

Study the Correlation of Red Blood Cell Indices and Electrolytes Imbalance in Anemic Patients in Ibb City, Yemen

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Background: Anemia is a widespread illness. It is often associated with an electrolyte imbalance. The correlation between electrolytes and anemia is crucial. Electrolyte balance is essential for maintaining the shape and function of red blood cells (RBC), including the exchange of O₂ and CO₂. Therefore, this study aimed to investigate the correlation between RBC indices and electrolyte imbalance in anemic patients, Ibb City, Yemen.

Methods: This study included 400 participants, consisting of 200 anemic patients and 200 non-anemic (controls). Approximately 5 mL of blood was collected directly from newly diagnosed anemic treatment-naïve patients and divided into tubes with and without EDTA to estimate RBC indices and serum electrolytes (sodium, potassium, chloride, calcium, and magnesium) directly.

Results: Red cell indices (Hb, RBC, MCV, HCT, MCH, and MCHC) and electrolyte levels (potassium, calcium, and magnesium) were decreased significantly among patients compared to controls. Serum sodium was not significantly different. Notably, levels of chloride were considerably higher in anemic individuals. Odds ratio (OR) of hypo-electrolytemia with anemia, including hypomagnesemia (OR=4.928, 95% CI: 2.278–10.47), hypo-kalemia (OR=2.967, 95% CI: 1.551–5.581), and hypo-calcemia (OR=2.833, 95% CI: 1.887–4.236), was significantly higher in anemic patients compared to controls. In contrast, OR of hyponatremia did not show a significant difference (OR =1.438, 95% CI: 0.9522–2.143). Notably, hyper-natremia was identified in the patient group, with no existence in controls, resulting in an infinite odds ratio (OR=∞, 95% CI: 0.5262–∞). Additionally, there were significant positive correlations between sodium and calcium levels with Hb, RBC, and HCT, as well as between magnesium levels with MCV and MCH. In contrast, significant negative correlations were found between chloride, magnesium, and calcium levels and Hb, RBC, and MCV, respectively.

Conclusion: The study concluded a correlation and a significant disparity in serum electrolytes, particularly calcium, potassium, magnesium, and chloride, among anemic patients.

Keywords: correlation, RBC, indices, electrolyte, imbalance, anemia

Introduction

Anemia normally results from various etiologies, including decreased red blood cell (RBC) production (bone marrow diseases, chronic kidney disease, and autoimmune diseases), blood loss (bleeding or increased RBC destruction (haemolysis), poor RBC maturation, and nutritional deficiencies (iron, folate, or vitamin B12)).^{1–4}

Electrolytes are electrical molecules required for metabolic homeostasis and the body's vital reactions. Electrolytes support cell membrane functions, muscle contraction, neuron impulses, bone structure, hormone action, maintaining fluid balance, and regulating pH levels (acid-base balance).^{5,6} Similarly, an imbalance of electrolytes happens when it is level abnormally higher or lower than the normal value as a result of a variety of physiological and pathological factors, including nutritional situation, acid-base imbalances, medications, acute sickness, or other co-morbid diseases such as

renal disorder.^{6–8} Anemia is a hematic disorder in which hemoglobin (Hb) levels are under normal values determined by a large and diverse global population.^{9,10} Anemia is a global public health problem that affects 60% of the population in low, and middle-income countries.⁹

Electrolytes such as potassium (K^+), sodium (Na^+), chloride (Cl^-), and bicarbonate (HCO_3^-) comprise approximately 1% of the plasma in the circulatory system. They play a central role in blood clotting. The electrolytes balance is essential for maintaining the RBC's shape and function and exchanging O_2/CO_2 between RBC and tissues.^{11,12} Moreover, the channels of calcium (Ca^{2+})-sensitive potassium (K^+) regulate RBC apoptosis. Sodium potassium ATPase (Na-K ATPase) regulates intracellular and extracellular RBC cationic homeostasis by binding to the cell membrane.^{11,13,14} Na-K ATPase-bound membrane plays a vital role in maintaining the circulatory system by modifying membrane proteins, leading to the exchange of two ions of K^+ with three ions of Na^+ ,^{11,14} which directly affects the serum K^+ and Na^+ .^{11,15} Nonetheless, there is little data on the association between RBC indices and electrolyte levels. The study objective was to study the correlation between RBC indices and electrolyte levels in anemia, Ibb City, Yemen.

Materials and Methods

Study Population

The population source consisted of 200 anemic patients (cases) and 200 healthy persons (control) who visited several hospitals in Ibb City, Yemen (26th July 2023 to 30th March 2024). The healthy control group was selected to match the cases in terms of gender, and the clinical baseline for both cases and controls remained homogeneous and free from confounding comorbidities. A multicenter prospective case-control study conducted in these hospitals: Al-Thaurah General Hospital, Al-Manar Hospital, Al-Noor Hospital, Al-Badr Hospital, Al-Hekma Specialized Clinic, Saeed Thabet Nasher Specialized Centre and Dr. Fares Almareh Medical Centre. Anemic patients were newly diagnosed anemic treatment-naïve patients and evaluated based on Hb values (Hb < 12 g% in females and < 13 g% in males) according to the World Health Organization (WHO) definition.^{12,14}

Participants were assessed physically by physicians, and a medical questionnaire was administered to both study groups to detect exclusion criteria. These criteria included diseases of the heart, liver, and kidneys, as well as fever, diarrhea, vomiting, diabetes, bleeding disorders, allergic conditions, skin rashes, high blood pressure, edema, inflammatory disorders (such as tonsillitis, arthritis, or appendicitis). Additionally, individuals taking aspirin or medications for diuretics, hypertension, or diabetes, as well as those who had received or been transfused blood within the last 12 months, were also excluded. For women, the exclusions included those who were pregnant, breastfeeding, experiencing a miscarriage, menstruating, or had menstruation lasting more than seven days.

Sampling Methods

Participants were interviewed using a questionnaire translated into Arabic, the native language of Yemen. The collected data included participant number, age, weight, gender, residence, education status, socioeconomic status, and other relevant information. Approximately 5 mL of blood was collected from anemic patients and healthy individuals, then divided into two tubes: 2.5 mL was mixed with anticoagulant (EDTA-K3) (Jiangsu Xinkang Medical Instrument Co., Ltd, Jiangsu, China) for the measurement of red blood cell (RBC) indices directly, while the remaining 2.5 mL was placed in test tubes without anticoagulant, and then the serum was isolated directly by centrifugation and analysis of electrolytes (Na^+ , Ca^{2+} , Mg^{2+} , K^+ , and Cl^-).

RBC Indices Tests

RBC indices tests were performed using the DF52 Dymind fully automatic hematological analyzer (Dymind Biotech Co., LTD, Shenzhen, China). A total of 15 μ L of whole blood sample with EDTA was aspirated into the open vial of the analyzer. The indices measured included hemoglobin (Hb) level, red blood cell (RBC) count, packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC).

Electrolyte Test

The blood sample was coagulated at room temperature, then centrifuged for 5 minutes at 3500 rpm to separate the serum. Electrolyte levels, including Na^+ , Ca^{2+} , K^{2+} , and Cl^- were measured using ion-selective electrode technology by the GE300 Genrui Electrolyte Analyzer (Genrui Biotech Inc., Shenzhen, China). The serum magnesium (Mg^{2+}) level was determined using flame atomic absorption photometry (Quimica Clinica Aplicada S.A., Amposta, Spain). The reference limit ranges for the electrolytes are as follows: Na^+ : 135–148 mmol/L, Mg^{2+} : 0.78–1.03 mmol/L, K^{2+} : 3.5–5.3 mmol/L, Ca^{2+} : 2.15–2.55 mmol/L, and Cl^- : 98–107 mmol/L. Electrolyte values below and higher than the limit were classified as hypo-electrolytemia, hyper-electrolytemia, respectively.

Data Analysis

The obtained data were recorded in Microsoft Excel spreadsheet, and statistical analyses were performed using GraphPad Prism version 8.0.1 (GraphPad Inc., USA). ROUT (Q=1%) method was used to identify outlier values. Kolmogorov–Smirnov and Shapiro–Wilk normality tests and skewness were conducted to check the normality of continuous variables. Mann–Whitney *U*-tests for abnormally distributed data were applied to determine the difference in medians. Unpaired *t*-tests were applied to compare means. The associations between electrolyte imbalance and anemia were detected using odds ratio (OR) with 95% Confidence Interval (CI), while Fisher's exact test was used to detect statistically significant associations. Pearson's coefficient was estimated to demonstrate a correlation between two variables. *P* values ≤ 0.05 were considered statistically significant.

Results

Sociodemographic Characteristics

This study included 200 anemic patients and 200 healthy individuals as control groups. This study included 200 anemic patients and 200 healthy individuals as control groups. Of the anemic patient group, 54 (27%) ranged from 1 year to 10 years, 49 (24.50%) were aged 11–20 years, 41 (20.50%) were aged 21–30 years, 30 (15%) were aged 31–40 years, 16 (8%) were aged 41–50 years and 10 (5%) were aged >50 years. Of the healthy control group, 34 (17%) were aged 1–10 years, 56 (23%) were aged 11–20 years, 67 (33.5%) were aged (21–30 years), 29 (14.5%) were aged 31–40 years, 9 (4.5%) were aged 41–50 years and 5 (2.5%) were aged >50 years. Regarding the weight, 51 (25.5%), 42 (21%), 75 (37.5%), and 32 (16%) of anemic patients were weighed 5–20 kgs, 21–40 kgs, 41–60 kgs, and >60 kgs, respectively. Moreover, 22 (11%), 38 (19%), 89 (44.5%), and 51 (25.5%) of the control group were weighed 5–20 kgs, 21–40 kgs, 41–60 kgs, and >60 kgs, respectively. Concerning gender, the anemic group comprised 95 females (47.5%) and 105 males (52.5%), while the control group included 99 females (49.5%) and 101 males (50.5%). Regarding residence, 124 participants (62%) from the anemic group resided in urban areas, while 76 (38%) were resided in rural areas. In control group, 183 participants (91.5%) were urban, and 17 (8.5%) resided in rural areas. Likewise, based on the daily behaviors, 7 (3.5%), 7 (3.7%), and 76 (38%) of anemic participants had smoking, tobacco chewing, and qat chewing habits. In comparison, 16 (8%), 3 (1.5%), and 75 (37.5%) of control participants had smoking, tobacco chewing, and qat chewing habits. Based on educational status, 74 (37%) and 78 (39%) of the anemic and control participants had a primary school level, respectively (Table 1). The analysis revealed significant differences in weight, residence, educational status, and smoking habits between the two groups.

Comparison of RBC Indices Between Anemic Group and Control Group

As illustrated in Table 2, the investigation revealed significant declines in Hb, RBC, MCV, HCT, MCH, and MCHC indices among anemic patients compared to healthy controls. The mean and SD of Hb, RBC, MCV, HCT, MCH, and MCHC in anemic patients were 8.369 ± 1.888 , 3.365 ± 1.034 , 77.36 ± 11.40 , 25.89 ± 6.082 , 25.63 ± 4.764 , and 32.84 ± 2.278 , respectively. Additionally, the mean and SD of Hb, RBC, MCV, HCT, MCH, and MCHC among the control group were 13.79 ± 1.733 , 5.020 ± 0.6822 , 82.97 ± 5.937 , 41.46 ± 5.262 , 27.83 ± 1.994 , and 33.32 ± 1.384 , respectively.

Table 1 Sociodemographic Characteristics of Participants

Variables		Study Participants (n=400)		p-value
		Anemic Group (Total No. 200 (%))	Control Group (Total No. 200 (%))	
Age	1–10 years	54 (27)	34 (17)	0.596
	11–20 years	49 (24.50)	56 (23)	
	21–30 years	41 (20.50)	67 (33.5)	
	31–40 years	30 (15)	29 (14.5)	
	41–50 years	16 (8)	9 (4.5)	
	>50 years	10 (5)	5 (2.5)	
Weight (Kgs)	5–20	51 (25.5)	22 (11)	<0.0001
	21–40	42 (21)	38 (19)	
	41–60	75 (37.5)	89 (44.5)	
	>60	32 (16)	51 (25.5)	
Gender	Male	105 (52.5)	101 (50.5)	0.839
	Female	95 (47.5)	99 (49.5)	
Residence	Urban	124 (62)	183 (91.5)	<0.0001
	Rural	76 (38)	17 (8.5)	
Education level	No formal education	64 (32)	22 (11)	<0.0001
	Primary school	74 (37)	78 (39)	
	Secondary school	43 (21.5)	39 (19.5)	
	University	19 (9.5)	61 (30.5)	
Employment status	Housewife	45 (22.5)	22 (11)	0.611
	Employed	20 (10)	57 (28.5)	
	Unemployed	135 (67.5)	121 (60.5)	
Smoking	Yes	7 (3.5)	16 (8)	0.041
	No	193 (96.5)	184 (92)	
Tobacco chewing	Yes	7 (3.5)	3 (1.5)	0.168
	No	193 (96.5)	197 (98.5)	
Qat chewing	Yes	76 (38)	75 (37.5)	0.549
	No	124 (62)	125 (62.5)	

Comparison of Electrolyte Level Among Anemic and Control Groups

In anemic patients, the median and SD of sodium, potassium, chloride, calcium, and magnesium were 136.0 ± 5.914 , 3.819 ± 0.4587 , 106.3 ± 4.886 , 2.018 ± 0.1853 , and 1.896 ± 0.4904 , respectively. Median and SD of sodium, potassium, chloride, calcium, and magnesium were 136.8 ± 4.723 , 3.937 ± 0.4392 , 104.7 ± 4.677 , 2.117 ± 0.1701 , and 1.991 ± 0.3575 in the control group, respectively. Potassium, calcium, and magnesium were significantly lower in the anemic group

Table 2 Comparison of RBC Indices Between Anemic Group and Control Group

RBC Indices	Anemic Group (Mean ± SD)	Control GROUP (Mean ± SD)	p-value
Hb (g/dL)	8.369 ± 1.888	13.79 ± 1.733	<0.0001
RBC ($\times 10^{12}/L$)	3.365 ± 1.034	5.020 ± 0.6822	<0.0001
MCV (fL)	77.36 ± 11.40	82.97 ± 5.937	<0.0001
HCT (%)	25.89 ± 6.082	41.46 ± 5.262	<0.0001
MCH (pg)	25.63 ± 4.764	27.83 ± 1.994	<0.0001
MCHC (g/dL)	32.84 ± 2.278	33.32 ± 1.384	0.0116

Abbreviations: Hb, hemoglobin; RBC, red blood cell; PCV, packed cell volume; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration.

compared to the control group. However, the chloride was significantly higher in the anemic group, while sodium levels did not show a significant difference between the two groups (Table 3).

Association of Electrolyte Imbalance with Anemia

The outcomes in Table 4 revealed that the odds ratio (OR) were showed a strong association of hypo-electrolytemia with anemia, including hypo-magnesemia (OR=4.928, 95% CI: 2.278–10.47), hypo-kalemia (OR=2.967, 95% CI: 1.551–5.581), and hypo-calcemia (OR=2.833, 95% CI: 1.887–4.236), which was significantly higher in anemic patients

Table 3 Comparison of Electrolyte Level Among Anemic and Control Groups

Variable	Anemic Groups (Median ± SD)	Control Groups (Median ± SD)	p-value
Sodium (Na^+) mmol/L	136.0 ± 5.914	136.8 ± 4.723	0.1987
Potassium (K^+) mmol/L	3.819 ± 0.4587	3.937 ± 0.4392	0.0442
Chloride (Cl^-) mmol/L	106.3 ± 4.886	104.7 ± 4.677	0.0009
Calcium (Ca^{2+}) mmol/L	2.018 ± 0.1853	2.117 ± 0.1701	<0.0001
Magnesium (Mg^{2+}) mmol/L	1.896 ± 0.4904	1.991 ± 0.3575	0.0096

Table 4 Association of Electrolyte Imbalance with Anemia

Electrolytes	Categories	Anemic Groups (No.=200)	Control Groups (No.=200)	Odd Ratio (OR)	95% CI	P-value
		No. (%)	No. (%)			
Sodium (Na^+) mmol/L	Normonatremia	117 (58.5)	135 (67.5)	1.00	–	–
	Hyponatremia	81 (40.5)	65 (32.5)	1.438	0.9522–2.143	0.0961
	Hypernatremia	2 (1)	0 (0)	∞	0.5262– ∞	0.2185
Potassium (K^+) mmol/L	Normokalemia	163 (81.5)	183 (91.5)	1.00	–	–
	Hypokalemia	37 (18.5)	14 (7)	2.967	1.551–5.581	0.0008
	Hyperkalemia	0	3 (1.5)	0.000	0.000–1.311	0.2511

(Continued)

Table 4 (Continued).

Electrolytes	Categories	Anemic Groups (No.=200)	Control Groups (No.=200)	Odd Ratio (OR)	95% CI	P-value
		No. (%)	No. (%)			
Chloride (Cl⁻) mmol/L	Normochloremia	140 (70)	158 (79)	1.00	–	–
	Hypochloremia	1 (0.5)	1 (0.5)	1.129	0.059–21.56	>0.9999
	Hyperchloremia	59 (29.5)	42 (20.5)	1.585	1.007–2.476	0.0508
Calcium (Ca²⁺) mmol/L	Normocalcemia	62 (31)	112 (56)	1.00	–	–
	Hypocalcemia	138 (69)	88 (44)	2.833	1.887–4.236	<0.0001
Magnesium (Mg²⁺) mmol/L	Normomagnesemia	149 (74.5)	178 (89)	1.00	–	–
	Hypomagnesemia	33 (16.5)	8 (4)	4.928	2.278–10.47	<0.0001
	Hypermagnesemia	18 (9)	14 (7)	1.536	0.7678–3.278	0.2695

compared to controls. In contrast, the OR of hyponatremia did not show a significant difference between the two groups (OR =1.438, 95% CI: 0.9522–2.143). Nonetheless, hyper-electrolytemia did not demonstrate a significant difference between anemic patients and healthy controls in hyper-kalemia (OR=0000, 95% CI: 0.000–1.311), hyper-chloremia (OR=1.585, 95% CI: 1.007–2.476), and hyper-magnesemia (OR=1.536, 95% CI: 0.7678–3.278). Notably, hyper-natremia was identified in the patient group, with no existence in controls, resulting in an infinite odds ratio (OR= ∞ , 95% CI: 0.5262– ∞).

Correlation of RBC Indices and Electrolytes Levels Among Anemic and Control Groups

In the anemic patients, Na⁺ showed positive correlations with Hb ($r=0.2219$, $P=0.0017$), RBC ($r=0.1483$, $P=0.0375$), and HCT ($r=0.2114$, $P=0.0029$). Ca²⁺ has positive correlations with Hb ($r=0.2076$, $P=0.0035$), RBC ($r=0.2320$, $P=0.0011$), and HCT ($r=0.1803$, $P=0.0119$), while it has a negative correlation with MCV ($r=-0.1397$, $P=0.0500$). Likewise, Mg²⁺ showed positive correlations with MCV ($r=0.1946$, $P=0.0059$) and MCH ($r=0.1865$, $P=0.0082$), and a negative correlation with RBC ($r=-0.1936$, $P=0.0061$). Cl⁻ was only shown a negative correlation with Hb ($r=-0.1366$, $P=0.0500$). Furthermore, K⁺ did not show a correlation with RBC indices.

In the control group, though there was no significant correlation between K⁺ and Mg²⁺ levels and RBC indices (Hb, RBC, MCV, HCT, MCH, and MCHC), as presented in Table 5, Na⁺ showed positive correlations with MCV ($r=0.1731$, $P=0.0143$), Cl⁻ showed a negative correlation with MCV ($r=-0.1478$, $P=0.0368$), and Ca²⁺ showed negative correlations with MCHC ($r=-0.1440$, $P=0.0419$).

Discussion

Electrolyte imbalances and anemia are common issues. Many studies indicated an association between electrolyte and anemia, particularly iron deficiency anemia.^{11,14,15} Anemia is a vital public health concern; the association between electrolyte imbalances and anemia is of interest. However, published studies addressing electrolyte changes in anemic patients are inconsistent. Some studies indicate that electrolyte levels in patients with iron deficiency anemia are higher than those in healthy controls, while other studies show lower electrolyte levels in iron deficiency anemia.^{14,16–18}

This current study assessed the correlation between RBC indices and electrolyte levels in patients with anemia compared to healthy people without anemia. The fact that red blood cell indices (Hb, RBC, MCV, HCT, MCH, and MCHC) were significantly lower in anemic patients compared to healthy individuals, which coincides with studies

Table 5 Correlation Between RBC Indices and Electrolytes Levels Among Anemic and Control Group

Group	Electrolyte	Hb		RBC		HCT		MCV		MCH		MCHC	
		<i>r</i>	<i>P</i> value	<i>r</i>	<i>P</i> value	<i>r</i>	<i>P</i> value	<i>r</i>	<i>P</i> value	<i>r</i>	<i>P</i> value	<i>r</i>	<i>P</i> value
Anemic	Na ⁺	0.2219	0.0017	0.1483	0.0375	0.2114	0.0029	0.00783	0.9130	−0.0216	0.7619	−0.0030	0.9669
	K ⁺	−0.02065	0.7722	−0.0227	0.7506	−0.0159	0.8243	0.03039	0.6709	0.02667	0.7085	0.01379	0.8483
	Cl [−]	−0.1366	0.0500	−0.1033	0.1485	−0.1074	0.1341	0.03769	0.5990	0.01355	0.8497	0.01990	0.7830
	Ca ²⁺	0.2076	0.0035	0.2320	0.0011	0.1803	0.0119	−0.1397	0.0500	−0.0819	0.2537	−0.0269	0.7108
	Mg ²⁺	−0.07332	0.3022	−0.1936	0.0061	−0.1024	0.1512	0.1946	0.0059	0.1865	0.0082	0.06946	0.3334
Control	Na ⁺	−0.04189	0.5559	−0.1003	0.1575	0.01191	0.8671	0.1731	0.0143	0.1185	0.0947	−0.0303	0.6694
	K ⁺	0.06245	0.3797	0.1022	0.1498	0.06669	0.3481	0.0195	0.7834	−0.0875	0.2177	−0.0089	0.9035
	Cl [−]	−0.003904	0.9563	−0.0025	0.9717	−0.1095	0.1227	−0.1478	0.0368	−0.0152	0.8309	0.1121	0.1141
	Ca ²⁺	−0.03971	0.5766	0.05401	0.4475	0.08253	0.2453	−0.0651	0.3595	−0.1271	0.0728	−0.1440	0.0419
	Mg ²⁺	0.03460	0.6267	0.01248	0.8607	−0.0026	0.9708	0.01023	0.8857	0.01959	0.7830	0.01358	0.8486

Abbreviations: Na⁺, sodium; K⁺, potassium; Cl[−], chloride; Ca²⁺, calcium; Mg²⁺, magnesium.

conducted by Rajagopal¹⁴ and Jundi.¹⁹ A study carried out in Xi'an, China, was showed similar results to this study in Hb, RBC, HCT, MCH, and MCHC.²⁰ Levels of Mg^{2+} , K^{+} and Ca^{2+} were significantly lower in anemic patients, consistent with the K^{+} level reported by Ashraf,²¹ Rajagopal¹⁴ and Abbas.²² Na^{+} levels were decreased without a significant difference, in contrast to the results of Mansoor,²³ Rafiq,¹¹ Rajagopal¹⁴ and Nnaji.²⁴ Additionally, the Cl^{-} levels were significantly higher in anemic patients, in accordance with results of Mansoor,²³ Rafiq,¹¹ Rajagopal¹⁴ and Nnaji.²⁴ The disparity may be due to the differences in the selection and sociodemographic factors of participants.^{6,8} The electrolyte imbalance in anemic patients were hypo-magnesemia, hypo-kalemia, and hypocalcemia, with odds ratios (OR) of 4.928 (95% CI: 2.278–10.47), 2.967 (95% CI: 1.551–5.581), and 2.833 (95% CI: 1.887–4.236), respectively. Additionally, in anemic group, the results showed a positive significant correlation between Na^{+} levels with Hb, RBC, and HCT, which is similar to the results of Rajagopal in Hb, RBC and HCT and disagrees with the same study in MCH, and MCHC.¹⁴ Moreover, there was a negative significant correlation between Cl^{-} levels with Hb, which corresponds to the result of study conducted by Rajagopal and et al.¹⁴ The results showed no significant correlation between K^{+} levels with RBC indices, which does not coincide with the results of Rajagopal¹⁴ and Agoreyo and Nwanzen.²⁵ The electrolyte imbalance might be associated with altered membrane integrity of RBC, leading to abnormally high red cell permeability. This leads to an efflux of K^{+} from the cell, and an influx of Na^{+} causes red cell dehydration.²⁴ Potassium chloride (K-Cl cotransport) is activated abnormally to cause dehydration due to loss of free K^{+} .^{11,26} The K-Cl co-transport is one of the ways through which K^{+} is lost, which is abnormally activated by low intracellular Mg^{2+} .²⁴ Likewise, deoxygenation in anemia is known to elevate the permeability of Na^{+} , K^{+} and Ca^{2+} through the RBC membrane.^{11,27,28} Erythrocyte Ca^{2+} levels may play a role in Cl^{-} homeostasis.^{29,30} The Ca^{2+} -sensitive K^{+} channels regulate the erythrocyte apoptosis process.^{12,14}

Conclusion

The study concluded a significant disparity in serum electrolytes, particularly Ca^{2+} , K^{+} , Mg^{2+} and Cl^{-} levels, between individuals with and without anemia. Furthermore, there were positive correlations between Na^{+} and Ca^{2+} levels with Hb, RBC, and HCT and between Mg^{2+} levels with MCV and MCH. This study also concludes that RBC indices, including Hb, RBC, MCV, HCT, MCH and MCHC were significantly lower in anemic patients compared to non-anemic individuals. The study's limitation included evaluating electrolyte levels in anemic patients without identifying the specific types of anemia. The relationship between RBC indices and electrolytes in specialized diseases, such as cardiac or rheumatic diseases, was also not considered. It is due to the lack of differential tests, which are expensive, and the absence of funding sources. Additionally, the study did not assess electrolyte levels before and after treatment due to difficulties tracking patients. Furthermore, we recommend prospective research on the correlation of RBC indices and electrolytes in specific populations, such as societies with high rates of consanguineous marriage.

Abbreviations

Na^{+} , sodium; K^{+} , potassium; Cl^{-} , chloride; Ca^{2+} , calcium and Mg^{2+} , magnesium; g/dl, gram per deciliter; fl, femtoliter; pg, picogram; RVs, reference values; Hb, Hemoglobin; RBC, red blood cells; HCT, hematocrit; MCV, mean cell volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration.

Data Sharing Statement

The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available because they contain information that can compromise the privacy of the research participants.

Ethical Considerations

Ethical consent for this research was granted by the Medical Laboratories Department at the Faculty of Medical Sciences, Al-Jazeera University, following the proper procedures (Reference Number: MDLMSJU/0A1/2023, dated July 26, 2023). The Ethics Research Committee follows the principles of the Helsinki Declaration to protect human subjects. All participants were informed about the study and provided their consent before enrollment. For participants under 18

years, parent's informed consent was obtained before participation. Additionally, consent to use the survey data was also secured. The paper did not use AI.

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, data acquisition, analysis, and interpretation, or in all these areas; they participated in drafting, revising, or critically reviewing the article. Final approval was given for publication; all authors have agreed to the journal to which the article has been submitted and agreed to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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