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Comparison of Mindray BC-60R Vet with Sysmex XT-2000iV hematology analyzer using total observed error, total allowable error, and QC rules defined in the American Society for Veterinary Clinical Pathology (ASVCP) guidelines

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Abstract

There are many hematology analysers available; however, the majority are designed for human use. Since the shape, size, and proportions of blood cells may differ significantly between species, these machines must be calibrated for the use of animal species (Harvey, 2012). Thus having an animal specific hematology analyzer is crucial for the proper analyses of blood tests. The Sysmex XT-2000iV has long been the gold standard of blood analysis in our clinic, providing accurate and precise results.

The purpose of this paper is to evaluate whether the Mindray BC-60R Vet offers similar precision and accuracy compared to the Sysmex XT-2000iV. Through the analysis of key hematological parameters, such as white blood cells, red blood cells and related parameters, we would be able to assess the performance of both hematological analyzers.

We collected samples from 28 dogs and 19 cats at the Veterinary Hematology and Oncology Centre Ltd. (ÁHOK Kft.). The animals were examined as oncology patients and routine clinical hematology and plasma biochemistry examinations were performed.

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List of abbreviations

Bas	Basophil
CV	Coefficient of variation
Eos	Eosinophil
HCT	Hematocrit
HFR	High fluorescence ratio
HGB	Hemoglobin
LFR	Low fluorescence ratio
Lym	Lymphocyte
MCH	Mean corpuscular hemoglobin
MCHC	Mean corpuscular hemoglobin concentration
MCV	Mean corpuscular volume
MFR	Medium fluorescence ratio
Mon	Monocyte
MPV	Mean platelet volume
Neu	Neutrophil
PCT	Plateletcrit
PDW	Platelet distribution width
P-LCR	Platelet large cell ratio
PLT	Platelet count
RBC	Red blood cell
RDW-CV	Red cell distribution width-coefficient of variation
RDW-SD	Red cell distribution width-standard deviation
RET	Reticulocyte
SD	Standard deviation
TEa	Total allowable error
TEo	Total observed error
WBC	White blood cell

1. Introduction

As the veterinary industry rapidly evolves, adapting and upgrading machinery, particularly hematology analyzers, is increasingly important. These machines play an essential role in narrowing down the diagnosis, monitoring health, and in facilitating the rapid and accurate detection of changes to the complete blood count to further aid in the treatment of patients (Bruegel et al., 2015).

The Sysmex (Sysmex XT-2000iV) has long been considered the gold standard in veterinary clinics, known for its accuracy and precision. The Mindray (Mindray BC-60R Vet) model had emerged as a potential alternative. This study aims to compare the performance of the Sysmex and Mindray analyser regarding accuracy and precision in analyzing canine and feline blood samples, specifically focusing on key parameters such as white blood cell counts, red blood cell counts, platelets and related factors.

1.1 Verification and quality control

Quality control in hematology analyzers is essential for the accuracy and reliability in clinical results.

1.1.1 Verification

Before the official usage of hematology analyzer in a clinical setting, it should be verified to ensure that it meets the standard and can deliver accurate results. Four main areas should be verified.

Firstly, precision checks for the consistency of the analyser by repeatedly testing the same sample repeatedly. Both within-run and between-batch precision should be verified. Within-run tests are done consecutively while between-batch tests are done over several days.

Secondly, accuracy and comparability. Accuracy measures how close the analyser's result is to the true values. Comparability is the analysis of a large amount of samples to those of a reference analyzer.

Thirdly, sensitivity and specificity. Sensitivity measures how well the analyzer identifies samples with true abnormalities. Specificity assesses the analyser's ability to avoid flagging normal samples.

Finally, Carryover, background and linearity. Carryover happens when residual blood from one sample contaminates the next, which often increases the measured parameters. Background is any signal not originating from the parameter of interest. Linearity measures the analyzer's ability to provide proportional results across a wide range of concentrations(Vis & Huisman, 2016).

1.1.2 Quality Control

Quality control is needed to ensure that the machine is still performing reliably after initial verification. It involves three key methods : internal quality control, inter-instrument quality control and external quality assessment.

Internal quality control should be done daily using control samples, always ensure that the sample is not expired. There is a phenomenon called the moving average, which can signal a potential issue with the analyzer if there is a shift in the overall average of CBC values. Regular monitoring of this average can help detect subtle changes in the analyzer's performance over time.

If multiple hematology analyzers are available, an inter-instrument quality control should be done weekly to ensure all analyzers are aligned and producing comparable results. This involves running the same sample across different analyzers and comparing results.

Lastly, external quality assessment gives a broader comparison by evaluating the lab's results against those from outside laboratories (Vis & Huisman, 2016).

1.1.3 Quality Control: Approaches Using Total Observed Error, Total Allowable Error

Using the guidelines provided by the American Society for Veterinary Clinical Pathology (ASVCP), the recommended TEa can be determined. The concept of TEa was first introduced in 1974 (Nabity et al., 2018), it is defined as "a quality goal that sets a limit for combined imprecision (random error) and bias (systematic error) that is tolerable in a single measurement to ensure clinical usefulness." Total observed error (TEo) should clinically be

lower than TEa and it can be calculated as : TEo = 2SD + absolute bias, or TEo(%) = 2CV(%) + absolute bias (%).

With the use of Quality control materials, the coefficient of variation (CV) which is derived from the standard deviation (SD) and the absolute bias can be measured. CV measures the variability of a data, absolute bias represents the difference between measured values and the true values. The sigma (σ) metric is also needed for the calculation, it is calculated as follows : σ = (TEa - absolute bias)/CV. Sigma is a metric that indicates the capability of the testing system, the higher the sigma, the higher the accuracy, precision, reliability and easier quality control monitoring. However, on the downside, the over emphasis of analytical performance might overlook the clinical relevance of the patients (Korchia & Freeman, 2022). .

1.2 Error in Pre-Analytical, Analytical, and Post-Analytical Phases

The testing of blood samples consists of three main phases : pre-analytical, analytical and post-analytical. Addressing these errors is crucial for maintaining high quality standards and reliability. To minimize errors, a combination of staff training, process standardization, and quality control measures is essential. If possible, the implementation of automated system is highly recommended. Good communications skills and proper workload management should be emphasized.

Pre-analytical error refers to any errors occurring before the sample reaches the analyzer. Some of the most common causes are hemolyzed specimens, mislabeled or unlabeled specimens, incorrect tube selection, bad blood collection timing, wrong sample volume, improper storage and transportation.

Analytical error occurs during the testing process, it can result from instrument malfunction, reagent issues, or operator error. Most frequent indicators of analytical error include nonlinear results without retesting, questionable results contradicted, EQC failed, preventive maintenance not performed, equipment malfunction.

Post-analytical errors occur after the test results are generated. The most common mistakes are requests released without result verification, critical values not communicated immediately (Teshome et al., 2021).

2. Materials and methods

2.1 Animals used

Altogether 28 dogs and 19 cats were examined.

2.2 Sample collection and preparation

Blood samples were collected from the vena cephalica antebrachii in 24 dogs and 8 cats and vena jugularis from 4 dogs and 11 cats. During the first diagnostic examinations blood samples were taken from the patients into the following test tubes:

For hematology analysis we used sample tube, K3 EDTA, 4 ml, Cap violet, (LxØ): 75 x 12 mm (Sarstedt, SARSTEDT AG & Co. KG, Sarstedtstraße 1, D-51588 Nümbrecht). Blood samples were evaluated within one to two hours after sampling by both analyzers.

2.3 Parameters measured

This study focuses on red blood cells, white blood cells and platelet counts, along with related parameters. For red blood cell parameters, the focus is on hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW-CV, RDW-SD), reticulocytes (RET), low fluorescence ratio (LFR), medium fluorescence ratio

(MFR), and high fluorescence ratio (HFR). For white blood cells, the counts and the percentages of neutrophils (Neu), lymphocytes (Lym), monocytes (Mon), eosinophils (Eos), and basophils (Bas) are evaluated. Finally, for platelets, platelet count (PLT), mean platelet volume (MPV), platelet distribution width (PDW), plateletcrit (PCT), and platelet large cell ratio (P-LCR) are measured.

2.4 Analytical methods of Mindray BC-60R Vet

The Mindray analyzer uses various measurement technologies to obtain the final results, including sheath flow impedance method, laser scatter method, SF Cube cell analysis, and colorimetric method.

2.4.1 WBC measurements

Mindray uses a technology known as SF cube technology; it utilizes fluorescence, biangular laser scatter signals and 3D analysis to map out the cell populations onto a 3 dimensional cube. The analyzer records two types of light scatters, the forward scatter which indicates the size of the cell, and the side scatter which reflects the granularity of the cells (Figure 3.1). The cube enables users to identify and distinguish cell populations based on their unique characteristics (Figure 3.2).

The process of white blood cell analysis begins with the addition of a lysing agent which breaks down all the red blood cells ensuring that only white blood cells remain as the focus of the analysis. Subsequently, fluorescent materials are added. Due to the difference in granularity, size, and content of the nucleic acid, the different cell population would be plotted.

Graph interpretation is based on the axis, where the x-axis represents the size of the cells and the y-axis represents the granularity or complexity. Smaller cells for example are positioned farther to the left, with lymphocytes typically located at the far left due to their smaller size. Moving toward the right, monocytes and neutrophils can be found, as they are larger. Eosinophils and basophils, which are the largest in size, are situated farthest to the

right. The y-axis represents the granularity or internal complexity of the cells, the more granular or complex a cell is, the higher it will appear on the plot (Mindray, 2023)

Table 2.1 Calculated WBC parameters

Parameter	**Formula**	**Unit**
White blood cell	Sum of all particles in the DIFF channel excluding the ghost area	10^9/L
Basophil#	Particles in the Bas region in the DIFF channel	10^9/L
Basophil%	Bas% = (Bas#/WBC)×100	%
Neutrophil#	Particles in the Neuregion in the DIFF channel	10^9/L
Neutrophil%	Neu% =(Neu#/WBC)×100	%
Eosinophil#	Particles in the Eos region in the DIFF channel	10^9/L
Eosinophil%	Eos% = (Eos#/WBC)×100	%
Lymphocyte#	Particles in the Lym region in the DIFF channel	10^9/L
Lymphocyte%	Ltm% = (Lym#/WBC)×100	%
Monocyte#	Particles in the Mon region in the DIFF channel	10^9/L
Monocyte%	Mon% = (Mon#/WBC)×100	%

2.4.2 Hemoglobin measurements

Hemoglobin measurement is based on the Lambert-Beer Principle, which states that the absorbance of monochromatic light passing through a solution is proportional to the concentration of absorbing substances and the thickness of the solution. In the HGB channel, the blood sample is treated with a reagent where red blood cells are lysed, releasing the hemoglobin. The analyzer passes a beam of monochromatic light through the sample, and the hemoglobin absorbs a portion of the light. By measuring the absorbance, the analyzer calculates the concentration of hemoglobin in the sample (Mindray, 2023).

Table 2.2 Calculated hemoglobin parameters

Parameter	Name	Formula	Unit
HGB	Hemoglobin concentration	Constant × Ln (blank photocurrent/sample photocurrent)	g/L

2.4.3 Red blood cell and platelet measurements

Red blood cells and platelets are measured with sheath flow impedance method, where cells are passing through a small opening one by one through the focusing effect of the fluid. Through such movement, electric pulses would be generated and recorded based on the Coulter Principle. These pulses are then amplified and sorted according to the voltage thresholds specific to the RBC and PLT channels. The number of pulses within the range of the RBC/PLT channels corresponds to the number of cells.

Such a method will generate a histogram, where the x-axis represents cell volume, the y-axis represents the number of cells. Compared to the standard impedance method, the sheath impedance method has greater efficiency, improved signal quality, more accurate results, and lower reagent consumption (Mindray, 2023).

Table 2.3 Calculated RBC parameter

Parameters	Name	Formula	Unit
RBC	Red blood cell	Based on the number of pulses in the RBC channel	10^{12}/L
MCV	Mean corpuscular volume	Based on RBC histogram	fL
HCT	Hematocrit	$\frac{RBC \times MCV}{10}$	%
MCH	Mean corpuscular hemoglobin	HGB/RBC	pg
MCHC	Mean corpuscular hemoglobin concentration	$\frac{HGB}{HCT} \times 100$	g/L
RDW-CV	Red blood cells distribution width - coefficient of variation	Based on RBC histogram	%
RDW-SD	Red blood cells	Based on standard deviation of RBC	fL

	distribution width - standard deviation	volume distribution	

Table 2.4 Calculated Platelet parameters

Parameters	**Name**	**Formula**	**Unit**
PLT	Platelet count	Directly measured from the RET channel	10^9 / L
MPV	Mean platelet volume	Calculated from PLT histogram	fL
PDW	Platelet distribution width	From platelet histogram, and is reported as 10 geometric standard deviation	/
PCT	Plateletcrit	$\frac{PLT \times MPV}{10000}$	%
P-LCR	Platelet-large cell ratio	From Platelet histogram	%
P-LCC	Platelet-large cell count	P-LCC = PLT × P-LCR	10^9 / L
IPF	Immature platelet fraction	Based on PLT-O scattergram $IPF = \frac{Immature\ platelet\ number\ in\ the\ optic\ channel}{Sum\ of\ all\ platelet\ particles\ in\ the\ optical\ channel} \times 100\%$	%

2.4.4 Reticulocyte measurements

Reticulocyte measurements are performed similarly to the DIFF channel where SF cube cell analysis technology is applied. However, the red blood cells are not lysed; instead, they are spherized by RET diluent. The fluorescent dyes then stain the nucleic acid of the spherized RBCs and PLTs (Mindray, 2023).

Table 2.5 Calculated reticulocyte parameters

Parameters	**Name**	**Formula**	**Unit**
RET%	Reticulocyte percentage	$\frac{No.\ of\ cells\ in\ RET\ region}{No.\ of\ cells\ in\ mature\ RBC\ region + No.\ of\ cells\ in\ RET\ region} \times 100\%$	%
RET#	Reticulocyte number	RBC-I × RET%	10^9/L

HFR	High fluorescent ratio	$\frac{Number\ of\ cells\ in\ HFR\ region}{Number\ of\ cells\ in\ RET\ region} \times 100\%$	%
MFR	Middle fluorescent ratio	$\frac{Number\ of\ cells\ in\ MFR\ region}{Number\ of\ cells\ in\ RET\ region} \times 100\%$	%
LFR	Low fluorescent ratio	$\frac{Number\ of\ cells\ in\ LFR\ region}{Number\ of\ cells\ in\ RET\ region} \times 100\%$	%
IRF	Immature reticulocyte fraction	IRF = MFR + HFR	%
RHE	Reticulocyte hemoglobin expression	Based on light scatter information of RET	pg

2.5 Analytical methods of Sysmex XT 2000iV

2.5.1 WBC measurements

The 4DIFF analysis procedure is used for the detection of different white blood cell subgroups. Namely lymphocyte, monocyte, neutrophils, basophils, eosinophils. A diluting reagent named STROMATOLYSER-4DL is added, followed by STROMATOLYSER-4DS, which lyses the RBCs and stains the WBCs. Subsequently, the solution is measured with flow cytometry method with a semiconductor laser.

The second method is the WBC/BASO analysis method which measures WBCs and basophils. The process is as follows : reagent STROMATOLYSER-FB is added as a diluent and RBCs would be lysed. The cells are then analysed using the flow cytometry method.

Finally, scattergrams are generated. The 4DIFF displays the ghost area, lymphocytes, monocytes, eosinophils, neutrophils and basophils. Whereas the WBC/BASO analysis shows ghost regions, basophils and other white blood cells (Sysmex, 2016).

2.5.2 Hemoglobin measurements

SLS method is used for hemoglobin measurements. Reagent CELLPACK is added first, followed by the addition of SULFOLYSER to lyse the red blood cells. CELLPACK serves to dilute the blood sample. Once the red blood cells are lysed, the hemoglobin is

converted into SLS-hemoglobin. Through the photometric method, the absorbance of the solution is then measured compared to the absorbance of the fluid prior to the addition of the sample.

Previously, cyanmethemoglobin and oxyhemoglobin methods were used for hemoglobin measurement. However, the cyanmethemoglobin method had significant disadvantages, it took too much time to process the sample and poisonous compound cyanide was used. It's problematic because it requires waste treatment and from the environmental aspect, it's also non favorable. The oxyhemoglobin method is advantageous, but since it cannot convert methemoglobin and oxyhemoglobin, it can result in lower values for the sample (Sysmex, 2016).

2.5.3 Red blood cell and platelet measurements

Reagent CELLPACK is first added to the sample, as it arrives at the RBC/PLT detector, the cells are measured accordingly using the hydrodynamic method, which ensures that the red blood cells and platelets are focused and passed through a small aperture one by one. This allows the accurate counting and analysis of the red blood cell population (Sysmex, 2016).

Table 2.6 Calculated RBC parameters

Parameters	**Name**	**Formula**	**Unit**
MCV	Mean corpuscular volume	$\frac{HCT}{RBC}\times 10$	fL
MCH	Mean corpuscular hemoglobin	$\frac{HGB}{RBC}\times 10$	pg
MCHC	Mean corpuscular hemoglobin concentration	$\frac{HGB}{HCT}\times 100$	g/L
RDW-CV	Red blood cells distribution width - coefficient of variation	$\frac{L2-L1}{L2+L1}\times 100$	%
RDW-SD	Red blood cells distribution width - standard deviation	Based on standard deviation of RBC volume distribution	fL

Table 2.7 Calculated Platelet parameters

Parameters	Name	Formula	Unit
MPV	Mean platelet volume	$\frac{PCT}{PLT} \times 10000$	fL
PDW	Platelet distribution width	From platelet histogram	fL
P-LCR	Platelet-large cell ratio	From Platelet histogram	%

2.5.4 Reticulocyte measurements

Flow cytometry method is used. The RET SEARCH diluent is first introduced, followed by the addition of RET SEARCH dye reagent. Utilizing flow cytometry, the cells can be analyzed. In the resulting scattergram, the x-axis represents the lateral fluorescent light, while the y-axis represents the forward scattered light.

Measurements are taken for RBCs, reticulocytes and platelet counts. The total reticulocyte count is measured from the sum of low fluorescence ratio, medium fluorescence ratio and high fluorescence ratio populations (Sysmex, 2016).

2.6. Control material

Bias was determined in Mindray BC-60R Vet using control material. This has not been validated for Mindray earlier but used for the Sysmex analyzer that is working by similar methodology. Artificial blood sample for QC as control material was purchased by Diagon Ltd. (D-Check XE normal 4,5 ml /code: DCXETN/). For sigma metrics we used the TEA guidelines, and where proper values were not indicated we used the 3SD according to TEA CLIA 2024 (Arnold et al., 2019, https://www.asvcp.org/page/QALS_Guidelines, https://westgard.com/clia-a-quality/quality-requirements/2024-clia-requirements.html).

2.7. Statistical analyses

Analysis of correlation and regression analysis was done. Comparison was performed using linear regression analysis. For comparison of automated NRBC counts with manual counts, automated NRBC values below 1% were set to zero. By slightly modifying the method of Bland and Altman, differences between single measurements and the median of the two analyzers were plotted against the median of all two analyzers. Systematic deviation (bias) was estimated by the mean value of the differences. These differences do not always correspond to a Gaussian distribution. In addition to standard deviations, 90% limits

of agreement were therefore calculated by the 5th and 95th percentile as a measure of scatter, which define the range containing 90% of the distribution. Thus, 90% limits of agreement are a measure of the degree to which an analyzer differs from the median of all instruments. We used absolute differences for all parameters.

Evaluations were performed by Microsoft Excel and Reference Value Advisor V 2.1.

3. Results

The following section presents a comparative study of the parameters generated among Sysmex and Mindray. This analysis evaluates correlations, percentage differences, and precision by using data from samples that include both canine and feline . By examining these results, we aim to identify where Sysmex and Mindray show consistency or differences in measurements, providing great insight into their reliability in veterinary diagnosis.

Linear regression curve is shown in figure 3.1, such graphs depict the relationship between two variables, in this case, it is the parameters of Mindray (y-axis) and Sysmex (x-axis). Most graphs do indicate strong correlations, although a few outliers are present, which may be present due to measurement errors or biological variability. The parameters with the lowest correlations are RDW-CV (0.44), Ret# (0.39), HFR (0.22), PDW (0.12), Bas% (0.002), Bas# (0.00001), suggesting possible inconsistencies between the analyzers for these specific measurements.

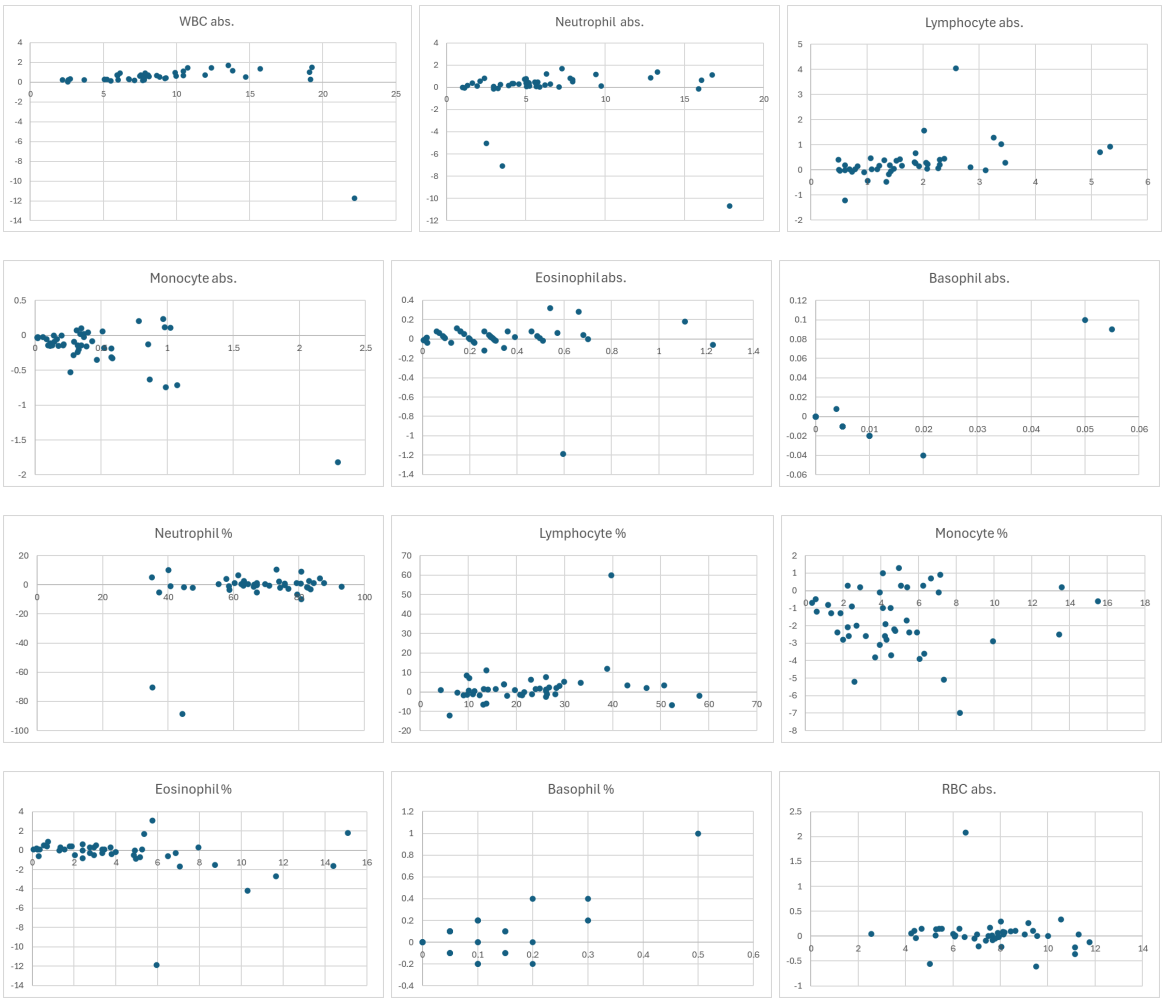
Figure 3.1 Regression curve of Mindray and Sysmex parameters, x-axis represents the Sysmex, y-axis represents the Mindray.

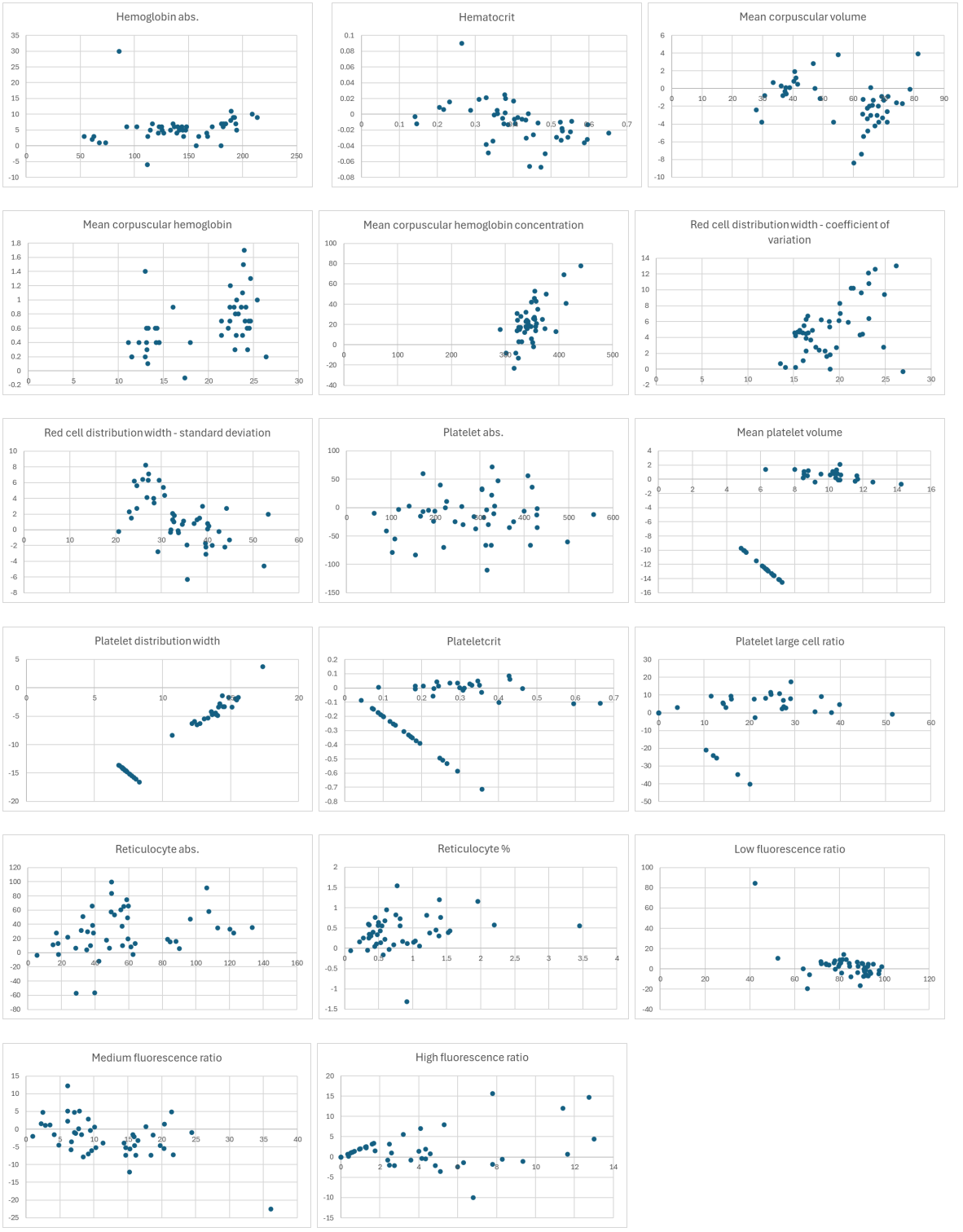
The Bland Altman plots are shown in figure 3.2, the two variables compared are the mean of Mindary and Sysmex measurements (y-axis) and the difference between the Mindary and Sysmex parameters (x-axis). The closer the data points are to the mean line (0 value), the

better the agreement between the variables. Certain parameter exhibit more variabilities, such as Bas#, Bas%, Hct, MCHC, RDW-CV, RDW-SD, PLT#, PDW, RET#, RET%, and HFR. Such differences could be caused by factors like calibration differences, sample quality, and limitations in the methodologies.

Compared to figure 3.1, the Bland-Altman plots reveal more discrepancies because the regression curve focuses primary more on correlation and the overall trend of the variables, whereas the Bland-Altman directly plots assess the actual differences between the measured values of the variables, making the difference in values more apparent. As a result, parameters that showed lower correlations in the regression analysis are also reflected in the Bland-Altman plots.

Figure 3.2 Bland-Altman plots including the mean and difference between the parameters between Sysmex and Mindary





In figure 3.3 and 3.4, the closer the numbers are to 0, the more comparable the Sysmex and Mindray parameters. Minor but notable differences are seen in MCHC (5.98%), Lym% (9.45%), PLT (-5.11%) and Eos% (-9.31%). Greater differences are observed in Lym# (15.04%) and Bas# (-15.5%). Immense difference is seen in MFR (-21.3%), RET%

(37.82%), RDW-CV (23.82%), HFR (34.52%), RET# (40.01%), Mon% (-40.81%), Mon# (-44.14%), PCT (-47.25%), MPV (-55.02%), PDW (-75.18%) and Bas% (50.8%). In cats monocyte counts (% and abs.), RDW-CV, RDW-SD, Reticulocyte abs. and % showed marked differences compared to dogs (Figure 3.4).

Figure 3.3 Value differences in % between Sysmex and Mindray

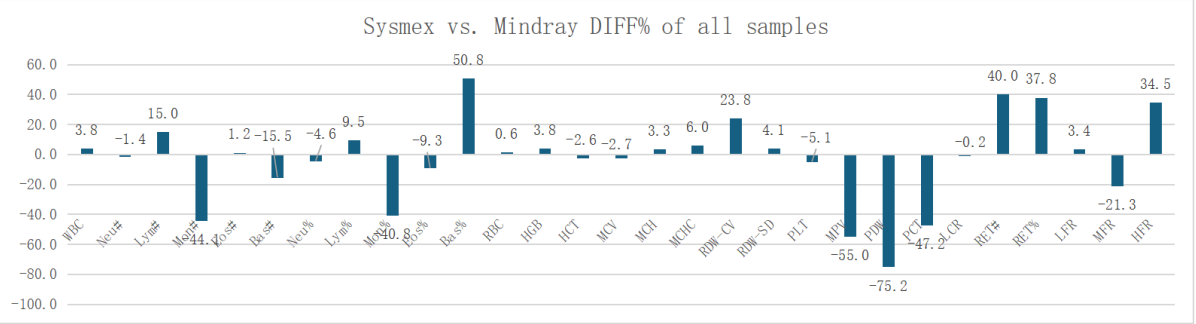
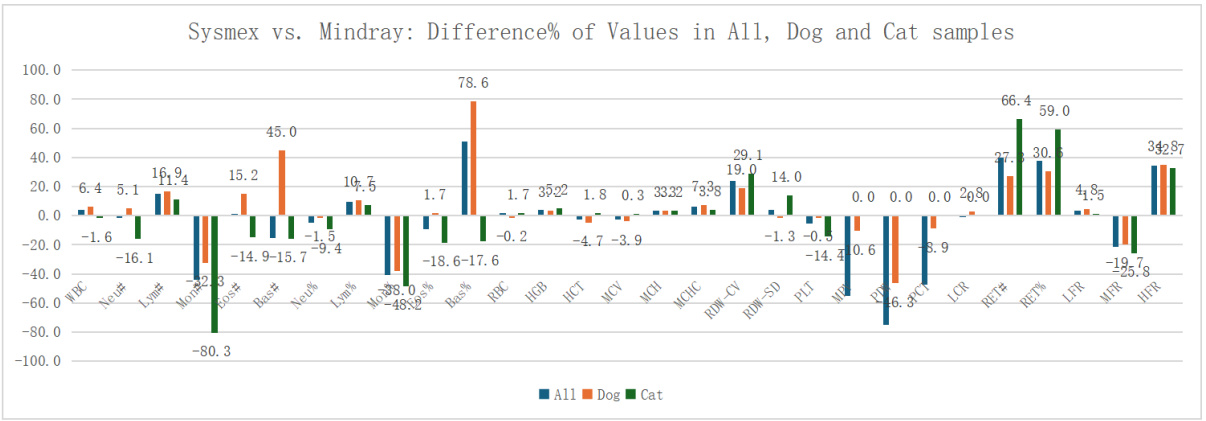


Figure 3.4 Sysmex vs Mindray value differences in % All, Dogs and Cats



The correlation coefficient values shown in Tables 3.5 and 3.6, as well as Figures 3.7 and 3.8, measure the strength and direction between two variables. It ranges from -1 to 1; the closer the value is to 1 or -1, the stronger the correlation between the two variables. Among all the r values, one of the most notable parameter with the worst correlation coefficient is Bas# and Bas%. This is likely because basophil count is so low in the blood, even little differences would lead to such a poor correlation coefficient. However, in reality, the difference between the basophil count is negligible. More notable correlations differences are

seen in cats for Lym#, Lym%, RDW-CV, RET#, RET%, LFR, MFR, and HFR; and in dogs for Mon#, Mon%, RDW-CV, PDW, RET#, and HFR.

Table 3.5 Correlation coefficient "r" values in All, Dog and Cat samples (White blood cell and red blood cell values)

Correlation Symex vs Mindray (r-value)	All	Dog	Cat
WBC	0,93	1,00	0,91
Neu#	0,93	1,00	0,90
Lym#	0,84	0,96	0,57
Mon#	0,81	0,73	0,94
Eos#	0,96	0,91	0,99
Bas#	-0,01	0,03	-0,22
Neu%	0,96	0,99	0,95
Lym%	0,76	0,97	0,56
Mon%	0,87	0,76	0,95
Eos%	0,96	0,91	0,98
Bas%	0,04	0,16	0,12
RBC	0,99	1,00	0,98
HGB	0,99	1,00	0,99
HCT	0,98	0,98	0,96
MCV	0,99	0,95	0,98
MCH	1,00	0,97	0,98
MCHC	0,86	0,82	0,91
RDW-CV	0,66	0,41	0,20
RDW-SD	0,94	0,92	0,96

Table 3.6 Correlation coefficient ("r") values in All, Dog and Cat samples (platelet and reticulocyte values)

Correlation Symex vs Mindray (r-value)	All	Dog	Cat
PLT	0,94	0,97	0,92

MPV	0,94	0,94	##########
MPV	0,94	0,94	##########
PDW	0,34	0,34	##########
PCT	0,94	0,94	##########
P-LCR	0,91	0,91	##########
RET#	0,63	0,79	-0,10
RET%	0,81	0,91	-0,31
IRF	##########	##########	##########
LFR	0,80	0,78	0,46
MFR	0,82	0,86	0,32
HFR	0,49	0,38	0,10

Figure 3.7 Correlation coefficient ("r") values in All, Dog and Cat samples

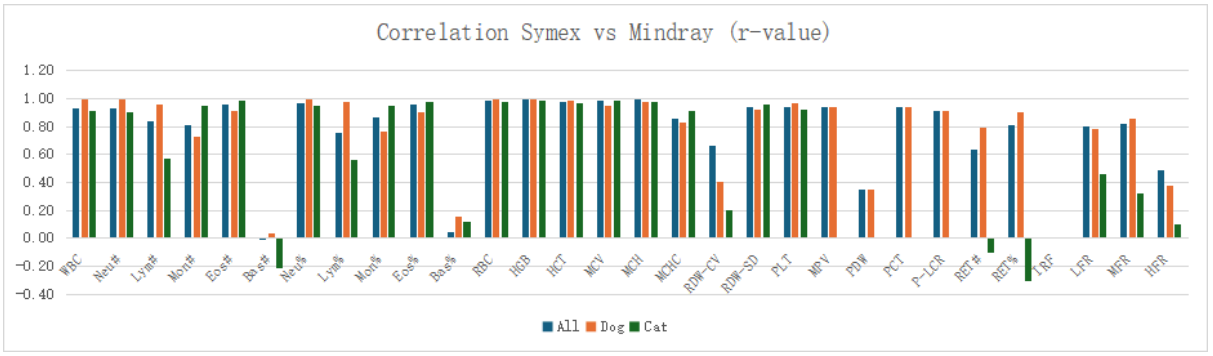
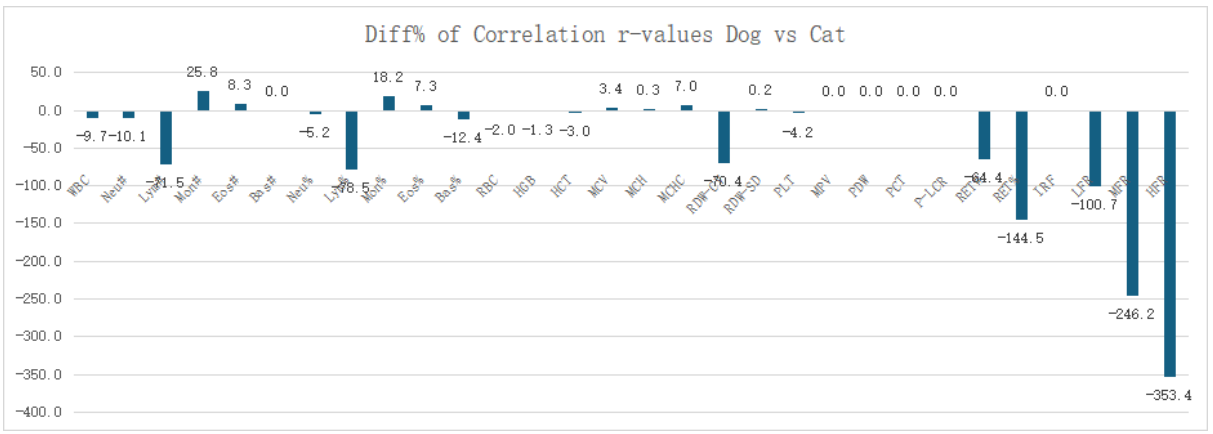
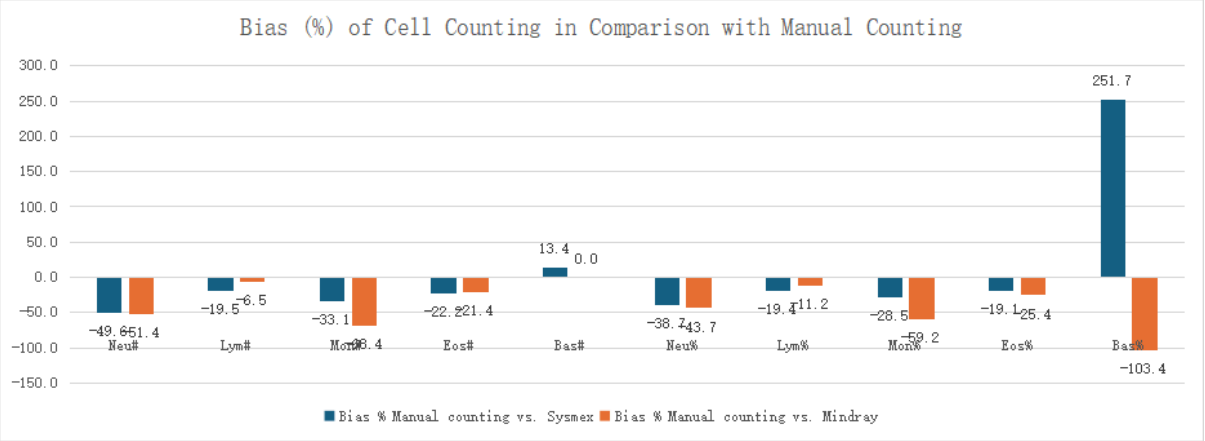


Figure 3.8 Differences between Canine and Feline correlation r-values in %



The bias% represents the deviation from the actual value, with values closer to 0% indicating better agreement with the manual counting, as shown in Figure 3.9. The bias% of Sysmex and Mindray interestingly are fairly similar, the parameter with the most significant differences between the hematology analyzers are the monocyte count and monocyte %. Basophil, due to known reasons, are excluded from consideration.

Figure 3.9 Bias % in differential white blood cell counting in Sysmex and in Mindray in comparison with manual microscopic cell counting



Both CV parameters in Mindray (within day and day-to-day) are acceptable with red blood cell parameters, moreover neutrophil and lymphocyte counts and less in monocyte counts, although greater differences were found in eosinophil and basophil counts. Bias are markedly high in all cell types except for WBC and Lymphocyte counts. These are marked by looking at Teo values, too (Table 3.10). Regarding red blood cell parameters, CV values are acceptable, with the exception of IRF and MFR fractions (Table 3.11). In spite of the good CV values bias values for reticulocyte parameters were very high compared to control (Table 3.11).

Table 3.10 Mindray Variation Coefficient % and Bias from the control - comparison statistics White Blood Cell and Red Blood Cell values

	CV% Within Day	CV% Day-to-Day	Bias % from the Control (> 10%)	TEo values	Sigma metrics (>3)

WBC	0,79	1,88	6,96	8,55	16,795
Neu#	1,33	1,75	36,06	38,72	2,1073
Lym#	6,70	4,39	2,14	15,54	1,9171
Mon#	17,07	14,05	61,70	95,84	2,03
Eos#	48,43	50,41	98,00	194,86	2,0197
Bas#	55,62	57,01	95,59	206,83	2,0099
Neu%	0,89	1,53	27,20	28,98	0,4395
Lym%	5,17	4,17	5,00	15,35	1,035
Mon%	17,58	13,94	63,38	98,55	1,9646
Eos%	48,43	50,41	98,37	195,22	2,0152
Bas%	55,53	55,52	95,89	206,96	1,9345
RBC	0,99	1,26	0,70	2,68	4,0646
HGB	0,55	0,37	0,31	1,41	10,769
HCT	0,96	1,28	3,47	5,39	4,1962
MCV	0,31	0,25	4,00	4,63	29,626
MCH	1,02	1,12	0,30	2,34	6,8143
MCHC	1,16	1,14	3,27	5,59	3,9967

Table 3.11 Mindray Variation Coefficient % and Bias from the control - comparison statistics Red Blood Cell Distribution Width, Platelet and Reticulocyte Values.

	CV% Within Day	CV% Day-to-Day	Bias % from the Control	TEo values	Sigma metrics (>3)
RDW-CV	0,84	0,78	2,28	3,97	2,4705
RDW-SD	0,93	0,67	4,36	6,21	2,0471
PLT	2,30	3,24	19,35	23,95	8,7822
MPV	1,44	1,82	9,49	12,37	6,9682
PDW	0,46	0,68	20,28	21,19	2,4452
PCT	2,03	3,84	8,33	12,40	2,041
P-LCR	3,16	4,05	6,37	12,69	2,0202
RET#	9,11	7,16	145,25	163,47	1,0618
RET%	8,77	8,13	76,90	94,43	2,0877
Ret abs (calc)	9,23	7,15	144,94	163,40	2,157

IRF	56,99	41,13	85,15	199,12	2,0149
LFR	1,74	1,43	0,08	3,56	2,0005
MFR	56,99	41,13	-	-	-
HFR	-	-	-	-	-

4. Discussion

The Mindray BC-60R Vet hematology analyzer (Mindray) performed well on most of the parameters evaluated compared to the reference analyzer Sysmex XT-2000iV (Sysmex). According to our observation Mindray is performing very well compared to Sysmex, which was used as the gold standard. In general RBC parameters were well correlated except for RDW-CV, absolute reticulocyte count and HFR. While white blood cell parameters correlated also well with Sysmex except for the basophil counts. Dog and cat parameters also differed in different analyzers. As mentioned at Results differences are seen in cats for Lym#, Lym%, RDW-CV, RET#, RET%, LFR, MFR, and HFR; and in dogs for Mon#, Mon%, RDW-CV, PDW, RET#, and HFR. This means that Mindray has different setups for cat samples.

Interestingly, some white blood cell type analyses were different in both analyzers compared to manual counting, such as neutrophil, monocyte and basophil values, although Mindray showed greater alteration in monocyte and basophil counting compared to manual microscopical cell counts. It seems that Mindray has a slight difference in recognition of monocytes. However, these differences might not cause greater diagnostic errors.

Day-to-day and within day values show a proper accuracy for Mindray, except for eosinophil and basophil count, which might indicate the necessity of a more proper fixing and recognition of these parameters. Regarding red blood cell parameters, CV values are acceptable, with the exception of IRF and MFR fractions which indicate an improper signing of reticulocytes.

Compared to control material, bias values are markedly high in all cell types except for WBC and lymphocyte counts. Regarding red blood cell parameters, bias values for reticulocyte parameters were very high compared to control. This could be caused by the

improper control material which we used due to the lack of adequate blood control not designed for Mindray.

Based on Table 3.10 it can be stated that higher alteration can be found in differential counting of white blood cell types. The following variables show marked alteration: Neu#, Lym#, Mon#, Eos#, Bas#, Neu%, Lym%, Mon%, Eos%, Bas%. Sigma metrics values are especially low with neutrophil percentage, which is markedly low. It can be explained by the damages of cells due to repeated measurements. Although the bias for other cell types are also high, but their sigma metric values are still more or less acceptable, although do not reach "3". Another explanation is that the blood control is not suitable for this device and its expected values are markedly different. It can be clearly stated that white blood cell count and red blood cell parameters provide adequate sigma values. Moreover, it can be seen clearly that there is a great error in repeated measurements, too in the following parameters, as Lym#, Mon#, Eos#, Bas#, Lym%, Mon%, Eos% which means that there is a real problem in differentiating some cell types. In Ne% the repeated error was low (CV% Within Day: 1,33% and CV% Day-to-Day: 1,75%), and the sigma metrics showed alteration rather due to the problem with the blood control. In reticulocyte parameters (RET#, RET%, Ret abs (calc), IRF, MFR) all repeated measurements showed large error values in day-to-day and within day analyses. Their TEo values were also very high, however the sigma metric values were almost acceptable this can be caused by that the TEa value was calculated by 3SD value and not the advised given TEa value was used, as these were not available.

Other large cohort comparisons of hematology analyzers revealed that differential blood count, were found as an overall high inter-instrument correlation. Especially, neutrophil, lymphocyte and eosinophil counts differed from microscopy (Bruegel et al., 2015). In their study monocyte counts between different instruments revealed a considerably lower agreement with Advia 2120i showing the maximum deviation to consistently lower values. Except Advia 2120i, automated differentials revealed higher percentages of monocytes in comparison with microscopy. Lower percentages of monocytes in automated analysis have already been described for Advia 120 and were suspected to be due to underestimation by the peroxidase staining (Meintker et al., 2013, Grimaldi et al., 2005). This problem was detected by our observations, too.

In general Mindray BC-60R Vet hematology analyzer is a suitable instrument for accuracy point of view and in comparison with Sysmex XT-2000iV. There are some

differences which should be corrected in Mindray such as the eosinophil, monocyte and reticulocyte identification. Further studies could be performed by using a larger database for the proper comparison with other hematology analyzers, such as Advia 2120.

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