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Clinical Research

POST-ACUTE COVID-19 SYNDROME AND THE RISK OF DEVELOPING HYPERTENSION AND DIABETES: THE ROLE OF COAGULATION DYSFUNCTION

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ABSTRACT **Background:** COVID-19 has been linked with chronic cardiovascular and metabolic consequences after the initial period of the acute infection. Increased risk of hypertension and diabetes mellitus among recovered patients may be attributed to coagulation abnormalities and systemic inflammation.**Methods:** In this study, 500 patients were collected in the Out Patient Department of District Combined Hospital, Noida, Uttar Pradesh, who were suffering from COVID-19 from the hospital. Demographic characteristics, disease severity, and hospitalization status were documented, as well as coagulation markers, such as D-dimer, fibrinogen, prothrombin time (PT), International Normalized Ratio (INR), platelet count and C-reactive protein (CRP). Patients were then followed for 6 months to detect new onset hypertension and diabetes mellitus. Descriptive statistics, independent-samples t-tests, Pearson's correlation and multivariable logistic regression were used for statistical analysis.**Results:** New-onset hypertension and diabetes mellitus were observed in 23.6% and 17.4% of participants, respectively. Patients developing these conditions exhibited significantly higher D-dimer, fibrinogen, and CRP levels than those without metabolic complications ($p<0.05$). Elevated D-dimer (>2 mg/L) was the strongest independent predictor of both hypertension (AOR=3.37) and diabetes mellitus (AOR=3.69). Significant positive correlations were observed between D-dimer, systolic blood pressure, HbA1c, and CRP.**Conclusion:** There is a strong association between the development of hypertension and diabetes mellitus with the persistence of coagulation dysfunction after a COVID-19 infection. Prompt detection of the high-risk individuals may be achieved through early monitoring of coagulation biomarkers and may lead to better long-term cardiometabolic outcomes.

KEYWORDS : COVID-19; Post-COVID syndrome; Hypercoagulability; D-dimer; Hypertension; Diabetes mellitus; Coagulation biomarkers; Inflammation.

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to significant morbidity and mortality worldwide and been the cause of a coronavirus disease 2019 (COVID-19) epidemic. While much has been studied on the acute respiratory symptoms and signs of COVID-19, growing evidence shows that many patients continue to have health symptoms after they have recovered, known as post-acute COVID-19 syndrome (PACS), or long COVID. These are chronic conditions which affect several organ systems and include cardiovascular, metabolic, neurological, pulmonary and hematological abnormalities that can last for several months after the original infection [1,2].

Coagulation dysfunction is one of the key pathophysiological characteristics of COVID-19, which includes endothelial injury, overactive inflammatory responses and platelet activation and hypercoagulable states. Upon infection with SARS-CoV-2, the infection causes damage to the vascular endothelial cells both by direct viral invasion and by inflammatory response to infection, which leads to activation of coagulation and microvascular thrombosis. Fibrinogen, D-dimer, and elevated coagulation biomarkers have been associated with higher severity, higher risk of thrombotic complications, and worse clinical outcomes, and prothrombin time (PT) is prolonged and mild alterations in International Normalized Ratio (INR) are associated with all of these [3,4].

In addition to the acute illness, chronic low-grade inflammation and endothelial dysfunction could play a role in the development of long-term cardiometabolic disorders. Multiple studies have shown that survivors of COVID-19 are at a higher risk for cardiovascular disease, hypertension, dysglycemia and incident diabetes mellitus than those not infected with SARS-CoV-2. These complications are thought to be caused by continued immune activation, endothelial damage, alteration in renin angiotensin aldosterone system signaling, pancreatic beta cell dysfunction, insulin resistance and the persistent activation of procoagulant pathways [5]. One of the most prevalent chronic diseases associated with cardiovascular morbidity globally is hypertension and diabetes mellitus. There are emerging reports that these conditions can also emerge as new-onset diseases after COVID-19, even in people who were not previously diagnosed with metabolic disease. Inflammatory changes in the blood vessels and hypercoagulability can lead to disrupted endothelial function, decreased vascular compliance and increased arterial stiffness, all of which can raise blood pressure. Similarly, COVID-19 may lead to impairment of insulin secretion and glucose metabolism due to inflammatory cytokines, endothelial dysfunction and damage to the microvasculature in the pancreas, which may contribute to development of diabetes mellitus following recovery from COVID-19 [6,7].

While there have been several reports from international studies that hypertension and diabetes mellitus (DM) are associated with higher cardiovascular and metabolic risk, there is little evidence from the hospital based population in India to assess the association between coagulation abnormalities during acute infection and the subsequent development of hypertension and DM [8]. This study aimed to investigate the correlation between coagulation disorders in the acute phase of COVID-19 and the development of new onset hypertension and diabetes mellitus in patients who have recovered from the acute COVID-19 infection.

METHODOLOGY

Study Design and Setting

In this study used a quantitative prospective cohort design with hospital-based data to assess the relationship between coagulation abnormality in acute COVID-19 infection and the development of new-onset hypertension and diabetes in recovered patients. The study was carried out in District Combined Hospital, Noida, UP, India, a tertiary level government hospital that provides comprehensive care services for both outpatient and inpatient departments, emergency and follow-up after COVID services The study lasted for 12 months and participants who were eligible for the study were followed for six months post-recovery from COVID-19 to evaluate the incidence of cardiometabolic complications.

Participants

The study comprised of 500 adult patients who attended the General Medicine and Post-COVID Out Patient Departments (OPDs) of the District Combined Hospital. Consecutive sampling was used to recruit participants in routine follow-up visits. After receiving written informed consent, demographic data, clinical history, anthropometric values, and laboratory data were recorded.

Inclusion and Exclusion Criteria

Inclusion criteria were: (i) adults aged 18 years or older; (ii) previous laboratory-confirmed COVID-19 infection by RT-PCR or rapid antigen test; (iii) completion of the acute phase of illness with clinical recovery; (iv) attendance at the hospital OPD within six months of recovery; and (v) willingness to provide informed consent.

Exclusion criteria included: (i) previously diagnosed hypertension or diabetes mellitus before COVID-19 infection; (ii) known coagulation disorders, chronic liver disease, malignancy, autoimmune disorders, or

chronic kidney disease; (iii) pregnancy; (iv) long-term anticoagulant therapy before COVID-19; and (v) incomplete medical records or inability to complete follow-up.

Data Collection

Demographic and clinical data such as age, sex, body mass index (BMI), severity of COVID-19, hospitalisation, intensive care unit (ICU) admission were obtained from hospital records. Laboratory reports were used to obtain coagulation and inflammatory biomarker levels, such as D-dimer, fibrinogen, prothrombin time (PT), International Normalized Ratio (INR), platelet count, and C-reactive protein (CRP), during the acute phase of COVID-19. Blood pressure was measured at 6-month follow-up OPD visit with a calibrated digital Sphygmomanometer following standard clinical protocol. The levels of fasting blood glucose and glycated hemoglobin (HbA1c) were measured in the hospital laboratory with standard automatic biochemical analyzers. All participants were assessed for the development of new-onset hypertension and diabetes mellitus using established diagnosis criteria.

Outcome Measures

The primary outcomes were new-onset hypertension and new-onset diabetes mellitus within six months after COVID-19 recovery. Hypertension was defined as BP ≥140/90 mmHg on two separate occasions or antihypertensive treatment, while diabetes was defined by FPG ≥126 mg/dL, HbA1c ≥6.5%, or physician diagnosis. Secondary outcomes included evaluating the association of coagulation biomarkers (D-dimer, fibrinogen, PT, INR, platelet count, and CRP) with cardiometabolic outcomes and identifying independent predictors of hypertension and diabetes.

Data Analysis

Microsoft excel was used to enter data and IBM SPSS Statistics version 27.0 was used to analyse the data. Data on continuous variables were shown as mean ± standard deviation (SD) and on categorical variables as frequencies and percentages. Independent-samples t test and chi-square test were used for group comparisons, as appropriate. To evaluate associations between coagulation biomarkers and metabolic parameters, Pearson's correlation analysis was used. Multivariable logistic regression was used to determine independent predictors of the development of new-onset hypertension and diabetes mellitus, and the results were presented as adjusted odds ratios (AORs) and 95% confidence intervals (CIs). A p value of <0.05 was declared as statistically significant.

RESULTS

Table 1. Demographic Characteristics of Post-COVID-19 Patients (N = 500)

Variable	Frequency (n)	Percentage (%)
Total participants	500	100
Male	295	59.0
Female	205	41.0
Mean age (years)	52.6 ± 12.4	—
BMI (kg/m²)	28.1 ± 4.6	—
Mild COVID-19	175	35.0
Moderate COVID-19	215	43.0
Severe COVID-19	110	22.0
Hospitalized	310	62.0
ICU admission	82	16.4

A total of 500 post-COVID-19 patients were enrolled, including 295 (59.0%) males and 205 (41.0%) females, with a mean age of 52.6 ± 12.4 years and a mean BMI of 28.1 ± 4.6 kg/m². During acute infection, 35.0% had mild, 43.0% moderate, and 22.0% severe COVID-19. Overall, 62.0% required hospitalization, while 16.4% were admitted to the ICU, indicating a considerable proportion of moderate-to-severe cases.

Table 2. Incidence of New-Onset Hypertension and Diabetes Six Months After COVID-19 (N = 500)

Variable	n	%
Newly diagnosed hypertension	118	23.6
Newly diagnosed diabetes mellitus	87	17.4
Both hypertension and diabetes	41	8.2
No new metabolic disorder	295	59.0

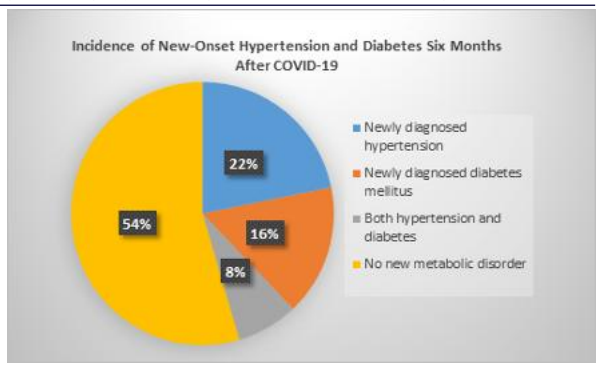

Figure 1. Incidence of New-Onset Hypertension and Diabetes Mellitus Six Months After COVID-19 Recovery.

At six months following COVID-19 recovery as shown in table 2 and figure 1 **118 (23.6%)** participants developed newly diagnosed hypertension, while **87 (17.4%)** were diagnosed with new-onset diabetes mellitus. Additionally, **41 (8.2%)** patients developed both hypertension and diabetes concurrently. The remaining **295 (59.0%)** participants did not develop any new metabolic disorder during the follow-up period.

Table 3. Coagulation Biomarkers During Acute COVID-19

Biomarker	Mean ± SD	Reference Range
D-dimer (mg/L FEU)	1.82 ± 0.91	<0.50
Fibrinogen (mg/dL)	518 ± 124	200–400
PT (seconds)	14.6 ± 1.8	11–13.5
INR (International Normalized Ratio)	1.24 ± 0.18	0.8–1.2
Platelet count (×10⁹/L)	276 ± 71	150–400
CRP (mg/L)	39.4 ± 22.7	<5

Assessment of coagulation and inflammatory biomarkers during acute COVID-19 demonstrated elevated levels compared with normal reference ranges. The mean D-dimer level was 1.82 ± 0.91 mg/L FEU, while fibrinogen was 518 ± 124 mg/dL, both indicating hypercoagulability. The mean prothrombin time (PT) and INR were slightly prolonged at 14.6 ± 1.8 seconds and 1.24 ± 0.18, respectively. Platelet counts remained within the normal range (276 ± 71 ×10⁹/L), whereas the mean C-reactive protein (CRP) level was markedly elevated (39.4 ± 22.7 mg/L), suggesting persistent systemic inflammation during acute infection.

Table 4. Comparison of Coagulation Markers Between Patients With and Without New-Onset Hypertension

Variable	Hypertension (n=118)	No Hypertension (n=382)	p-value
D-dimer (mg/L)	2.34 ± 0.86	1.61 ± 0.72	<0.001
Fibrinogen (mg/dL)	561 ± 118	489 ± 110	<0.001
CRP (mg/L)	46.8 ± 24.1	34.9 ± 19.5	0.002
BMI (kg/m²)	29.5 ± 4.8	27.7 ± 4.3	0.011

Patients with new-onset hypertension had significantly higher D-dimer (2.34 ± 0.86 vs. 1.61 ± 0.72 mg/L; p < 0.001), fibrinogen (561 ± 118 vs. 489 ± 110 mg/dL; p < 0.001), CRP (46.8 ± 24.1 vs. 34.9 ± 19.5 mg/L; p = 0.002), and BMI (29.5 ± 4.8 vs. 27.7 ± 4.3 kg/m²; p = 0.011) compared with normotensive participants, suggesting that coagulation abnormalities, inflammation, and obesity are associated with post-COVID hypertension.

Table 5. Comparison Between Patients With and Without New-Onset Diabetes

Variable	Diabetes (n=87)	No Diabetes (n=413)	p-value
D-dimer (mg/L)	2.47 ± 0.88	1.68 ± 0.74	<0.001
Fasting glucose (mg/dL)	139 ± 23	95 ± 11	<0.001
HbA1c (%)	7.1 ± 0.8	5.5 ± 0.4	<0.001
CRP (mg/L)	48.2 ± 20.9	35.8 ± 18.6	<0.001

Participants who developed new-onset diabetes demonstrated significantly worse metabolic and inflammatory profiles than those without diabetes. The diabetes group had significantly higher D-dimer levels (2.47 ± 0.88 vs. 1.68 ± 0.74 mg/L; p < 0.001), fasting glucose (139 ± 23 vs. 95 ± 11 mg/dL; p < 0.001), and HbA1c (7.1 ± 0.8% vs. 5.5

± 0.4%; p < 0.001). Additionally, CRP concentrations were significantly elevated among diabetic patients (48.2 ± 20.9 vs. 35.8 ± 18.6 mg/L; p < 0.001), suggesting a strong association between persistent inflammation, coagulation dysfunction, and the development of diabetes following COVID-19.

Table 6. Multivariable Logistic Regression Analysis for Predictors of New-Onset Hypertension and Diabetes Mellitus Following COVID-19

Variable	Hypertension AOR	95% CI	p-value	Diabetes Mellitus AOR	95% CI	p-value
Age >50 years	2.48	1.56–3.94	<0.001	2.16	1.28–3.66	0.004
Severe COVID-19	2.91	1.75–4.83	<0.001	2.83	1.61–4.98	<0.001
Elevated D-dimer (>2 mg/L)	3.37	2.01–5.65	<0.001	3.69	2.09–6.51	<0.001
Obesity (BMI ≥30 kg/m²)	1.82	1.10–3.02	0.019	1.74	1.01–2.99	0.043
ICU admission	2.24	1.29–3.87	0.004	—	—	—
CRP >40 mg/L	—	—	—	2.12	1.26–3.57	0.005

Multivariable logistic regression identified several significant predictors of both new-onset hypertension and diabetes mellitus following COVID-19. Age >50 years, severe COVID-19, and elevated D-dimer (>2 mg/L) were common independent risk factors for both conditions. Elevated D-dimer was the strongest predictor of hypertension (AOR = 3.37, p < 0.001) and diabetes mellitus (AOR = 3.69, p < 0.001). Additionally, obesity (BMI ≥30 kg/m²) was significantly associated with both outcomes. ICU admission independently increased the risk of hypertension (AOR = 2.24, p = 0.004), whereas CRP >40 mg/L was a significant predictor of new-onset diabetes (AOR = 2.12, p = 0.005), highlighting the important role of disease severity, coagulation dysfunction, inflammation, and obesity in post-COVID cardiometabolic complications.

Table 7. Correlation Between Coagulation Markers and Metabolic Outcomes

Variables	r	p-value
D-dimer vs Systolic BP	0.42	<0.001
D-dimer vs HbA1c	0.39	<0.001
Fibrinogen vs Systolic BP	0.36	<0.001
CRP vs HbA1c	0.34	<0.001
D-dimer vs CRP	0.48	<0.001

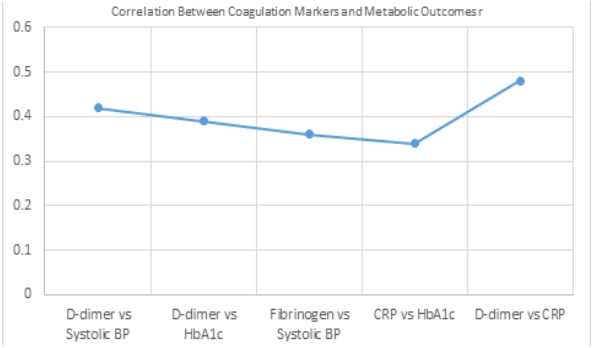

Figure 2: Correlation Between Coagulation Biomarkers and Metabolic Outcomes Among Post-COVID-19 Patients.

Correlation analysis demonstrated significant positive associations between coagulation biomarkers and metabolic parameters. D-dimer showed a moderate positive correlation with systolic blood pressure (r = 0.42, p < 0.001) and HbA1c (r = 0.39, p < 0.001), indicating that higher coagulation activity was associated with worsening blood pressure and glycemic control. Fibrinogen was positively correlated with systolic blood pressure (r = 0.36, p < 0.001), while CRP exhibited a positive correlation with HbA1c (r = 0.34, p < 0.001). The strongest relationship was observed between D-dimer and CRP (r = 0.48, p < 0.001) as shown in figure 2 , highlighting the close interaction between coagulation dysfunction and systemic inflammation in the development of post-COVID cardiometabolic complications..

DISCUSSION

The present study confirmed a significant link between coagulation abnormalities during the acute COVID-19 infection and new onset hypertension and diabetes mellitus six months after recovery. Cardiometabolic complications were also a significant part of post-COVID syndrome as nearly one-fifth of participants were diagnosed with diabetes mellitus and one-quarter were diagnosed with hypertension. The results are in line with growing evidence of SARS-CoV-2 infection causing long-lasting vascular and metabolic changes beyond the acute stage of illness. The elevated levels of D-dimer, fibrinogen, prolonged prothrombin time (PT) and elevated C-reactive protein (CRP) seen in the present study are indicative of ongoing activation of coagulation and inflammatory pathways during acute infection. SARS-CoV-2 directly binds to endothelial cells via angiotensin-converting enzyme-2 (ACE2) receptors causing endothelial dysfunction, cytokine-mediated inflammation, platelet activation and microvascular thrombosis. The persistent endothelial injury has been identified as one of the main mechanisms for long term cardiovascular complications after COVID-19 [9] . Similarly, Libby and Lüscher [10] suggested that endothelial inflammation is one of the characteristics of COVID-19, and may contribute to vascular remodeling and arterial stiffness, making patients susceptible to hypertension following the virus recovery. In patients who developed hypertension in the present study, D-dimer, fibrinogen, CRP, and BMI levels were significantly higher than in normotensive patients. Furthermore, high D-dimer levels, severe COVID-19, obesity, and meeting the criteria for ICU admission were independently associated with hypertension. Dina et al. [11] reported a significantly higher prevalence of hypertension in COVID-19 survivors during follow-up, especially those hospitalized for a longer period and those who suffered severe COVID-19 illness. .

This enhanced cardiovascular risk is likely due to an ongoing endothelial dysfunction, renin-angiotensin-aldosterone activation, and chronic vascular inflammation. The finding of the present study that coagulation dysfunction is associated with new onset diabetes is also biologically feasible. Patients with diabetes showed significantly higher levels of D-dimer, CRP, fasting glucose and HbA1c, and D-dimer was the most powerful independent predictor in multivariable analysis. Persistent activation of cytokines could lead to peripheral insulin resistance, while hyperinflammation and endothelial injury can cause a decrease in insulin production and secretion from pancreatic β-cells. This is in line with Ayoubkhani et al. [12] who found that diabetes was significantly more common in patients discharged following COVID-19 hospitalization versus matched control patients.

In addition, Steenblock et al. [13] proposed that inflammatory and thrombotic reactions caused by SARS-CoV-2 could lead to an increased metabolic dysfunction in susceptible people. The strong positive relationships between D-dimer and SBP, HbA1c and CRP further underscore the close relationship between activation of coagulation, systemic inflammation and metabolic dysfunction. The results indicated that blood coagulation markers might be useful in predicting the risk of subsequent cardiometabolic diseases in people recovering from COVID-19. Regular follow-up coagulation testing, blood pressure and blood glucose monitoring can thus help in identifying early and timely intervention in a timely manner among high risk survivors [14] . In conclusion, the present results support the concept that hypercoagulability and endothelial dysfunction are important factors in the pathogenesis of post-COVID hypertension and diabetes mellitus. In order to minimize SARS-CoV-2 cardiovascular and metabolic morbidity, long-term follow up and multidisciplinary follow-up of recovered patients are warranted.

CONCLUSION

The present study shows that patients with new-onset hypertension and diabetes mellitus have a significantly higher prevalence among patients suffering from COVID-19, especially in those with clinical signs of coagulation dysfunction during acute COVID-19 infection. High levels of D-dimer, fibrinogen and CRP were found to be significantly linked with adverse cardiometabolic outcomes, indicating that chronic endothelial damage, hypercoagulability and inflammation can play a role in the pathogenesis of these diseases. Multivariable analysis additionally uncovered that elevated D-dimer, severe COVID-19, advanced age, obesity, and admission to the intensive care unit (ICU) were important predictors of hypertension and diabetes after recovery, independently. The observed correlations between the coagulation biomarkers and the metabolic parameters confirm the close relationship between thrombo-inflammatory

processes and long-term cardiovascular risk. The results underscore the need to integrate coagulation and metabolic laboratory testing into the standard clinical follow-up of COVID-19 patients. Biomarker-based risk stratification could aid in identifying high-risk patients and thereby allow timely intervention, minimize burden of chronic cardiometabolic disease and enhance long-term clinical outcomes. The results need to be confirmed by further multicenter, longitudinal studies, and to set up evidence-based surveillance strategies following the COVID-19.

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