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*Research Article*

# Haemocytometric Profile of Nigerian Patients with Covid-19

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**Abstract**
The haemocytometric changes and possible interplay with duration of hospital stay, gender and age in Nigerians with COVID-19 were determined in this study. Routine haemocytometry was evaluated using a standard method and thereafter, neutrophil-lymphocyte ratio (NLR); a marker of inflammation was calculated. Neutrophil percentage, total white blood cell (WBC) count and NLR were significantly higher while lymphocyte percentage was significantly lower in patients with COVID-19 compared with the controls. In females with COVID-19, neutrophil percentage was significantly higher compared with the males. Considering length of hospital stay, monocyte percentage was significantly higher in patients who spent more than 10 days on admission compared with those with 10 or fewer days of admission. At discharge, the proportion of patients with monocyte percentage above the reference range was significantly lower compared with baseline. Also, monocyte percentage in COVID-19 patients had significant positive correlation with days on admission. Alteration in haemocytometry worsens with increasing age as percentages of monocyte and neutrophil, NLR and WBC count were significantly higher while the lymphocyte percentage was significantly lower in patients aged 40 years and above compared with younger patients. Also, age had significant positive correlation with percentages of monocyte and neutrophil, NLR and WBC count but a significant negative correlation with lymphocyte percentage. Haemocytometric changes and inflammation in COVID-19 patients increase with age. Also, monocyte count could be an indicator of longer hospital stay and its reduction might be an indicator of recovery from the disease.

**Key Words:** Age, COVID-19, Inflammation, Monocyte, Neutrophil-lymphocyte ratio, Nigeria

## INTRODUCTION

Coronavirus disease 2019 (COVID-19) is not just a respiratory disease but a systemic disease affecting multiple systems including the cardiovascular, neurological, haematopoietic and immune system among others (Bangash *et al*., 2020; Driggin *et al*., 2020; Mehta *et al*., 2020). The haematopoietic system performs myriads of vital functions including haemostasis and body defence. Regrettably, its functions are significantly impacted upon infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Terpos *et al*., 2020; Debuc and Smadja, 2021) thereby, playing an essential role in defining the course of infection.

Inclusion of abnormalities in haemocytometry in several diagnostic criteria for SARS-CoV-2 infection underscores its importance (Khartabil *et al*., 2020). The Chinese authorities

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included normal or decreased white blood cell counts and decreased lymphocyte counts in their diagnostic criteria (National Health Commission, 2020). Similarly, the United States Centre for Disease Control and Prevention stressed that leukopenia (9 – 25%), leukocytosis (24 – 30%), and lymphopenia (63%) are among the most common laboratory abnormalities in COVID-19 (Centers for Disease Control and Prevention, 2020). Furthermore, the Australia and New Zealand Guidelines identified lymphopenia and neutrophilia as prognostic markers for severe cases of COVID-19 (Weinkove and McQuilten, 2020).

Blood cell analysis is one of the most widely performed haematological and immunological tests in the clinic. In the current novel coronavirus pandemic, it is therefore not surprising that inexpensive and rapid laboratory tests such as immune cell analysis is pivotal in predicting the disease course with a view to facilitating quick interventions that might reduce patients' mortality. Reports have shown that inexpensive markers derivable from haemocytometry profile play important roles in everyday clinical practice as they can aid in the risk stratification and prognosis of several diseases (Tamhane *et al*., 2008; Lattanzi *et al*., 2021).

Several reports have shown that there were changes in the peripheral blood immune cells following SARS-CoV-2 infection and such changes have the potential to provide clues or guidance for the diagnosis, treatment, and prognosis of COVID-19. The Diagnosis and Treatment Guidelines of China (National Health Commission, 2020) showed that the total number of peripheral white blood cells is normal or decreased while the lymphocyte count is reduced in patients at the early stage of COVID-19. Tan *et al*. (2020) also reported that lymphocyte percentage was inversely related to the severity and prognosis of COVID-19 patients, and may be used to predict the severity and prognosis of patients with COVID-19.

COVID-19 cases can be stratified based on the clinical manifestations of the patient's disease into mild, moderate, severe and critical with each having peculiar cellular haemocytometric profile. The report of the World Health Organization (WHO) showed that about 80% of infected people have mild to moderate infections (including those with or without pneumonia), 13.8% with severe infection, and 6.1% with critical illness (National Health Council, 2020).

Although there is an avalanche of reports on haemocytometric changes in COVID-19 infection at different stages of the disease (Lu and Wang, 2020; Sun *et al*., 2020), the roles of these changes in indicating disease progression and outcome is still poorly understood especially in Nigerian patients with COVID-19. In addition, the contribution of haemocytometric changes to gender differences in COVID-19 severity is not explored in this environment; these thus serve as the basis for this study.

## MATERIALS AND METHODS

### Study Design

This was a case-control study.

### Study site

The Infectious Diseases Centre, Olodo, Oyo State, Nigeria.

**Study Population:** A total of 209 participants were enrolled into this study. They comprised 167 patients with COVID-19 (not in severe or critical stage) and 42 age and gender matched apparently healthy participants who served as controls. The COVID-19 cases were confirmed positive while the controls were certified negative using real-time reverse-transcriptase polymerase-chain reaction (RT-PCR) assay to test nasal and pharyngeal swab specimens following WHO guideline (World Health Organization, 2020). The COVID-19 group was further categorized into groups based on gender and duration of hospitalization.

**Sample collection:** Ten millilitre (10 ml) of venous blood was obtained from the SARS-CoV-2 infected patients at point of admission and at discharge but at enrolment only in controls. The blood samples were dispensed into lithium heparin containing sample bottles.

**Exclusion criteria:** Participants with haematological diseases or those with recent history of blood transfusion were excluded from the study. Also, all the participants had no HIV or pulmonary TB infections and had no history of chronic diseases including diabetes mellitus, hypertension and cancer.

**Ethical consideration:** Before commencement, the study was approved by the University of Ibadan/University College Hospital (UI/UCH) Joint Ethics Review Committee (UI/EC/20/0233). Also, informed consent was obtained from the study participants.

**Laboratory analyses:** An automated haemocytometer (URIT: 5160E-01262, China) was used to estimate the total white blood cell (WBC) count and percentages of lymphocytes, neutrophils, eosinophils and monocytes. Thereafter, Neutrophil-Lymphocyte Ratio (NLR) was calculated as the ratio of neutrophil percentage to lymphocyte percentage.

**Statistical Analysis:** Statistical analysis was carried out using SPSS statistical software version 21 for windows. Differences in the mean of variables were determined using the independent and paired Student's t-test as appropriate. Chi-square test or Fischer's exact test, as appropriate, were used to determine the association between categorical variables. Also, correlation between the variables was determined using the Pearson correlation. P-values less than 0.05 were considered as statistically significant. Results were presented as Mean ± Standard deviation or in proportion as appropriate.

## RESULTS

As shown in Table 1, there was significantly higher percentage of neutrophils and significantly lower percentage of lymphocytes in patients with COVID-19 compared with the controls. In addition, patients with COVID-19 had significantly higher NLR and WBC count compared with the controls. Considering the gender of the participants with COVID-19, only the neutrophil percentage was significantly higher in females compared with the males. However, the percentages of lymphocyte, monocyte and eosinophil were slightly lower in females compared with the males (Table 2).

**Table 1:**
Haemocytometric parameters in patients with COVID-19 on admission

| White blood cell profile | COVID-19 (n = 167) | Controls (n = 42) | *ρ*-value |
|---|---|---|---|
| WBC (x10$^9$/L) | 5.55±1.79 | 4.45±1.97 | 0.007* |
| Lymphocyte (%) | 45.73±12.60 | 51.54±11.92 | 0.018* |
| *Lymphocyte (x10$^9$/L)* | *2.43 ± 0.73* | *2.18 ± 0.84* | |
| Monocyte (%) | 8.17±3.29 | 9.24±3.76 | 0.154 |
| *Monocyte (x10$^9$/L)* | *0.45 ± 0.20* | *0.39 ± 0.22* | |
| Neutrophil (%) | 42.65±13.00 | 34.89±13.65 | 0.008* |
| *Neutrophil (x10$^9$/L)* | *2.49 ± 1.55* | *1.69 ± 1.14* | |
| Eosinophil (%) | 3.52 ± 2.92 | 3.04 ± 2.36 | 0.446 |
| *Eosinophil (x10$^9$/L)* | *0.19 ± 0.16* | *0.15 ± 0.12* | |
| NLR | 1.14 ± 0.91 | 0.77 ± 0.49 | 0.024* |

*Significant at *P*<0.05, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

**Table 2:**
Haemocytometric parameters in males and females with COVID-19

| White blood cell profile | Male (n = 83) | Female (n = 46) | *ρ*-value |
|---|---|---|---|
| WBC (x10$^9$/L) | 5.42 ± 2.04 | 5.74 ± 1.66 | 0.364 |
| Lymphocyte (%) | 47.09 ± 13.61 | 43.84 ± 12.91 | 0.189 |
| *Lymphocyte (x10$^9$/L)* | *2.43 ± 0.79* | *2.43 ± 0.78* | |
| Monocyte (%) | 8.72 ± 3.95 | 7.76 ± 2.49 | 0.138 |
| *Monocyte (x10$^9$/L)* | *0.46 ± 0.23* | *0.44 ± 0.18* | |
| Neutrophil (%) | 40.47 ± 13.58 | 45.38 ± 13.09 | 0.049* |
| *Neutrophil (x10$^9$/L)* | *2.35 ± 1.79* | *2.71 ± 1.32* | |
| Eosinophil (%) | 3.77 ± 3.27 | 2.79 ± 1.72 | 0.061 |
| *Eosinophil (x10$^9$/L)* | *0.20 ± 0.16* | *0.15 ± 0.10* | |
| NLR | 1.11 ± 1.08 | 1.25 ± 0.80 | 0.460 |

*Significant at *P*<0.05, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

Comparing the haematological routine parameters in patients with COVID-19 on admission and at discharge, there was slight reduction in the percentage of lymphocyte and monocyte while NLR and the percentages of neutrophil and eosinophil were slightly elevated at discharge compared with baseline. The mean WBC count was significantly elevated at discharge compared with baseline (Table 3).

Changes in the haematology profile with number of days on admission are shown in Table 4. It was observed that monocyte percentage was significantly higher while the percentage of lymphocyte was lower in patients who spent more than 10 days on admission compared with those with 10 or less days of admission. All other parameters were not significantly different between the 2 groups (Table 4). Similarly, the proportion of patients with monocyte percentage above the reference range at discharge was significantly lower compared with the baseline (Table 5). Furthermore, the percentage of monocyte in COVID-19 patients had significant positive correlation with days on admission (Table 6).

**Table 3:**
Haemocytometric parameters in COVID-19 patients at baseline and at discharge

| White blood cell profile | Baseline (n = 33) | Discharge (n = 33) | *ρ*-value |
|---|---|---|---|
| WBC (x10$^9$/L) | 5.19 ± 1.79 | 6.17 ± 2.29 | 0.001* |
| Lymphocyte (%) | 49.27 ± 14.92 | 45.55 ± 12.62 | 0.126 |
| *Lymphocyte (x10$^9$/L)* | *2.45 ± 0.90* | *2.76 ± 1.24* | |
| Monocyte (%) | 8.78 ± 3.10 | 7.76 ± 1.91 | 0.066 |
| *Monocyte (x10$^9$/L)* | *0.44 ± 0.20* | *0.46 ± 0.15* | |
| Neutrophil (%) | 38.29 ± 14.61 | 41.72 ± 12.13 | 0.093 |
| *Neutrophil (x10$^9$/L)* | *2.11 ± 1.36* | *2.67 ± 1.63* | |
| Eosinophil (%) | 3.58 ± 3.18 | 3.65 ± 2.67 | 0.852 |
| *Eosinophil (x10$^9$/L)* | *0.18 ± 0.15* | *0.21 ± 0.15* | |
| NLR | 1.03 ± 1.04 | 1.13 ± 0.90 | 0.540 |

*Significant at *P*<0.05, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

**Table 4:**
Changes in haemocytometric parameters with number of days on admission

| White blood cell profile | DOA ≤ 10 days (n = 55) | DOA >10 days (n = 40) | *ρ*-value |
|---|---|---|---|
| WBC (x10$^9$/L) | 5.46 ± 2.85 | 5.50 ± 1.44 | 0.913 |
| Lymphocyte (%) | 50.53 ± 12.29 | 45.80 ± 12.14 | 0.066 |
| *Lymphocyte (x10$^9$/L)* | *2.67 ± 0.82* | *2.45 ± 0.69* | |
| Monocyte (%) | 7.49 ± 2.35 | 9.11 ± 4.30 | 0.021* |
| *Monocyte (x10$^9$/L)* | *0.41 ± 0.19* | *0.49 ± 0.23* | |
| Neutrophil (%) | 38.69 ± 12.09 | 40.99 ± 12.71 | 0.371 |
| *Neutrophil (x10$^9$/L)* | *2.23 ± 1.43* | *2.33 ± 1.20* | |
| Eosinophil (%) | 3.60 ± 2.83 | 3.98 ± 3.27 | 0.546 |
| *Eosinophil (x10$^9$/L)* | *0.19 ± 0.16* | *0.21 ± 0.18* | |
| NLR | 0.89 ± 0.57 | 1.10 ± 0.94 | 0.186 |

*Significant at *P*<0.05, DOA = Days on admission, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

**Table 6:**
Correlation between the haemocytometric parameters and number of days on admission

| Correlating pair | r-value | *ρ*-value |
|---|---|---|
| DOA | | |
| WBC (x10$^9$/L) | -0.052 | 0.616 |
| Lymphocyte (%) | -0.124 | 0.230 |
| Monocyte (%) | 0.334 | 0.001* |
| Neutrophil (%) | 0.028 | 0.787 |
| Eosinophil (%) | 0.103 | 0.323 |
| NLR | 0.042 | 0.668 |

*Significant at *P*<0.05, DOA = Days on admission, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

**Table 5:**
Haemocytometric parameters in COVID-19 patients based on reference range

| White blood cell profile | Category | Admission (n = 33) | Discharge (n = 33) | Chi-square | *ρ*-value |
|---|---|---|---|---|---|
| WBC (x$10^9$/L) | Below ref range | 3 (9.1) | 1 (3.0) | 2.667 | 0.102 |
| | Within ref range | 30 (90.9) | 30 (90.9) | | |
| | Above ref range | 0 (0.0) | 2 (6.1) | | |
| Lymphocyte (%) | Below ref range | 1 (3.0) | 1 (3.0) | 0.000 | 1.000 |
| | Within ref range | 12 (36.4) | 13 (39.4) | | |
| | Above ref range | 20 (60.6) | 19 (57.6) | | |
| Monocyte (%) | Below ref range | 0 (0.0) | 0 (0.0) | 5.444 | 0.020* |
| | Within ref range | 24 (72.7) | 31 (93.9) | | |
| | Above ref range | 9 (27.3) | 2 (6.1) | | |
| Neutrophil (%) | Below ref range | 22 (66.7) | 23 (69.7) | 0.111 | 0.739 |
| | Within ref range | 9 (27.3) | 8 (24.2) | | |
| | Above ref range | 2 (6.1) | 2 (6.1) | | |
| Eosinophil (%) | Below ref range | 6 (18.2) | 4 (12.1) | 1.600 | 0.206 |
| | Within ref range | 25 (75.8) | 25 (75.8) | | |
| | Above ref range | 2 (6.1) | 4 (12.1) | | |

*Significant at P<0.05, Reference range: WBC (3.5 – 10 x $10^9$/L), Lymphocyte (16 – 45%), Monocyte (3 – 10%), Neutrophil (45 – 62%), Eosinophil (1 – 7%)

**Table 7:**
Changes in haemocytomeric parameters in patients below the age of 40 years and above

| White blood cell profile | < 40 years (n = 91) | ≥ 40 years (n = 38) | ρ-value |
|---|---|---|---|
| WBC (x$10^9$/L) | 5.33 ± 1.54 | 6.04 ± 2.56 | 0.052* |
| Lymphocyte (%) | 48.63 ± 12.29 | 39.47 ± 13.92 | 0.000* |
| *Lymphocyte (x$10^9$/L)* | *2.53 ± 0.75* | *2.19 ± 0.83* | |
| Monocyte (%) | 7.93 ± 3.32 | 9.45 ± 3.80 | 0.025* |
| *Monocyte (x$10^9$/L)* | *0.42 ± 0.19* | *0.54 ± 0.25* | |
| Neutrophil (%) | 40.02 ± 12.29 | 47.50 ± 15.11 | 0.004* |
| *Neutrophil (x$10^9$/L)* | *2.21 ± 1.27* | *3.10 ± 2.19* | |
| Eosinophil (%) | 3.51 ± 2.93 | 3.20 ± 2.66 | 0.569 |
| *Eosinophil (x$10^9$/L)* | *0.18 ± 0.16* | *0.18 ± 0.16* | |
| NLR | 0.95 ± 0.58 | 1.65 ± 1.49 | 0.000* |

*Significant at *P*<0.05, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

**Table 8:**
Correlation between the haemocytometric parameters and age

| Correlating pair | r-value | *ρ*-value |
|---|---|---|
| Age (years) | | |
| WBC (x$10^9$/L) | 0.202 | 0.021* |
| Lymphocyte (%) | -0.318 | 0.000* |
| Monocyte (%) | 0.256 | 0.003* |
| Neutrophil (%) | 0.274 | 0.002* |
| Eosinophil (%) | -0.183 | 0.038* |
| NLR | 0.327 | 0.000* |

*Significant at *P*<0.05, WBC = White blood cell, NLR = Neutrophil lymphocyte ratio

Changes in haemocytomeric parameters in patients below the age of 40 years and 40 years and above are shown in Table 7. The mean percentages of monocyte and neutrophil, NLR and WBC count were significantly higher while the mean lymphocyte percentage was significantly lower in patients aged 40 years and above compared with patients below the age of 40 years (Table 7). Furthermore, age had significant positive correlation with percentages of monocyte and neutrophil, NLR and WBC count but a significant negative correlation with lymphocyte percentage (Table 8).

## DISCUSSION

Generally, routine blood tests including haematological profile are common indicators reflecting the course of diseases. They are sensitive to many pathological changes and offers assistance in the diagnosis and prognosis of several diseases (Lu and Wang, 2020) especially, diseases like COVID-19 whose pathogenesis is still poorly understood. Haematological abnormalities which worsen with severity have been reported in patients with COVID-19 (Terpos *et al*., 2020).

Lymphocytes are types of white blood cells with decisive roles in the direction of cell-mediated killing of virus-infected and tumour cells, antibody production, and maintenance of immune homeostasis (Larosa and Orange, 2008). Several reports have shown that there is decreased number of lymphocytes in patients with COVID-19 and that lymphopenia is an effective and reliable indicator of severity and deaths from COVID-19 (Khartabil *et al*., 2020; Sun *et al*., 2020; Tan *et al*., 2020; Velavan and Meyer, 2020).

In this study, lymphocyte percentage was significantly lower in patients with COVID-19 compared with the controls. The low percentage of lymphocyte observed in this study could be attributed to increased cell death, cell membrane destruction or reduced formation. Xu *et al*. (2020) reported lysis of lymphocytes as a result of lymphocyte infection through direct binding of SARS-CoV-2 to ACE2 receptor on lymphocyte surface. In addition, cytokine storm is one of the characteristics of COVID-19 known to cause atrophy of lymphoid organs (Aggarwal *et al*., 1999; Liao *et al*., 2002) and may promote inflammation-induced lymphocyte apoptosis and impaired lymphocyte turnover. Furthermore,

lymphopenia could be due to redistribution of lymphocytes from circulation to infected lungs as pathological studies have reported dominant lymphocytes infiltration in the interstitial lung of COVID-9 patients (Sun *et al*., 2020; Xu *et al*., 2020; Yao *et al*., 2020). Therefore, full elucidation of the mechanisms resulting in lymphopenia might provide an effective treatment strategy for COVID-19 (Tan *et al*., 2020).

Neutrophils play important roles in the innate immune system as they are involved in coordinating the initiation, propagation and resolution of inflammation. There are substantial data suggesting that neutrophils are among the first phagocytic responders to viral infection in the lung (Prince *et al*., 2011; Galani and Andreakos, 2015), and they remain in great numbers throughout the development of acute respiratory distress syndrome (ARDS) and may be instrumental in determining disease outcome. Therefore, a better understanding of the role of neutrophils with respect to viral infections will reveal important information about disease outcome. Neutrophils infected with influenza virus have increased apoptosis (Ivan *et al*., 2013) and undergo programmed cell death called netosis, in which neutrophil extracellular trap (NETs) are formed (Agraz-Cibrian *et al*., 2017). NETs have the effect of killing many pathogens, including bacteria (Brinkmann *et al*., 2004), fungi (Urban *et al*., 2006), protozoan (Guimarães-Costa *et al*., 2009), and viruses (Agraz-Cibrian *et al*., 2017). The observed elevated percentage of neutrophils in COVID-19 patients corroborates the reports of Lo *et al*. (2020) and Chen *et al*. (2020) which showed that neutrophilia is present in COVID-19 patients even from the early stages of hospitalization. The neutrophilia might also be related to cytokine storm in COVID-19 patients (Wang *et al*., 2020), which is a feature of early stage of COVID. We thus, proposed that the elevated percentage of neutrophil in COVID-19 patients in this present study might suggest increased production from stem cell and attraction to blood circulation by its attractants. Neutrophil chemotaxis in humans is thought to be mediated by many factors, such as the chemokine CXCL8, cytokines IL-1 and TNFα, and complement C5a (Borregaard *et al*., 2007; Prince *et al*., 2011; Thomas and Schroder, 2013).

The neutrophil-lymphocyte ratio (NLR) is an established indicator of systemic inflammation and an excellent predictor of infections, especially bacterial infection (Liu *et al*., 2016; Curbelo *et al*., 2017; Berhane *et al*., 2019). Peng *et al*. (2020) reported that NLR could be a valuable index of COVID-19 severity. In this study, NLR was significantly elevated in COVID patients and this observation corroborates the report of Qin *et al*. (2020) which showed that NLR is elevated in patients with COVID-19 and that the elevation is more pronounced in patients with severe COVID-19 compared with patients with mild COVID-19. The elevation in NLR, which is due to the observed low lymphocyte percentage and high neutrophil percentage in COVID-19 patients suggest inflammation.

A number of studies have reported normal or decreased WBC count upon admission (Huang *et al*., 2020; Khartabil *et al*., 2020; Qu *et al*., 2020; Sun *et al*., 2020). However, leucocytosis has been reported in over 25% of the most severe cases (Gan *et al*., 2020). Although WBC count is presumed not to have prognostic value due to variability (Li *et al*., 2020), elevated levels (as observed in this study) could be due to co-infection or variability in immune response.

The observed elevated neutrophil percentage in females with COVID-19 in this study further alluded to the fact that the recognition of antigens and responses by the innate arm of the immune system and the adaptive immune responses during viral infections differ between females and males (Gebhard *et al*., 2020). The reports of Boissier *et al*. (2003) Xia *et al*. (2009) and Melgert *et al*. (2010) showed that the number and activity of innate immune cells are higher in females than in males. This may have hormonal and genetic basis which needs further clarification especially, in COVID-19 patients.

Reports have shown that WBC count increased as COVID-19 progressed, especially in severe cases and non-survivors (Khartabil *et al*., 2020; National Health Council, 2020). Gan *et al*. (2020) reported that leucocyte count was higher in the COVID-19 patients that died and predicted mortality in the patients. The observed elevated WBC count in COVID-19 patients at discharge in this study might mean that the reported increase in WBC count with progression of COVID-19 is not only peculiar to severe cases and non-survivors but could be a feature even in patients with mild COVID-19.

Monocytes are cells of the innate immune system with a plasticity to develop into macrophages or dendritic cells (Karlmark *et al*., 2012). They participate in phagocytosis, antigen presentation, inflammatory responses, and a variety of other immune function processes (Jakubzick *et al*., 2017). In COVID-19, monocytes play principal roles in cytokine storm and associated pathologies (Pence, 2020; Zhou *et al*., 2020). The observed elevated percentage of monocyte in COVID-19 patients who spent more than 10 days on admission compared with those who spent fewer days corroborates the report of Zhou *et al*. (2020) which showed that there was a significant increase in the circulating proportion of monocytes (especially IL-6 producing monocytes) in patients with COVID-19 and that the monocyte percentage increased further with the severity of the disease especially, acute respiratory distress syndrome (ARDS). Our observation suggests that monocyte percentage could be useful in determining possible duration of hospital stay and even, the tendency towards severity of COVID-19 patients. This suggestion is further buttressed by the observed significant reduction in the proportion of COVID-19 patients with monocyte percentage above the reference range at discharge compared with baseline, and the observed significant positive correlation between monocyte percentage and days on admission. Therefore, elevation of monocyte percentage at admission might indicate longer hospital stay and its progressive reduction during the course of COVID-19 treatment might be an indicator of recovery from the disease. Thus, monocyte functions may be targeted in the management of COVID-19 patients as early as admitted.

Although the extent of immune system dysregulation and its contribution to COVID-19 pathogenicity in older adults is not well-understood, advanced age is considered a principal risk factor for COVID-19 complications, and this was largely attributed to immunosenescence (Nikolich-Zugich *et al*., 2020; Pence, 2020). It has been reported that with increase in the age of infected patients, the mortality rate also increases, and the crude mortality rate in people over 80 years old was reported to be 21.9% (National Health Council, 2020).

The observed lower lymphocyte percentage with concurrent higher percentage of monocyte and neutrophil as well as higher NLR in COVID-19 patients aged 40 years and above compared with patients less than age 40 years might indicate that heightened inflammation with possible superimposed

bacterial infection and impaired adaptive immune responses to SARS-CoV-2 are associated with older age. This is further alluded to by the observed significant positive correlation between age and percentages of monocyte and neutrophil, and NLR as well as significant negative correlation between age and percentage lymphocyte. A number of studies showed that a disproportionate number of severe cases and deaths due to COVID-19 are observed in older adults (Onder *et al*., 2020; Shahid *et al*., 2020; Wang *et al*., 2020; Wang *et al*., 2020).

Inability to determine dynamic changes (by collecting samples at different intervals during the course of treatment) in the routine haemocytometric profile of the patients was a limitation in this study. Also, inability to rule out possible co-infections apart from human immunodeficiency virus (HIV) infection and pulmonary tuberculosis infection was also a limitation.

It could be concluded from this study that haemocytometric changes and inflammation in COVID-19 patients increase with age. Also, monocyte count could be an indicator of longer hospital stay and its reduction during the course of COVID-19 treatment might be an indicator of recovery from the disease. In addition, findings from this study further allude to the wide potentialities inherent in inexpensive and rapid laboratory tests such as haemocytometry in disease stratification and prognostication.

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