution when there is an abnormal increase or decrease (B, C), LD/WL Flag (D), UD/WU Flag (E), T1 Flag (F), T2 Flag (G) and FI, F2, F3 Flag (H). In LD Flag, curve does not start at baseline. In UD Flag, the curve does not end at baseline (arrow head). In T1, there is no differentiation between lymphocytes and mixed cell population. In T2, there is no differentiation between mixed cells and neutrophils. In F1, F2, F3 flags, T1 and T2 discriminators are set but there is no clear separation between different populations.

WBC Histogram Flags in Childhood Anemia

WL flag (LD flag): This is an abnormal curve at the LD that occurs when the height of LD exceeds the present 2% of the *Y*-axis. This may be seen in the presence of nucleated RBCs, clotted sample and cold agglutinins.

WU flag (UD flag): This is an abnormal curve at the UD. A WU flag appears when the height of UD is greater than the preset 10% on *Y*-axis. WU flagging occurs in case of inadequate WBC lysing, WBC aggregation and extreme leukocytosis.

T1 flag: This is an abnormal curve at T1 level. T1 and T2 flags appear when discrimination between 3 populations is not possible. A T1 flag appears when differentiation between lymphocytes and medium-sized cell populations is not possible, for example, in cases of chronic myeloid leukemia and leukocytosis.

F1, F2 and F3 flags: This occurs when the height of T1 surpasses the present limit of 40%. The F1 flag denotes that the discrimination between small cell and middle cell populations is not an accurate example in acute lymphoblastic leukemia. An F2 flag occurs when the middle cell data is inaccurate. The T1 and T2 exceed the preset limits of 40% and 50%, respectively. Examples of F2 flags are eosinophilia, acute myeloid leukemia and monocytosis. F3 flag occurs when the T2 exceeds the preset limit of 50%, denoting that the large cells data is inaccurate.

Utility of histograms can be demonstrated by interpreting few common case scenarios (**Web Box I**). Automated hematology analyzers do not provide a complete answer regarding the underlying etiology of anemia and may leave room for misinterpretation. Thus, further testing is required to make a confirmatory diagnosis. However, despite these pitfalls, it plays a role in early decision-making and can help in reducing the time lag between clinical presentation and institution of appropriate therapy.

Note: Additional material related to this article is available at *www.indianpediatrics.net*

Contributors: SD, TJ: concept, design, definition of intellectual

Table IV Other Causes of Abnormal Values in Complete Blood Count (CBC) Reports

Factor	*CBC report*
Nucleated RBCs (nRBCs)	High WBCs, R1 flag
Cryoglobulins	High WBCs, High platelets, High MCV
Hyperlipidemia	High MCHC, High hemoglobin
Hyperbilirubinemia	High MCHC, High hemoglobin
Cold agglutinins	Low RBCs, high MCV. high MCH, high MCHC
Schistocytes	Low RBCs, High platelets, left shift in RBC histogram, Platelet histogram not touching baseline
Fragmented WBCs	High platelets
Large platelet clumps	High WBCs, High RBCs, low platelets, R1 flag, Platelet histogram not touching baseline
Unlysed RBCs	High WBCs, high lymphocytes, R1 flag
Clotted sample	Low counts
Heparinized sample	High WBCs
Very high WBCs	High hemoglobin, High MCHC
Smudge cells	Low WBCs

MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration, MCV: mean corpuscular volume, RBC: red blood cell, WBC: white blood cell.

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REFERENCES

1. Marcdante KJ, Kliegman RM. Nelson essentials of pediatrics. 7th Edition. Elsevier Saunders. 2016.
2. Paul VK. Ghai Essential Pediatrics. 9th Edition. CBS Publishers and Distributors. 2019.
3. Kapur D, Agarwal KN, Sharma S, et al. Iron status of children aged 9-36 months in an urban slum integrated child development services project in Delhi. Indian Pediatr. 2002;39:136-44
4. Kumar T, Taneja S, Yajnik CS, et al. Prevalence and predictors of anemia in a population of North Indian children. Nutrition. 2014;30:531-37.
5. Xie D, Xie Y, Liu P, et al. Performance of a cost effective and automated blood counting system for resource limited settings operated by trained and untrained users. J Biophotonics. 2018;11:e201700030.
6. Gounari E, Tsavdaridou V, Koletsa T, et al. Utility of hematology analyzer and flow cytometry in timely and correct detection of circulating plasma cells: Report of three cases. Cytometry B Clin Cytom. 2016;90:531-37.
7. Kujovich JL. Evaluation of anemia. Obstet Gynecol Clin North Am. 2016;43:247-64.
8. Nathan D, Orkin S, Oski F. Nathan and Oski's hematology and oncology of infancy and childhood. Elsevier. 2015.
9. Balci YI, Akpinar FO, Polat A, et al. Evaluation of reticulocyte parameters in iron deficiency, vitamin B12 deficiency and mixed anemia. Clin Lab. 2016;62:343-47.
10. Piva E, Brugnara C, Spolaore F, Plebani M. Clinical utility of reticulocyte parameters. Clin Lab Med. 2015;35:133-63.
11. Arkin CF, Davis BH, Bessman JD, et al. Methods for reticulocyte counting (automated blood cell counters, flow cytometry, and supravital dyes); approved guideline. The National Committee for Clinical Laboratory Standards. 2004;24:1-34.
12. Briggs C. Quality counts: New parameters in blood cell counting. Int J Lab Hemat. 2009;31:277-97.
13. Markoviæ M, Majkiæ-Singh N, Subota V. Usefulness of soluble transferrin receptor and ferritin in iron deficiency and chronic disease. Scand J Clin Lab Invest. 2005;65: 571-76.
14. Angeles Vázquez López M, Molinos FL, Carmona ML, et al. Serum transferrin receptor in children: usefulness for determinating the nature of anemia in infection. J Pediatr Hematol Oncol. 2006;28:809-15.
15. Urrechaga E, Borque L, Escanero JF. Erythrocyte and reticulocyte indices on the LH 750 as potential markers of functional iron deficiency. Anemia. 2010;2010:625919.
16. Osta V, Caldirola MS, Fernandez M, et al. Utility of new mature erythrocyte and reticulocyte indices in screening for iron-deficiency anemia in a pediatric population. Int J Lab Hematol. 2013;35:400-05.
17. Thomas ETA, Bhagya S, Majeed A. Clinical utility of blood cell histogram interpretation. J Clin Diagn Res. 2017;11:OE01-04.
18. Dastjerdi, MS, Emami, T, Najafian, A, Amini, M. Mean platelet volume measurement, EDTA or citrate? Hematology. 2006;11:317-19.
19. Korniluk A, Koper-Lenkiewicz OM, Kamiñska J, et al. Mean platelet volume (MPV): new perspectives for an old marker in the course and prognosis of inflammatory conditions. Mediators of Inflammation. 2019; 2019: 9213074.

Web Box I Case Based Interpretation of Histograms

a. A 1-year-old female presented with pallor and frequent episodes of breathlessness. CBC parameters show a fall in MCV, MCH, MCHC and a left shift of RBC histograms indicating a microcytic anemia. Raise in RDW and a widening of RBC curve is suggestive of IDA, which was in turn, confirmed by estimating serum iron, total iron binding capacity (TIBC) and serum ferritin.

b. A 2-year-old male presented with pallor, breathlessness and early fatigability. Very low MCV, MCH, MCHC and abundant platelets along with left-shift of RBC curve give a clue for thalassemia trait. On further testing, HPLC showed mildly raised HbA2 and HbF, suggesting a diagnosis of beta thalassemia trait. RDW is usually not raised in beta thalassemia trait. However, here in view of raised RDW, further work-up for other associated conditions such as IDA is suggested.

c. A 5-year-old male presented with low-grade fever, abdominal distension, loss of weight and loss of appetite. Examination revealed hepatosplenomegaly and multiple enlarged palpable lymph nodes. CBC showed high WBC counts. WBC histogram shows lack of differentiation between medium and small cell population, suggestive of blasts. A peripheral smear examination and further characterization using special stains and flow cytometry is required.

d. An 8-year-old male presented with high grade fever and generalized weakness. CBC showed high WBC counts. However, the population can be identified as neutrophils on WBC histogram indicating leukemoid reaction.

e. A 13-year-old female presented with fever for 4 days, associated with one episode of vomiting, severe weakness and dyspnea on exertion. RBC histogram was normal. WBC histogram showed dual peak in small-medium cell population, small peak in large cell population suggestive of atypical cells/activated lymphocytes. Platelet histogram showed downward shift suggestive of thrombocytopenia with increased PDW for giant platelets. Dengue NS1 antigen was found positive.