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Research Article

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Comparative Study between Automated and Manual Methods of Complete Blood Counting in Patients Using Intravenous Solutions

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Abstract

Objective: This study examines the impact of diluting IV fluids on blood parameters using two automated haematology analyzers (Sysmex KX-21 and Medonic M32) alongside manual techniques, highlighting the importance of laboratory services in healthcare and medical diagnosis.

Materials and Methods: Blood samples were collected before and after intravenous administration of solutions and sent to the laboratory for measurement of hematological parameters, including Hb, RBC count, WBC count, PCV, MCV, MCH, and MCHC. Additional samples were collected after administration of intravenous solutions.

Results: Sysmex KX-21 showed higher hematocrit and mean corpuscular volume than manual methods and Medonic M32. However, both showed significantly lower mean corpuscular hemoglobin compared to manual measurements. Medonic M32 had an elevated mean corpuscular hemoglobin concentration. White blood cell counts were comparable between Sysmex KX-21 and manual methods, with Medonic M32 showing lower counts, though the difference was not statistically significant.

Conclusion: Automated haematological analyzer readings are as reliable as the standard manual method. WBC count, RBC count, Hb, and Hct were the most commonly affected by intravenous solutions when automated haematology analyzers and manual methods were used to measure them. WBC, MCH, and MCHC were slightly affected by intravenous solutions. RBC and MCHC by the Medonic M32 automated haematology analyzer were slightly higher than those by the Sysmex KX-21 automated haematology analyzer and the manual method. HCT and MCV by the Sysmex KX-21 automated haematology analyzer were higher than those by the Medonic M32 automated haematology analyzer and the manual method.

Keywords: CBC; Intravenous Solutions; Sysmex Kx-21; Medonic M32; Manual.

INTRODUCTION

Laboratory services are crucial to the population's health, as the hematology department plays a vital role in the laboratory. Furthermore, due to the need for proper clinical evaluation in Yemen, blood studies and analyses have proven to be among the most important tools in healthcare and medical diagnosis [1]. The Complete Blood Count (CBC) is the most commonly requested test in hematology laboratories, and numerous prior studies have demonstrated that it provides valuable insights into the pathophysiology of blood cells and the reticuloendothelial system. Age, gender, altitude above sea level, sample type, available technology, staff, and dynamic resources can all affect normal CBC levels across laboratories. Depending on the technology staff and financial resources available, the quantity and type of investigations vary greatly among laboratories. Hemoglobin (Hb), White Blood Cell (WBC) count, Red Blood Cell (RBC) Erythrocyte Volume (PCV), and platelet count are all included in CBC [2]. CBC analysis provides information on specific parameters associated with each type of blood cell, used to estimate the overall heal th state [3]. Many components of CBC can be identified using manual, semi-automated, or automated procedures. Although many laboratories today use semi-automated and fully automated machinery, traditional manual methods remain vital, serving as reference methods for most automated applications. Clinicians occasionally order a manual CBC because they know the patient's history, symptoms, and therapeutic drugs that may need to be evaluated to detect abnormal results that the tools alone may not reveal [4].

Manual approaches, although they have reasonable accuracy, have certain downsides in terms of errors that arise in different measurements. Incorrect mixture, incorrect anticoagulant, insufficient or prolonged mixing can all impact the measured and computed parameters of blood samples. Improper preparation and storage of hemoglobin estimation reagents, inaccurate addition of blood volume to the test reagent, and errors in red cell counts, including both technical and inherent errors, all impact the outcomes [5]. Technical errors include the use of inaccurate straws, poorly calibrated pipettes or counting chambers, insufficient red mixing of cell suspensions, incorrect filling of counting chambers, and careless counting of cells in the chamber. Inadequate mixing of excess anticoagulant blood, tubular lumen deviation, and reading difficulty can all lead to misleading PCV findings. All of these elements contribute to inaccurate blood test results and miscalculation errors. However, in the calculation of specific blood parameters, such as hemoglobin, there is a link between manual and automated procedures [6].

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The majority of automated counters use a modified version of the manual cyanohemoglobin test. In specific counters, HICN has been replaced by a nontoxic chemical technique [7]. Furthermore, electronic cell counting technologies are available. In modern hospitals and clinics, manual CBCs have been replaced by automated blood analyzers, which, although reducing the number of medical technicians in medical laboratories, result in lower expenses [4]. Even though automated techniques incur costs, they ultimately lead to lower expenses. Although highly capitalized, it provided a high level of accuracy and achievability for what was once a difficult laboratory task. Because of their speed, they can process a large number of blood samples, and the quality of the results makes them suitable even for small laboratories with few technicians [6], despite their initial use in laboratories in the early 1960s. Counting instruments have advanced since then, but they are still relatively simple, high-tech analyzers that can count all three types of blood cells, calculate hemoglobin levels, and calculate red cell indices all at the same time, these tools' analytical reach has recently been increased to include data on cell size variation With the help of automated techniques, erythrocyte derivation, PCV, and MCV are all linked [8]. The inaccuracy could be caused by chance, for example, when cells pass through an aperture one at a time and are counted as a single cell, or by a pulse created during the circuit's electronic dead period, for example count bubbles, lipid droplets, bacteria, or extraneous particles as cells by recycling cells that have previously been counted by agglutinating red blood cells [6].

Because of blood loss and dilution from fluids administered to patients, Hb and Hct concentrations fall in patients who are bleeding, and changes in the quantities of WBCs, RBCs, and platelets, as well as in erythrocyte indices (MCV, MCH, and MCHC), are made to reduce Hct and Hb. Isotonic solutions, such as Normal Saline (NS), are currently the most popular Fluid resuscitation solutions in the emergency department [9]. While prior research has linked lower hemoglobin levels caused by NS infusion to a small number of patients, other studies have reported a higher number [10]. Despite this, there is rarely a link between automatic blood analyzers and manual technology.

Clinical laboratories are aware of the problem of differences in haematological parameter values between automated and manual methods. One important but often overlooked confounding factor is administering Intravenous (IV) fluids before taking a sample, which may dilute the sample and alter the results. Additionally, it is not standard practice in many places to record the timing of phlebotomy in relation to IV therapy, which could affect the accuracy of the results. This study aimed to investigate the effect of diluting IV fluids on a group of blood parameters. We performed a comparative examination of data from diluted and non-diluted blood samples using two automated haematology analysers (Sysmex KX-21 and Medonic M32) alongside standard manual techniques.

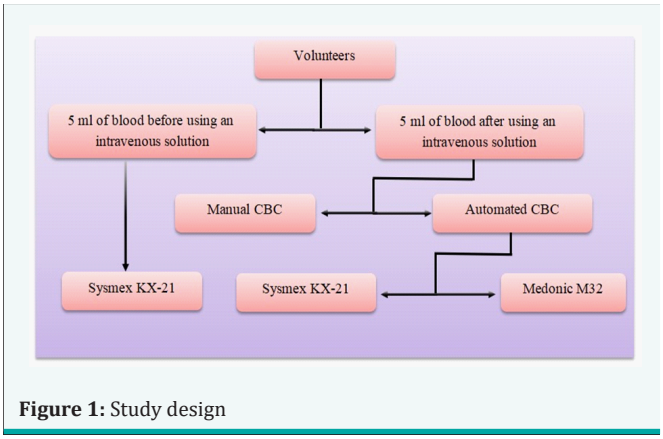

Figure 1: Study design

MATERIALS AND METHODS

Materials

Micropipette (Mettler Toledo, China), Capillary tube (Mettler Toledo, China), Tube (Mettler Toledo, China), Tips (yellow and blue) (Mettler Toledo, China), Chamber (hemocytometer)(Horsham, Germany), 1000 mL Drabkin reagent (Hb) (AGAPE, China), 500 mL Turk's solution(WBC) (AGAPE, China), 500 mL Normal saline (RBC) (Shijiazhuang, China), 500 mL Lysis (CBC) (Guangdong, China), 5 Liter Diluent (CBC) (Guangdong, China). Equipment used in this study: KX-21(Sysmex Corporation, Japan), Medonic M32 (German Spanish company, Germany), Spectrophotometer for Hb (Rayto RT-9200, Germany), Hematocrit Hct (Jiangsu, China), Light microscope (Olympus, Philippines), Shaker (Biobase, China).

Study Design

This study is an experimental investigation designed to compare manual and automated CBC analysis, with a specific focus on Hb analysis and the total counts of WBC, RBC, and PCV, as well as MCV, MCH, and MCHC (Figure 1).

Study Population and Samples

Eleven adults visited the emergency departments of Taiba Consultation Hospital and the General Dhamar Hospital Authority. Those people needed an intravenous solution. Two types of blood samples were used: A Non-diluted sample (before using the intravenous solution) and a diluted sample (after using the intravenous solution 250 ml). They agreed to share in this study as volunteers.

Blood Samples Collection

Blood samples were of two types. The first type of sample was a Non-diluted sample (before using the intravenous solution). 5 mL of intravenous blood was collected using a new, disposable 5 mL syringe. Blood was placed in an EDTA tube and thoroughly mixed. The second sample was diluted (after use of any intravenous solution). Five milliliters of intravenous blood were taken using a new, disposable 5 ml syringe.

1. Hemoglobin

1.1. Cyanomet-Hemoglobin Method Principle

Whole blood is diluted in a solution containing Potassium Ferricyanide and Potassium Cyanide, Hemoglobin will be oxidized by the action of Potassium Ferricyanide to form Methemoglobin (Hemoglobin, Hi) Potassium Cyanide will provide Cyanide ions to form Cyanomethemoglobin (HiCN), This solution can be measured spectrophotometrically and compared to known hemoglobin standards or in filter colorimeter using a yellow green filter, This procedure is applicable in diagnosing and monitoring therapy in cases of hemoglobin deficiency anemia's [11]. Hb+K3Fe(CN)6→Hi, Hi+KCN→HiCN.

1.2. Cyanmethemoglobin Procedures

Add 20 µL of blood to 4 mL of Drabkin's solution (1:251 dilution). Put the stopper in the tube and invert it several times. Allow the sample to stand at room temperature for 5 minutes. Then, pour the sample into a cuvette. Read the Absorbance at 540 nm (yellow-green filter) in a spectrophotometer (Rayto RT-9200, Germany) against the reagent as blank. Hb (g/dL) = Absorbance of test sample X factor (37) or extract the unknown hemoglobin concentration, using the previous equation [12].

PCV (Packed Cell Volume)

1. Principle of PCV

Hematocrit is the ratio of the total volume of RBCs to that of whole blood, expressed as a percentage (%) (whole blood = total volume of cells + plasma). The second synonym for hematocrit is PCV (Packed Cell

Volume). The procedure is easy to perform, Whole blood is centrifuged in a narrow tube (capillary tube), and cellular elements will be separated from the plasma, after centrifugation blood will be separated into three layers: The bottom layer contains packed RBCs, The Middle layer contains WBC's and Platelets (on top of RBC's), Upper plasma layer [13].

2. Procedures of PCV

Mix EDTA with blood. After adequate mixing, fill the self-sealing capillary tubes two-thirds to three-fourths full. Seal the tube with a plastic seal (such as a creased mini seal) or by heating the dry end of the tube rapidly in a fine flame (using the pilot light of a Bunsen burner). Centrifuge for 5 minutes at 12000 g, so that additional centrifugation does not pack the red blood cells more. Carefully locate the filled capillary in one of the numbered slots of the microhaematocrit rotor with the sealed end against the rim gasket (to prevent breakage). Write the slot number on the patient's form. Position the inner lid carefully to avoid dislodging the tubes. Read the PCV using a special HCT reader. Express the results in percentage (%) [14].

RBC Count

1. Principle of RBC Count

A specified volume of blood is diluted with a specified volume of isotonic fluid. This isotonic diluting fluid will not lyse RBCs and will facilitate counting with a hemacytometer [15].

2. Procedures of RBC Count

Pipette 4.0 ml of diluting fluid into a tube. Pipette 20 µL of will mix anticoagulated whole blood into the tube. Let it stand for 2-3 minutes. Load the cleaned hemacytometer. Place the hemacytometer on the microscope stage, and lower the condenser. Focus with an x10 objective lens on the large central square. This square is divided into 25 small squares, each of which is further divided into 16 smaller squares. Of the 25 squares, only the four corner squares and one middle square are used to count RBCs. Switch to the 40x objective lens and start counting in the five designated squares. Diluting fluid-(1:200) Isotonic saline: 0.85% sodium chloride (NaCl) in distilled water (8.5 g of NaCl in 1ml of D.W). The diluted specimen (1:200) is stable for 6 hours [16]. Total RBC count = N x Dilution factor x volume correction factor, N the total number of red blood cells counted in the counting chamber, Dilution factor = 200 (since it is 1:200). Each counted square has a volume of 0.2 x 0.2 x 0.1 = 0.004, five squares' volume = 5 x 0.004 = 0.02. volume correction factor = 1/0.02 = 50. The value was calculated according to the references. Using the previous equation [17].

WBC Count

1. Principle of WBC Count

A sample of whole blood is mixed with a diluent, which lyses red blood cells and stains the nuclei of white blood cells. White blood cells are counted in a hemocytometer counting chamber under the microscope, and the result is expressed as the total number of leukocytes per microliter (µL) of blood or liter (L) of blood [18].

2. Procedures of WBC Count

Mix the blood sample with the anticoagulant gently but thoroughly, either by inversion, manual mixing, or mechanical rocking. Pipette 0.38 ml (380 µL) of diluting fluid into a 12x75 mm tube, Pipette 0.02 ml (20 µL) of well-mixed blood to be counted, wipe the tip with gauze into the tube containing diluting fluid, and mix the tube. Let the tube stand for 2-3 minutes to ensure complete RBC lysis, then mix well. Prepare the clean hemacytometer and cover it with the designed coverslip. Load one side of the hemacytometer using a capillary tube or micropipette, ensuring it is neither overloaded nor underloaded. Allow the hemacytometer to sit for several minutes, allowing the WBCs to settle in the counting chamber. To prevent drying, place the loaded hemacytometer in a covered Petri dish lined with moist gauze until counting. Place the hemacytometer on the microscope stage, Focus with a 10x objective lens (low power), and lower the condenser. The WBCs are counted in the four large corner squares, using a hand tally counter. Diluting Fluid: 2% Acetic Acid in distilled water (2 ml glacial acetic acid + 98 ml distilled water). Turk's solution: Glacial acetic acid – 2 ml. Lyses RBCs. Gentian violet 1% w/v 2ml, 2ml stains the nucleus of WBCs. Distilled water – 98 ml [19].

RBC Indices MCV, MCH, and MCHC

MCV, MCH, and MCHC are calculated according to the following equation [20].

$$MCV = \frac{PCV(\%)}{RBC} \times 10$$

$$MCH = \frac{Hb\ concentration}{RBC} \times 10$$

$$MCHC = \frac{Hb\ concentration}{Hct} \times 100$$

Automated CBC Analysis

Used KX-21 Sysmex and Medonic M 32 instructions.

1. CBC Analysis (KX-21 Sysmex Corporation)

This device works by analyzing blood tests, which are typically taken in the following manner. Hb analysis, RBC count, WBC count, PCV, MCV, MCH, and MCHC. According to the following references [4].

2. CBC Analysis (Medonic M 32)

The device operates by analyzing blood tests, which are as follows. Hb analysis, RBC count, WBC count, PCV, MCV, MCH, and MCHC. According to the following references. (Boule Medical AB, Medonic M-series M32 system Service Manual BM850, No. 1504435 Version 03).

Statically Analysis Tests

The data among CBC analysis methods were analyzed by using one-way analysis of variance (ANOVA). A comparison between non-diluted and diluted samples was analyzed using the t-test. The data was analyzed using SPSS 22 computer software. The significant difference between groups was accepted at p 0.05.

RESULTS

Comparison between Hematological Analysis Methods

Our results are presented in the following tables. Table 1 shows that WBC count in Sysmex KX-21 system was 6.35±2.97, whereas in the manual method, it was 6.22±3.24. In contrast, Medonic M32 analyzer yielded a decreased level of 5.90±3.22, with a non-significant difference. Additionally, the study found that RBC count in Sysmex KX-21 system was 4.64±0.839, in the manual method was 4.46±1.198, and in Medonic M32 system was 4.49±0.944, with no significant difference. HGB in the Sysmex KX-21 system recorded 12.76±2.072 as a value of mean ±SD and in the manual method mean ±SD was 12.40±2.306, but in the Medonic M32 system showed a low level of mean ±SD 11.72±2.237 with non-significantly different, in addition to, Hct in Sysmex KX-21 system showed increase level 40.96±6.036 and in manual method recorded decrease level mean of ±SD 36.63±6.328 with significantly different P 0.025 compared with Sysmex KX-21 system, whereas in Medonic M32 system recorded decrease level 33.49±6.305 (Figure 2),(Table 1).

Statically analysis showed that MCV in the Sysmex KX-21 analyzer appeared a high size of RBC 89.39±9.769 with a significantly different 0.002 compared with the manual method and Medonic M32 system, also manual method recorded a low size of RBC, but it was very low size 72.11±11.273 in Medonic M32 analyzer with P 0.002 compared with Sysmex KX-21 analyzer and with P 0.013 compared with manual method (Figure 3). MCH analysis showed 27.84±3.69 on Sysmex KX-21 analyzer. It was a decreased level of about 28.65±6.321 in the manual method, whereas, in Medonic M32 analyzer, it was a decreased level of about 26.29±3.340 with P 0.001 compared with the manual method (Figure 4), also in Table 1, MCHC in Medonic M32 analyzer showed an increased level of mean ±SD 35.04±1.139 with a significantly different 0.001 compared with Sysmex KX-21 analyzer and Medonic M32 analyzer. However, in the manual method, the level was also increased by about 33.05±0.121, with P=0.001, compared with Sysmex KX-21 and the manual method. In contrast, the lowest mean ± SD was 31.08 ± 1.704 in Sysmex KX-21(Figure 5).

Comparison of Hematological CBC Parameters between Non-Diluted and Diluted Groups:

Statistical analysis in Table 2 showed that, in comparison between the -diluted group and diluted group, WBC recorded an increased level of 6.86±2.97 in the - diluted group. However, it showed a decreased level of about 5.85±3.03 in the diluted group, with a non-significant difference (Figure 6). Additionally, the mean RBC level ±SD was mainly 4.95±0.676 in the diluted group. The mean ±SD RBC level was approximately 4.33±0.900 in the diluted group, with a P value of 0.082 by Sysmex KX-21 analyzer compared with the manual method and Medonic M32 analyzer (Figure 7). In the non-diluent group, HGB recorded a 13.59±1.653 increase level, which was significantly different from the 0.059 level measured by Sysmex KX-21 analyzer compared with the manual method and Medonic M32 analyzer. However, the decreased level in the diluted group was 11.93±2.186 (Figure 8). Additionally, Hct showed a high mean ± SD level of 43.63 ± 4.814 in the non-diluted group, with a P value of 0.035 by Sysmex KX-21 analyzer compared with the manual method and Medonic M32 analyzer. Conversely, it was 38.30 ± 6.138 at a low level mean ± SD in the diluent group. MCV mean ± SD was a convergent value, which was 88.93 ± 9.690 in the diluent group and 89.85 ± 10.298 in the diluent group. In the non-diluent group, MCH showed a mean ±SD of 27.77±3.871 and 27.91±3.691 in the diluent group, with non-significantly different results. In addition, MCHC in the non-diluent group was 31.12±1.327, and in the diluent group, it was 31.04±2.082, with significantly different results. In the diluent group, platelets showed a 237.72±85.798 increase in level, with no significant difference compared to the manual method and Medonic M32 analyzer using Sysmex KX-21 analyzer. However, it was a 200.36±92.789 decrease level in the diluted groups.

Comparison of Hematological CBC Analysis between Methods in Diluted Groups

Laboratory analysis in Table 3 recorded a comparison between methods. In diluted groups, WBC count using the manual method showed a high level of 6.22±3.328. However, the values were 5.90±3.223 and 5.85±3.037 using Medonic M32 analyzer. Sysmex KX-21 analyzer showed non-significantly different results. Additionally, RBC count was recorded

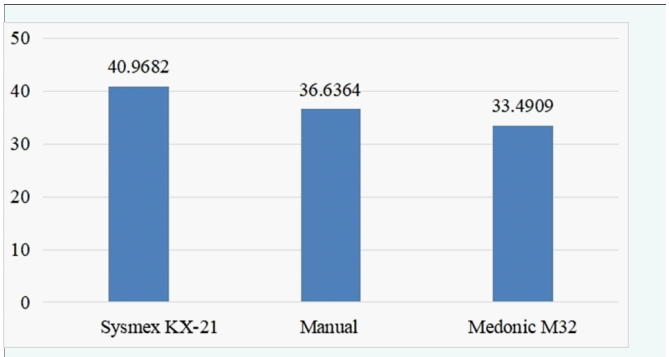

Figure 2: Comparison between Hct in hematological analysis methods of (non-diluted and diluted groups.

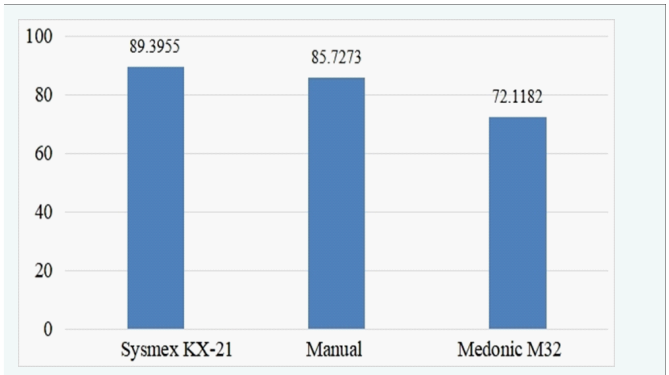

Figure 3: Comparison between MCV in hematological analysis methods of (non-diluted and diluted groups.

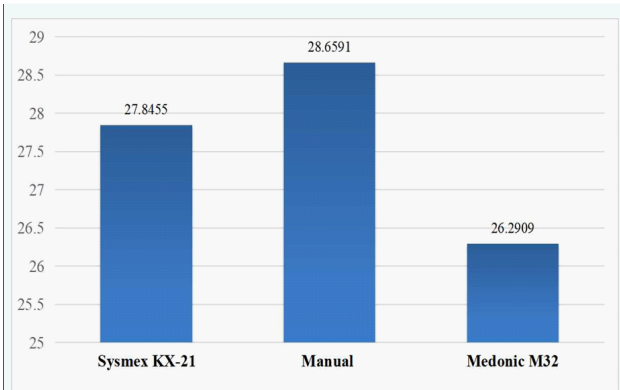

Figure 4: Comparison between MCH in hematological analysis methods of (non-diluted and diluted groups.

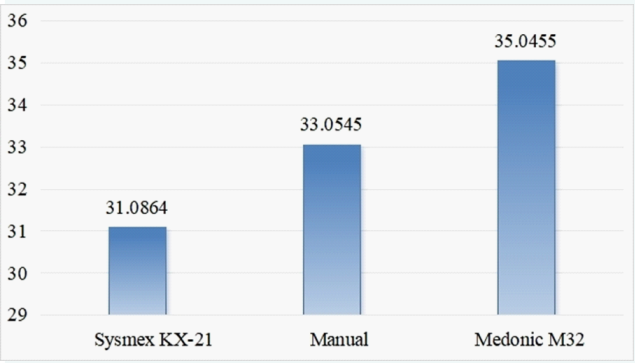

Figure 5: Comparison between MCHC in hematological analysis methods of (non-diluted and diluted groups.

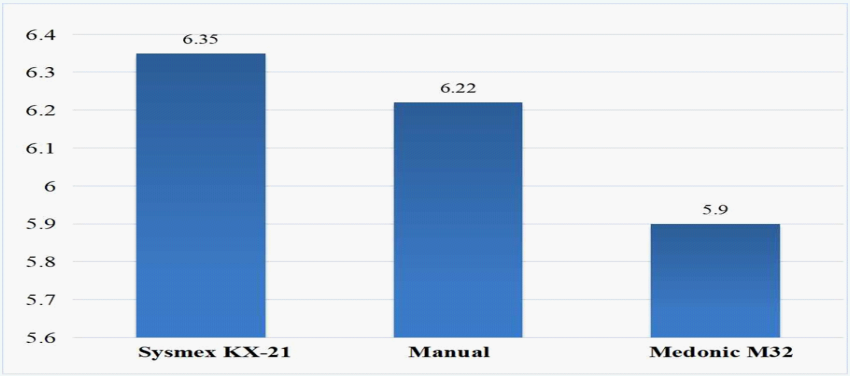

Figure 6: Comparison between WBC in the hematological analysis of (non-diluted and diluted groups

Table 1. Comparison Between Haematological Analysis Methods of (Non-Diluted and Diluted Groups)

CBC	Analyzers	Mean±SD	*P. Value*
WBC	Sysmex KX-21	6.35±2.97	
	Manual	6.22±3.24	
	Medonic M32	5.90±3.22	
RBC	Sysmex KX-21	4.64±0.839	
	Manual	4.46±1.198	
	Medonic M32	4.49±0.944	
HGB	Sysmex KX-21	12.76±2.072	
	Manual	12.40±2.306	
	Medonic M32	11.72±2.237	
HCT	Sysmex KX-21	40.96±6.036	
	Manual	36.63±6.328	A=0.025
	Medonic M32	33.49±6.305	
MCV	Sysmex KX-21	89.39±9.769	A=0.002
	Manual	85.72±18.802	
	Medonic M32	72.11±11.273	A=0.002 B=0.013
MCH	Sysmex KX-21	27.84±3.692	
	Manual	28.65±6.321	
	Medonic M32	26.29±3.340	B=0.001
MCHC	Sysmex KX-21	31.08±1.704	
	Manual	33.05±0.121	A=0.001
	Medonic M32	35.04±1.139	A=0.001

A comparison between Sysmex KX-21 and Manual or Medonic M32.
B comparison between Manual and Medonic M32.

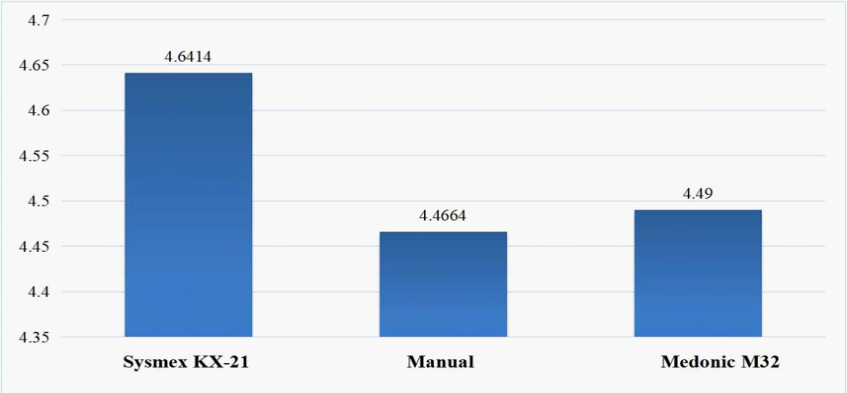

Figure 7: Comparison between RBC in the hematological analysis of (non-diluted and diluted groups.

Table 2. Comparison Between Non-Diluted and Diluted

CBC	Group	Mean SD	*P.Value*
WBC	Non-Diluted	6.86±2.97	
	Diluted	5.85±3.03	
RBC	Non-Diluted	4.95±0.676	A=0.082
	Diluted	4.33±0.900	
HGB	Non-Diluted	13.59±1.653	A=0.059
	Diluted	11.93±2.186	
HCT	Non-Diluted	43.63±4.814	A=0.035
	Diluted	38.30±6.138	
MCV	Non-Diluted	88.93±9.690	
	Diluted	89.85±10.298	
MCH	Non-Diluted	27.77±3.871	
	Diluted	27.91±3.691	
MCHC	Non-Diluted	31.12±1.327	
	Diluted	31.04±2.082	
PLT	Non-Diluted	237.72±85.798	
	Diluted	200.36±92.789	

A comparison between Sysmex KX-21 and Manual or Medonic M32.
B comparison between Manual and Medonic M32

as 4.33±0.90 using Sysmex KX-21 analyzer, 4.46±1.23 with the manual method, and 4.49±0.94 with Medonic M32 analyzer, with no significant differences. In the manual method, HGB recorded 12.40±2.363 mean ±SD, which is high compared with mean ±SD by Sysmex KX-21 analyzer and Medonic M32 analyzer, which are 11.93±2.186 and 11.72±2.237, consecutively, with non-significantly different means, also a high level mean ±SD 38.30±6.138 of HCT by Sysmex KX-21 analyzer, which is in contrast to the mean ±SD level by Medonic M32 analyzer, which is 33.49±6.305. In contrast, the increase is more pronounced than the mean ± SD by the manual method, which is 36.63 ± 6.484, and this difference is significant (p = 0.084) compared with the manual method and Medonic M32 analyzer.

MCV showed an increased size mean ±SD 89.85±10.298 in Sysmex KX-21 analyzer with a significantly different 0.006 compared with the manual method and Medonic M32 analyzer, decrease size mean ±SD 85.72±19.267 in the manual method with different P 0.032 compared with Medonic M32 analyzer and immensely decrease size mean ±SD 72.11±11.273 in Medonic M32 analyzer, in addition to MCH recorded high level mean ±SD 28.65±6.477 in manual method, slightly low level compared with manual mean ±SD 27.91±3.691 by Sysmex KX-21 analyzer and low level mean ±SD 26.29±3.340 in Medonic M32 analyzer without significantly, finally MCHC showed high level mean ±SD 35.04±1.139 in Medonic M32 analyzer. In contrast, it recorded a low mean ± SD of 31.04 ± 2.082, with a non-significant difference, as measured by Sysmex KX-21 analyzer.

DISCUSSION

This study, conducted in Dhamar City, Yemen, in 2022, aimed to compare hematological parameters using two automated hematological analyzers, Sysmex KX-21 and Medonic M32, with the manual method in patients receiving venous solutions. The present study was done on 11 patients using intravenous solutions. Our results showed that Hb values in the methods of non-diluted and diluted groups by using Sysmex KX-21, Medonic M32 automated hematology analyzer, and manual method were the same with non -significantly different, which agreed with the study done in Iran which found that there was only significantly different P 0.01 between the value of hemoglobin in the sample per 60 patients [21].

Hct in manual and Medonic M32 automated hematology analyzer showed a decreased level compared to Sysmex -KX-21 automated hematology analyzer which showed an increase with a significant relationship at a significant level of P < 0.025 and this study agreed with the study done in Sudan which found that there were strongly

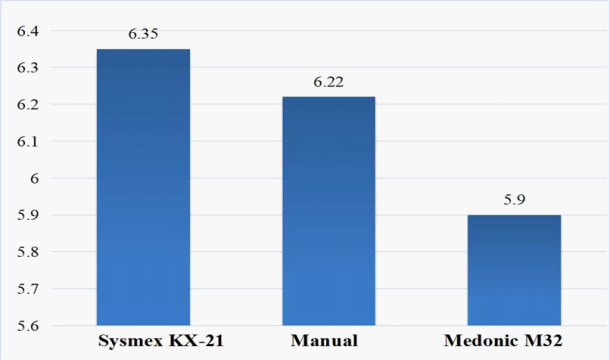

Figure 8: Comparison between HGB in the hematological analysis of (non-diluted and diluted groups

Table 3. Comparison Between Methods in Diluted

CBC	Methods	Mean SD	*P. Value*
WBC	Sysmex KX-21	5.85±3.037	
	Manual	6.22±3.328	
	Medonic M32	5.90±3.223	
RBC	Sysmex KX-21	4.33±0.900	
	Manual	4.46±1.227	
	Medonic M32	4.49±0.944	
HGB	Sysmex KX-21	11.93±2.186	
	Manual	12.40±2.363	
	Medonic M32	11.72±2.237	
HCT	Sysmex KX-21	38.30±6.138	
	Manual	36.63±6.484	A=0.084
	Medonic M32	33.49±6.305	
MCV	Sysmex KX-21	89.85±10.298	A=0.006
	Manual	85.72±19.267	B=0.032
	Medonic M32	72.11±11.273	
MCH	Sysmex KX-21	27.91±3.691	
	Manual	28.65±6.477	
	Medonic M32	26.29±3.340	
MCHC	Sysmex KX-21	31.04±2.082	
	Manual	33.05±0.121	
	Medonic M32	35.04±1.139	

significantly different P 0.025 per 50 patients [22], and disagreed with a study done in Sudan found Hct decreased with significant difference of P < 0.0011[6]. The current study revealed that there was no significant difference between RBC count in Sysmex KX-21, Medonic M32 automated hematology analyzers, and the manual method which strongly agreed with a study done in Italy by which found that RBC count was decreased with a significant difference with P 0.001 per 30 patients by using Sysmex KX- 21 automated hematology analyzer and manual method [23]. The results showed that WBC counts in Medonic M32 automated hematology analyzer were decreased when compared to Sysmex KX-21 automated hematology analyzer and manual method, with no significant difference, and this agreed with a study done in Turkey that found that WBC count decreased without a significant difference using Beckman Coulter LH-780 hematology autoanalyzer for 29 patients [24]. This study revealed a strongly significant difference at a significant level of P 0.002 between MCV in Sysmex KX-21 compared with Medonic M32 and manual method, P 0.002 in Medonic M32 compared with Sysmex KX-21 and P 0.013 compared with the manual method and this agreed with a study that done in Sudan that found that MCV decreased with significant P 0.002 per 438 cases using Sysmex KX-21 automated hematology analyzer [25].

The current study found a significant relationship at a p-value of 0.001 between MCH in Medonic M32 and the manual method. It was nearly similar to the study conducted in Sudan by Awad et al. (2019), who reported significant differences in MCH with P value of 0.001 per 438 cases using Sysmex KX-21 automated hematology analyzer. In Medonic M32, MCHC showed an increased level, with a significantly different P value of 0.001 compared with Sysmex KX-21 automated hematology analyzer. In the manual method, the increase was statistically significant at a different P value of 0.001 compared to Sysmex KX-21 automated hematology analyzer, which is in strong agreement with a study conducted in India that found an increase in MCHC with P value of 0.000 per 30 cases [26].

The present study recorded Hb with a significant level of P = 0.059 in the non-diluted group using Sysmex KX-21 automated hematology analyzer compared with the manual method and Medonic M32 automated hematology analyzer; however, the level was decreased in the diluted group. In addition, Hct showed a high level in non -the diluted group with a different P 0.035 by Sysmex KX -21 automated hematology analyzer compared with the manual method and Medonic M32 automated hematology analyzer, whereas it was a low level in the diluent group with the same results by Sysmex KX- XP 300 [25] and this disagreed with Hct levels decreased with difference was statistically significant P < 0.005 [26]. The current study showed a high RBC level in the diluted group and a low RBC level in the diluted group, with different P 0.082 by Sysmex KX-21 automated hematology analyzer compared with the manual method and Medonic M32 automated hematology analyzer, and this is similar to a study that was done in Indonesia, which found RBC count without significant difference [27]. WBC level increased in the non-diluted group. However, it showed a decreased level in the diluted group, with no significant difference between pre-saline replacement and post-saline replacement, as measured using a Beckman Coulter LH-780 hematology autoanalyzer in 29 patients [24].

MCV, MCH, and MCHC had similar values in both the non-diluent and diluent groups, with no significant differences. This finding agrees with a study conducted in Indonesia, which found no significant differences [10]. The present study recorded that Hb in diluted groups was high compared with Sysmex KX-21 and Medonic M32 automated hematology analyzers, with non-significantly different levels, also a high level of HCT by Sysmex KX-21 automated hematology analyzer, which is increased compared with Medonic M32 automated hematology analyzer and manual method, with significantly different P 0.084, and this disagreed with any previous studies.

Our study revealed no significant difference in RBC count in Sysmex KX-21, Medonic M32 automated hematology analyzers, and the manual method. However, WBC count was decreased in Sysmex-KX-21 and Medonic M32 automated hematology analyzers compared with a manual method, with a non-significant difference, and this agreed with a study done by Ike et al. (2010), who found that RBC and WBC count showed a significant difference by Sysmex KX-21 automated hematology analyzer and manual method. This study demonstrated an increase in MCV using Sysmex KX-21 automated hematology analyzer, with a significantly different result of 0.006 compared to the manual method and Medonic M32 automated hematology analyzer. However, in the manual method, it was decreased by a different amount, P = 0.032, compared with Medonic M32 automated hematology analyzer. MCH recorded a high level in the manual method. However, the level was slightly lower compared to the manual method and Sysmex KX-21 automated hematology analyzer, as well as Medonic M32 automated hematology analyzer, without a significant difference. Finally, MCH showed a high level in Medonic M32 automated hematology analyzer. In contrast, it recorded a low level on Sysmex KX-21 automated hematology analyzer, with non-significantly different results [4].

CONCLUSIONS

The results of the present study confirmed that automated hematology analyzer readings are as reliable as those obtained using the standard manual method. WBC count, RBC count, Hb, and Hct are the most common tests that are affected by intravenous solutions when automated hematology analyzers and the manual method are used to measure them. WBC, MCH, and MCHC were slightly affected by the intravenous solutions and were slightly higher with the manual method than with Sysmex KX-21 and Medonic M32 automated hematology analyzers. RBC and MCHC values obtained using Medonic M32 automated hematology analyzer are slightly higher than those obtained with Sysmex KX-21 automated hematology analyzer and the manual method. Hct and MCV values obtained using Sysmex KX-21 automated hematology analyzer are higher than those obtained using Medonic M32 automated hematology analyzer and the manual method.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

M. AL-Dulaiei. Concepted, designed the study, drafted the paper. B.A.R. acquired, analyzed, and interpreted the data. All authors critically reviewed the draft, approved the final version, and accepted accountability for all aspects of the work.

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ETHICS OF APPROVAL STATEMENT

Thamar University Institute for Continuing Education deanship granted ethical approval (decision no: 317, decision date: 2022-03-15) in addition to human resources in healthcare institutions.

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