Asian Journal of Biochemistry

ISSN 1815-9923

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Asian Journal of Biochemistry

ISSN 1815-9923
DOI: 10.3923/ajb.2024.17.25

Research Article
Prevalence of Dyslipidemia and Comorbidities in Patients Infected with SARS-COV-2 in Saint-Louis (Senegal)

[1]Doupa Dominique, [2]Dieye Alassane, [1,2]Ahmed Jemila Dahi Soueid, [3]Dia Diatou Gueye, [4]Beye Serigne Mor, [1]Makalou Demba, [1]Sagna Hélène Ange, [5]Thiam Souleymane, [5]Coly Nadja Fatou, [5]Cssé Fatou, [5]Ndiaye Arame, [6]Kandji Pape Matar, [6]Djité Moustapha, [7]Lo Seynabou, [6]Gueye Madieye and [5]Diallo-Agne Fatou

[1]Laboratory of Biochemistry, Health Sciences Research and Training Unit, Gaston Berger University of Saint-Louis, Senegal
[2]Infectious Diseases Services, Health Sciences Training and Research Unit, Gaston Berger University of Saint-Louis, Senegal
[3]Internal Medicine Service, Health Sciences Research and Training Unit, Gaston Berger University of Saint-Louis, Senegal
[4]Cardiology Service, Health Sciences Training and Research Unit, Gaston Berger University of Saint-Louis, Senegal
[5]Medical Biochemistry Laboratory, Cheikh Anta Diop University, Dakar, Senegal
[6]Laboratory of Pharmaceutical Biochemistry, Cheikh Anta Diop University, Dakar, Senegal
[7]Laboratory of Bacteriology and Virology, Health Sciences Training Unit, Gaston Berger University of Saint-Louis, Senegal

Abstract

Background and Objective: The COVID-19 was a global health emergency. Epidemiological studies have shown the association between comorbidities and morbidity-mortality related to COVID-19. The general objective of the present study was to evaluate the impact of SARS-CoV-2 infection on lipid metabolism. **Materials and Methods:** A retrospective cross-sectional descriptive study was conducted at the ETC level of the Saint Louis Regional Hospital from March, 2020 to December, 2021. All patients in whom the diagnosis of COVID-19 was mentioned based on clinical and biological arguments (RT-PCR positive) were included and benefited from a lipid balance during the period. Data processing and recording were carried out using Excel 2013 for averages, spreadsheets and plots. The means were compared using the Student's t-test and a $p<0.05$ was considered a significant difference. **Results:** The lipid testing was performed on 219 of 448 patients, with a realization rate of 48.9%. Male predominance was observed, with a sex ratio of 1.36. The most common comorbidity was hypertension (hypertension), accounting for 59 cases (62%). Dyslipidemia was found in 80.8% of patients, with hypoalphalipoproteinemia (Hypo-HDL) in 134 cases (75.7%), total hypercholesterolemia: Hyper-TC (2 g/L) in 69 cases (39%), hypertriglyceridemia: Hyper-TG (1.5 g/L) in 45 cases (25.4%) and hyper-LDL cholesterol: Hyper-LDL (1.6 g/L) in 33 cases (18.6%). A bivariate analysis of dyslipidemia and evolutionary modalities found that total hypercholesterolemia and hypertriglyceridemia had a significant association with death ($p<0.05$). **Conclusion:** The study showed a high prevalence of dyslipidemia in SARS-CoV-2 infected patients despite a low rate of achievement of lipid balance. Hypercholesterolemia and hypertriglyceridemia were significantly associated with death. Due to poor sampling, additional studies are needed to confirm these preliminary results.

Key words: Dyslipidemia, SARS-CoV-2, comorbidities, hypercholesterolemia, hypertriglyceridemia

Citation: Dominique, D., D. Alassane, A.J.D. Soueid, D.D. Gueye and B.S. Mor *et al.*, 2024. Prevalence of dyslipidemia and comorbidities in patients infected with SARS-COV-2 in Saint-Louis (Senegal). Asian J. Biochem., 19: 17-25.

Corresponding Author: Doupa Dominique, Laboratory of Biochemistry, Health Sciences Research and Training Unit, Gaston Berger University of Saint-Louis, Senegal Tel: 00221776490562

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The World Health Organization (WHO) has identified COVID-19 as the virus's cause of illness. It is an acute pandemic infectious disease that spreads primarily through the respiratory tract. One of its main symptoms is dyspnea, a subjective sense of breathing trouble. After SARS-CoV-1 in 2003 in China, then MERS-CoV in 2012 in the Arabian Peninsula, responsible for respiratory distress syndromes (SDR) often fatal, this is the third global health threat related to a coronavirus in less than twenty years[1]. The COVID-19 is a disease with a wide spectrum of clinical severity: Benign, moderate, severe or even critical. The severity of COVID-19 is in the development of large amounts of pro-inflammatory cytokines that may contribute to Acute Respiratory Distress Syndrome (ARDS) and multi-visceral failure[2]. From the beginning of the epidemic, authors have reported coagulation disorders, including disease venous thromboembolism associated with SARS-CoV-2 infection[3]. These events increase the risk of death during the disease.

The SARS-CoV-2 infection can lead to significant alterations in metabolism, directly influencing lipid levels in the blood. The virus can affect the liver, a central organ in lipid metabolism, by disrupting its functions of lipoprotein synthesis and regulation. This disruption can lead to abnormal levels of cholesterol and triglycerides. In addition, the virus can induce insulin resistance, a state where the body's cells do not respond properly to insulin, thus disrupting glucose and lipid metabolism. Insulin resistance is often associated with increased triglyceride levels and decreased HDL cholesterol[4].

Dyslipidemias may be associated with an increased risk of blood clots. The COVID-19 is also linked to blood clotting problems. Thus, the combination of these two factors can increase the risk of thrombosis in patients with COVID-19 with dyslipidemia. On the other hand, patients with dyslipidemia have an increased risk of cardiovascular disease and COVID-19 can exacerbate these risks. Infection can cause systemic inflammation, which, combined with high levels of LDL cholesterol or triglycerides, can increase the risk of heart attacks or other heart problems in patients[5]. However, very few studies have focused on assessing the lipid profile in patients with COVID-19. The study aimed to describe the epidemiological profile of patients with COVID-19 and assess the lipid profile of patients with COVID-19. Moreover, the relationship between lipid profile and clinical severity spectrum was also studied.

MATERIALS AND METHODS

Study area: This cohort, cross-sectional, retrospective, descriptive and analytical investigation lasted 21 months, from March, 2020 to December, 2021.

Study population: The study population consisted of all patients hospitalized at the Epidemic Treatment Center (ETC) of the Regional Hospital Center (CHR) of Saint-Louis, Senegal.

Inclusion criteria: All patients in whom the diagnosis of COVID-19 was evoked based on clinical and biological arguments (RT-PCR positive) were included and who benefited from a lipid assessment during the period of hospitalization at the CTE of the Saint-Louis CHR.

Criteria for exclusion: The study did not concern suspected patients (RT-PCR doubtful), in observation as well as patients whose medical records were incomplete.

Sampling: Recruitment was exhaustive including systematically all patients infected with SARS-CoV-2, admitted to the CTE of Saint-Louis, Senegal during the study period and meeting the inclusion criteria.

Data collection: Data were collected using a questionnaire with the following parameters:

- **Epidemiological parameters:** Age, sex and occupation
- **Clinical data:** Medical history, comorbidities, nature of cases (contact cases, community cases, imported cases), forms according to severity and clinical signs on admission
- **Paraclinical data:** Blood count, CRP, fasting blood glucose, glycated Hemoglobin (HBA1C), creatinine and lipid balance (total cholesterol, triglycerides, LDL and HDL)

The parameters of the biological balance which are total cholesterol, HDL-cholesterol, triglycerides and blood sugar were measured by the usual enzymatic methods. The reading is made on a spectrophotometer (CyanSmart CY009, Belgium) using the Biosystems kit (COD 11055 Spain, Barcelona) and the results a expressed in (g/L). Serum LDL-cholesterol concentrations were calculated using the Friedewald method[6]. When the triglyceride level was above 4 g/L, the LDL was determined by the direct method. Dyslipidemias were defined

according to the recommendations of the American Adult Treatment Program III (ATPIII) of the National Cholesterol Education Program (NCEP)[7]:

- High cholesterol (total cholesterol >2 g/L)
- Hypertriglyceridemia (triglycerides >1.5 g/L)
- Hypoalphalipoproteinemia (HDL cholesterol 0.40 g/L in men and 0.5 g/L in women)
- Hypobetalipoproteinemia (LDL cholesterol >1.30 g/L)
- Mixed hyperlipidemia (total cholesterol >2 g/L and triglycerides >1.5 g/L)
- Blood count was performed with the XN-1000 system. The cells are counted by flow cytometry and thanks to a sheath liquid, they pass one by one in front of a laser beam. Hemoglobin is measured after cell lysis by a lysis solution (sulfolyser) and reacts with sodium lauryl sulfate (SLS). This reaction results in the formation of a colored compound that is measured by spectrophotometry and whose concentration is proportional to that of hemoglobin
- Protein C-reactive ultra-sensible assay was performed by immunoturbidimetry using the Architect ci4100 system (Abbott USA)
- Creatinine by the kinetic Jaffe method[8]
- Hemoglobin glycated by immunochemical technique
- Blood ionogram was determined by potentiometric method using ion-specific electrodes[9]

Data management and statistical analysis: The operation and recording of the data were carried out with the Excel 2013 software for the calculation of averages and the preparation of tables and graphs. The mean comparison was made using the Student's t-test and a $p<0.05$ was considered a significant difference.

Ethical considerations: The collection of data has been authorized by the CTE manager. The management of information and medical records was done in strict respect of medical secrecy and anonymity. Ethical principles were applied throughout the course of this study.

RESULTS

Epidemiological aspects: The average age of patients was 55.3±16.7 years. The most representative age group was between 61 and 80 with a caseload of 70 (39.5%) illustrated in Fig. 1.

Clinical aspects: Medical history was dominated by a peptic ulcer with 11 cases (6.2%), followed by pneumonia and ischemic stroke (AVCI) with 02 cases each (1.1%) as shown in Table 1.

In the current series, 95 patients (53.7%) had at least one comorbidity. Hypertension was the main comorbidity with 59 cases (62%), followed by diabetes mellitus with 38 cases (40%) and asthma with 07 cases (7.4%) as shown in Table 2.

The majority of patients were community cases with 148 cases (84%). Severe forms of COVID-19 were predominant with 81 cases (45.8%) as shown in Table 3.

Fever was the most frequent general sign with 87 cases (49.2%), followed by asthenia with 55 cases (31%) and diffuse algia with 50 cases (28.2%) as shown in Table 4.

Biological data

Hematological parameters: Blood count was performed in 170 patients (96.4%) as described in Table 5.

Biochemical parameters: The biochemical parameters investigated in this study were reported in Table 6.

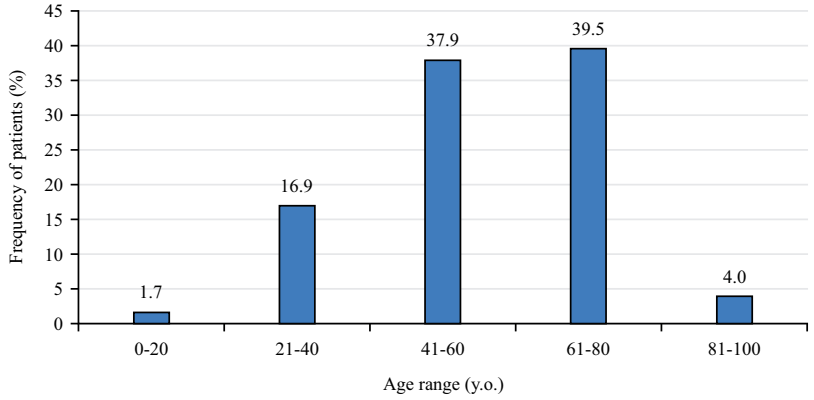

Fig. 1: Age group distribution within the study population

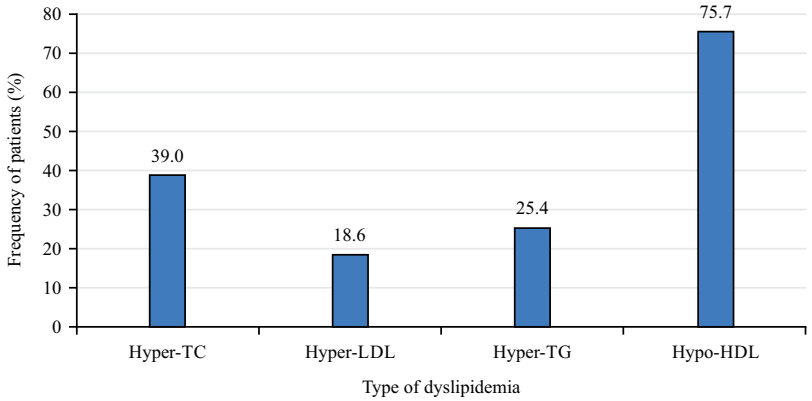

Fig. 2: Distribution of patients by type of dyslipidemia

Table 1: Distribution of patients by medical history

Medical history	Number of cases	Percentage
Peptic ulcer disease	11	6.2
Pneumonia	02	1.1
Stroke	02	1.1
Pulmonary tuberculosis	01	0.6
Pleurisy	01	0.6
Malaria	01	0.6
Typhoid fever	01	0.6
Influenza	01	0.6
Gestational diabetes	01	0.6
Myocardial infarction	01	0.6
Rheumatoid arthritis	01	0.6

Table 2: Distribution of patients by comorbidities

Comorbidities	Number of patients	Percentage
High blood pressure	59	62
Diabetes mellitus	38	40
Asthma	07	7.4
Obesity	05	5.3
Sickle cell trait	03	3.2
Chronic kidney disease	02	2.1
Gout disease	02	2.1
Rheumatoid arthritis	02	2.1
Pernicious anemia	01	01
Dementia	01	01
Auricular articular block	01	01
Pregnancy	01	01

Table 3: Distribution of patients by severity of COVID-19 cases

Shapes according to gravity	Number of patients	Percentage
Severe forms	81	45.8
Moderate forms	25	14
Simple forms	70	39.5
Critical forms	01	0.6
Total	177	100

In our series, dyslipidemia was found in 177 patients/219 a prevalence of 80.8% hypoalphalipoproteinemia HDL-cholesterolemia (<0.4 g/L) was found in 134 cases (75.7%), followed by total hypercholesterolemia (>2 g/L) with 69 cases (39%), followed by hypertriglyceridemia (>1.5 g/L) with 45 cases (25.4%) and hyper-LDL-cholesterolemia (>1.6 g/L) with 33 cases (18.6%) illustrated in Fig. 2.

Table 4: Distribution of patients by general signs on admission

General signs on admission	Number of patients	Percentage
Fever	87	49.2
Asthenia	55	31
Diffuse myalgias	50	28.2
Anorexia	29	16.4
Chills	25	14
Arthralgia	25	14
Myalgia	21	12
Back pain	08	4.5
Sweat	05	2.8
Weight loss	01	0.6
Lethargy	01	0.6

Table 5: Distribution of patients by blood count data

Parameter	Effective	Percentage
Lymphopenia (<1500/mm^3)	90	53
Hyperleukocytosis (>10000/mm^3)	36	21
Neutropenia (<1500/mm^3)	23	13
Anemia (Hb <10 g/dL)	12	7
Hyperleukocytosis (>10000/mm^3)	36	21
Thrombocytopenia (<150000/mm^3)	11	6

Table 6: Distribution of patients by biochemical abnormalities

Parameter	Effective	Percentage
Hypoalphalipoproteinemia (<0.40)	134	75.7
Hypercholesterolemia (>2 g)	69	39
Hypertriglyceridemia (>1.5)	45	25.4
Hyper LDL cholesterolemia	33	18.6
Hyperglycemia (>1.26)	33	20.8
HbA1c (>7%)	08	40
CRP (>12 mg/L)	12	7
Serum creatinine (>14 mg/L)	27	15.7
Hyponatremia (<135 meq/L)	19	36.6

Table 7: Relation between progressive modalities and hypercholesterolemia

	Death			
Total hypercholesterolemia	Yes	No	Total	p-value
Yes	04	65	69	0.03
No	18	90	118	
Total	22	155	177	

Table 8: Relation between progressive modalities and hypertriglyceridemia

	Death			
Hypertriglyceridemia	Yes	No	Total	p-value
Yes	10	38	48	0.04
No	12	117	129	
Total	22	155	177	

The bivariate analysis between dyslipidemia and progressive modalities showed a statistically significant association (p>0.05) between both total hypercholesterolemia and hypertriglyceridemia with mortality, as illustrated in Table 7 and 8.

DISCUSSION

Gender: This study found a male predominance (57.6%), with a sex ratio of 1.36, which was consistent with the Global Health 5050 report that objected to this male predominance with, respectively (55%) of men against (45%) of women a sex ratio :1.2[10]. In a single-center retrospective study conducted in Wuhan, a total number of 138 hospitalized patients (54.3%) were men[11]. These results were also similar to those obtained by the Chinese emergency response epidemiology team, which counted 51.4% of men among the 72,314 hospitalized patients[9]. In Algeria, Tunis and Morocco, studies also showed a male predominance with 60.5, 60.1 and 55.3% men, respectively[12,13]. Most studies have shown that men are most

affected by SARS-CoV-2, which is consistent with the results of this study. In fact, in the present study, this male predominance may reflect gender disparities in social and cultural activities. In general, the man is the main source of income for families, which encourages him to work to meet the needs of everyone. Because of his mobility and contact with a large number of people compared to women, is more likely to expose himself to a higher risk of contamination than women. The latter are often confined to household tasks and therefore sedentary. For other studies, the low hospitalization rate of women could be attributed to their low susceptibility to infections[14,15].

Age: The patients had an average age of 55.3±16.7 years. The most affected population was those in the 61-80 age group, with 70 cases (39.5%), which was consistent with the study conducted by Donamou *et al.*[16]. In a study conducted in Lombardy, 1591 patients were included, whose median age was 63 years[17]. Ketfi *et al.*[12] and Ouedraogo *et al.*[18] reported an average age of 53 and 61.8 years, respectively. Other authors, Zhou *et al.*[19], found a median age of 56 in their retrospective cohort in Wuhan. Another retrospective descriptive study within the Nord Essonne hospital group conducted by Mbaku *et al.*[20] found that patients hospitalized for COVID-19 had an average age of 64 years. In a prospective observational study of 1.527 COVID-19 patients admitted to the military hospital in Tunis, the average age was 64.9 years[13]. These findings are explained by the fact that in Senegal, hospitalization was a priority for individuals at risk, especially those over 45 years of age.

Clinical admission symptoms: Cough was the most common functional manifestation at admission, accounting for 87 cases (49.2%), followed by dyspnea in 78 cases (44%) and headaches in 60 cases (33.9%). The most common general sign was fever, which occurred in 87 cases (49.2%), followed by asthenia in 55 cases (31%) and diffuse myalgias in 50 cases (28.2%). Multiple studies in China have likewise confirmed these symptoms in most patients, the most common of which were cough, fever, dyspnea and asthenia[21-23]. A prospective longitudinal observational study conducted by Slama *et al.*[24], on 55 patients, total anosmia was observed in 85.5% of patients, dysgeusia in 80% of cases. This symptomatology can be explained by the intensification of the inflammatory response caused by lung inflammation.

In this study, the simple form was observed in 39.5% of patients and the severe form in 45.8% while 14% of our patients presented a moderate form. The results were similar to Zhang *et al.*[5], which revealed that 41.2% of patients were severely affected by COVID-19. A slight increase in the number of asymptomatic patients was described in a study in Japan of 634 cases infected with SARS-CoV-2, only 17.9% were asymptomatic[25]. In a meta-analysis of 72.314 patient records, China's emergency response epidemiology team found 1.2% of asymptomatic patients among confirmed cases[11]. Ouedraogo *et al.*[18], in a study conducted in Burkina Faso, the severity rate was 32.1%.

Goyal *et al.*[26] in their study of 1099 patients, found 84.2% of patients with non-severe form at admission compared to 15.7% with a severe form. Compared to other studies, the percentage of people with severe forms is higher. The high prevalence of cardiovascular risk factors in this study population would seem to explain the severity of the disease observed.

Comorbidities: In our sample, 53% of individuals had at least one comorbidity. The main cause of comorbidity was high blood pressure (hypertension) (62%), followed by diabetes mellitus (40%) and asthma (7.4%). In Burkina Faso, Ouédraogo *et al.*[18] found a predominance of high blood pressure (21.7%) compared to diabetes mellitus (8.3%). According to the study conducted by Donamou *et al.*[16], the main comorbidities were high blood pressure (55%) and diabetes mellitus (38%). Guan *et al.*[27] observed the same trend in China where the main comorbidities were represented by hypertension (31.2%), followed by diabetes mellitus (10.1%) and cardiovascular diseases (14.5%).

Paraclinical aspects

Blood count: In current study, the blood count was performed in (96%).

- Leukocytosis (10000/µL) was found in 21.2%
- Lymphopenia (1500/µL) was found in 53%
- Neutropenia (1500/µL) was found in 13.5%
- Thrombocytopenia (150000/µL) was found in 6.5%

Anemia with a hemoglobin level 10 g/L was found in (7%). These hematological dysfunctions, the pathophysiology of which is not yet sufficiently explained, are often observed in patients with especially severe COVID-19[28]. Lymphopenia may be due to a defective immune response to the virus. Leukocytosis in a small number of patients suggests bacterial infection or superinfection[28]. The presence of thrombocytopenia associated with consumer coagulopathy was an essential element in assessing the severity of the disease in COVID-19 patients[28]. Wu *et al.*[22] have shown that anemia is mainly caused by inflammation, sometimes linked to iron and/or vitamin deficiencies.

Inflammatory assessment

CRP: The CRP was measured in 80 patients (45.2%) and was positive in 44 patients (55%). The average CRP was 65.3 mg/L (66.4). It is reported by Hariyanto and Kurniawan[29] and Ouédraogo *et al.*[30], COVID-19, a high CRP with proportions ranging from 28.6 to 85.6%. The CRP was high in 83.6% of patients in our study. This result could explain the large number of severe forms (29.6%) in our study. Indeed, CRP has been considered since 1930 as a sensitive marker of inflammation, since it increases in almost all inflammatory processes[31]. Its elevation in COVID-19 is associated on the one hand with cytokine storm[32] and on the other hand with bacterial co-infections[33,34]. Severe forms of COVID-19 were closely related to the elevation of CRP[35].

Parameters of the lipid balance: The lipid assessment was performed on 219 patients out of a total of 448 or a realization rate of 48.9%. In our series, dyslipidemia was found in 177 patients/219 a prevalence of 80.8%. Hypoalphalipoproteinemia (HDL). Cholesterolemia (<0.5 g/L) was found in 134 cases (75.7%), followed by total hypercholesterolemia (2 g/L) with 69 cases (39%), followed by hypertriglyceridemia (1.5 g/L) with 45 cases (25.4%) and hyper-LDL-cholesterolemia (1.6 g/L) with 33 cases (18.6%). In a study conducted at the National Institute of Nutrition in Tunis including 39 diabetic patients infected with SARS-COV-2, a lipid balance disruption was also found in 61.5% with an average of LDL cholesterol before COVID-19 of 0.98, 0.31 and 10.33 g/L post COVID-19[36]. An average of triglycerides before the disease was 1.38 and 0.47 mmol/L and increased to 1.7 and 0.57 mmol/L after the COVID-19 episode. In a study conducted in France and involving 3663 patients, the prevalence of dyslipidemia was 18% (4-32%). In this same study, dyslipidemia was statistically significantly associated with an adverse prognosis (RR 1.39 [1.02, 1.88], p = 0.010; I2: 56.7%, p = 0.018). Subgroup analysis showed that dyslipidemia was associated with severe COVID-19 (RR 1.39 [1.03, 1.87], p = 0.008; I2: 57.4%, p = 0.029)[37]. Meta-regression showed that dyslipidemia, age (coefficient: -0.04, p = 0.033), male sex (coefficient: -0.03, p = 0.042) and hypertension (coefficient: -0.02, p = 0.033) were associated with poor prognosis. However, this relationship was not found in diabetics (coefficient: -0.24, p = 0.135) and patients with cardiovascular diseases (coefficient: -0.01, p = 0.506). These studies noted a relationship between the severity of COVID-19 with hypercholesterolemia and hypertriglyceridemia. These two factors were significantly associated with death (p = 0.05).

This study found a high prevalence of dyslipidemia in SARS-CoV-2 infected patients. Hypercholesterolemia and hypertriglyceridemia were significantly associated with death (p<0.05). These preliminary, although promising results should not obscure a number of limitations. These include incompleteness of lipid balance in all patients and insufficiency of the technical platform did not allow to perform chest scan in order to objectify cardiac lesions

For these reasons, additional studies with a larger cohort are needed to support these results. Public awareness of the adverse consequences of dyslipidemia on the prognosis of the disease is very important.

CONCLUSION

Infection with SARS-CoV-2 can cause alterations in metabolism, directly affecting levels of lipids in the blood. Various mechanisms were discussed to explain the influence of COVID-19 on lipid metabolism. Among these, inflammation seems to play a role. Knowing that it is a key factor in the response to immune to COVID-19, high levels of inflammation pre-existing dyslipidemia could potentially influence the severity of the disease in a patient with COVID-19. At the end of this study, high prevalence of dyslipidemia and associated factors were noted in patients with COVID-19 despite low prescription of lipid balance. The factors significantly associated with death were hypertriglyceridemia and total hypercholesterolemia. These preliminary results should be supplemented by larger cohort studies to support this relationship.

SIGNIFICANCE STATEMENT

This study revealed a high prevalence of dyslipidemia in patients with COVID-19 despite a low achievement rate in the cohort of patients admitted to the Center for Epidemic Treatment Center. Hypoalphalipoproteinemia was the most predominant anomaly. Bivariate analysis showed a strong association between dyslipidemia and evolutionary modalities. In other words, hypercholesterolemia and hypertriglyceridemia were associated with death. These preliminary results show an interest in their detection and early follow-up, especially in patients infected with SARS-CoV-2 to improve their prognosis. These results suggest that the early and systematic prescription of lipid balance in patients with COVID-19 improved their prognosis and reduced mortality. Meanwhile, public awareness of the adverse consequences of dyslipidemia on the prognosis of COVID-19 is required for health professionals.

ACKNOWLEDGMENTS

We appreciate the Director of the Regional University Hospital of Saint-Louis and the Head of the Epidemic Treatment Center for granting us access to patient records during the course of this study. We extend our gratitude to the Ministry of Health of Senegal, which funded all of the studies conducted as part of the management of patients with COVID-19 (n°3683106 spécial Fonds Coronavirus/COVID 19).

REFERENCES

1. Kristiansen, P.A., M. Page, V. Bernasconi, G. Mattiuzzo and P. Dull *et al*., 2021. WHO International Standard for anti-SARS-CoV-2 immunoglobulin. Lancet, 397: 1347-1348.
2. Yuki, K., M. Fujiogi and S. Koutsogiannaki, 2020. COVID-19 pathophysiology: A review. Clin. Immunol., Vol. 215. 10.1016/j.clim.2020.108427.
3. Martín-Rojas, R.M., G. Pérez-Rus, V.E. Delgado-Pinos, A. Domingo-González and I. Regalado-Artamendi *et al*., 2020. COVID-19 coagulopathy: An in-depth analysis of the coagulation system. Eur. J. Haematol., 105: 741-750.
4. Henry, B.M., M.H.S. de Oliveira, S. Benoit, M. Plebani and G. Lippi, 2020. Hematologic, biochemical and immune biomarker abnormalities associated with severe illness and mortality in coronavirus disease 2019 (COVID-19): A meta-analysis. J. Clin. Chem. Lab. Med., 58: 1021-1028.
5. Zhang, D., R. Guo, L. Lei, H. Liu and Y. Wang *et al*., 2021. Frontline science: COVID-19 infection induces readily detectable morphologic and inflammation-related phenotypic changes in peripheral blood monocytes. J. Leukocyte Biol., 109: 13-22.
6. Friedewald, W.T., R.I. Levy and D.S. Fredrickson, 1972. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin. Chem., 18: 499-502.
7. Lipsy, R.J., 2003. The National Cholesterol Education Program adult treatment panel III guidelines. J. Managed Care Pharm., 9: 2-5.
8. Delatour, V., B. Lalere, G. Dumont, J.M. Hattchouel, M. Froissart, J. de Graeve and S. Vaslin-Reimann. 2011. Development of a reference method for creatinine measurement to improve diagnosis and follow-up of kidney disease [In French]. Rev. Fr. Métrologie, 26: 21-31.
9. Burnett, R.W., A.K. Covington, N. Fogh-Andersen, W.R. Külpmann and A. Lewenstam *et al*., 2000. Recommendations for measurement of and conventions for reporting sodium and potassium by ion-selective electrodes in undiluted serum, plasma or whole blood. Clin. Chem. Lab. Med., 38: 1065-1071.
10. Wang, D., B. Hu, C. Hu, F. Zhu and X. Liu *et al*., 2020. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA, 323: 1061-1069.
11. Surveillances, V., 2020. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19)-China, 2020. China CDC Wkly., 2: 113-122.
12. Ketfi, A., O. Chabati, S. Chemali, M. Mahjoub and M. Gharnaout *et al*., 2020. Clinical, biological and radiological profile of Algerian patients hospitalized for COVID-19: Preliminary data [In French]. Pan Afr. Med. J., Vol. 35. 10.11604/pamj.supp.2020.35.2.23807.
13. Rachdi, R., S. Hannachi, S. Zribi, O. Ayed and R. Abid *et al*., 2022. Comparative study of patients hospitalized for SARS-CoV-2 infection during two consecutive waves in Tunisia. Med. Trop. Santé Int., Vol. 2. 10.48327/mtsi.v2i3.2022.207.
14. Shi, C., L. Wang, J. Ye, Z. Gu and S. Wang *et al*., 2021. Predictors of mortality in patients with coronavirus disease 2019: A systematic review and meta-analysis. BMC Infect. Dis., Vol. 21. 10.1186/s12879-021-06369-0.
15. Wang, J., C.M. Syrett, M.C. Kramer, A. Basu, M.L. Atchison and M.C. Anguera, 2016. Unusual maintenance of X chromosome inactivation predisposes female lymphocytes for increased expression from the inactive X. Proc. Natl. Acad. Sci. U.S.A., 113: E2029-E2038.
16. Donamou, J., A. Bangoura, L.M. Camara, D. Camara and D.A. Traoré *et al*., 2021. Epidemiological and clinical characteristics of COVID-19 patients admitted to the intensive care unit of Donka Hospital in Conakry, Guinea: Descriptive study of the first 140 hospitalised cases. Anesth. Resuscitation, 7: 102-109.
17. Grasselli, G., A. Zangrillo, A. Zanella, M. Antonelli and L. Cabrini *et al*., 2020. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. JAMA, 323: 1574-1581.
18. Ouedraogo, E., A. Lucie, A. Sutton, M. Didier and B. Giroux-Leprieur *et al*., 2020. Metabolic syndrome and COVID-19: What is the risk of severe pneumonia? [In French]. Med. Infect. Dis., 50: S85-S85.
19. Zhou, F., T. Yu, R. Du, G. Fan and Y. Liu *et al*., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. Lancet, 395: 1054-1062.
20. Mbaku, A.B., L. Decoux, D. Cobarzan and K. Chaouche, 2021. Clinical and paraclinical characteristics of patients hospitalized for COVID-19 at the Nord Essonne Hospital Group [In French]. Respir. Dis. Rev. News, 13: 115-115.
21. Cummings, M.J., M.R. Baldwin, D. Abrams, S.D. Jacobson and B.J. Meyer *et al*., 2020. Epidemiology, clinical course, and outcomes of critically ill adults with COVID-19 in New York City: A prospective cohort study. Lancet, 395: 1763-1770.

22. Wu, C., X. Chen, Y. Cai, J. Xia and X. Zhou *et al*., 2020. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan, China. JAMA Intern. Med., 180: 934-943.
23. Mahieu, R. and V. Dubée, 2020. Clinical and epidemiological characteristics of COVID-19 [In French]. Actualités Pharm., 59: 24-26.
24. Slama, D., S. Bartier, C. Hautefort, E. Bequignon and N. Etienne *et al*., 2020. Anosmia: Specific criterion of COVID-19 disease "Coranosmia1" [In French]. Méd. Mal. Infectieuses, 50: S78-S78.
25. Guan, W.J., Z.Y. Ni, Y. Hu, W.H. Liang and C.Q. Ou *et al*., 2020. Clinical characteristics of Coronavirus disease 2019 in China. N. Engl. J. Med., 382: 1708-1720.
26. Goyal, P., J.J. Choi, L.C. Pinheiro, E.J. Schenck and R. Chen *et al*., 2020. Clinical characteristics of COVID-19 in New York City. N. Engl. J. Med., 382: 2372-2374.
27. Guan, W.J., W.H. Liang, Y. Zhao, H.R. Liang and Z.S. Chen *et al*., 2020. Comorbidity and its impact on 1590 patients with COVID-19 in China: A nationwide analysis. Eur. Respir. J., Vol. 55. 10.1183/13993003.00547-2020.
28. Bergamaschi, G., F.B. de Andreis, N. Aronico, M.V. Lenti and C. Barteselli *et al*., 2021. Anemia in patients with COVID-19: Pathogenesis and clinical significance. Clin. Exp. Med., 21: 239-246.
29. Hariyanto, T.I. and A. Kurniawan, 2020. Dyslipidemia is associated with severe coronavirus disease 2019 (COVID-19) infection. Diabetes Metab. Syndr.: Clin. Res. Rev., 14: 1463-1465.
30. Ouédraogo, A.R., G. Bougma, A. Baguiya, A. Sawadogo and P.R. Kaboré *et al*., 2021. Factors associated with the occurrence of acute respiratory distress and death in patients with COVID-19 in Burkina Faso. Respir. Dis. Rev., 38: 240-248.
31. Wang, J., M. Jiang, X. Chen and L.J. Montaner, 2020. Cytokine storm and leukocyte changes in mild versus severe SARS-CoV-2 infection: Review of 3939 COVID-19 patients in China and emerging pathogenesis and therapy concepts. J. Leukocyte Biol., 108: 17-41.
32. Chen, X., B. Liao, L. Cheng, X. Peng and X. Xu *et al*., 2020. The microbial coinfection in COVID-19. Appl. Microbiol. Biotechnol., 104: 7777-7785.
33. Holliday, Z.M., M.M. Alnijoumi, M.A. Reed, A.P. Earhart, A.G. Schrum, L.A.H. Allen and A. Krvavac, 2021. Neutrophils and secondary infections in COVID-19 induced acute respiratory distress syndrome. New Microbes New Infect., Vol. 44. 10.1016/j.nmni.2021.100944.
34. Sakthivadivel, V., G.K. Bohra, N. Maithilikarpagaselvi, S. Khichar and M. Meena *et al*., 2021. Association of inflammatory markers with COVID-19 outcome among hospitalized patients: Experience from a tertiary healthcare center in Western India. MÆDICA J. Clin. Med., 16: 620-627.
35. Liu, W., Z.W. Tao, L. Wang, M.L. Yuan and K. Liu *et al*., 2020. Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease. Chin. Med. J., 133: 1032-1038.
36. Bani, I., Z. Hadjali, M. Dalhoum, A. Bouzid and Y. Htira *et al*., 2023. The metabolic profile of diabetic patients post-COVID-19 [In French]. Ann. Endocrinol., 84: 211-212.
37. Frater, J.L., G. Zini, G. d'Onofrio and H.J. Rogers, 2020. COVID-19 and the clinical hematology laboratory. Int. J. Lab. Hematol., 42: 11-18.