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RESEARCH ARTICLE

Hematological, Biochemical, and Inflammatory Markers in Patients Suffering from SARS-CoV-2 in Kassala, Sudan: A Cross-Sectional Hospital-Based Study

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ABSTRACT

Introduction: **Sudan faces the impact of SARS-CoV-2, emphasizing the urgency of timely detection and effective management. This study, conducted in Kassala, Sudan, aimed to evaluate key hematological, biochemical, and inflammatory markers in confirmed and suspected COVID-19 patients.**

Methodology: **A cross-sectional hospital investigation was carried out in Kassala State, eastern Sudan, spanning from September 2020 to January 2021. Clinical and sociodemographic data were collected from individuals suspected of having COVID-19 using a structured questionnaire. Nasopharyngeal swab was targeted for the detection of SARS-CoV-2 while a blood sample was processed for haematological and biochemical parameters.**

Results: **The study included 371 participants, revealing a prevalence of COVID-19 PCR positive of 61.7% (229/371). In particular, most were male (65%), with a mean age of 42.9 ± 19.9 years. A substantial case fatality rate of 15.7% (36/229) was observed, predominantly among people 60 years and older ($P < 0.001$). RT-PCR-confirmed patients exhibited significant associations with elevated erythrocyte sedimentation rate, C-reactive protein levels, prolonged Prothrombin time, extended partial thrombin time, leucocytosis, neutrophilia, lymphopenia and hypocalcemia ($P < 0.000$).**

Conclusion: **This study illuminates the impact of COVID-19 on crucial hematological, renal electrolyte, inflammatory, and coagulation markers. These findings have the potential to enhance patient outcomes and reduce mortality rates by guiding informed actions and shaping public health policies.**

Keywords: Biomarkers, COVID-19, Inflammatory Markers, Sudan.

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1. Introduction

SARS-CoV-2, is a respiratory pathogen that causes corona virus disease 2019 (COVID-19) and it remains a public health concern (Global: deaths 6,955,141; cases 769,774,646; Africa 175,421 deaths; 9,546,789 cases (https://covid19.who.int/) [1]. Clinically it causes pneumonia and respiratory complications, and the common symptoms during manifestation of the disease include, fever, cough, headache, and fatigue [2], [3]. However, these symptoms can swiftly turn into shortness of breath, acute respiratory distress syndrome, cardiac damage, septic shock, multi-organ failure, and death [4].

The mortality from COVID-19 is higher in people 65 years of age and older, and in people with underlying comorbidity, such as chronic lung disorders, cardiac diseases, hypertension, and diabetes [5], [6]. Moreover, health workers are more vulnerable to COVID-19 infection for instance health workers and people living in conflict areas and high poverty levels [7].

Recent studies have shown how crucial it is to identify reliable laboratory biomarkers relevant to the progression of COVID-19. For illustration, Alsafi *et al*., revealed that variations in D-dimer, white blood cells (WBC), neutrophils, ferritin, C-reactive protein (CRP), lactate dehydrogenase (LDH), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were more elevated in patients admitted to the ICU compared to non-ICU COVID-19 patients [8].

The identification of reliable biomarkers offers the opportunity to assess the severity of SARS-CoV-2 infection as well as cellular and organ damage. The clinical monitoring of COVID-19 would also greatly benefit from the accuracy and dependability of such biomarkers, which would make it easier to group patients into risk cohorts after a diagnosis. In turn, this segmentation would make it easier to intervene quickly, prevent the development of serious consequences, and allocate medical resources as efficiently as possible [9], [10]. In a similar study, we recorded a high COVID-19 mortality rate in the study area, especially when compared to neighboring countries such as Ethiopia [11].

The main goal of this study was to thoroughly examine the various biomarkers associated with COVID-19, with an emphasis on their potential value as diagnostic markers and indicators of disease severity within the context of COVID-19. Three unique categories of laboratory biomarkers—haematological, biochemical, and inflammatory biomarkers—were meticulously analyzed as part of the current investigation.

2. Methods

2.1. Study Design and Settings

This was a cross-sectional hospital-based study, conducted during the COVID-19 pandemic period in Kassala Eastern Sudan. Participated subjects were COVID-19 patients who attended the isolation center of Kassala Hospital. This study was approved by Faculty of Medical Laboratory Sciences, University of Gezira, Sudan. Demographic data and clinical information of COVID-19 patients were obtained through a structured questionnaire including age, occupation, residence, educational level, contact tracing, symptoms, signs, and underlying diseases.

2.2. Samples

Nasopharyngeal swabs specimens were collected from suspected cases, and transported into a viral transport medium (VTM) for viral RNA extraction while blood specimen was collected in EDTA, lithium heparin, and sodium citrate anticoagulant anticoagulant containers.

2.3. Hematological, Biochemical, and Inflammatory Markers Analysis

Complete blood count, bleeding profiles, C-reactive protein level, and renal function tests were accomplished using Mindray BC30 Auto Hematology Analyzer, Coatron M1 Coagulation Analyzer, Fluorescence immunochromatographic analysing system and Spectrophotometer Mindray BA-88A & Ion Selective Electrode, Medica Easylyte respectively.

2.4. RNA Extraction and the Molecular Detection of SARS-CoV-2

The viral RNA was extracted using Da An Gene RNA extraction kits according to the manufacturer's instructions (Da An Gene Co., Ltd., China). In brief, a mixture of 50 µl proteinase K, 200 µl VTM, 200 µl lysis buffer, and 4 µl carrier RNA was prepared and incubated at 72 °C C for 10 minutes. 250 µl of absolute ethanol was added. Centrifugation was performed to accomplish washing several times by using an inhibitor remover solution. Elution of RNA was done in 50 µl of preheated elution buffer. Storage was obtained in deep-freezing at −80 °C.

A real-time PCR protocol for the rapid SARS-Cov-2 detection was followed according to the manufacturer's instructions (Da An Gene Co., Ltd. China).

2.5. Data Analysis

The retrieved data were exported to IBM SPSS V.26.0 and STATA V.12.0 (STATA Corporation, College Station, Texas, USA), where they were processed for analysis. Descriptive statistics for categorical variables were analysed using the chi-square (χ^2) or Fisher's exact test and summarized using frequency and percentage. Depending on the data distribution, quantitative data were summarized using mean (±SD) or median (IQR). Suitable parametric or non-parametric statistics were used to evaluate differences. Incidence of attrition was calculated per 1000 person-months (95% CI). All p-values were two-tailed and p-values of <0.05 were considered statistically significant.

3. Results

In total 371 COVID-19 suspected cases were recruited. The prevalence of RT-PCR COVID-19 positive cases during the study period were 61.7% (229/371). Participants

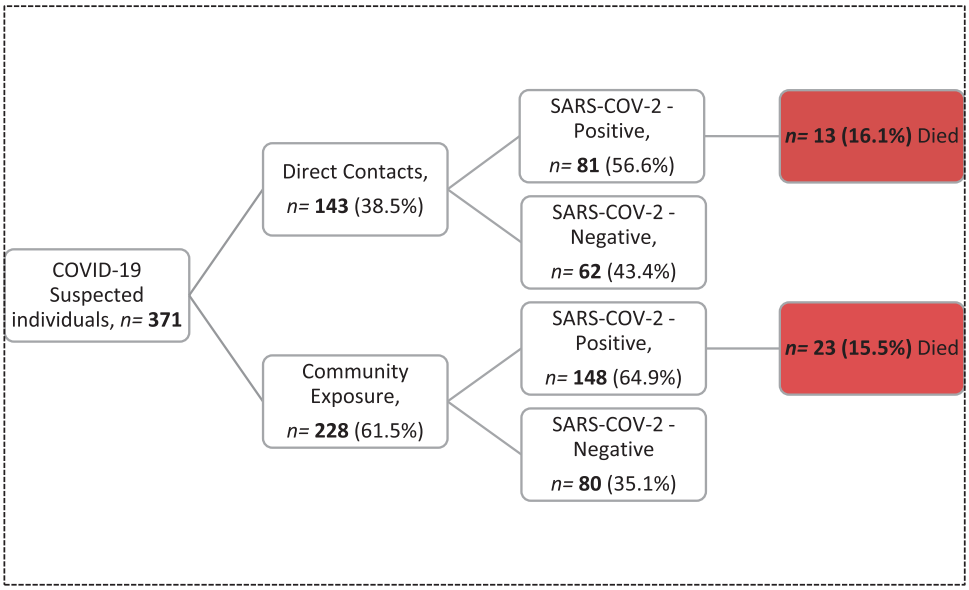

Fig. 1. Flow diagram.

were (65.0% male vs. 35.0% female). Their mean ± SD age was 42.9 ± 19.9 (Fig. 1).

The study found that age was significantly associated with COVID-19 infection status, with positive patients younger (median age of 36 [27–60]) compared to negative patients (median age 68.7 [60.5–80.5]). Additionally, sex was found to be significantly associated with COVID-19 infection status, with a higher proportion of males (67.9%) testing positive compared to females (32.1%).

The level was also found to be significantly associated with COVID-19 infection status, with a higher proportion of patients with tertiary education (49.7%) testing positive compared to those without formal education (15.5%) or primary education (20.2%). The presence of symptoms was significantly associated with COVID-19 infection status, with a higher proportion of patients reporting positive symptoms (94.8%) compared to those who did not report symptoms (5.2%).

In terms of chronic diseases, diabetes was found to be significantly associated with infection status, with a higher proportion of patients with diabetes who were positive (91.1%) compared to those without diabetes (8.9%). Hypertension, chronic kidney disease, congestive heart failure, asthma, epilepsy, tuberculosis, and systemic lupus erythematosus were also significantly associated with COVID-19 infection status.

3.1. Baseline and Sociodemographic Characteristics

The study investigated the sociodemographic and clinical characteristics of COVID-19 infected individuals in Sudan, with a focus on comparing those who died with those who recovered. Of the total COVID-19 positive patients, 36 (15.9%) died while 193 (84.8%) recovered.

Age was found to be significantly associated with the outcome of COVID-19, with patients who died significantly younger than those who recovered. The median age of the patients who died was 42 [28–69], which was significantly younger than the median age of the patients who recovered (60.5 [50–72]). This finding is consistent with previous studies that have reported higher mortality rates among younger patients with COVID-19. Gender was not found to be significantly associated with COVID-19 outcomes, with no significant difference between the proportion of males and females who died or recovered. This finding is consistent with previous studies that have reported similar mortality rates among males and females.

In terms of address, there was no significant difference between the proportion of patients from urban or rural areas who died or recovered. This finding suggests that COVID-19 affects both urban and rural populations in Sudan in a similar way.

However, the level of education was found to be significantly associated with the outcome of COVID-19. Patients without formal education or primary education were more likely to die from COVID-19 compared to those with tertiary education. Specifically, 36.1% of patients with no formal education and 36.1% of patients with primary education died from COVID-19, while only 19.4% of patients with tertiary education died from the disease. This finding highlights the importance of education in promoting health literacy and adopting preventive measures against COVID-19. In terms of clinical characteristics, the study found that diabetes was significantly associated with the outcome of COVID-19, with a higher proportion of patients with diabetes dying of the disease compared to those without diabetes. Specifically, 91.1% of patients with diabetes died from COVID-19, while only 8.9% of patients without diabetes died from the disease. Hypertension, chronic kidney disease, congestive heart failure, asthma, epilepsy, tuberculosis, and systemic lupus erythematosus were also significantly associated with the outcome of COVID-19 (Table I).

3.2. Laboratory Measures of the Participants

As shown in (Table II) and (Fig. 2):

3.3. Hematologic Parameters

The study found that COVID-19 positive patients had significantly lower lymphocyte counts compared to

TABLE I: Baseline and Sociodemographic Characteristics

Characteristics	COVID-19 positive *n (%)*			COVID-19 negative *n (%)*	p-value (χ^2)	Total
	Recovered	Dead	Total			
Age	36 [27–60]	68.7 [60.5–80.5]	42 [28–69]	29 [25–42]	<0.001[a,d]	35 [27–60]
Gender						
Male	131 (67.9)	28 (77.8)	159 (69.4)	82 (57.7)	0.022 (5.3)[b]	241 (65)
Female	62 (32.1)	8 (22.2)	70 (3.6)	60 (42.3)		130 (35)
Address						
Urban	175 (90.7)	32 (88.9)	207 (90.4)	125 (88)	0.5 (0.5)[b]	332 (89.5)
Rural	18 (9.3)	4 (11.1)	22 (9.6)	17 (12)		39 (10.5)
Educational level						
No formal education	30 (15.5)	13 (36.1)	43 (18.8)	13 (9.2)	<0.001 (21.55[b], 17.3[e])[b,e]	56 15.1
Primary level	39 (20.2)	13 (36.1)	52 (22.7)	15 (10.6)		67 18.1
Secondary level	28 (14.5)	3 (8.3)	31 (13.5)	17 (12.0)		48 12.9
Tertiary level	96 (49.7)	7 (19.4)	103 (45.0)	97 (68.3)		200 53.9
Presence of symptom						
Yes	183 (94.8)	33 (91.7)	216 (94.3)	120 (84.5)	0.002 (9.8)[b]	336 90.6
No	10 (5.2)	3 (8.3)	13 (5.7)	22 (15.5)		35 9.4
Contact tracing						
Direct contact	68 (35.2)	13 (36.2)	81 (35.4)	62 (43.7)	0.13[c]	143 38.5
Community Exposure	125 (64.8)	23 (63.9)	148 (64.6)	80 (56.3)		228 61.5
Chronic illnesses						
Diabetes	113 (91.1)	28 (93.3)	141 (91.6)	1 (5.9)	<0.001 (137.4)[b]	142
Hypertension	8 (6.5)	5 (16.7)	13 (8.4)	1 (5.9)	0.02[c]	14
CKD	6 (4.8)	8 (26.7)	14 (9.1)	1 (5.9)	0.012[c]	15
CHF	1 (0.8)	0	1 (0.6)	0	1[c]	1
Asthma	17 (13.7)	4 (13.3)	21 (13.6)	13 (76.5)	1[c]	34
Epilepsy	9 (7.3)	3 (10)	12 (7.8)	1 (5.9)	0.02[c]	13
TB	5 (4)	8 (26.7)	13 (8.4	1 (5.9)	0.02[c]	14
SLE	0	1 (3.3)	1 (0.6)	0	1[c]	1

Note: Abbreviations: CKD—Chronic Kidney Diseases, CHF—Congestive Heart Failure, TB—Tuberculosis, and SLE—Systemic Lupus Erythematous.

Superscripts: a—Independent Mann-Whitney U-test between COVID-19 positive and negative patients, b—Chi-square test between COVID-19 positive and negative patients, c—Fisher's Exact Test between COVID-19 positive and negative patients, d—Independent Mann-Whitney U-test between COVID-19 positive recovered and dead patients. e—Chi-square test between COVID-19 positive recovered and dead patients.

COVID-19 negative patients. The mean lymphocyte count in COVID-19 positive patients who recovered was 13.9 ± 7.3, with a median of 13.7 [9.3–16.9], while the mean lymphocyte count in COVID-19 negative patients was 11.2 ± 7.6, with a median of 10.7 [6–14.9]. The difference was statistically significant ($p < 0.001$). Similarly, neutrophil counts were significantly higher in COVID-19 positive patients who died compared to those who recovered. The mean neutrophil count in COVID-19 positive patients who died was 77.9 ± 9.4, with a median of 79.9 [74.7–82.8], while the mean neutrophil count in COVID-19 positive patients who recovered was 78.4 ± 9.4, with a median of 79.9 [74.7–82.8]. The difference was statistically significant ($p < 0.001$).

3.4. Renal Electrolytes Parameters

The study found that COVID-19 positive patients had significantly higher levels of BUN and creatinine compared to COVID-19 negative patients. The mean level of BUN in COVID-19 positive patients who recovered was 5.6 ± 2.5, with a median of 5 [4–7], while the mean BUN level in COVID-19 negative patients was 4.1 ± 1.3, with a median of 4 [3–5]. The difference was statistically significant ($p < 0.001$). Similarly, the mean creatinine level in COVID-19 positive patients who recovered was 70 ± 12.6, with a median of 68 [60–80], while the mean creatinine level in COVID-19 negative patients was 61 ± 11.1, with a median of 60 [50–70]. The difference was statistically significant ($p < 0.001$).

3.5. Inflammatory Parameters

The study found that COVID-19 positive patients who died had significantly higher ESR and CRP compared to those who recovered. The mean ESR level in COVID-19 positive patients who died was 70.5 ± 22.7, with a median of 70 [50–90], while the mean ESR level in COVID-19 positive patients who recovered was 26.8 ± 17.1, with a median of 20 [12–38]. The difference was statistically significant ($p < 0.001$). Similarly, the mean CRP level in COVID-19 positive patients who died was 146 ± 56, with a median of 141 [98–200], while the mean CRP level in COVID-19 positive patients who recovered was 39 ± 31, with a median of 31 [12–63]. The difference was statistically significant ($p < 0.001$).

TABLE II: Laboratory Measures of the Participants

Characteristics	COVID-19 positive						COVID-19 negative		p-value
	Recovered		Dead		Total				
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	
Hematologic parameters									
WBCs (cells × 10^6/L)	11.7 ± 4.2	12.1 [8.9–13.6]	13.1 ± 4.8	12.4 [10.7–16.5]	11.9 ± 4.3	12.2 [9.5–14]	7.7 ± 3.2	6.75 [5.55–8.9]	<0.001¶,0.1§
Lymphocyte (%)	13.9 ± 7.3	13.7 [9.3–16.9]	11.2 ± 7.6	10.7 [6–14.9]	13.4 ± 7.4	13.6 [9.2–16.8]	38.8 ± 14.8	34.7 [29.9–14.8]	<0.001¶, 0.007§
Neutrophil (%)	77.9 ± 9.4	79.9 [74.7–82.8]	81 ± 7.7	81.3 [75–88]	78.4 ± 9.4	79.9 [74.7–82.8]	52.3 ± 9.4	57.5 [39.6–62.9]	<0.001¶,0.053§
RBCs (cells × 10^9/L)	4.4 ± 0.5	4.4 [4.1–4.7]	4.3 ± 0.5	4.3 [3.9–4.9]	4.4 ± 0.58	4.4 [4.1–4.7]	4.4 ± 0.58	4.45 [4.1–4.7]	0.53¶,0.33§
Platelets (cells × 10^6/L)	287 ± 102.3	256 [209.5–362.5]	262.2 ± 129.9	215.5 [167.5–332.3]	283.2 ± 107.2	254 [196.5–355]	277.3 ± 104.8	252 [190.5–349]	0.73¶,0.04§
MCV (%)	83.3 ± 5.7	83.4 [80.2–86.3]	83.5 ± 6.2	83.4 [78–87.2]	83.4 ± 5.9	83.4 [80.2–86.4]	83.2 ± 4.9	83.4 [80.3–86.4]	0.88¶,0.92§
MCH	27.8 ± 2.3	27.6 [26.5–29.1]	28.2 ± 2.4	28 [27–29.4]	27.8 ± 2.3	27.6 [26.6–29.2]	27.9 ± 2.3	27.7 [26.6–29.1]	0.77¶,0.28§
MCHC	33.3 ± 1.3	33.2 [32.5–34.1]	33.4 ± 1.4	33.1 [32.7–34]	33.3 ± 1.3	33.1 [32.6–34.1]	33.3 ± 1.5	33 [32.3–34.1]	0.36¶,0.7§
Haemoglobin (g/dl)	12.4 ± 1.7	12.6 [11.1–13.3]	12.3 ± 2.1	11.9 [10.6–13.6]	12.3 ± 1.8	12.6 [10.9–13.3]	12.4 ± 1.7	12.6 [10.9 –13.3]	0.62¶,0.51§
Renal functions and electrolytes									
BUN (mg/dl)	30.3 ± 22.7	25 [22–33.5]	56.5 ± 57.6	31 [23–48]	34.4 ± 32.2	25 [22–34]	26 ± 21.1	23 [21–29]	0.001¶,0.004§
Creatinine (mg/dl)	0.89 ± 0.57	0 .9 [0.6–1]	1.6 ± 2.9	1 [0.7–1.2]	1.01 ± 1.3	0 .9 [0.7–1]	0.81 ± 0.22	0 .8 [0.6–1]	0.057¶,0.02§
Potassium (mmol/l)	3.8 ± 0.45	3.8 [3.6–4.1]	3.9 ± 0.64	3.9 [3.6–4.3]	3.8 ± 0.5	3.8 [3.6–4.1]	3.9 ± 0.3	3.9 [3.7–4.1]	0.3¶,0.67§
Sodium (mmol/l)	137 ± 3.9	317 [136–140]	137.9 ± 4.4	138.5 [135–140.8]	137.2 ± 4.04	137 [136–14]	137.6 ± 2.8	137 [136–14]	0.4¶,0.5§
Calcium (mg/dl)	9.1 ± 0.47	9 [9–9.2]	7.3 ± 0.6	7.1 [7–7.2]	8.8 ± 0.84	9 [8.9–9.1]	9.1 ± 0.5	9 [8.9–9.3]	0.07¶,<0.001§
Inflammatory markers									
ESR (mm/hr)	39.8 ± 23.5	35 [20–55]	70 ± 24.4	72.5 [51.2–83.8]	44.6 ± 26.1	20 [15–40]	18 ± 7.7	20 [15–20]	<0.001¶,§
CRP (mg/dl)	18.4 ± 17.2	14 [3–30]	43.5 ± 25.6	37.5 [30.3–58.8]	22.4 ± 2.83	18 [3–32]	2.6 ± 1.7	2 [2–3]	<0.001¶,§
Coagulation profile									
PT (second)	15.4 ± 2.9	14.4 [12.9–17.8]	17.8 ± 3.3	18.8 [14.4–18.9]	15.8 ± 3.1	14.5 [12.9–18.3]	13.65 ± 1.3	13.4 [12.9–14.4]	<0.001¶,§
aPTT (second)	39.2 ± 7.9	37.5 [32.3–47.1]	44.9 ± 8.3	48.4 [35–51.1]	40.1 ± 8.3	38.3 [33.1–48.4]	34.86 ± 4.6	34.1 [32.1–37.5]	<0.001¶,§
INR	1.11 ± 0.22	1.03 [0.92–1.3]	1.3 ± 0.25	1.36 [1.03–1.4]	1.14 ± 0.24	1.04 [0.92–1.32]	0.98 ± 0.1	0 .95 [0.92–1.03]	<0.001¶,§

Note: Superscripts: ¶—Independent Mann-Whitney U-test between COVID infected and not infected individuals, §—Independent Mann-Whitney U-test between COVID infected those who recovered and those who passed away.

3.6. Coagulation Parameters

The study found that COVID-19 positive patients who died had significantly higher PT, aPTT, and INR compared to those who recovered. The mean PT level in COVID-19 positive patients who died was 16.9 ± 3.8, with a median of 17 [14–20], while the mean PT level in COVID-19 positive patients who recovered was 13.6 ± 1.6, with a median of 13 [12–14]. The difference was statistically significant ($p < 0.001$). Similarly, the mean level of aPTT in COVID-19 positive patients who passed away was 51 ± 17, with a median of 48 [38–60], while the mean aPTT level in COVID-19 positive patients who recovered was 31 ± 6, with a median of 30 [28–34]. The difference was statistically significant ($p < 0.001$). Additionally, the mean INR level in COVID-19 positive patients who passed away was 1.8 ± 0.5, with a median of 1.8 [1.5–2.2], while the mean INR level in COVID-19 positive patients who recovered was 1.2 ± 0.2, with a median of 1.2 [1.1–1.3]. The difference was statistically significant ($p < 0.001$).

Overall, the study provides important information on the hematology, renal electrolyte, inflammatory and coagulation profiles of COVID-19 infected individuals in Sudan, which could inform public health interventions and policies aimed at improving outcomes for patients with COVID-19 and reducing mortality rates. When comparing the hematology, renal electrolyte, inflammatory, and coagulation profiles between COVID-19 positive and negative patients who recovered or died, there were significant differences in most parameters.

For example, WBC counts were significantly higher in COVID-19 negative patients compared to COVID-19 positive patients who recovered or passed away ($p < 0.001$). Lymphocyte counts were significantly lower in COVID-19 positive patients compared to COVID-19 negative patients ($p < 0.001$) and significantly lower in COVID-19 positive patients who died compared to those who recovered ($p = 0.007$). Neutrophil counts were significantly higher in COVID-19 positive patients who passed away compared to those who recovered ($p = 0.053$).

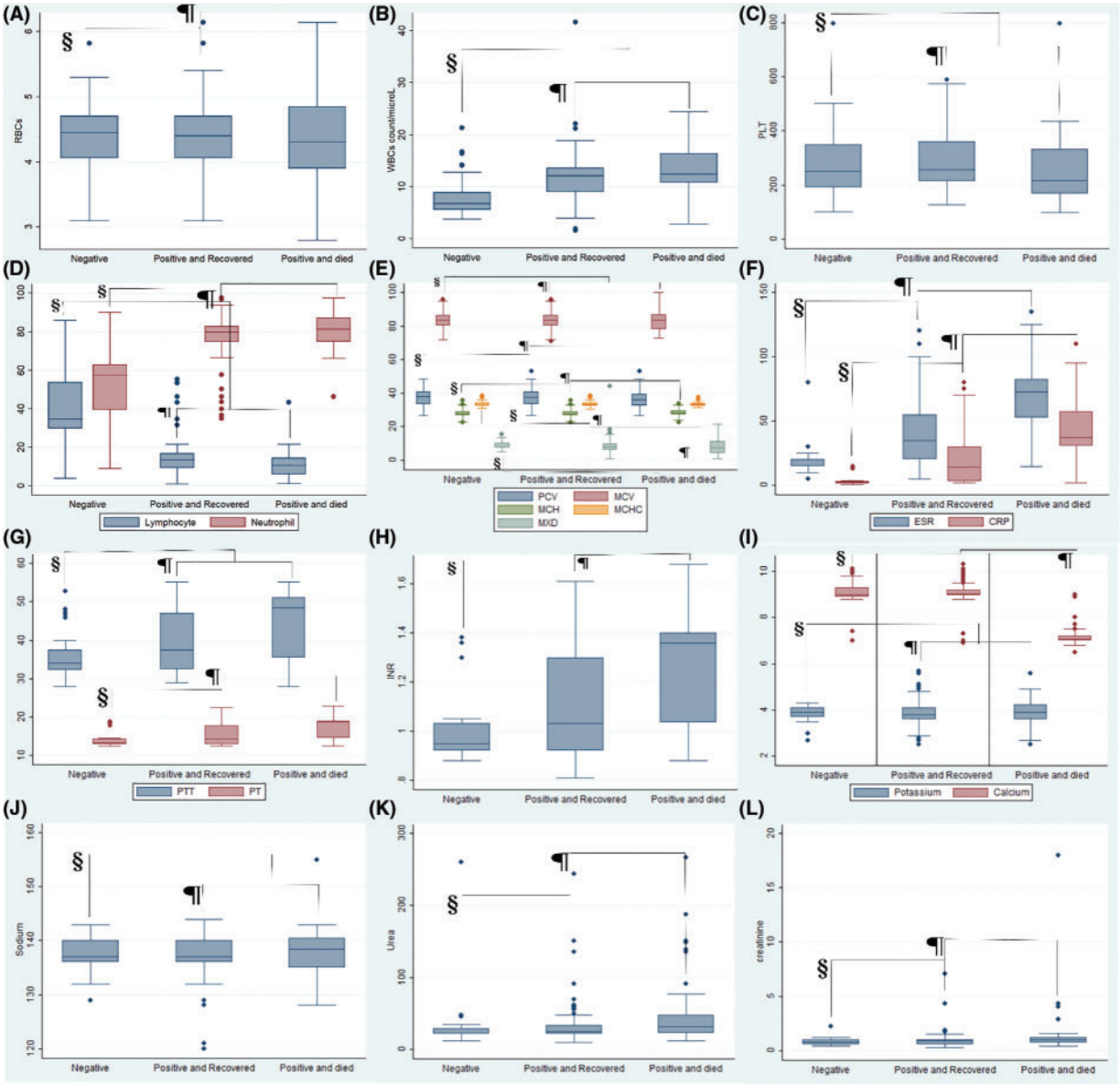

Fig. 2. Haematological panel (A-E); A: RBCs, B: WBCs, C: PLT, D: Lymphocyte & Neutrophile count, E: RBCs indexes. Inflammatory panel F (ESR and CRP). Coagulation panel G: (PT and PTT), H: (INR). Renal panel (I to L); I: (Potasium and Calcium), J: (Soduim), K: (Urea), L: (Creatinine).

In terms of renal electrolyte parameters, BUN and creatinine levels were significantly higher in COVID-19 positive patients compared to COVID-19 negative patients ($p < 0.001$), and significantly higher in COVID-19 positive patients who died compared to those who recovered ($p < 0.001$).

Inflammatory markers such as ESR and CRP were significantly higher in COVID-19 positive patients who died compared to those who recovered ($p < 0.001$). Coagulation profile measures such as PT, aPTT and INR were significantly higher in COVID-19 positive patients who died compared to those who recovered ($p < 0.00$).

Table III shows the logistic regression of the positivity determinants among COVID-19 patients. The study found that lymphocyte count and urea level were significant predictors of COVID-19 positivity. The unadjusted odds ratio (OR) for lymphocyte count was 0.799, with a p-value less than 0.001, while the unadjusted OR for urea level was 0.97, with a p-value of 0.03. After adjusting for other variables, the adjusted OR for lymphocyte count was 0.79, with a p-value of less than 0.001, and the adjusted OR for urea level was 0.97, with a p-value of 0.008. The CRP level was also found to be a significant predictor of COVID-19 positivity, with an unadjusted OR of 1.31 and an adjusted OR of 1.28, both with a p-value of less than 0.001.

Table IV shows the logistic regression of the determinants of mortality among COVID-19 patients. The study found that age and calcium level were significant predictors of COVID-19 mortality. The unadjusted OR for age was 1.08, with a p-value of 0.088, while the unadjusted OR for calcium level was 0.024, with a p-value of less than 0.001. After adjusting for other variables, the adjusted OR for age was 1.08, with a p-value of 0.004, and the adjusted OR for calcium level was 0.028, with a p-value of less than 0.001. Educational level, lymphocyte count, PT, platelets, creatinine level, and ESR were not found to be significant predictors of COVID-19 mortality.

TABLE III: Logistic Regression of Determinants of Positivity among COVID-19 Patients

Characteristics	Unadjusted OR	p-value	Adjusted OR	p-value
Age	0.97 [0.92–1.01]	0.18		
Gender (Male-reference)	2.58 [0.94–7.06]	0.06	2.3 [0.89–5.9]	0.08
Educational level				
No formal	1 *reference*	0.91		
Primary	0.94 [0.08–11.04]	0.96		
Secondary	1.53 [0.13–18.3]	0.73		
Tertiary	0.91 [0.096–8.69]	0.93		
Lymphocyte	0.799 [0.75–0.84]	<0.001	0.79 [0.75–0.84]	<0.001
Urea	0.97 [0.95–0.99]	0.03	0.97 [0.95–0.99]	0.008
CRP	1.31 [1.14–1.5]	<0.001	1.28 [1.13–1.45]	<0.001
PT	1.34 [0.98–1.8]	0.058	1.33 [0.99–1.79]	0.055

TABLE IV: Logistic Regression of Mortality Determinants among COVID-19 Patients

Characteristics	Unadjusted OR	p-value	Adjusted OR	p-value
Age	1.08 [0.98–1.18]	0.088	1.08 [1.025–1.14]	0.004
Educational level				
No formal	*Ref*	0.68		
Primary	0.17 [0.008–3.3]	0.24		
Secondary	0.99 [0.027–36.67]	0.99		
Tertiary	0.41 [0.014–11.9]	0.60		
Lymphocyte	0.9 [0.77–1.09]	0.36		
Calcium	0.024 [0.0056–0.106]	<0.001	0.028 [0.008–0.102]	<0.001
PT	1.19 [0.85–1.67]	0.29		
Platelets	0.99 [0.98–1.003]	0.19		
Creatinine	1.21 [0.8–1.8]	0.35		
ESR	0.99 [0.93–1.05]	0.8		

3.7. Logistic Regression of Positivity Determinants among COVID-19 Patients

3.7.1. Lymphocyte Count

For every 1% increase in lymphocyte count, the odds of being positive for COVID-19 decrease by 21% after adjusting for other variables. This suggests that a higher lymphocyte count may be protective against COVID-19 infection.

3.7.2. Urea Level

For every 1% increase in the urea level, the odds of being positive for COVID-19 decrease by 3% after adjusting for other variables. This suggests that higher urea levels may protect against COVID-19 infection.

3.7.3. CRP Level

For every 1% increase in the CRP level, the odds of being positive for COVID-19 increase by 28% after adjusting for other variables. This suggests that higher CRP levels may increase the risk of COVID-19 infection.

3.8. Logistic Regression of Mortality Determinants among COVID-19 Patients

3.8.1. Age

For every 1% increase in age, the chances of dying of COVID-19 increase by 8% after adjusting for other variables. This suggests that older age is a risk factor for COVID-19 mortality.

3.8.2. Calcium Level

For every 1% increase in calcium level, the odds of dying of COVID-19 decrease by 2.8% after adjusting for other variables. This suggests that higher calcium levels may protect against COVID-19 mortality.

It is important to note that logistic regression only identifies associations between variables and outcomes and does not establish causality. Therefore, more research is needed to confirm these findings and determine the underlying mechanisms behind these associations.

4. Summary

The study aimed to investigate the hematology, renal electrolyte, inflammatory, and coagulation profiles of COVID-19 positive and negative patients, classified by recovery or death. The study found that hematologic parameters such as WBC, lymphocytes, neutrophils, and platelets showed significant differences between COVID-19 positive and negative patients, as well as between those who recovered and those who died. Renal functions and electrolytes such as BUN and creatinine also showed significant differences. Inflammatory markers such as ESR and CRP were significantly higher in COVID-19 positive patients who died compared to those who recovered. Measurements of the coagulation profile, such as PT, aPTT, and INR, also showed significant differences between COVID-19 positive and negative patients, as well as between those who recovered and those who passed away.

Furthermore, the study conducted two binary logistic regressions to determine the predictors of COVID-19

positivity and mortality. Logistic regression of the determinants of positivity among patients with COVID-19 found that lymphocyte count, urea level, and CRP level were significant predictors of positivity for COVID-19. The logistic regression of mortality determinants among COVID-19 patients found that age and calcium level were significant predictors of COVID-19 mortality.

In summary, the study findings suggest that hematologic parameters, renal functions and electrolytes, inflammatory markers, and measures of coagulation profile are important indicators of the severity and prognosis. The binary logistic regressions further identified specific predictors of COVID-19 positivity and mortality. These findings can help healthcare professionals better understand disease progression and develop targeted interventions for COVID-19 patients.

5. Discussion

The COVID-19 pandemic has put significant stress on healthcare institutions and infrastructure since 2020. COVID-19 clinical symptoms range from mild, self-resolving cases to severe, life-threatening disorders. The ability to predict severe inflammatory responses is still a challenge. Therefore, clinicians can use laboratory biomarkers to help in decision making, interpret clinical symptoms more confidently, provide data on the underlying biological processes, start treatment, and assess the progression of the disease [12]. This study analyzed a number of COVID-19 biomarkers, including hematological, biochemical, and inflammatory markers, to determine their usefulness in indicating the severity of COVID-19.

The findings of our study reveal significant associations between COVID-19 infection status and demographic and socioeconomic factors, including age, gender, and educational level. Similar associations have been reported in previous studies [13], [14]. The observation that younger people are more likely to test positive for COVID-19 may be attributed to behavioral factors, such as increased social interaction and mobility among younger age groups. Furthermore, the higher proportion of males who tested positive is in line with global trends that have consistently shown a higher susceptibility of males to COVID-19 [14]. The association between higher educational levels and a higher probability of COVID-19 infection is an intriguing finding that warrants further investigation. It is possible that individuals with higher education levels have more opportunities for exposure to the virus due to their occupational or social circumstances. Understanding the mechanisms behind this association could provide valuable information for targeted public health interventions.

Our study highlights the significant association between the status of COVID-19 infection and various chronic illnesses, including diabetes, hypertension, chronic kidney disease, congestive heart failure, asthma, epilepsy, tuberculosis, and systemic lupus erythematosus. These findings corroborate the growing body of evidence suggesting that pre-existing health conditions are risk factors for severe COVID-19 outcomes [15], [16]. Patients with diabetes were significantly more likely to test positive for COVID-19, reflecting the well-established link between diabetes and immune system dysfunction, which can exacerbate the severity of viral infections [17], [18]. Similarly, the association with hypertension and other chronic illnesses underscores the importance of managing comorbidities in the context of COVID-19.

The alterations in the hematologic and coagulation profile observed in COVID-19 patients in this study shed light on the complex interplay between the virus and the immune and coagulation systems. Significantly lower lymphocyte counts in COVID-19 positive patients, particularly those who passed away, corroborate existing literature indicating lymphopenia as a common feature of COVID-19 [19], [20]. Lymphopenia suggests impaired immune responses, which may contribute to the severity of the disease. The higher neutrophil counts in COVID-19 positive patients who died compared to those who recovered suggest a potential association between excessive neutrophil activation and disease severity. Neutrophils are crucial in the defense against infections, but their excessive activation can lead to collateral tissue damage and inflammation, potentially contributing to adverse outcomes [21].

Furthermore, coagulation abnormalities, including prolonged PT, aPTT, and elevated INR, in COVID-19 positive patients who passed away are indicative of COVID-19-associated coagulopathy [22], [23]. The hypercoagulable state seen in severe COVID-19 may contribute to thromboembolic complications and worsen clinical outcomes.

Significantly elevated levels of BUN and creatinine in COVID-19 positive patients, especially those who died, underscore the importance of monitoring renal electrolyte parameters in COVID-19 management. The observed differences may indicate renal involvement in the pathophysiology of severe COVID-19. Acute kidney injury (AKI) has been identified as a complication of COVID-19 and is associated with a higher risk of mortality [24]. The mechanisms behind COVID-19-related AKI can include direct viral effects, inflammatory responses, and hemodynamic changes. Furthermore, significantly higher levels of inflammatory markers, ESR and CRP, in COVID-19 positive patients who died highlight the role of excessive inflammation in disease severity. Elevated levels of ESR and CRP are indicative of systemic inflammation and have been associated with severe cases of COVID-19 [25]. The cytokine storm, characterized by the release of pro-inflammatory cytokines, is considered a major contributor to the pathogenesis of severe COVID-19. These findings suggest that monitoring renal electrolyte parameters and inflammatory markers may serve as predictive tools to identify COVID-19 patients at higher risk of developing severe disease. Early interventions targeting inflammation and renal complications could potentially improve clinical outcomes.

The logistic regression analysis conducted in this study revealed several significant predictors of COVID-19 positivity, shedding light on the factors that influence susceptibility to the virus. Among these predictors, lymphocyte count emerged as a key factor. For every 1% increase in lymphocyte count, there was a 21% reduction in the odds of testing positive for COVID-19 after adjusting for other variables. This finding aligns with previous

research indicating that lymphopenia is a common feature of COVID-19 and that a higher lymphocyte count may confer some degree of protection against infection [26]. Furthermore, urea level was identified as another significant predictor of COVID-19 positivity. For every 1% increase in the urea level, there was a 3% decrease in the odds of testing positive for COVID-19 after adjusting for other variables. Although the underlying mechanisms of this association require further investigation, it suggests that higher urea levels could play a protective role against COVID-19 infection.

On the contrary, the CRP level emerged as a significant risk factor for COVID-19 positivity. For every 1% increase in the CRP level, there was a substantial 28% increase in the odds of testing positive for COVID-19 after adjusting for other variables. Elevated CRP levels are indicative of systemic inflammation and have been associated with the severity of COVID-19 [25], [27]. This finding underscores the potential role of inflammation as a contributor to an increased risk of COVID-19 infection. Understanding these predictors can help to stratify risk and identifying individuals who may be more vulnerable to COVID-19. Public health interventions, such as vaccination campaigns and targeted preventive measures, can be tailored based on these risk factors to reduce the transmission of the virus in Kassala State, Eastern Sudan.

Logistic regression analysis focusing on predictors of COVID-19 mortality revealed crucial information on factors that influence the severity of outcomes among infected individuals. Age emerged as a significant predictor, with a notable 8% increase in the odds of dying of COVID-19 for every 1% increase in age after adjusting for other variables. This finding is consistent with the well-established understanding that older individuals are more susceptible to severe outcomes of COVID-19 [28], [29]. Age-related changes in immune function and a higher prevalence of comorbidities contribute to the increased risk among the elderly. Interestingly, calcium levels were identified as a significant protective factor against COVID-19 mortality. For every 1% increase in calcium level, there was a 2.8% decrease in the chances of dying of COVID-19 after adjusting for other variables. The mechanisms underlying this protective effect of higher calcium levels merit further investigation. It should be noted that calcium plays a vital role in various physiological processes, including immune function and coagulation, which can indirectly impact COVID-19 outcomes.

6. Limitations of the Study

One limitation of this study is that it is based on data collected from a single center in Kassala State, Eastern Sudan. This may limit the generalization of the findings to a broader population, as regional variations in the prevalence and demographics could impact the results. The cross-sectional design only provides a snapshot of COVID-19 biomarkers and their associations at a specific point in time. Longitudinal data would have allowed for a better understanding of how these biomarkers change over the course of the disease and their predictive value. The study sample size may not be sufficient to capture rare or less common biomarker variations and their associations with COVID-19 severity. Larger sample sizes are often needed for more robust statistical analyses. The study may have inherent selection bias, as it includes only individuals who sought medical care and were tested for COVID-19. Asymptomatic or mildly symptomatic cases that did not seek medical attention may not be represented in the data.

7. Conclusions

In summary, this study investigates COVID-19 in Kassala State, eastern Sudan, highlighting key associations and predictors. Younger individuals and men show higher susceptibility. Preexisting chronic diseases, particularly diabetes, elevate infection risk. The changes in the hematological and coagulation profile suggest immune and coagulation system involvement. Altered renal parameters and increased inflammatory markers reveal potential renal complications and their role in severe cases. Logistic regression identifies the lymphocyte count and the urea level as protective factors against infection, while the CRP level and age are risk factors. Higher calcium levels appear to be protective against mortality. These findings help to assess risk, allocate resources, and clinical management in the ongoing fight against COVID-19.

Conflict of Interest

Authors declare no conflict of interest.

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