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ORIGINAL ARTICLE

Evaluation and comparison of the new Mindray BC-6200 hematology analyzer with ADVIA 2120i

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Abstract

Background: The Mindray BC-6200 is a new automatic hematology analyzer that quantifies the parameters of blood morphology and leukocyte differential in five populations (5-Diff). The aim of the study was to evaluate the BC-6200 and compare it with the Siemens ADVIA 2120i analyzer.

Materials and Methods: The comparison between BC-6200 and ADVIA 2120i analyzers was performed using 390 whole blood samples collected on K_3EDTA. For the BC-6200, the carryover effect, precision, and linearity were evaluated. 138 samples were used to assess the sensitivity and flag ability, suggesting the presence of abnormal cells such as blasts, immature granulocytes, or atypical lymphocytes. Flagging results were compared with microscopic evaluation of blood smears.

Results: The BC-6200 analyzer showed a high correlation ($r \geq .97$) with ADVIA 2120i for most of the compared parameters except RDW ($r = .8350$), MPV ($r = .7634$), Mon# ($r = .8366$), Baso# ($r = .9205$), and NRBC ($r = .3768$). The BC-6200 had better correlation with microscopic evaluation for NRBC ($r = .8902$) compared with ADVIA 2120i ($r = .5677$). The BC-6200 has shown high efficiency for flagging blasts (80.4%), immature granulocytes (80.5%), and atypical lymphocytes (69.0%).

Conclusion: The new Mindray BC-6200 hematology analyzer provides high measurements precision and good correlation with ADVIA 2120i for most of the morphology and 5-diff parameters.

KEYWORDS

ADVIA2120i, automated hematology analyzer, blood cell count, Mindray BC-6200, performance evaluation

1 | INTRODUCTION

Fast and accurate performance of the peripheral blood morphology and white blood cell differentiation is essential for all hematology laboratories. To meet these requirements, more and more manufacturers are working to improve the analytical effectiveness of hematological analyzers. Therefore, nowadays we have seen a continuous increase in the capacity and efficiency of hematological analyzers. The introduction of new measurement techniques such as laser scattering, chemical, and fluorescent dyeing has allowed more parameters to be determined.[1] In addition to the standard parameters determined in blood morphology, other cells such as blasts, nucleated red blood cells (NRBCs), or immature granulocytes (IGs), which are most frequently observed in various pathological states, have started to be identified.[1] In blood samples of patients treated in hematological departments, determined parameter values often exceed the analytical capabilities of hematological analyzers. The presence of abnormal leukocytes, platelet aggregates, or

the appearance of red blood cell agglutinates may cause difficulties in analyzing these samples. Fast and accurate results are crucial for establishing the diagnosis and starting treatment. In order to select the most suitable analyzer for a laboratory, it must meet certain criteria. It should guarantee high precision and a wide range of linearity of measurements, generate results comparable to those obtained with the analyzer used so far and correctly identify all samples containing abnormal cells and requiring microscopic evaluation.[2]

The aim of the study was to evaluate and compare the new hematology analyzer Mindray BC-6200 (Mindray Bio-Medical Electronics Co., Ltd) with Siemens ADVIA 2120i (Siemens Healthcare Diagnostics), whose usefulness in routine diagnostics was confirmed by earlier studies.[3-5] The repeatability, reproducibility, and linearity for the BC-6200 were checked, and the results of complete blood count (CBC) and white blood cell differentiation into five populations (5-Diff) were compared with the ADVIA 2120i. The possibility of correct "flagging" of samples in which abnormal cells such as blasts, NRBCs, atypical lymphocytes, or IGs were present was also evaluated using microscopic smear evaluation.

2 | MATERIALS AND METHODS

2.1 | Analyzer

The BC-6200 is a new automatic hematology analyzer that quantifies the parameters of blood morphology and leukocyte differentiation. It provides 37 diagnostic parameters and 29 additional research parameters for whole blood, and 7 diagnostic and 11 research parameters for body fluids (BF). It uses the SF Cube method based on laser scattering (S), fluorescence (F), and 3D analysis (Cube) to differentiate white blood cells into five populations, measuring reticulocytes, PLT-O, and NRBC. In the DIFF channel, the red cells are lysed, and then, the nucleic acids contained in the cells are marked with fluorescent dye. WBC separation is based on cell size, intracellular granularity content, and fluorescence signal intensity depending on the nucleic acid content of the cell. In the DIFF channel, white blood cells are identified and separated into 5 populations, and abnormal cells such as blasts and IG are detected and flagged. In the WNB channel white cells, basophiles and erythroblasts are differentiated. Impedance method was used to measure RBC and PLT. Hemoglobin is measured using the cyanotic-free colorimetric method.

On the ADVIA 2120i, the sample is analyzed in several channels. In the PEROX and BASO channels, the WBC is separated into six populations based on cell size, number of lobes in the nucleus, and staining of cells for the presence of myeloperoxidase. In the RBC/PLT channel, the measurement is performed using the optical method with laser scattering analysis at two angles. Hemoglobin is measured using two methods: a cyanide free colorimetric method and an optical method in which it is directly measured in each red blood cell.[5]

In our Haematology Laboratory, the ADVIA 2120i was the instrument currently used while the BC-6200 was installed by the manufacturer's representative to evaluate the usefulness in routine diagnostics.

2.2 | Samples

390 whole blood samples taken on K_3EDTA collected from oncohematology patients diagnosed and followed in the Haematology Department were used. The blood was taken as part of routine hematological tests. The analysis was carried out within 4 hours after the sample was taken.

2.3 | Carryover

The aim of the assessment was to analyze the possible effect of high concentration samples influencing on the measurement value in the sample analyzed immediately afterward. There is a concern that a sample with high concentrations analyzed immediately before the cytopenic or anemic sample may incorrectly overstate the measured parameters. The carryover effect was assessed using the procedure recommended by the International Council for Standardization in Haematology (ICSH).[2] The analysis of H sample (high concentrations) was performed 3 times (H1, H2, and H3) and then L sample (low concentrations) also 3 times (L1, L2, and L3). The percentage carryover was calculated according to the formula:

$$Carryover\,\% = \frac{L1 - L3}{H3 - L3} \times 100\,\%$$

2.4 | Linearity

Linearity was assessed by performing a series of dilutions of whole blood samples and comparing the results with the expected values. Series of dilutions were prepared using the diluent (DS Diluent) provided by the manufacturer.

2.5 | Precision

Repeatability (within-run precision) was evaluated by repeating the analysis for three patient blood samples 10 times and calculating the coefficient of variation (CV) and standard deviation (SD) for the parameters tested. Reproducibility (between-run precision) was assessed using control blood samples provided by the manufacturer. Measurements were taken at 3 levels: low (L), normal (N), and high (H) once daily for 30 days.

2.6 | Comparison of methods

Comparison of results obtained on the ADVIA2120 and on the BC-6200 was performed using 390 whole blood samples. The hemoglobin (HGB), red blood cells (RBC), platelets (PLT), white blood cells count (WBC), and differential (5-Diff) parameters were compared.

2.7 | Flagging sensitivity evaluation

To assess the sensitivity and specificity of the flags, 138 samples were used. In these samples, analyzers generated flags which suggest the presence of abnormal cells such as blasts, IG, NRBC, and atypical lymphocytes. For these samples, smears were made and stained using May-Grunwald-Giemsa method. A microscopic evaluation was performed on two blood smears for each sample and counting 200 cells in each slide by two experienced technicians. All procedures were performed according to the Clinical & Laboratory Standards Institute document CLSI H20-A2.[6] Samples with >1% IG, >0.5% blasts, >1% NRBC, and >5% atypical lymphocytes were taken into consideration like positive in microscopic evaluation. Then, the flags generated in both analyzers were compared with the results of microscopic evaluation and classified as true positive (TP), false positive (FP), true negative (TN), and false negative (FN). According to the ICSH recommendations, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall performance were calculated for each flag.[2]

2.8 | Statistical analysis

STATISTICA 12 (Stat Soft) was used to perform statistical results. The assessment of the significance of differences was carried out using Student's t test. The significance level $P < .05$ was considered statistically significant. The results were presented in the form of mean values and standard deviation (SD) for all the determined parameters. The correlation analysis according to Pearson and regression by Passing-Bablock method was used to assess the relationship between the results.

3 | RESULTS

3.1 | Carryover

The samples analyzed showed a no significant carryover. For all parameters analyzed, it was within the range declared by the manufacturer < 1%.

3.2 | Linearity

The BC-6200 showed linearity $r \geq .99$ in all studied parameters but for WBC the linearity assessment was performed only in 0.47-4.97 range. The results are presented in Table 1.

TABLE 1 Linearity for BC-6200 analyzer

Parameters	Range	*r*	Intercept	Slope
WBC ($\times 10^3/\mu L$)	(0.47-4.97)	.9930	0.988	0.202
RBC ($\times 10^6/\mu L$)	(0.57-5.91)	.9990	0.986	0.084
HGB (g/dL)	(1.6-17.2)	.9990	0.984	0.317
HCT (%)	(5.2-51.7)	.9990	0.987	0.368
PLT high ($\times 10^3/\mu L$)	(102-1110)	.9940	1.009	25.98
PLT low ($\times 10^3/\mu L$)	(30-360)	.9960	0.966	11.36

Abbreviations: HCT, hematocrit; HGB, hemoglobin; PLT, platelets; RBC, red blood cells; WBC, white blood cells.

3.3 | Precision

The obtained values of within-run precision for HGB, RBC, HCT, MCV, PLT, neutrophils, and lymphocytes are presented in Table 2. For all studied parameters, CV was below 5%, except CV value for lymphocytes (39%) in sample 1 where mean lymphocyte number was $0.09 \times 10^3/\mu L$ (min = $0.03 \times 10^3/\mu L$, max = $0.13 \times 10^3/\mu L$). The studied parameter CV values for between-run precision were lower than 5%, except monocytes (Mon#), which were higher for low control 15.2%, normal control 9.5%, high control 7.8%, respectively. However, they are within the range declared by the manufacturer ≤ 16% (Table 3).

3.4 | Method comparison

The comparative evaluation for CBC and 5-Diff parameters was performed on 390 whole blood samples. In 131 samples determined on ADVIA 2120i, there were no results for NRBC. Therefore, 259 pairs of results obtained on both analyzers were included in the comparative analysis. Table 4 shows the mean values obtained for the compared parameters. Statistically significant differences ($P < .05$) were shown for mean values of MCV, MPV, RDW, and Mon#. The mean values of MCV, MPV, and Mon# obtained for the BC-6200 were statistically significantly higher than those obtained on ADVIA 2120i whereas the mean values of RDW obtained for the BC-6200 were statistically significantly lower than those obtained on ADVIA 2120i. The analysis of the results obtained on both analyzers showed statistically significant correlation between the compared parameters. The values of correlation coefficients (*r*) are shown in Appendix (Table A1). For most of the compared parameters, they were ≥0.97 except RDW ($r = .8350$), MPV ($r = .7634$), Mon# ($r = .8366$), Baso# ($r = .9205$), and NRBC ($r = .3768$). Due to the low correlation for NRBC, the results were compared with microscopic evaluation of 18 blood samples in which NRBC ≥ 1% were determined in blood smears. The BC-6200 showed better correlation with the results of microscopic evaluation ($r = .8902$) compared with ADVIA 2120i ($r = .5677$).

3.5 | Assessment of flagging sensitivity

138 samples were used to assess the sensitivity and specificity of the flags. The values for each flag are shown in Table 5. The BC-6200 generated a Blast flag for 6 out of 11 samples with blasts confirmed

TABLE 2 Within-run precision

	Sample 1			Sample 2			Sample 3		
	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%
WBC ($\times10^3/\mu L$)	1.61	0.038	2.3	7.28	0.135	1.9	24.17	0.220	4.7
RBC ($\times10^6/\mu L$)	2.68	0.021	0.8	4.81	0.045	0.9	3.76	0.018	1.5
HGB (g/dL)	8.7	0.05	0.5	14.4	0.07	0.5	10.0	0.04	0.5
HCT (%)	25.2	0.23	0.9	43.2	0.44	1.0	30.4	0.19	0.6
MCV (fL)	94.0	0.38	0.4	89.8	0.14	0.2	80.8	0.04	0.9
RDW-CV(%)	19.6	0.31	1.6	14.5	0.12	0.8	17.6	0.21	1.2
PLT ($\times10^3/\mu L$)	62	2.3	3.6	250	5.4	2.2	610	0.267	1.9
NEUT ($\times10^3/\mu L$)	1.42	0.032	2.3	4.88	0.083	1.7	20.1	0.267	1.3
LYMPH ($\times10^3/\mu L$)	0.09	0.035	39.3	1.73	0.041	2.3	1.22	0.057	4.7
MON ($\times10^3/\mu L$)	0.00	0.000	0.0	0.51	0.023	4.5	2.33	0.069	3.0

Abbreviations: CV, coefficient of variation; HCT, hematocrit; HGB, hemoglobin; LYMPH, lymphocytes; MCV, mean corpuscular volume; MON, monocytes; NEUT, neutrophils; PLT, platelets; RBC, red blood cells; RDW-CV, red blood cell distribution width-coefficient of variation; SD, standard deviation; WBC, white blood cells.

TABLE 3 Between-run precision

	Low control (L)			Normal control (N)			High control (H)		
	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%
WBC ($\times10^3/\mu l$)	3.549	0.09	2.5	7.512	0.162	2.2	20.656	0.251	1.2
RBC ($\times10^6/\mu l$)	2.318	0.036	1.6	4.749	0.082	1.7	5.724	0.082	1.4
HGB (g/dl)	5.94	0.05	0.9	13.31	0.1	0.8	17.64	0.12	0.7
HCT (%)	19.61	0.23	1.2	42.96	0.59	1.4	57.21	0.6	1.1
MCV (fL)	84.6	0.98	1.2	90.5	0.74	0.8	99.95	0.79	0.8
RDW-CV(%)	16.66	0.19	1.1	15.04	0.14	1.0	13.86	0.14	1.0
PLT ($\times10^3/\mu l$)	57.4	2.9	5.1	206.8	6.7	3.2	410.9	7.8	1.9
NEUT ($\times10^3/\mu l$)	1.949	0.06	3.1	3.812	0.095	2.5	11.287	0.187	1.7
LYMPH ($\times10^3/\mu l$)	0.902	0.039	4.3	2.76	0.1	3.6	6.75	0.157	2.3
MON ($\times10^3/\mu l$)	0.087	0.013	15.2	0.335	0.032	9.5	0.953	0.074	7.8

Abbreviations: CV, coefficient of variation; HCT, hematocrit; HGB, hemoglobin; LYMPH, lymphocytes; MCV, mean corpuscular volume; MON, monocytes; NEUT, neutrophils; PLT, platelets; RBC, red blood cells; RDW-CV, red blood cell distribution width-coefficient of variation; SD, standard deviation; WBC, white blood cells.

by microscopic examination. For the remaining five samples in which blast cells were present, the BC-6200 indicated flags, suggesting the presence of other than blasts. Microscopic evaluation showed the presence of >1% IG in 36 samples. The BC-6200 correctly indicated 34 of them showing 94.4% sensitivity and 75.5% specificity. For comparison, the ADVIA 2120i analyzer showed lower sensitivity (41.7%) but higher specificity (98.0%).

4 | DISCUSSION

The key role of modern hematology analyzers is the precise measurement of blood morphology parameters, white blood cells differential, and the indication of samples containing pathological cells which require further microscopic evaluation. The blood film and its microscopic evaluation are time- and labor-intensive. Therefore, it is very important to select algorithms for flagging the presence of abnormal cells to minimize the risk of false-negative results and without leading to unnecessary increase in the number of smears performed. It is therefore extremely important to evaluate each new analyzer before introducing it into routine laboratory work and check whether it meets the required criteria.

This is the first study in which the new Mindray BC-6200 hematology analyzer was evaluated and compared with the ADVIA 2120i analyzer commonly used in routine hematology diagnostics.

In the presented evaluation of the Mindray BC-6200, a minimal carryover within the reference values declared by the manufacturer was observed. The assessment of within-run precision showed very good results for all determined parameters (CV < 5.0) except lymphocytes (CV 39%) for sample 1 what is probably connected with

TABLE 4 Means of CBC and 5-Diff parameters on ADVIA 2120i and BC-6200

Parameters	ADVIA 2120i (mean ± SD)	BC-6200 (mean ± SD)	*P*-value
WBC ($\times 10^3/\mu L$)	9.59 ± 11.51	10.14 ± 12.33	0.5188
RBC ($\times 10^6/\mu L$)	3.83 ± 0.88	3.84 ± 0.93	0.8692
HGB (g/dL)	11.70 ± 2.42	11.87 ± 2.57	0.5672
HCT (%)	34.68 ± 7.24	35.33 ± 7.66	0.2224
MCV (fL)	91.23 ± 9.05	92.98 ± 9.04	**0.0069**
RDW-CV (%)	16.19 ± 2.59	15.50 ± 3.04	**0.0007**
PLT ($\times 10^3/\mu L$)	210.70 ± 145.6	208.78 ± 143.6	0.8531
MPV (fl)	9.66 ± 1.58	10.51 ± 1.61	**0.0000**
NEUT ($\times 10^3/\mu L$)	5.02 ± 6.65	5.45 ± 7.19	0.3843
LYMPH ($\times 10^3/\mu L$)	3.54 ± 7.87	3.90 ± 9.02	0.5554
MON ($\times 10^3/\mu L$)	0.48 ± 0.36	0.59 ± 0.58	**0.0026**
EOS ($\times 10^3/\mu L$)	0.15 ± 0.18	0.15 ± 0.23	0.8033
BASO ($\times 10^3/\mu L$)	0.67 ± 0.26	0.05 ± 0.32	0.5194
NRBC ($\times 10^3/\mu L$)	0.02 ± 0.11	0.01 ± 0.05	0.0839
NRBC (%)	0.41 ± 1.65	0.22 ± 0.93	0.0645

Abbreviations: BASO, basophils; EOS, eosinophils; HCT, hematocrit; HGB, hemoglobin; LYMPH, lymphocytes; MCV, mean corpuscular volume; MON, monocytes; MPV, mean platelet volume; NEUT, neutrophils; NRBC, nucleated red blood cells; PLT, platelets; RBC, red blood cells; RDW-CV, red blood cell distribution width-coefficient of variation; SD, standard deviation; WBC, white blood cells.

low number of lymphocytes in studied sample. The CV values obtained during the between-run precision assessment were in the range ≤ 5.0% except for Mon#. CV was highest for low control (15.2%) in which the mean of monocytes was 0.087 ×103/μl. The CV value decreased with the increase in the number of monocytes in the tested samples amounting to 9.5% ($0.335 \times 10^3/\mu L$) and 7.8% ($0.953 \times 10^3/\mu L$). This confirms the observations of other authors, suggesting that with a decrease in the number of cells in the sample CV increasing.[3] The linearity for all studied parameters obtained on BC-6200 was excellent but the limitation of our study is that we performed analysis only the low range of WBC.

Both compared analyzers show high correlation in most of studied CBC parameters. Similar results were obtained in comparison of ADVIA 2120 and other Mindray analyzer BC-6800 Plus.[7]

Statistically significant differences ($P < .05$) were shown for mean values of MCV, RDW, MPV, and Mon#. The mean MCV values obtained for the BC-6200 were statistically significantly higher than those obtained for ADVIA2120. This may be due to the difference in MCV measurement technology used in both analyzers. In ADVIA 2120i, MCV is measured directly in each single erythrocyte using the method of hydrodynamic focusing and optical analysis of laser light scattering at 2 angles.[5] In the BC-6200, the MCV value is calculated based on the RBC histogram which is measured using the impedance method. Similar results were obtained during studies in the Hospital Clinic of Barcelona where the BC-6800 was compared with the ADVIA 2120i. They obtained higher mean MCV values for the BC-6800 (94.76 fl) comparing to ADVIA 2120 (93.68fl). However, the study does not include information whether the difference observed was statistically significant.[8]

Statistically significant differences were observed for mean RDW-CV values which were lower for the BC-6200 (15.50%) compared with ADVIA 2120i (16.19%). Moreover, the correlation coefficient for RDW was slightly lower ($r = .8350$) compared with other parameters. The value of the RDW-CV is determined based on the RBC volume histogram. Therefore, the difference in MCV measurements may affect the final RDW value. Furthermore, the method used to calculate the RDW can vary from one analyzer to another. The different methods used to estimate the RDW limit the comparability of this parameter and the use of the same reference range for different analyzers.[9,10]

Comparative analysis of mean MPV values showed that the mean determined on the BC-6200 (10.51 fl) was significantly higher than those on the ADVIA 2120i (9.66 fl). The lower correlation coefficient ($r = .7634$) also confirmed differences between MPV measurements on both analyzers. At the same time, there were no statistically significant differences between the mean PLT values for compared analyzers. Additionally, it was found very good correlation ($r = .9939$) for this parameter. The difference between mean MPV values may result from different measurement methods for PLT used in both analyzers. In BC-6200, impedance method was used for PLT measurement while ADVIA 2120i analyzer using optical method. A similar correlation between mean MPV values observed Latger-Cannard et al[11] who compared the ADVIA 2120 (optical method), Beckman Coulter LH 750 (impedance method), and Sysmex XE-2100D (impedance method). They have shown that the mean MPV values obtained on the ADVIA 2120 are lower than those obtained with the LH 750 (with a mean difference of 0.89) and XE-2100D (with a mean difference of 1.11). The use of different methods to MPV measurements makes it impossible to compare without knowing the method used for its determination. Another reason for obtaining higher MPV values for the BC-6200 may be the order of measurements which were first performed on the ADVIA 2120i and then (in no more than 2 hours) on the Mindray BC-6200. In fact, in samples taken on EDTA were observed the phenomenon of MPV increase in time since the blood sample was taken due to platelet swelling. It was demonstrated that the value of MPV measured with the impedance method increases within 30 minutes by about 7.9% and the total MPV increase within 24 hours is 13.4% showing the highest increase within 6 hours.[12] The MPV value measured using the optical method (where MPV is expressed as platelet size fashion) decreases probably due to dilution of cytoplasmic PLT content leading to a decrease in the ability to scatter laser light.[3]

A statistically significant difference was found in the mean Mon# ($P < .05$) values which were higher for the BC-6200 ($0.59 \times 103/\mu l$) compared with the ADVIA 2120 ($0.48 \times 103/\mu l$). Also, the correlation coefficient ($r = .8366$) for Mon# was slightly lower than for the other parameters, which was also shown in earlier publications comparing different hematology analyzers.[13-16] Differences between the

TABLE 5 Assessment of sensitivity, specificity, overall efficiency, positive predictive value (PPV), and negative predictive value (NPV) for individual flags

	True positive (TP)	False positive (FP)	True negative (TN)	False negative (FN)	Sensitivity (%)	Specificity (%)	Overall efficiency (%)	PPV	NPV
Blasts (n = 11)									
BC-6200	6	22	105	5	54.5	82.7	80.4	21.4	95.5
Advia 2120i	8	26	101	3	72.7	79.5	78.9	23.5	97.1
IG (n = 36)									
BC-6200	34	25	77	2	94.4	75.5	80.5	57.6	97.5
Advia 2120i	15	2	100	21	41.7	98.0	83.3	88.2	82.6
Atypical lymphocytes /Blasts (n = 53)									
BC-6200	32	7	77	22	59.3	91.7	79.0	82.1	77.8
Advia 2120i	23	12	73	30	43.4	85.9	69.6	65.7	70.9

Abbreviations: IG, immature granulocytes; NPV, negative predictive value; PPV, positive predictive value.

analyzers sometimes quite significant may indicate that the technologies used in the measurement do not always recognize the same type of cell.[17] High morphological variability of monocytes difficulties in distinguishing small monocytes from large lymphocytes and the fact that monocytes are usually present in the blood in small amounts may reduce the correlation coefficient values between the analyzers being compared.[18,19]

Another significant difference between BC-6200 and ADVIA 2120 was in NRBC determinations for which a low correlation was observed ($r = .3768$). Additionally for NRBC, BC-6200 showed a higher correlation ($r = .8902$) with microscopic evaluation than ADVIA 2120i ($r = .5677$). Bruegel et al and Da Rin et al in their work also observed a low NRBC correlation between the ADVIA2120i and the microscopic evaluation.[15,20] These differences were probably caused by using different measurement technologies in both analyzers. The use of a separate WNB channel for counting NRBCs using laser scattering and fluorescence measurement which has been used in the Mindray BC-6200 allows for much better separation of NRBCs from other cell populations compared with the method based on the integration of information provided from two channels (peroxidase and basophilic) used in ADVIA2120i.[20] Accurate identification and measurement of NRBC is a necessary for right correction of the WBC level.[15]

Flagging ability for the ADVIA 2120i and BC-6200 was carried out by comparison with the microscopic evaluation results for 138 samples.

For the "Blast" flag, the ADVIA 2120i analyzer obtained a higher sensitivity (72.7%) compared with the Mindray BC-6200 (54.5%) but slightly lower specificity (79.5%). For comparison, Bruegel et al showed lower sensitivity (65.0%) and comparable specificity (88.0%) for the "Blast" flag obtained for ADVIA 2120i.[15] Shelat et al[21] received higher sensitivity (100.0%) with a much lower specificity (49.3%) and overall efficiency (53.1%). Zini et al in a recently published evaluation of the Mindray BC-6800 Plus analyzer obtained much higher specificity (93.8%) and sensitivity (97.6%) for the “Blast” flag by testing a larger number of samples (n = 125) containing these cells.[7] The reason for this incompatibility may be differences in the number of circulating blasts. In samples containing a small amount of these cells, the analyzer may not indicate their presence which results in a decrease in sensitivity for this flag. The difference may also be due to the fact whether the authors of the publication considered only the "Blasts" flag as in our opinion or whether they considered more than one flag such as LUC or atypical lymphocytes like Shelat et al[21] this increases sensitivity while reducing specificity.

The results of sensitivity, specificity, and IG flagging efficiency for the BC-6200 were 94.4%, 75.5%, and 80.4%, respectively. Similar results were presented by Shen et al in their work obtained for the Mindray BC-6000.[22] They showed that it has a high sensitivity (91.7%), but low specificity (65.6%) and overall efficiency of 74.9%. The high sensitivity of the flagging for IG with a decrease in specificity may increase the number of smears. The sensitivity obtained for ADVIA 2120i was 41.7% with a specificity of 98.0%, which is consistent with the results obtained by Bruegel et al.[15]

The flagging sensitivity of atypical lymphocytes (>5%) was low for both analyzers compared (59.3% for BC-6200 and 43.1% for ADVIA 2120i, respectively). Bruegel et al[15] reported the sensitivity ranged between 74.0% and 81.0% depend on analyzers. They obtained higher sensitivity for ADVIA 2120i (77.0%) compared to that obtained in our work (43.1%). Deporter et al showed lower sensitivity in atypical lymphocyte flags for the analyzers compared between 28.0% and 86.0% with a sensitivity of 45.0% for ADVIA 2120i.[23] Such large differences in sensitivity and specificity in the recognition of atypical cells presented in different publications could be obtained depending on whether a given flag was assessed alone or in combination with other flags.[23] Another possible reason may be the difference in the study group. Our studied group was onco-hematology patients often during treatment, what may affect the correct flagging of atypical cells in blood samples of these patients.[24]

In conclusion, the comparative assessment showed that the new Mindray BC-6200 analyzer provides good linearity and precision. There was a very good correlation for morphology and 5-diff results with the ADVIA 2120i analyzer for most compared parameters. The

BC-6200 also showed a higher correlation with microscopic evaluation in NRBC determination than ADVIA 2120i. The analysis of scattergrams and flags generated by the BC-6200 allows to obtain a lot of important information about the tested sample and facilitates the identification of samples requiring further microscopic evaluation.

CONFLICT OF INTEREST

The authors state no conflict of interest.

AUTHOR CONTRIBUTIONS

KK, IK, and ER conceptualized the project. KK and BC designed the methodology. KK, BC, IK, and ER collected and analyzed data. KK, IK, and BC wrote the manuscript. PR and ER revised the manuscript and supervised the project. All the co-authors have read and agreed to the published version of the manuscript.

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APPENDIX

TABLE A1 Correlations between parameters determined on Mindray BC-6200 and ADVIA 2120i

Parameter	*r*	Intercept	Slope
WBC ($\times 10^3/\mu L$)	.9991	−0.123	1.070
RBC ($\times 10^6/\mu L$)	.9894	−0.112	1.030
HGB (g/dL)	.9940	−0.534	1.054
HCT (%)	.9771	−0.352	1.030
MCV (fL)	.9858	3.118	0.985
RDW-CV (%)	.8350	−0.328	0.978
PLT ($x10^3/\mu L$)	.9939	2.525	0.979
MPV (fl)	.7634	2.989	0.779
NEUT ($\times 10^3/\mu L$)	.9978	0.038	1.078
LYMPH ($\times 10^3/\mu L$)	.9983	−0.152	1.144
MON ($\times 10^3/\mu L$)	.8366	−0.068	1.356
EOS ($\times 10^3/\mu L$)	.9758	−0.032	1.262
BASO ($\times 10^3/\mu L$)	.9205	−0.023	1.149
NRBC ($\times 10^3/\mu L$)	.3768	0.009	0.218

Abbreviations: BASO, basophils; EOS, eosinophils; HCT, hematocrit; HGB, hemoglobin; LYMPH, lymphocytes; MCV, mean corpuscular volume; MON, monocytes; MPV, mean platelet volume; NEUT, neutrophils; NRBC, nucleated red blood cells; PLT, platelets; RBC, red blood cells; RDW-CV, red blood cell distribution width-coefficient of variation; WBC, white blood cells.