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ARTICLE

DETERMINATION OF COMPLETE BLOOD COUNT REFERENCE VALUES OF MINDRAY BC-760 HEMATOLOGY ANALYZER

Anggraini Iriani[1*], Dhinasty Armenia[1], Dian Eka Putri[1], Ritki F Shafwandi[1], Rendy Murdianto[1], Legina Aditya[1], Endah Purnamasari[1], Syukrini Bahri[1], Henri Aprilio[1], Bambang Poerwantoro[1]

[1]Fakultas Kedokteran, Universitas Yarsi, Jakarta, Indonesia

*Correspondence email : anggraini.iriani@yarsi.ac.id

ABSTRACT

Hematological assessment serves as a standard examination in supporting diagnostics in clinical practice. The advanced hematology analyzer instrument namely Mindray BC 760 has recently introduced several new hematological parameters which previously unavailable. This study set out to establish the value of the reference interval of those new parameters on the Mindray BC 760 device in the Indonesian adult population. A total of 352 subjects who underwent medical check-ups at pathology clinics laboratory in the hospital were enrolled. All participants comprised both females and males aged > 17 years and were confirmed to be healthy through examination. Hematological was assessed using Mindray BC 760 device. It is recommended to adjust of reference interval value according to gender for several novel hematological parameters assessed through the Mindray BC 760 instrument. Significant gender-based differences ($p < 0.05$) were found in multiple new parameters such as Hb, Ht, RBC, MCH, MCHC, RHE, RDW-CV, RET#, MON#, EOS#, NEU%, MON%, EOS%, PLT_I, PLT_H, PLT_O, PDW, PCT, and PLCC, suggesting the need for gender-specific reference intervals. Conversely, certain parameters showed no significant gender differences ($p \geq 0.05$) including MCV, RDW-SD, RET%, LFR, MFR, HFR, NRBC#, NRBC%, WBC, NEU#, LYM#, BAS#, IMG#, LYM%, BAS%, IMG%, MPV, PLCR, and IPF.

Keywords: Reference Values; Complete Blood Count; Mindray BC-760.

АБСТРАКТ

Гематологическая оценка служит стандартным исследованием для вспомогательной диагностики в клинической практике. Современный гематологический анализатор Mindray BC 760 недавно представил несколько новых гематологических параметров, которые ранее были недоступны. Целью данного исследования было определить значение референсного интервала этих новых параметров на приборе Mindray BC 760 среди взрослого населения Индонезии. В исследование было включено 352 человека, которые проходили медицинское обследование в лаборатории патологической клиники в больнице. Все участники включали женщин и мужчин в возрасте старше 17 лет и были признаны здоровыми по результатам обследования. Гематологические показатели определялись с помощью прибора Mindray BC 760. Рекомендуется скорректировать значение референтного интервала в зависимости от пола для нескольких новых гематологических параметров, оцениваемых с помощью прибора Mindray BC 760. Значительные гендерные различия ($p < 0,05$) были обнаружены для нескольких новых параметров, таких как Hb, Ht, RBC, MCH, MCHC, RHE, RDW-CV, RET#, MON#, EOS#, NEU%, MON%, EOS%, PLT_I, PLT_H, PLT_O, PDW, PCT и PLCC, что указывает на необходимость использования гендерно-ориентированных референсных интервалов. Напротив, некоторые параметры не показали значительных гендерных различий ($p \geq 0,05$), включая MCV, RDW-SD, RET%, LFR, MFR, HFR, NRBC#, NRBC%, WBC, NEU#, LYM#, BAS#, IMG#, LYM%, BAS%, IMG%, MPV, PLCR и IPF.

Ключевые слова: Референсные Значения; Полный Анализ Рови; Mindray BC-760.

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INTRODUCTION

A hematological assessment involves the examination of cellular elements in the blood to assist in diagnosis and patient management. This standard examination is routinely performed to provide crucial information for diagnosing hematological diseases and other conditions. In addition, the findings from hematological assessment can serve as an underlying basis for recommending further laboratory assessment such as infection markers or anemia testing panel.[1,2]

It is well known and has been verified that the accuracy of hematological assessment may be influenced by several factors, including age, gender, race, nutrition, and environment, as well as the specific device and methodologies employed. Advancements in technology have prompted the evolution of hematological assessment methods, particularly through the incorporation of cutting-edge technologies by laboratory instrument manufacturers. One notable addition to the latest generation of laboratory instruments used for hematological assessment is the Mindray BC-760. The Mindray BC-760 offers distinct advantages compared to the previous generation in the context of the inclusion of several additional hematological parameters. New additional features include the measurement of new reticulocyte blood cells (NRBC), reticulocyte count and index, reticulocyte hemoglobin equivalent, immature granulocyte, platelet impedance, optic and hybrid reader, as well as for large and immature platelets. These new parameters enhance the comprehensive analysis of hematological examinations, which were not previously available.

Despite technological advancement, the determination of reference value by laboratory instrument manufacturers remains limited. As a consequence, clinics and laboratories are compelled to establish their respective reference values.[5] Furthermore, the Mindray BC-760 instrument reference values for the latest hematology parameters have yet to be established in Indonesia. These reference values play an essential role in patient diagnosis and management.[1–3] Thus, there is an urgent need to establish standard reference values for the hematological parameters specific to the Mindray BC-760 instruments within the Indonesian adult population. The purpose of this study was to ascertain reference values for hematological parameters of the Mindray BC-760 device in the Indonesian adult population.

MATERIAL AND METHODS

Study participants

This study was carried out at the Clinical Pathology Laboratory of Yarsi University in Jakarta from March 2023 to August 2023. Research subjects comprised Indonesian adult males and females aged >17 years old, selected from patients who had undergone a medical check-up at Yarsi Hospital and were confirmed to be healthy according to comprehensive examinations including both physical and laboratory tests conducted by physicians. The exclusion criteria for this study encompassed subjects with underlying conditions that could affect hematological conditions such as chronic infections, inflammatory diseases, hematological disorders, or blood clotting, as well as pregnant patients, as determined from their medical records.

Blood Collection and Hematological Assessment

A volume of 2–3 mL of whole blood samples was collected into a K3-EDTA tube, and a comprehensive hematological assessment was carried out using the Mindray BC-760 device. The analysis included a complete blood count (CBC), 5-part/differential count, and reticulocyte measurement. The obtained results encompass a range of crucial parameters, including: Hemoglobin (Hb), Hematocrit (Ht), Red Blood Cell (RBC), Mean Cell Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), Red Cell Distribution (RDW- SD), Red Cell Distribution (RDW-CV), Absolute Reticulocyte Count (RET#), Reticulocyte Count (RET%), Immature Reticulocyte Fraction (IRF), Low Fluorescence Reticulocyte (LFR), Moderate Fluorescence

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Reticulocyte (MFR), High Fluorescence Reticulocyte (HFR), Reticulocyte Hemoglobin Equivalent (RHE), Absolute Nucleated Red Blood Cell Count (NRBC#), Nucleated Red Blood Cell Count (NRBC%), White Blood Cell (WBC), Absolute Neutrophils Count (NEU#), Absolute Lymphocytes Count (LYM#), Absolute Monocytes Count (MON#), Absolute Eosinophils Count (EOS#), Absolute Basophils Count (BAS#), Absolute Immature Granulocyte Count (IMG#), Neutrophils Count (NEU%), Lymphocytes Count (LYM %), Monocytes Count (MON%), Eosinophils Count (EOS%), Basophils Count (BAS%), Immature Granulocyte Count (IMG%), Platelet Count Impedance (PLT-I), Platelet Count Hybrid (PLT-H), Optical Platelet Count (PLT-O), Mean Platelet Volume (MPV), Platelet Distribution Width (PDW), Plateletcrit (PCT), Platelet Large Cell Count (PLCC), Platelet Large Cell Ratio (PLCR), Immature Platelet Fraction (IPF).

Statistical Analysis

The research findings were analyzed using Microsoft Excel and SPSS 25.0. The data normality test was carried out using Kolmogorov-Smirnov. From the results obtained, hematological parameters exhibiting a normal distribution were presented as mean (SD) values, while those with an abnormal distribution were conveyed as median values [IQR]. Differences in hematological parameters between male and female groups were carried out using the Mann-Whitney U test for non-normal data distribution and the Independent T-test for normal distribution.

RESULT

The establishment of reference intervals following CLSI recommendations[2,3], involved an examination of a minimum of 120 samples originating from healthy individuals for each sex and age category. A total of 383 subjects were initially recruited for hematological assessment. However, 31 subjects were subsequently excluded due to abnormal results, resulting in a final research cohort of 352 individuals. Among these, 192 (54.55%) were male, and 160 (45.45%) were female. Furthermore, 162 (46.02%) subjects fell within the age group of >30 to ≥ 45 years, with an additional 7 samples representing patients over 60 years (**Table 1**).

Table 1. Subject Characteristic

Variable	n (352)	%
Sex		
Male	192	54.55
Female	160	45.45
Age (years)		
> 17-≤ 30	74	21.02
> 30-≤ 45	162	46.02
> 45-≤ 60	109	30.97
> 60	7	1.99

The analysis revealed that the male cohort demonstrated elevated levels in parameters such as Hb, Ht, RBC, MCV, MCH, MCHC, RDW-CV, RET#, RET%, LFR, RHE, WBC, NEU#, LYM#, MON#, EOS#, BAS#, IMG#, LYM%, MON%, EOS%, BAS%, IMG%, and PDW compared to female group. Conversely, the female group displayed higher values in parameters including RDW-SD, IRF, MFR, HFR, NEU%, PLT-I, PLT-H, PLT-O, MPV, PCT, PLCC, PLCR, and IPF as presented in **Table 2**. However, statistical analysis indicated significant differences ($p<0.05$) only in RBC, hemoglobin, hematocrit, MCH, MCHC, platelet count, RDW CV, PDW, PCT, PLCC, absolute reticulocyte count, RHE, monocyte count, and basophil count (**Table 3**).

DISCUSSION

The hematology assessment involves the examination of parameters related to RBC, WBC, and platelet parameters. Within each group, various sub-parameters contributed to the overall assessment.[4,5] Investigation of this study revealed notable differences between male and female groups in several red blood cell parameters, such as hemoglobin, hematocrit, RBC count, absolute reticulocyte count, and RHE. The male group exhibited elevated scores compared to the female group, aligning closely with prior research conducted in Thailand.[1] The difference in RBC levels between genders can be attributed to the

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influence of androgen, estrogen, and testosterone hormones, which affect erythropoiesis. Additionally, the heightened occurrence of iron deficiency anemia in females due to blood loss during menstruation was noted.[4,6,7]

Erythrocyte indexes such as MCV, MCH, and MCHC serve as indicators of erythropoiesis in patients with iron deficiency. This study identified significant gender-based in MCH and MCHC parameters. These results were partially supported by findings from Wongkrajang et al.[1] which highlighted differences only in MCHC. Parameters including RDW-SD and RDW-CV describe the average RBC volume and aid in distinguishing the causes of anemia. Anemia with elevated RDW may indicate iron deficiency, while normal RDW levels may pinpoint thalassemia. The present study established an RDW-SD reference interval of 40–46.6 fL and an RDW-SD of 12.4–14.7 fL, aligning closely with previous research.[8]

Reticulocytes are young RBCs retaining granules or reticulum tissue when subjected to supravital staining. This parameter could serve as a valuable indicator for measuring erythropoiesis activity.[9,10] The advancement in quantifying reticulocytes using automatic tools like flow cytometry yields results with high accuracy and precision compared to manual methods.[11] The reticulocyte count reference interval in this investigation was set at 1.18 to 2.4%. There were notable variations in absolute reticulocyte numbers between the male and female groups, but no significant changes were seen in reference interval reticulocyte counts. The absolute reticulocyte count values in the male and female groups were 0.06–0.12 × 103 µL and 0.06–0.10 × 103 µL, respectively. Notably, the reference interval value found in a prior study is comparable to this observation.[11] The absolute parameter for reticulocyte count is obtained by multiplying the percent reticulocyte count by the total number of RBCs.[12]

The assessment of reticulocyte maturity based on fluorescence intensity depends upon the cellular RNA content. This evaluation categorizes reticulocyte maturity into three distinct groups: low fluorescent (LFR), moderate fluorescent (MFR), and high fluorescent (HFR). The percentage of reticulocyte count is the cumulative values of LFR, MFR, and HFR. The computations for MFR and HFR yield results interpreted as the immature reticulocyte fraction (IRF).[9,10,12] The value of the IRF indicates the fraction of young reticulocytes that have the greatest RNA content relative to the total number of cells. When erythropoiesis activity is at its peak, such as when there is bleeding, anemia, a response to therapy, or when there is stimulation of bone marrow formation, the young reticulocytes may be discharged into the circulation.[9,10] The assessment of IRF reference intervals between male and female groups in this study revealed no significant differences.

The RHE parameter describes the hemoglobin content within reticulocytes.[9] RHE examination can detect early alteration in the body's iron status compared to the evaluation of hemoglobin in erythrocytes.[13] Furthermore, RHE emerges as a valuable marker for diagnosing conditions related to iron deficiency, including iron deficiency anemia, and for monitoring response to therapy.[14] Its distinctive capability to rapidly discern between iron deficiency and iron deficiency anemia is noteworthy, as it remains unaffected by the presence of infections or other chronic disease conditions.[14] When attempting to identify iron deficiency, the two criteria that are utilized are the existence of low ferritin levels and plasma saturation that does not exhibit any signs of anemia. The findings of the current study reveal that the RHE reference interval ranges from 26.52 to 30.48 pg for the female group, whereas it falls between 27.0 and 30.8 pg for the male group. This information pertains to the RHE reference interval. The findings of these investigations showed levels that were marginally lower than those discovered in previous investigations, when compared to the findings of other investigations.[9] Transcutaneous auricular vagus nerve stimulation (taVNS) examines how 14 sessions of taVNS affect cortisol levels before and after therapy.[15]

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Table 2. Complete Blood Count Data Distributions Test with Mindray BC-760 Instrument

Parameters	Units	Mean (SD)	Median [IQR]	p-value	Parameters	Units	Mean (SD)	Median [IQR]	p-value
Hb	g/dL				MON#	$\times10^3/\mu L$			
Male		14.8 (1.04)	14.9 [1.47]	0.2*	Male		0.42 (0.13)	0.39 [0.19]	<.001
Female		12.7 (1.03)	12.8 [1.3]	0.048	Female		0.35 (0.10)	0.37 [0.14]	0.03
Ht	%				EOS#	$\times10^3/\mu L$			
Male		46.2 (3.20)	46.7 [4.48]	0.061*	Male		0.23 (0.16)	0.2 [0.23]	<.001
Female		40.0 (3.18)	40.3 [3.95]	0.2*	Female		0.17 (0.13)	0.14 [0.14]	<.001
RBC	$\times10^6/\mu L$				BAS#	$\times10^3/\mu L$			
Male		5.32 (0.46)	5.28 [0.48]	0.001	Male		0.02 (0.02)	0.02 [0.03]	<.001
Female		4.67 (0.39)	4.67 [0.51]	0.2*	Female		0.02 (0.02)	0.01 [0.02]	<.001
MCV	fl				IMG#	$\times10^3/\mu L$			
Male		87.1 (5.20)	87.6 [4.88]	<.001	Male		0.02 (0.02)	0.01 [0.02]	<.001
Female		85.8 (5.70)	87.0 [5.8]	<.001	Female		0.01 (0.02)	0.01 [0.01]	<.001
MCH	pg				NEU%	%			
Male		28.0 (1.91)	28.3 [1.9]	<.001	Male		58.6 (7.34)	58.1 [9.6]	0.098*
Female		27.3 (2.07)	27.7 [2.08]	<.001	Female		60.5 (7.77)	59.9 [10.1]	0.2*
MCHC	g/dL				LYM%	%			
Male		32.1 (0.73)	32.2 [0.9]	0.002	Male		31.6 (6.61)	32.5 [9.28]	0.001
Female		31.7 (0.77)	31.8 [1]	0.012	Female		31.2 (7.16)	31.7 [8.8]	0.095*
RDW-SD	fl				MON%	%			
Male		43.3 (2.66)	43.1 [3.15]	0.004	Male		5.93 (1.35)	5.7 [1.7]	0.014
Female		43.9 (3.12)	43.4 [3.5]	0.023	Female		5.27 (1.46)	5 [1.6]	0.001
RDW-CV	%				EOS%	%			
Male		13.4 (0.73)	13.3 [0.9]	<.001	Male		3.39 (2.35)	2.9 [2.95]	<.001
Female		12.80 (1.14)	13.60 [1.10]	<.001	Female		2.56 (1.87)	2.2 [2.1]	<.001
RET#	$\times10^6/uL$				BAS%	%			
Male		0.10 (0.02)	0.09 [0.03]	0.002	Male		0.37 (0.32)	0.3 [0.5]	<.001
Female		0.08 (0.02)	0.08 [0.03]	0.089*	Female		0.34 (0.30)	0.2 [0.5]	<.001
RET%	%				IMG%	%			
Male		1.88 (0.45)	1.81 [0.56]	<.001	Male		0.30 (0.33)	0.2 [0.3]	<.001
Female		1.81 (0.52)	1.73 [0.68]	<.001	Female		0.26 (0.25)	0.2 [0.2]	<.001
IRF	%				PLT-I	$\times10^3/\mu L$			
Male		13.9 (4.00)	13.5 [5.9]	0.023	Male		282 (56.0)	280 [85.5]	0.2*
Female		14.1 (4.78)	13.6 [5.58]	<.001	Female		317 (70.3)	308 [103]	0.03
LFR	%				PLT-H	$\times10^3/\mu L$			
Male		86.0 (4.00)	86.4 [5.9]	0.023	Male		282 (59.0)	281 [89]	0.2*
Female		85.8 (4.78)	86.4 [5.57]	<.001	Female		315 (71.6)	307 [99.5]	0.06*
MFR	%				PLT-O	$\times10^3/\mu L$			
Male		12.1 (2.87)	11.8 [4.4]	0.058*	Male		285 (59.4)	283 [73.7]	0.065*
Female		12.1 (3.26)	11.9 [4.15]	0.042	Female		321 (71.5)	312 [90.2]	0.003
HFR	%				MPV	fl			
Male		1.78 (1.34)	1.5 [1.8]	<.001	Male		9.85 (0.91)	9.7 [1.1]	<.001
Female		2.02 (1.77)	1.6 [1.88]	<.001	Female		9.93 (0.97)	9.8 [1.4]	0.011
RHE	pg				PDW	fl			
Male		28.7 (1.71)	28.9 [1.9]	0.002	Male		16.1 (0.31)	16.1 [0.4]	<.001
Female		28.1 (1.92)	28.5 [1.98]	<.001	Female		16.0 (0.30)	16 [0.4]	0.001
NRBC#	$\times10^3/\mu L$				PCT	mL/L			
Male		0	0	-	Male		2.77 (0.48)	2.8 [0.7]	0.003
Female		0	0	-	Female		3.14 (0.67)	3 [0.9]	<.001
NRBC%	%				PLCC				
Male		0	0	<.001	Male		70.2 (17.7)	68.5 [25]	0.2*
Female		0	0	-	Female		80.7 (23.7)	78.5 [29]	0.005
WBC	$\times10^3/\mu L$				PLCR	%			
Male		7.15 (1.86)	6.84 [2.85]	0.005	Male		25.2 (6.44)	24 [7.8]	0.002
Female		6.92 (1.50)	6.81 [2.19]	0.2*	Female		25.5 (6.85)	24.8 [10.1]	0.037
NEU#	$\times10^3/\mu L$				IPF	%			
Male		4.24 (1.39)	4.03 [1.75]	0.005	Male		2.32 (1.45)	1.85 [1.78]	<.001
Female		4.22 (1.21)	4.07 [1.64]	0.2*	Female		2.42 (1.50)	2.1 [1.6]	<.001
LYM#	$\times10^3/\mu L$								
Male		2.22 (0.63)	2.2 [0.79]	0.044					
Female		2.13 (0.61)	2.07 [0.77]	0.033					

Data distribution was performed by Kolmogorov Smirnov; Normal data distribution: *p>0.05 data recommended presenting as mean (SD). Hb, Hemoglobin; Ht, Hematokrit; RBC, Red Blood Cell; MCV, Mean Cell Volume; MCH, Mean Corpuscular Hemoglobin; MCHC, Mean Corpuscular Hemoglobin Concentration; RDW-SD, Red Cell Distribution; RDW-CV, Red Cell Distribution; RET#, Absolut Reticulocyte Count; RET%, Reticulocyte Count; IRF, Immature Reticulocyte Fraction; LFR, Low Fluorescence Reticulocyte; MFR, Moderate Fluorescence Reticulocyte; HFR, High Fluorescence Reticulocyte; RHE, Reticulocyte Hemoglobin Equivalent; NRBC#, Absolut Nucleated Red Blood Cell Count; NRBC%, Nucleated Red Blood Cell Count; WBC, White Blood Cell; NEU#, Absolut Neutrophils Count; LYM#, Absolut Lymphocytes Count; MON#, Absolut Monocytes Count; EOS#, Absolut Eosinophils Count; BAS#, Absolut Basophils Count; IMG#, Absolut Immature Granulocyte Count; NEU%, Neutrophils Count; LYM%, Lymphocytes Count; MON%, Monocytes Count; EOS%, Eosinophils Count; BAS%, Basophils Count; IMG%, Immature Granulocyte Count; PLT-I, Platelet Count Impedance; PLT-H, Platelet Count Hybrid; PLT-O, Optical Platelet Count; MPV, Mean Platelet Volume; PDW, Platelet Distribution Width; PCT, Plateletcrit; PLCC, Platelet Large Cell Count; PLCR, Platelet Large Cell Ratio; IPF, Immature Platelet Fraction.

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Table 3. Reference Intervals for Complete Blood Count in Indonesian Adults with Mindray BC-760 Instrument

Parameters	Units	Reference Interval	p value	Parameters	Units	Reference Interval	p value
Hb	g/dL		<.001	LYM#	x 10^3/µL		0.142*
Male		13.76 – 15.84		Male		1.41 – 2.99	
Female		11.5 – 14.1		Female		1.3 – 2.84	
Ht	%		<.001	All		1.37 – 2.93	
Male		43 – 49.4		MON#	x 10^3/µL		<.001
Female		36.82 – 43.18		Male		0.2 – 0.58	
RBC	x10^6/µL		<.001	Female		0.23 – 0.51	
Male		4.8 – 5.76		EOS#	x 10^3/µL		<.001
Female		4.28 – 5.06		Male		0 – 0.43	
MCV	fl		0.059*	Female		0 – 0.28	
Male		82.72 – 92.48		BAS#	x 10^3/µL		0.345*
Female		81.2 – 92.8		Male		0 – 0.05	
All		82.2 – 92.8		Female		0 – 0.03	
MCH	pg		<.001	All		0 – 0.06	
Male		26.4 – 30.2		IMG#	x 10^3/µL		0.106*
Female		25.62 – 29.78		Male		0 – 0.03	
MCHC	g/dL		<.001	Female		0 – 0.02	
Male		31.3 – 33.1		All		0 – 0.02	
Female		30.8 – 32.8		NEU%	%		0.02
RDW-SD	fl		0.054*	Male		51.26 – 65-94	
Male		39.95 – 46.25		Female		52.73 – 68.27	
Female		39.9 – 46.9		LYM%	%		0.264*
All		40 – 46.6		Male		23.22 – 41.78	
RDW-CV	%		<.001	Female		24.04 – 38.36	
Male		12.4 – 14.2		All		22.72 – 41.28	
Female		12.5 – 14.7		MON%	%		<.001
RET#	x 10^3/µL		<.001	Male		4 – 7.4	
Male		0.06 – 0.12		Female		3.4 - 6.6	
Female		0.06 – 0.10		EOS%	%		<.001
RET%	%		0.053*	Male		0.5 – 5.85	
Male		1.25 – 2.37		Female		0.1 – 4.3	
Female		1.05 – 2.41		BAS%	%		0.444*
All		1.18 – 2.4		Male		0 – 0.8	
IRF	%		0.988*	Female		0 – 0.5	
Male		7.6 – 19.4		All		0 – 0.7	
Female		8.02 – 19.18		IMG%	%		0.381*
All		8 – 19.2		Male		0 – 0.5	
LFR	%		0.988*	Female		0 – 0.4	
Male		80.5 – 92.3		All		0 – 0.5	
Female		80.83 – 91.97		PLT_I	x 10^3/µL		<.001
All		80.8 – 92		Male		226 – 338	
MFR	%		0.742*	Female		205 – 411	
Male		9.23 – 14.97		PLT_H	x 10^3/µL		<.001
Female		7.75 – 16.05		Male		223 – 341	
All		7.5 – 16.1		Female		243.4 – 386.6	
HFR	%		0.459*	PLT_O	x 10^3/µL		<.001
Male		0 - 3.3		Male		225.6 – 344.4	
Female		0 – 3.48		Female		221.8 – 402.2	
All		0 – 3.38		MPV	fl		0.491*
RHE	pg		0.002	Male		8.6 – 10.8	
Male		27 – 30.8		Female		8.4 – 11.2	
Female		26.52 – 30.48		All		8.4 – 11	
NRBC#	x 10^3/µL		1.000*	PDW	fl		<.001
Male		0		Male		15.7 – 16.5	
Female		0		Female		15.6 – 16.4	
All		0		PCT	mL/L		<.001
NRBC%	%		0.361*	Male		2.1 – 3.5	
Male		0		Female		2.1 – 3.9	
Female		0		PLCC	x 10^3/µL		<.001
All		0		Male		52.5 – 87.9	

 DOI: https://doi.org/10.33533/jpm.v18i1.7644 Vol 18: No : 1 (2024)

WBC	x 10^3/µL		0.439*	Female		49.5 – 107.5	
Male		3.99 – 9.69		PLCR	%		0.709*
Female		5.42 – 8.42		Male		16.2 – 31.8	
All		4.37 – 9.31		Female		14.7 – 34.9	
NEU#	x 10^3/µL		0.784*	All		15.45 – 33.35	
Male		2.28 – 5.78		IPF	%		0.317*
Female		3.01 – 5.43		Male		0.07 – 3.63	
All		2.38 – 5.76		Female		0.5 – 3.7	
				All		0.35 – 3.75	

*p> 0.05 There are no differences between male and female groups, so reference intervals can use combined data (all). Hb, Hemoglobin; Ht, Hematokrit; RBC, Red Blood Cell; MCV, Mean Cell Volume; MCH, Mean Corpuscular Hemoglobin; MCHC, Mean Corpuscular Hemoglobin Concentration; RDW-SD, Red Cell Distribution; RDW-CV, Red Cell Distribution; RET#, Absolut Reticulocyte Count; RET%, Reticulocyte Count; IRF, Immature Reticulocyte Fraction; LFR, Low Fluorescence Reticulocyte; MFR, Moderate Fluorescence Reticulocyte; HFR, High Fluorescence Reticulocyte; RHE, Reticulocyte Hemoglobin Equivalent; NRBC#, Absolut Nucleated Red Blood Cell Count; NRBC%, Nucleated Red Blood Cell Count; WBC, White Blood Cell; NEU#, Absolut Neutrophils Count; LYM#, Absolut Lymphocytes Count; MON#, Absolut Monocytes Count; EOS#, Absolut Eosinophils Count; BAS#, Absolut Basophils Count; IMG#, Absolut Immature Granulocyte Count; NEU%, Neutrophils Count; LYM%, Lymphocytes Count; MON%, Monocytes Count; EOS%, Eosinophils Count; BAS%, Basophils Count; IMG%, Immature Granulocyte Count; PLT-I, Platelet Count Impedance; PLT-H, Platelet Count Hybrid; PLT-O, Optical Platelet Count; MPV, Mean Platelet Volume; PDW, Platelet Distribution Width; PCT, Plateletcrit; PLCC, Platelet Large Cell Count; PLCR, Platelet Large Cell Ratio; IPF, Immature Platelet Fraction.

In the context of nucleated red blood cells (NRBC), our findings indicated an absence of NRBC among the study population because it comprised healthy adults. NRBCs are premature erythrocyte precursors that typically do not circulate in the bloodstream of healthy adults. NRBC can be found in the fetal circulation but naturally diminishes within the first month of life in healthy neonates.[8,16] In the adult population, the presence of NRBC in the circulation serves as a valuable prognostic indicator for mortality in patients with trauma, sepsis, and other critical conditions. In addition, this parameter also proves as an additional predictor in predicting therapeutic efficacy in patients with hematological disorders such as chronic myeloid leukemia (CML), the progression of myelodysplastic syndrome (MDS), and the potential risk of transformation into acute myeloid leukemia (AML).[8,16] The latest hematology analyzers offer precise NRBC calculations compared to manual examination through blood smears. In addition, utilizing the flow cytometry method enables the differentiation between NRBC and WBC, eliminating the need for correction per-100 WBC.[17]

In this investigation, there were no remarkable differences observed in the WBC counts between the female and male groups. This finding emphasizes results from previous investigations in the current literature.[4,18] The reference value for WBC serves as an essential indicator for detecting the presence of infections, inflammatory responses, and other medical conditions. While leukocytosis commonly accompanies most bacterial infections, certain infections such as viral infections, sepsis, or other abnormalities in the bone marrow, may result in leukopenia. Moreover, high elevation in WBC count can also be indicative of leukemoid reactions and malignancies. Evaluation by morphological studies or other procedures is essential for confirming such situations.[4,5,18]

Our study observed notable differences in both the absolute number and percentage of monocytes, eosinophils, and neutrophils between the male and female groups. However, a comparison of the absolute number of neutrophils between the two groups did not exhibit a significant difference. These results were similar to other study[1]. Abdullah et al. "reported that the reference value for leucocyte counts did not exhibit gender-based variations, except for the absolute number of neutrophils which was higher in females than in males". [4] Additionally, the study demonstrated that IMG characteristics defined the myeloid young series, which includes myelocytes, promyelocytes, and metamyelocytes. The presence of IMG in the circulation may signify increased hematopoiesis in the bone marrow

 DOI: https://doi.org/10.33533/jpm.v18i1.7644 Vol 18: No : 1 (2024)

and extramedullary sites. In addition to that, employing IMG parameters in an automated device proves to be an alternative to manual blood smear analysis.[19] The reference interval for IMG parameters in this study was 0–0.5%, a value consistent with prior research.[20]

The hematology analyzer instrument incorporates three parameters for platelet count: platelet count impedance (PLT-I), platelet count hybrid (PLT-H), and optical platelet count (PLT-O). While the impedance method stands out as one of the most widely used methods for platelet counts, its inherent limitation lies in its inability to distinguish particles of similar size to platelets. This limitation arises from the measurement method, which relies on sizing particles passing through a gap carrying an electric current. In conditions involving small RBCs, the impedance method may produce inaccurate platelet counts due to the potential interference of RBC and WBC fragments, resulting in a false increase. In addition, platelet aggregation and giant platelet conditions can lead to a false decrease in platelet count. In response to these challenges, several manufacturers have endeavored to mitigate inaccuracies associated with impedance methods by developing optical methods. However, even the optical method has limitations, especially potential interference from small RBCs and cell debris. In an effort to address this issue, the Mindray BC-760 device incorporates an additional parameter, namely PLT-H, enhancing the accuracy and reliability of platelet count measurements.

PLT-H stands as a platelet count calculation algorithm that combines small platelet assessment from the impedance method and large platelet assessment from the DIFF channel. This integration effectively mitigates interference issues encountered in platelet counts. In the investigation conducted by Prompetchara et al[21], it was observed that PLT-H parameters exhibited superior reproducibility in comparison to PLT-I, demonstrating a good correlation with PLT-O. Notably, this study identified a higher platelets count (PLT-H) in females than in males, aligning with the findings of another study.[3] The observed differences in platelet reference values based on gender can be attributed to variations in hormone levels unique to each gender. These hormonal differences significantly impact erythropoiesis and megakaryopoiesis. Specifically, the menstrual cycle in female subjects plays a role in stimulating megakaryopoiesis activity as noted in previous studies.[3,22]

The Mindray BC-760 hematology analyzer offers calculations for various platelet indexes such as MPV, PDW, PCT, PLCR, and PLCC. These platelet indexes are useful as a valuable marker for inflammation in conditions associated with systemic inflammation.[23] Additionally, it aids in the differential diagnosis of cases involving thrombocytopenia and thrombolysis.[24] MPV is the representation of platelet size, while PDW indicates the variation of platelet size. Thrombocytopenia, resulting from peripheral platelet destruction, triggers the release of large platelets into the circulation, thereby affecting an increase in MPV. The aforementioned mechanisms highlighted the BC-760's ability to not only detect but also characterize such conditions with precision.

Plateletcrit (PCT), or total platelet mass represents the percentage of platelets in the blood. The PCT value describes the product of platelet counts obtained from the ratio of platelet volume to total blood volume. Furthermore, PCT can also be used as an indicator of platelet activity in the blood, with a low PCT value reflecting diminished platelet activity.[25] MPV reflects alterations in both platelet number and size. The MPV value serves as a direct indicator of the rate of platelet production in the bone marrow.[24,25] Meanwhile, the PLCC value indicates the concentration of large platelets, and the PLCR is the ratio of large platelets (>12 fL) to normal platelets.[24] The MPV reference interval in this study was observed to be 8.4–11 fl, consistent with previous research.[3] Furthermore, the findings of this research showed that there are substantial gender differences in regard to PDW, PCT, and PLCC.

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IPF represents recently released platelets in the circulation and serves as an informative marker for measuring bone marrow recovery. Both IPF and IRF examinations employ fluorescence methods and light scatter technology for comprehensive analysis. The immature fraction demonstrates a higher RNA content in comparison to mature platelets. The IPF examination offers insights into thrombopoiesis activity in the bone marrow. Its clinical utility extends to conditions such as thrombocytopenia, monitoring bone marrow regeneration post-transplantation, and evaluating responses post-chemotherapy. This study obtained a reference interval value that aligns with findings from previous research.[9]

The presence of this study would enhance the currently limited research literature on the advanced capabilities of Mindary BC-760 for hematological assessment. On the other hand, this study pertains to a limitation that the research solely recruited patients from a single hospital center.

CONCLUSION

Hemoglobin, RBC, hematocrit, MCH, MCHC, RDW-CV, RET#, RHE, MON#, EOS#, NEU%, MON%, EOS%, PLT-I, PLT-H, PLT-O, PDW, PCT, and PLCC reference values differ by gender. In contrast, measures such as MCV, RDW-SD, RET%, IRF, LFR, MFR, HFR, NRBC#, NRBC%, WBC, NEU#, LYM#, BAS#, IMG#, LYM%, BAS%, IMG%, MPV, and IPF showed no significant differences between genders.

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DECLARATIONS

Conceptualization and research design were conceived by AI, DA, DEP, RM; Collected samples: DA, DEP, RFS, EP, SB; Data analysis and interpretation were conducted by AI, DA, DEP, RM, LA, RFS; Critical revision and review of the manuscript was performed by AI, DA, DEP, RM, LA. The authors read and approved the final manuscript.

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The authors report there are no competing interests to declare.

This study has received ethical approval from the Ethics Committee of the Faculty of Medicine Yarsi University No: 037/KEP-UY/EA.20/II/2023. This study was conducted following the declaration of Helsinki. Moreover, informed consent forms were duly signed by all participants.

The datasets used and/or analyzed during the current study are available in our institutionalized database.

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