

Article

Cardiovascular and Multisystem Outcomes Identified at Short- and Long-Term Follow-Up After COVID-19 Hospitalization: A Retrospective Cohort Study

Sofia Teodora Muntean ^{1,2,3} , Andreea-Raluca Cozac-Szoke ^{2,4,*} , Andreea Cătălina Tinca ^{2,4} ,
Diana Maria Chiorean ^{2,4}, Adrian Horațiu Sabău ^{2,4}, Iuliu Gabriel Cocuz ^{2,4} , Raluca Niculescu ² ,
Claudia Raluca Mariean ^{2,5}, Nadja Emily Pop ^{1,6} , Ovidiu Simion Cotoi ^{2,4} and Anca Ileana Sin ⁷

- ¹ Doctoral School of Medicine and Pharmacy, George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, 540139 Targu Mures, Romania; sofia.harsan@umfst.ro (S.T.M.)
 - ² Department of Pathophysiology, George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, 540139 Targu Mures, Romania
 - ³ Pneumology Department, Clinical County Hospital of Mures, 540142 Targu Mures, Romania
 - ⁴ Pathology Department, Clinical County Hospital of Mures, 540011 Targu Mures, Romania
 - ⁵ Radiology Department, Emergency Clinical County Hospital of Mures, 540136 Targu Mures, Romania
 - ⁶ Neurosurgery Department, Emergency County Hospital, 540136 Targu Mures, Romania
 - ⁷ Department of Genetics and Cellular and Molecular Biology, George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, 540139 Targu Mures, Romania
- * Correspondence: andreea-raluca.szoke@umfst.ro

Abstract

Background: Persistent cardiovascular and multisystem manifestations remain an important concern following hospitalization for coronavirus disease 2019 (COVID-19). However, the spectrum of newly identified conditions during follow-up and their relationship with acute disease severity remain incompletely characterized. This study aimed to describe cardiovascular and multisystem diagnoses, identified during short-term and long-term follow-up and to evaluate the association between acute-phase clinical characteristics, biomarkers, and subsequent outcomes. **Methods:** We conducted a retrospective observational cohort study including 762 adults hospitalized with laboratory-confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection between January 2021 and December 2022. Follow-up data were obtained from patients who re-presented to the same hospital during short-term follow-up (mean 4.33 months; $n = 130$) or long-term follow-up (mean 2.06 years; $n = 186$). Newly documented cardiovascular and non-cardiovascular diagnoses recorded during routine clinical care were analyzed separately for each follow-up cohort. Multivariable logistic regression was used to identify predictors of in-hospital mortality and cardiovascular outcomes. **Results:** At least one newly documented diagnosis was identified in 120/130 patients (92.3%) during short-term follow-up and in 175/186 patients (94.1%) during long-term follow-up. Cardiovascular diagnoses were identified in 32.3% and 45.2% of patients attending short-term and long-term follow-up, respectively. Hypertension and atherosclerosis were the most frequent cardiovascular diagnoses during short-term follow-up, whereas heart failure and ischemic heart disease predominated among patients attending long-term follow-up. Pulmonary fibrosis was the most common non-cardiovascular diagnosis at both follow-up periods. Elevated D-dimer and fibrinogen levels during acute COVID-19 were independently associated with in-hospital mortality, whereas acute-phase NT-proBNP was not independently associated with cardiovascular diagnoses identified during follow-up. **Conclusions:** Patients who re-presented for clinical evaluation after hospitalization for COVID-19 exhibited a substantial burden of newly documented cardiovascular and multisystem diagnoses. Given the retrospective design,



Academic Editor: Luis Vicente Franco Oliveira

Received: 18 May 2026

Revised: 13 July 2026

Accepted: 14 July 2026

Published: 16 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

independent follow-up cohorts, and absence of a non-COVID control group, these findings should be interpreted as observational post-hospitalization data rather than evidence of causal or progressive post-COVID-19 disease. Prospective controlled longitudinal studies are needed to better define the long-term health consequences of SARS-CoV-2 infection.

Keywords: COVID-19; SARS-CoV-2; post-COVID-19; long COVID-19; cardiovascular disease; multisystem complications

1. Introduction

Although the acute phase of the COVID-19 pandemic has subsided, persistent health problems following SARS-CoV-2 infection remain an important clinical challenge. Long COVID generally refers to the persistence of symptoms beyond the acute phase of infection [1]. Post-COVID-19 conditions also include newly diagnosed diseases affecting one or more organ systems after recovery. Long COVID syndrome has a heterogeneous clinical spectrum comprising more than 200 reported symptoms [2], that include fatigue, dyspnea, cognitive impairment, and sleep disorders [3,4]. Because the present study evaluates newly diagnosed cardiovascular and multisystem diseases after hospitalization for COVID-19, the term post-COVID-19 is used throughout the manuscript to describe these outcomes.

From a clinical point of view, cardiovascular involvement is one of the most clinically relevant manifestations of post-COVID-19 [5]. Previous studies have reported an increased risk of newly diagnosed conditions, such as arrhythmias, ischemic heart disease, heart failure, myocarditis, or autonomic dysfunction [6], and other cardiovascular disorders after SARS-CoV-2 infection. These complications are the result of several overlapping mechanisms that include [7], direct myocardial injury [8], endothelial dysfunction [9], dysregulation of the renin–angiotensin–aldosterone system [10], excessive coagulation pathway activation [11], systemic inflammation and immune dysfunction [12].

It is important to note that post-COVID-19 is not limited to the cardiovascular system, as patients recovering from SARS-CoV-2 infection can develop respiratory, renal, endocrine, gastrointestinal, neuropsychiatric, and other systemic manifestations [8,9]. All of these support the theory that post-COVID-19 is a multisystem disease rather than an isolated post viral syndrome [13].

Pre-existing cardiovascular and metabolic comorbidities are important determinants of both acute COVID-19 severity and long-term post-COVID-19 outcomes. Karakasis et al. [14] highlighted, in their review, that patients with pre-existing cardiovascular disease are particularly vulnerable to severe COVID-19. This is due to the combined effects of viral-induced endothelial injury and systemic inflammation, which result in poorer clinical outcomes. In another systematic review, conducted by Rus et al. [15], it is reported that patients with established cardiovascular disease experienced a greater risk of severe disease and worse long-term prognosis following SARS-CoV-2 infection. Hypertension, diabetes mellitus, and obesity have also been consistently identified as major risk factors for hospitalization, intensive care admission, cardiovascular complications, and mortality [16]. These findings emphasize the importance of baseline metabolic status when evaluating post-COVID-19 outcomes. All these comorbidities share a common pathophysiological mechanism, that includes endothelial dysfunction, chronic inflammation, immune dysregulation and a prothrombotic state, which may amplify the vascular injury induced by SARS-CoV-2 infection [17]. Chronic inflammation and immune dysregulation have been proposed as contributors to a pro-tumorigenic environment [18], that may overlap with the mechanisms involved in carcinogenesis [19]. Furthermore, smoking is an impor-

tant and often underappreciated factor in the context of COVID-19 and post-COVID-19, but overlaps its mechanisms through endothelial dysfunction, oxidative stress, and systemic inflammation [20,21]. The combined effect of smoking-related vascular damage and COVID-19-induced endothelial damage contributes to a greater susceptibility to long-term cardiovascular sequelae [22].

Several biomarkers, measured during the acute phase of SARS-CoV-2 infection, can provide information regarding disease severity and outcomes. Cardiac biomarkers, such as natriuretic peptides and troponins, have been used to assess myocardial stress and injury during COVID-19 disease [23]. Inflammatory and coagulation markers, including C-reactive protein, fibrinogen and D-dimer, reflect systemic inflammation, endothelial dysfunction and activation of thrombotic pathways and have been associated with adverse clinical outcomes [7,24,25]. However, their value in predicting long-term cardiovascular and multisystem manifestations after COVID-19 remains incompletely understood.

Despite the growing body of literature on post-COVID-19 conditions, important gaps remain in understanding the true burden and course of post-COVID-19 complications and the spectrum of cardiovascular and non-cardiovascular disease, after SARS-CoV-2 infection. Furthermore, limited data are available regarding the temporal evolution of these complications and the potential association between acute-phase biomarkers and subsequent cardiovascular and multisystem outcomes.

Therefore, the aim of this study was to describe the spectrum and frequency of newly diagnosed cardiovascular and non-cardiovascular outcomes, after SARS-CoV-2 infection, at short-term and long-term follow-up. In addition, we aimed to evaluate in-hospital mortality during the acute infection and to investigate the association between acute-phase biomarkers and subsequent cardiovascular and multisystem outcomes.

2. Materials and Methods

2.1. Study Design and Population

We conducted a retrospective, observational, cohort study that included patients who were hospitalized with confirmed SARS-CoV-2 infection, at the Pneumology Department of Mureş Clinical County Hospital, in Târgu- Mureş, Romania, between 1 January 2021, and 31 December 2022. A total of 1200 patients were initially identified, of which 762 met the inclusion criteria and were included in the study.

Inclusion criteria consisted of: age older than 18 years old, hospitalization with confirmed SARS-CoV-2 infection during the study period and availability of complete electronic medical records that included demographic, clinical, and laboratory data from the acute hospitalization. Exclusion criteria included: duplicate admissions, incomplete electronic medical records, unavailable essential laboratory parameters and transfer to another institution before completion of hospitalization.

Patients were subsequently evaluated for follow-up presentations within the same institution. Follow-up data were obtained from patients who subsequently re-presented to the same hospital system for inpatient or outpatient evaluation, including presentations to departments other than the initial Pneumology Department.

Follow-up data were collected for patients who subsequently re-presented to the same hospital system within a short-term follow-up window centered around 4 months after the acute COVID-19 episode or during a longer-term follow-up period, between 1 and 3 years after COVID-19 hospitalization. Because follow-up assessments were performed as part of routine clinical care, the exact timing of visits varied between patients.

Patients attending short-term and long-term follow-up did not necessarily represent the same individuals. Follow-up evaluations reflected routine clinical practice, rather than a predefined longitudinal protocol. Patients were included in each follow-up period,

according to their subsequent clinical presentations. Therefore, the short-term and long-term follow-up cohorts should be interpreted as independent observational groups rather than sequential assessments of a single longitudinal cohort.

The database included follow-up visits recorded between 1 January 2022, and 31 December 2024. A total of 130 patients attended the short-term follow-up visit, while 186 patients attended the long-term follow-up, after the initial COVID-19 hospitalization. The mean time to follow-up was 4.33 months for the short-term visit and 2.06 years for the long-term follow-up. Follow-up analyses were performed only in patients who subsequently re-presented to the same hospital system during the predefined follow-up periods.

The study protocol was approved by the local Ethics Committee Nr. 5138/05.05.2026, and all procedures were conducted in accordance with the Declaration of Helsinki.

2.2. Data Collection

Demographic data, including age and sex, as well as baseline clinical characteristics and pre-existing comorbidities, were collected from electronic medical records of included patients. Smoking status and the burden of chronic disease were also assessed. Overall comorbidity burden was quantified using the Charlson Comorbidity Index. Clinical data related to the acute COVID-19 episode were systematically reviewed, including hospitalization characteristics, Intensive Care Unit admission and laboratory biomarkers obtained during hospitalization. Recorded laboratory parameters included N-terminal pro-B-type natriuretic peptide (NT-proBNP), peak troponin, D-dimer, fibrinogen, ferritin, and C-reactive protein (CRP) levels.

Biomarkers were analyzed either as continuous variables or dichotomized according to institutional laboratory reference ranges and clinically relevant thresholds, including CRP > 5 mg/L, fibrinogen > 600 mg/dL, D-dimer > 500 ng/mL FEU, and ferritin > 300 ng/mL. In the mortality model, D-dimer and fibrinogen were entered as dichotomous variables using predefined thresholds: D-dimer > 500 ng/mL FEU and fibrinogen > 600 mg/dL. For patients who subsequently presented to the same institution during follow-up, additional laboratory and clinical data were extracted from electronic medical records. Attention was given to NT-proBNP values obtained during follow-up visits to evaluate their temporal evolution after the acute COVID-19 episode.

The occurrence of newly diagnosed conditions after COVID-19 hospitalization was systematically assessed based on diagnoses recorded in hospital discharge documents, outpatient evaluations, and available electronic medical records. Newly identified diagnoses were categorized into cardiovascular and non-cardiovascular outcomes.

A condition was classified as a new diagnosis when it was not documented in the available electronic medical records during the index COVID-19 hospitalization or in the recorded past medical history and was first identified during a subsequent follow-up evaluation. Diagnoses were extracted from hospital discharge summaries, specialist consultations, outpatient records, and other available electronic medical documentation. No additional diagnostic adjudication process was performed beyond the review of documented clinical diagnoses.

Cardiovascular outcomes included newly diagnosed hypertension, ischemic heart disease, heart failure, arrhythmias, atherosclerotic disease, and other cardiovascular events occurring after the acute infection. Non-cardiovascular outcomes included pulmonary, renal, metabolic, endocrine, gastrointestinal, oncologic, dermatologic, rheumatologic, ophthalmologic, and neuropsychiatric conditions identified during follow-up.

In addition, mortality occurring during the acute hospitalization period was recorded and included in the analysis.

2.3. Definitions and Outcomes

The primary outcome of the study was the occurrence of new cardiovascular pathology identified during follow-up after the acute COVID-19 episode.

Secondary outcomes included:

- The occurrence of any newly diagnosed condition after COVID-19;
- The development of non-cardiovascular complications during follow-up, and;
- In-hospital mortality during the acute SARS-CoV-2 infection.

Newly identified conditions were defined as diagnoses that were not documented in the patient's medical records before the index COVID-19 hospitalization and were subsequently recorded during follow-up in the electronic hospital information system by the treating physician. Diagnoses were extracted from inpatient and outpatient medical records across all hospital departments and were based on routine clinical evaluation according to standard diagnostic criteria. The present study did not independently adjudicate the etiology of newly diagnosed conditions, and no additional diagnostic investigations beyond those performed during routine clinical care were undertaken. Therefore, diagnoses like heart failure and arrhythmias were analyzed as newly identified clinical diagnoses, regardless of their underlying cause.

Cardiovascular outcomes were defined as newly diagnosed cardiovascular conditions or clinically relevant cardiovascular events occurring after initial COVID-19 hospitalization. These included newly diagnosed heart failure, ischaemic heart disease, arrhythmias, hypertension, atherosclerotic disease and other cardiovascular complications documented during subsequent hospital admissions or outpatient evaluations. Heart failure and arrhythmias were recorded as clinical diagnoses documented during routine care, irrespective of their underlying etiology, which was beyond the scope of the present retrospective study. Myocarditis was not evaluated as a separate predefined outcome.

Non-cardiovascular outcomes comprised newly identified pulmonary, renal, metabolic, endocrine, gastrointestinal, oncologic, dermatologic, rheumatologic, ophthalmologic, and neuropsychiatric conditions recorded during follow-up. For descriptive purposes, newly identified diagnoses were grouped according to the affected organ system. Medical records documented both autoimmune inflammatory disorders, like systemic lupus erythematosus and related connective tissue diseases, and degenerative musculoskeletal conditions, such as osteoarthritis and spondylosis. Endocrinopathies encompassed endocrine disorders, other than diabetes mellitus, including thyroid diseases like hypothyroidism hyperthyroidism and autoimmune thyroiditis as well as other conditions observed during routine clinical care. Pulmonary outcomes included pulmonary fibrosis and chronic obstructive respiratory disease. Metabolic outcomes included newly diagnosed diabetes mellitus and gout.

The outcome "any new diagnosis" was defined as the occurrence of at least one newly documented medical condition during follow-up, regardless of organ system involvement.

Follow-up outcomes were assessed separately at short-term follow-up (approximately 4 months after the acute COVID-19 episode) and at long-term follow-up (between 1 and 3 years after hospitalization), in order to evaluate the temporal evolution of post-COVID-19 complications.

Mortality analysis included deaths occurring during the acute hospitalization period, as recorded in the hospital electronic database.

2.4. Statistical Analysis

All statistical analyses were performed using GraphPad Prism, version 10.4.1 (GraphPad Software, Boston, MA, USA) and Python version 3.14, Amsterdam, Netherlands for multivariable regression. Continuous variables were tested for normality (Shapiro–Wilk), summarized as median (IQR), and compared using the Mann–Whitney U test or the Wilcoxon signed-rank

test for paired data. Categorical variables were expressed as counts and percentages and compared using the chi-square test or Fisher's exact test, as appropriate.

Associations between baseline characteristics, biomarkers, and clinical outcomes (in-hospital death, new cardiovascular events at short-term follow-up, and at long-term follow-up) were evaluated using logistic regression. Results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Multivariable models were adjusted for age, sex, and Charlson Comorbidity Index; ICU admission was included when clinically relevant. Firth penalized logistic regression was used when near-complete separation occurred. Biomarkers were analyzed as continuous variables or dichotomized (normal vs. elevated) according to predefined thresholds. Analyses were performed using available-case data, and no imputation methods were applied for missing values. A two-tailed p value < 0.05 was considered statistically significant.

Generative artificial intelligence tools were used to assist with figure generation, language refinement, text organization, and manuscript editing during the preparation of this article. All scientific content, data analysis, interpretation of results, and final manuscript revisions were performed and verified by the authors.

3. Results

3.1. Study Population

A total of 762 patients hospitalized with confirmed SARS-CoV-2 infection between January 2021 and December 2022 were included in the study. The median age was 72 years (IQR 63–79). The median Charlson Comorbidity Index was 2 (IQR 1–3), with a median of 3 comorbidities per patient (IQR 2–4). Hypertension was the most prevalent cardiovascular comorbidity (78.2%), followed by coronary artery disease (38.3%), atrial fibrillation (26.2%) and heart failure (23.9%). Among non-cardiovascular comorbidities, obesity was the most frequent (37.5%), followed by COPD (26.8%), diabetes mellitus (26.5%), chronic kidney disease (18.1%), cancer history (13.4%) and asthma (11.8%). During the acute COVID-19 episode, 8.9% of patients required ICU admission. Median NT-proBNP was 1168.5 pg/mL (IQR 450.8–3465.0), and peak troponin was 36.0 ng/L (IQR 15.0–112.3). Baseline characteristics are summarized in Tables 1 and 2, below.

Table 1. Baseline characteristics (categorical variables, $n = 762$).

Variable	<i>n</i>	%
Sex		
Male	420	55.1%
Female	342	44.9%
Cardiovascular comorbidities		
Hypertension	596	78.2%
Coronary artery disease	292	38.3%
Heart failure	182	23.9%
Atrial fibrillation	200	26.2%
Stroke history	80	10.5%
Other comorbidities		
Diabetes mellitus	202	26.5%
Chronic kidney disease	138	18.1%
Obesity	286	37.5%
COPD	204	26.8%
Asthma	90	11.8%
Cancer history	102	13.4%
COVID-19 severity		
ICU admission	68	8.9%

Table 2. Baseline characteristics (continuous variables, $n = 762$).

Variable	Median	IQR
Age, years	72	63–79
Charlson Comorbidity Index	2	1–3
Number of comorbidities	3	2–4
Length of hospitalization, days	10	7–14
NT-proBNP (acute), pg/mL	1168.5	450.8–3465.0
Peak troponin, ng/L	36.0	15.0–112.3

Values are presented as number (percentage) or median [interquartile range, IQR].

3.2. Follow-Up

Within the short-term follow-up window, 130 patients (17.1%) re-presented for clinical evaluation, while 186 patients (24.4%) re-presented during the long-term follow-up, between 1 and 3 years after COVID-19 hospitalization. The mean time to follow-up was 4.33 months (95% CI 3.41–5.25) and 2.06 years (95% CI 1.92–2.20), respectively. Median follow-up times were 3.17 months (IQR 2.22–4.24) and 1.99 years (IQR 1.17–2.81). Follow-up attendance is summarized in Table 3, below.

Table 3. Follow-up attendance.

Variable	Short-Term Follow-Up	Long-Term Follow-Up
Patients attending	130 (17.1%)	186 (24.4%)
Mean time	4.33 months	2.06 years
Median time	3.17 months	1.99 years

3.3. Newly Diagnosed Conditions During Follow-Up

During short-term follow-up, 120 of 130 patients (92.3%) had at least one new diagnosis. At long-term follow-up, 175 of 186 patients (94.1%) had at least one new diagnosis. The frequency of newly diagnosed conditions and cardiovascular outcomes during follow-up is illustrated in Figure 1. The remaining 5.9% of patients attended follow-up but did not receive any newly documented cardiovascular or non-cardiovascular diagnosis during the observation period.

Using the specific cardiovascular diagnosis variables available in the current dataset, new cardiovascular diagnoses were identified in 42 patients (32.3%) at short-term follow-up and in 84 patients (45.2%) at long-term follow-up. During the short-term follow-up, the most frequent cardiovascular diagnoses were new hypertension (18.5%) and new atherosclerosis (13.8%), while at long-term follow-up new heart failure (19.4%) and new ischemic heart disease (18.3%) were the predominant cardiovascular outcomes. Cardiovascular outcomes were identified in 32.3% of patients attending short-term follow-up and in 45.2% of patients attending long-term follow-up.

Non-cardiovascular morbidity was also frequent at both time points. At short-term follow-up, the most common non-cardiovascular outcomes were pulmonary fibrosis (29.2%), gastroenterological disease (15.4%), chronic kidney disease (13.8%), and depression (12.3%). At long-term follow-up, pulmonary fibrosis remained frequent (17.2%), while asthma/COPD (16.1%), renal disease (14.0%), gastro-hepatopathy (14.0%), and cancer (12.9%) were also common. Outcomes during short-term follow-up and long-term follow-up are summarized in Table 4.

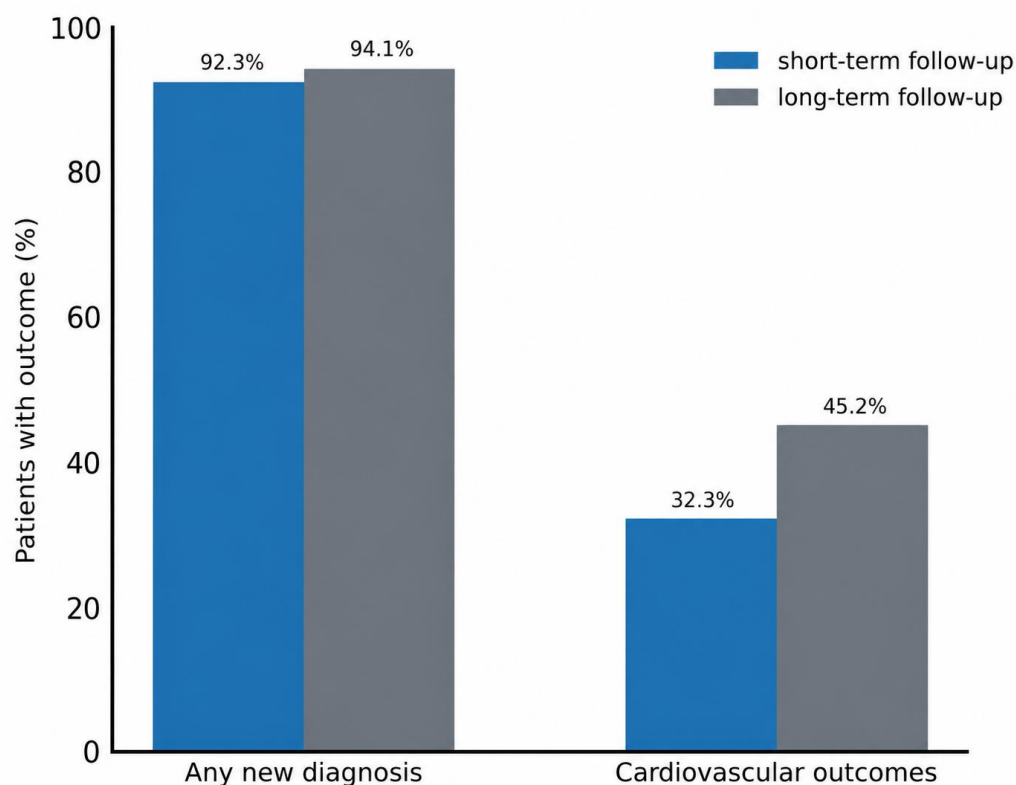


Figure 1. This figure illustrates the proportion of patients in whom at least one new diagnosis was identified during short-term and long-term follow-up after COVID-19 hospitalization. It also shows the proportion of patients with newly identified cardiovascular diagnoses during each follow-up period.

Table 4. New diagnoses at short-term follow-up ($n = 130$) and new diagnoses at long-term follow-up ($n = 186$).

Outcome	Short-Term Follow-Up ($n = 130$)		Long-Term Follow-Up ($n = 186$)	
	n	%	n	%
Any new diagnosis	120	92.3%	175	94.1%
Cardiovascular outcomes				
Any new cardiovascular diagnosis	42	32.3%	84	45.2%
Heart failure	14	10.8%	36	19.4%
Ischemic heart disease	6	4.6%	34	18.3%
Hypertension	24	18.5%	18	9.7%
Non-cardiovascular outcomes				
Pulmonary fibrosis	38	29.2%	32	17.2%
Chronic kidney disease	18	13.8%	2	1.1%
Asthma/COPD	22	16.9%	30	16.1%
Gastro-hepatopathy	20	15.4%	26	14.0%
Cancer	14	10.8%	24	12.9%
Depression	16	12.3%	20	10.8%
Dermatologic disease	10	7.7%	12	6.5%
Ophthalmologic disease	9	6.9%	12	6.5%
Rheumatologic disease	8	6.2%	10	5.4%
Endocrine disease	6	4.6%	8	4.3%
Diabetes mellitus	5	3.8%	6	3.2%

3.4. Evolution of NT-proBNP

Paired analyses showed that no statistically significant change in NT-proBNP levels could be detected between the acute phase and short-term follow-up. (Table 5).

Table 5. Evolution of NT-proBNP.

Comparison	<i>n</i>	Median Values (pg/mL)	<i>p</i> -Value
Acute vs. short-term follow-up	27	635 vs. 1427	0.878
Acute vs. long-term follow-up	25	1427 vs. 1324	0.895

Between the acute phase and short-term follow-up ($n = 27$), median values were 635 vs. 1427 pg/mL ($p = 0.878$). Between the acute phase and long-term follow-up ($n = 25$), median values were 1427 vs. 1324 pg/mL ($p = 0.895$).

3.5. Predictors of Outcomes

3.5.1. Mortality

Overall, 130 patients (17.1%) died during the index hospitalization and were included in the mortality analysis. Multivariable predictors of death, during COVID admission, are presented, below, in Table 6. Increasing age was independently associated with higher odds of in-hospital mortality (adjusted OR 1.04 per year, 95% CI 1.02–1.06, $p = 0.0011$). Male sex was also an independent predictor of death (adjusted OR 1.88, 95% CI 1.15–3.06, $p = 0.012$). ICU admission during the index hospitalization remained the strongest clinical predictor of in-hospital mortality (adjusted OR 9.19, 95% CI 5.67–14.89). Because of separation, the odds ratio and 95% confidence interval for ICU admission were estimated using penalized logistic regression, and a classical p -value was not reported. Elevated D-dimer and fibrinogen were significantly associated with in-hospital mortality (adjusted OR 2.15, 95% CI 1.00–4.24, $p = 0.047$ and adjusted OR 4.24, 95% CI 2.34–7.67, $p = 0.00023$, respectively), while peak C-reactive protein and the need for supplemental oxygen outside the ICU were not independent predictors after adjustment for the other variables.

Table 6. Multivariable predictors of death during COVID admission.

Variable	OR	95% CI	<i>p</i>
Age at admission	1.04	1.02–1.06	0.0011
Male sex	1.88	1.15–3.06	0.0118
Charlson Comorbidity Index	1.13	0.94–1.36	0.179
ICU admission during acute COVID-19 (yes vs. no) *	9.19	5.67–14.89	-
Need for supplemental oxygen during acute COVID-19 (yes vs. no)	1.16	0.62–2.14	0.646
Peak CRP	0.84	0.46–1.52	0.563
Peak D-dimer	2.15	1.00–4.24	0.047
Peak fibrinogen	4.24	2.34–7.67	0.00023

* odds ratio and 95% CI for ICU admission during acute COVID-19 were obtained from a penalized logistic regression model; a classical p -value is not reported due to separation.

3.5.2. Cardiovascular Outcomes

We next explored predictors of incident cardiovascular disease, using multivariable logistic regression models and results are presented in Table 7, below. In Model 1, which evaluated new cardiovascular disease events occurring between 1 and 3 years after COVID-19, higher peak C-reactive protein levels during the acute infection were associated with an increased odd of subsequent cardiovascular pathology. However, this association did not reach statistical significance after adjustment for age at admission, sex, and Charlson

Comorbidity Index. None of the other covariates in this model, including age, sex, or comorbidity burden, showed a statistically significant independent association with late cardiovascular outcomes.

Table 7. Multivariable predictors of cardiovascular outcomes at short- and long-term follow-up.

Outcome and Predictors	OR	95% CI	<i>p</i>
Model 1. New cardiovascular disease at long-term follow-up			
Peak CRP	2.16	0.84–5.53	0.109
Age at admission	0.98	0.95–1.01	0.148
Male sex	0.60	0.23–1.57	0.297
Charlson Comorbidity Index	1.15	0.87–1.51	0.326
Model 2. New cardiovascular disease at short-term follow-up			
ICU admission during acute COVID-19 (yes vs. no) *	Not reliably estimable	—	—
Age at admission	1.03	0.99–1.08	0.164
Male sex	0.97	0.10–9.74	0.898
Charlson Comorbidity Index	0.83	0.50–1.39	0.450

* the effect of ICU admission could not be reliably estimated because of near-complete separation and the limited number of events in this subgroup.

Model 2 focused on new cardiovascular disease at short-term follow-up after the index COVID-19 hospitalization. Because almost all ICU patients developed new cardiovascular pathology, we applied a penalized logistic regression approach for this predictor. Because almost all ICU patients developed new cardiovascular pathology at short-term follow-up, near-complete separation occurred and an independent effect of ICU admission could not be reliably estimated, in the multivariable model. In this context, conventional *p*-values for the ICU term were therefore not reported. Age, sex, and Charlson Comorbidity Index were not independently associated with 3-month cardiovascular outcomes in the multivariable model. These findings are in line with the crude subgroup comparisons, which showed a higher proportion of new cardiovascular pathology at short-term follow-up, among patients requiring ICU admission compared with non-ICU patients (53.8% vs. 28.8%, crude OR 2.88, 95% CI 1.19–6.94, *p* = 0.019), whereas the difference in cardiovascular events at long-term follow-up did not reach statistical significance (69.7% vs. 54.2%, crude OR 1.94, 95% CI 0.86–4.35, *p* = 0.108).

3.5.3. NT-proBNP and Cardiovascular Outcomes

Acute NT-proBNP levels tended to be higher in patients who developed cardiovascular outcomes at long-term follow-up, but this association did not reach statistical significance in adjusted analyses. No robust association was identified between acute NT-proBNP and long-term cardiovascular outcomes. Differences in acute-phase NT-proBNP levels according to long-term cardiovascular outcomes are illustrated in Figure 2.

3.5.4. Non-Cardiovascular Outcomes at Long-Term Follow-Up

At long-term follow-up, non-cardiovascular sequelae were also frequent. The most common non-cardiovascular diagnoses were pulmonary fibrosis (17.2%), new asthma/COPD (16.1%), new renal disease (14.0%), new gastro-hepatopathy (14.0%), and new cancer (12.9%). Depression was observed in 10.8% of patients, while dermatologic and ophthalmologic diagnoses each occurred in 6.5%, rheumatologic disorders in 5.4%, and endocrinopathies in 4.3%.

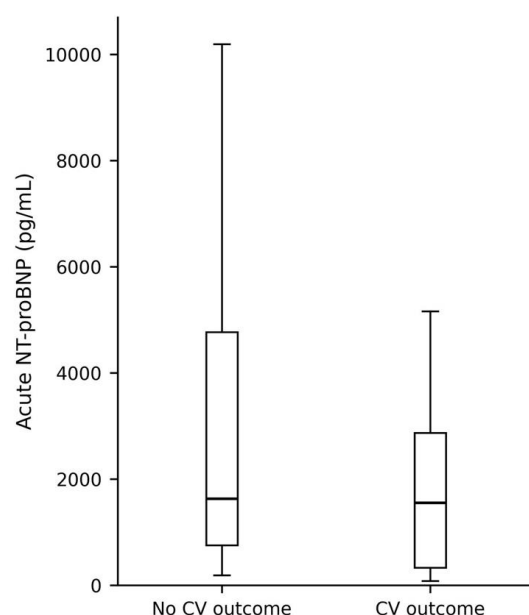


Figure 2. Acute NT-proBNP according to long-term cardiovascular outcome. This figure compares acute-phase NT-proBNP levels between patients with and without long-term cardiovascular outcomes. A tendency toward higher values in affected patients is observed, suggesting a potential association that warrants cautious interpretation due to limited sample size.

3.6. Exploratory Association Analyses

In exploratory analyses, several nominal associations were identified between acute-phase biomarkers, baseline comorbidities, and specific long-term non-cardiovascular outcomes. Elevated D-dimer during acute COVID-19 was associated with subsequent oncologic diagnoses at long-term follow-up, while ICU admission was associated with selected long-term non-cardiovascular diagnoses, including cancer and endocrinopathy. However, these findings were not robust after correction for multiple testing and should be interpreted as hypothesis-generating.

4. Discussion

This retrospective cohort study involving 762 patients hospitalized with SARS-CoV-2 infection revealed a significant burden of long-term morbidity following acute COVID-19. Over 90% of patients who returned for follow-up had at least one new diagnosis. Cardiovascular diagnoses were identified at approximately one-third of patients, at short-term follow-up and nearly half, at those attending long-term follow-up. Inflammatory and coagulation biomarkers, particularly fibrinogen and D-dimer, that were measured during the acute phase of COVID-19 infection, were independently linked to in-hospital mortality. On the other hand, biomarker NT-proBNP showed no strong association with long-term cardiovascular outcomes.

4.1. Cardiovascular Outcomes After COVID-19

These findings align with growing evidence, that suggest COVID-19 extends beyond an acute respiratory infection and potentially leads to prolonged cardiovascular and multisystem consequences. Large cohort studies have shown increased risks of heart failure, ischemic heart disease, arrhythmias, thromboembolic disease and cerebrovascular events following SARS-CoV-2 infection, even in patients without severe acute illness. For example, a study by Sooji Lee et al., of over 30 million participants from South Korea and Japan, found a long-term increased risk of cardiovascular outcomes following SARS-CoV-2 in-

fection [26]. The risk was highest in the first 30 days post-infection and persisted for up to 18 months, with a gradual attenuation of risk over time. Similar findings have been reported in a meta-analysis of eight studies with a combined participant pool of 10 million individuals. Ting Zhang et al. found an increased risk of new-onset cardiovascular diseases after SARS-CoV-2 infection [27]. Their meta-analysis showed a higher risk of stroke, arrhythmia, myocarditis, cardiomyopathy, coronary heart disease, hypertension, heart failure, thromboembolic disease, and cardiogenic shock in individuals with previous COVID-19 disease, compared to non-COVID-19 controls.

A key observation in our cohort was the higher frequency of cardiovascular diagnoses among patients attending long-term follow-up compared with those attending short-term follow-up. However, because the two follow-up groups did not consist of the same individuals, these findings should not be interpreted as evidence of temporal progression, but rather as differences observed between the two follow-up periods. Heart failure and ischemic heart disease were the most frequently identified cardiovascular diagnoses at long-term follow-up. Several mechanisms may contribute to these observations. SARS-CoV-2 infection is associated with endothelial dysfunction, ongoing immune activation, oxidative stress, microvascular damage and dysregulation of the renin–angiotensin–aldosterone system. Research by A. Ribeiro et al. found that post-COVID-19 patients have elevated levels of erythropoietin VEGF and MCP-1. They also state that the SARS-CoV-2 spike protein subunit 1 induces endothelial dysfunction in human retinal endothelial cells (HRECs) via HIF-2 α signaling. This pathway can be modulated by belzutifan. [28]. These mechanisms likely contribute to chronic vascular inflammation, accelerated atherosclerosis, myocardial fibrosis and ventricular remodeling. Furthermore, the prothrombotic state seen in acute COVID-19 may persist beyond the initial infection, potentially leading to ischemic and vascular complications.

The different distribution of diagnoses identified during short-term and long-term follow-up may also reflect differences in the natural history and clinical presentation of these conditions. Hypertension and pulmonary fibrosis are frequently recognized relatively early after hospitalization because blood pressure assessment and thoracic imaging are routinely performed during post-discharge evaluations. In contrast, conditions such as heart failure and ischemic heart disease often require a longer period for symptom development, clinical recognition, and diagnostic confirmation. Consequently, the differences observed between the two follow-up cohorts are likely to reflect differences in disease presentation, diagnostic pathways, and the timing of clinical evaluation rather than temporal progression attributable to SARS-CoV-2 infection.

A study by A. Curtiaud et al. [29] investigated the incidence of major adverse cardiovascular events (MACE), in COVID-19 survivors. They compared those admitted to intensive care units with those admitted in medical wards. The findings revealed a significantly higher risk of MACE, within the first year for ICU patients. Furthermore, the severity of COVID-19 infection emerged as a standalone risk factor for MACE in ICU patients.

4.2. Biomarkers and Mortality

Our findings further support the idea that systemic inflammation plays a central role in the pathophysiology of severe and long-term COVID-19 complications. Elevated D-dimer and fibrinogen levels during hospitalization were independently linked to in-hospital mortality, consistent with previous research linking hypercoagulability and endothelial injury to severe COVID-19 outcomes. The association between elevated D-dimer, fibrinogen levels and mortality, that was observed in our cohort, further supports the role of thromboinflammation, in severe cases of COVID-19. Levels of D-dimer reflect activation of coagulation and fibrinolysis, whereas fibrinogen is an acute-phase reactant, that is closely

linked to systemic inflammation and endothelial dysfunction. Othman et al. have found that persistent activation of these pathways is linked to microvascular injury, thromboembolic complications and poor clinical outcomes in COVID-19 patients [30]. While D-dimer and fibrinogen were linked to mortality in our study, their connection to subsequent cardiovascular complications was less pronounced. This suggests these biomarkers might mainly reflect the severity of the acute illness rather than long-term cardiovascular risk.

Elevated CRP levels, during the acute infection, were associated with a higher risk of subsequent cardiovascular complications, at long-term follow-up. However, this link was not statistically significant after accounting for other factors. This suggests the inflammatory response, during the initial SARS-CoV-2 infection, might contribute to ongoing cardiovascular issues, but larger studies are needed to fully understand the prognostic value of CRP, for long-term cardiovascular outcomes. A study by V. Briciu et al. analyzed 8614 COVID-19 hospitalized patients across four pandemic waves, finding significant variations in demographics, comorbidities, disease severity, and outcomes. The Delta wave was the most severe, characterized by the longest hospitalizations and highest mortality. While inflammatory biomarkers generally decreased during the Omicron wave, CRP levels continued to rise. This suggests a shift towards a less severe clinical profile with different variants of the virus [31].

In contrast to inflammatory and coagulation biomarkers, NT-proBNP did not show a statistically significant link to long-term cardiovascular outcomes in adjusted analyses. No statistically significant changes in paired NT-proBNP measurements could be detected over time, although interpretation is limited by the small number of paired observations. First, NT-proBNP may predominantly reflect acute hemodynamic stress and myocardial strain during severe infection rather than chronic post-COVID-19 remodeling processes. Second, interpretation of NT-proBNP values in our cohort is complicated by the advanced age of the population and the relatively high prevalence of pre-existing cardiovascular disease and chronic kidney disease, both of which independently influence natriuretic peptide levels. Finally, paired NT-proBNP measurements were available only in a limited subset of patients, reducing statistical power and limiting the ability to detect subtle temporal changes. Similar inconsistencies regarding the prognostic role of NT-proBNP in post-COVID-19 populations have also been described in previous observational studies. A study, published in 2025, that compared BNP and NT-proBNP levels, in heart failure patients, with and without COVID-19, found significantly higher levels, in both groups, compared to the control group. The study also found increased levels of IL-12, IL-10, and TNF- α in the heart failure with COVID-19 group, indicating illness progression [32].

4.3. Impact of Acute Disease Severity

Disease severity during the acute infection appeared to influence early post-COVID-19 cardiovascular outcomes. Patients requiring ICU admission had a higher frequency of cardiovascular diagnoses at short-term follow-up, after SARS-CoV-2 hospitalization. Severe COVID-19 is linked to extensive systemic inflammation, prolonged hypoxia, endothelial dysfunction, catecholamine excess and thrombotic complications. These factors likely contribute to ongoing cardiovascular damage, but the link between ICU admission and long-term cardiovascular issues was less apparent. This could be due to survival bias, varied recovery patterns or differences in healthcare-seeking behavior during follow-up. The wide confidence intervals in the penalized regression models also suggest limited subgroup sizes and statistical instability for some estimates.

4.4. Multisystem Outcomes

Beyond cardiovascular disease, our findings support the idea of post-COVID-19 as a multisystem disorder. During follow-up, pulmonary fibrosis, chronic respiratory disease, renal problems, gastro-hepatopathy, depression, endocrine disorders and oncological diagnoses were frequently reported. Persistent pulmonary abnormalities were among the most common non-cardiovascular sequelae, aligning with previous studies showing residual inflammatory and fibrotic pulmonary changes months after severe COVID-19 pneumonia. The relatively high prevalence of oncological diagnoses in our cohort should be interpreted cautiously. Chronic inflammation, immune dysregulation and oxidative stress, might theoretically foster a tumor-promoting environment; delayed cancer diagnosis during the pandemic and heightened medical monitoring post-hospitalization could also explain these observations. [33]. The relatively high frequency of newly identified malignancies during early follow-up should not be interpreted as evidence that these cancers developed as a consequence of SARS-CoV-2 infection. They should rather be interpreted as incidental diagnoses, identified during routine post-hospitalization clinical evaluation.

4.5. Interpretation of Findings and Clinical Implications

The very high prevalence of newly diagnosed conditions, observed in our cohort should be interpreted with caution. In addition to the possible effects of SARS-CoV-2 infection, the advanced age of the study population, the substantial burden of pre-existing comorbidities, and the long-term consequences of severe illness or intensive care hospitalization may also have contributed to the occurrence of cardiovascular and non-cardiovascular diagnoses during follow-up. Therefore, these findings should be interpreted as post-hospitalization outcomes, that occur after COVID-19, rather than conditions that can be exclusively attributed to SARS-CoV-2 infection.

These findings have several important clinical implications. The significant burden of cardiovascular and multisystem comorbidities, seen after COVID-19 disease hospitalization, emphasizes the need for structured, longitudinal follow-up. The need is heightened especially for older patients and those with severe acute illness. Inflammatory and coagulation biomarkers, obtained during the acute phase, may help identify patients at increased risk of adverse outcomes. This could contribute to future risk stratification strategies for patients with SARS-CoV-2 infection. Finally, our results further support the concept that post-COVID-19 represents a heterogeneous and multisystem condition requiring multidisciplinary evaluation and appropriate clinical follow-up.

In summary, hospitalized COVID-19 patients experienced significant long-term cardiovascular and multisystem morbidity. Cardiovascular diagnoses were more frequently observed during long-term follow-up and were especially prevalent in those with severe acute illness. Inflammatory and coagulation biomarkers during acute infection correlated with poor outcomes while NT-proBNP did not appear a reliable predictor of long-term cardiovascular problems. Prospective longitudinal studies are needed to better understand the mechanisms predictors and long-term clinical implications of post-COVID-19 cardiovascular disease.

5. Limitations of the Study

Several limitations of this study should be acknowledged. First, the retrospective design introduces the possibility of selection bias and residual confounding. Follow-up data were derived from patients who subsequently re-presented to the same hospital system for additional medical evaluation, including admissions or consultations in departments other than the initial Pneumology Department. Consequently, the follow-up population likely included patients with persistent symptoms, worsening clinical status or newly

diagnosed medical conditions. This could have contributed to an overestimation of the overall burden of post-COVID-19 morbidity in the study. Furthermore, because patients attending short-term and long-term follow-up were individuals who re-presented for clinical evaluation, independent baseline characteristics for each follow-up cohort could not be comprehensively assessed.

Secondly, complete baseline demographic and clinical characteristics were only available for the initial hospitalized cohort. Outcome definitions were based on diagnoses documented during routine clinical care and extracted from electronic medical records; therefore, some degree of diagnostic misclassification cannot be excluded. In addition, incomplete availability of paired biomarker measurements, particularly NT-proBNP, reduced statistical power for some longitudinal analyses.

Thirdly, the absence of a non-COVID-19 control group precludes distinguishing diagnoses, potentially related to SARS-CoV-2 infection from those attributable to aging, progression of pre-existing diseases or the long-term consequences of severe illness. Although multivariable regression models were applied, residual confounding cannot be completely excluded.

To conclude limitations of this study, the findings should be interpreted as observational, post-hospitalization data, rather than evidence of causal relationships between COVID-19 and subsequent cardiovascular or multisystem diagnoses.

6. Conclusions

Hospitalized patients with COVID-19, who re-presented for follow-up, experienced a substantial burden of cardiovascular and multisystem diagnoses during the post-hospitalization period. When interpreting these findings, it is important to consider the impact of aging, pre-existing comorbidities and the long-term consequences of severe illness. Patients who attended long-term follow-up were more likely to have cardiovascular diagnoses, particularly heart failure and ischaemic heart disease. However, due to the retrospective study design and non-sequential follow-up cohorts, these findings should not be seen as evidence of disease progression, but rather as differences observed between the two follow-up periods.

Our findings support the concept that post-COVID-19 is a complex multisystem condition and it needs extended clinical surveillance and multidisciplinary management. This is true especially for older patients and those with severe acute illness. However, the high prevalence of newly diagnosed conditions, in this study, should be interpreted cautiously, due to the follow-up methodology and potential healthcare-seeking bias among patients who returned for further evaluation. Prospective longitudinal studies with appropriate control populations are needed to better understand the true long-term burden mechanisms and predictors of post-COVID-19 cardiovascular disease.

Author Contributions: Conceptualization, S.T.M. and A.I.S.; methodology, S.T.M., A.-R.C.-S. and D.M.C.; validation, A.-R.C.-S., A.I.S. and O.S.C.; formal analysis, S.T.M. and D.M.C.; investigation, S.T.M., A.C.T., A.H.S., I.G.C., R.N., C.R.M. and N.E.P.; resources, O.S.C., A.H.S. and A.C.T.; data curation, S.T.M., R.N. and C.R.M.; writing—original draft preparation, S.T.M.; writing—review and editing, A.-R.C.-S., A.I.S., D.M.C., O.S.C. and A.C.T.; visualization, S.T.M., C.R.M. and N.E.P.; supervision, A.I.S. and O.S.C.; project administration, A.-R.C.-S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Spitalul Clinic Județean Mures (Nr. 5138/5 May 2026).

Informed Consent Statement: Patient consent was waived due to the retrospective nature of this study. Patient data were extracted retrospectively from medical records, anonymized prior to analysis and handled in accordance with institutional policies and applicable data protection regulations.

Data Availability Statement: Patient data were extracted retrospectively from medical records, anonymized prior to analysis, and handled in accordance with institutional policies and applicable data protection regulations.

Acknowledgments: This article is part of a PhD thesis of S.T.M., from the Doctoral School of Medicine and Pharmacy within the University of Medicine, Pharmacy, Science, and Technology “George Emil Palade” of Targu Mures, entitled “The involvement and effects of the SARS-CoV2 virus in cardiovascular pathology”.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ACE2	Angiotensin-converting enzyme 2
BNP	B-type natriuretic peptide
CI	Confidence interval
COVID-19	Coronavirus disease 2019
COPD	Chronic obstructive pulmonary disease
CRP	C-reactive protein
D-dimer	D-dimer
ED	Endothelial dysfunction
FEU	Fibrinogen equivalent units
HIF-2 α	Hypoxia-inducible factor 2 alpha
HREC	Human retinal endothelial cell
ICU	Intensive Care Unit
IL-10	Interleukin-10
IL-12	Interleukin-12
IQR	Interquartile range
MACE	Major adverse cardiovascular events
MCP-1	Monocyte chemoattractant protein-1
NT-proBNP	N-terminal pro-B-type natriuretic peptide
OR	Odds ratio
PCT	Procalcitonin
RAAS	Renin–angiotensin–aldosterone system
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
TNF- α	Tumor necrosis factor alpha
VEGF	Vascular endothelial growth factor

References

1. Gaffney, A.W. The Long COVID Conundrum. *Am. J. Med.* **2022**, *135*, 56. [[CrossRef](#)] [[PubMed](#)]
2. Gameil, M.A.; Marzouk, R.E.; Elsebaie, A.H.; Rozaik, S.E. Long-Term Clinical and Biochemical Residue After COVID-19 Recovery. *Egypt. Liver J.* **2021**, *11*, 74. [[CrossRef](#)] [[PubMed](#)]
3. Sudre, C.H.; Murray, B.; Varsavsky, T.; Graham, M.S.; Penfold, R.S.; Bowyer, R.C.; Pujol, J.C.; Klaser, K.; Antonelli, M.; Canas, L.S.; et al. Attributes and Predictors of Long COVID. *Nat. Med.* **2021**, *27*, 626–631. [[CrossRef](#)] [[PubMed](#)]
4. Iba, T.; Levy, J.H.; Maier, C.L.; Connors, J.M.; Levi, M. Four Years into the Pandemic, Managing COVID-19 Patients with Acute Coagulopathy: What Have We Learned? *J. Thromb. Haemost.* **2024**, *22*, 1541–1549. [[CrossRef](#)] [[PubMed](#)]
5. Sahranavard, M.; Rezayat, A.A.; Bidary, M.Z.; Omranzadeh, A.; Rohani, F.; Farahani, R.H.; Hazrati, E.; Mousavi, S.H.; Ardalan, M.A.; Soleiman-Meigooni, S.; et al. Cardiac Complications in COVID-19: A Systematic Review and Meta-Analysis. *Arch. Iran. Med.* **2021**, *24*, 152–163. [[CrossRef](#)] [[PubMed](#)]

6. Sarfraz, Z.; Sarfraz, A.; Barrios, A.; Garimella, R.; Dominari, A.; Kc, M.; Pandav, K.; Pantoja, J.C.; Retnakumar, V.; Cherrez-Ojeda, I. Cardio-Pulmonary Sequelae in Recovered COVID-19 Patients: Considerations for Primary Care. *J. Prim. Care Community Health* **2021**, *12*, 21501327211023726. [[CrossRef](#)] [[PubMed](#)]
7. Budin, C.E.; Nemeş, A.F.; Răjnoveanu, R.-M.; Nemeş, R.M.; Răjnoveanu, A.G.; Sabău, A.H.; Cocuz, I.G.; Mares, R.G.; Oniga, V.I.; Pătrîntaşu, D.E.; et al. The Inflammatory Profile Correlates with COVID-19 Severity and Mortality in Cancer Patients. *J. Pers. Med.* **2023**, *13*, 1235. [[CrossRef](#)] [[PubMed](#)]
8. Bolland, W.; Marechal, I.; Petiot, C.; Porrot, F.; Guivel-Benhassine, F.; Brelot, A.; Casartelli, N.; Schwartz, O.; Buchrieser, J. SARS-CoV-2 Entry and Fusion Are Independent of ACE2 Localization to Lipid Rafts. *J. Virol.* **2025**, *99*, e01823-24. [[CrossRef](#)] [[PubMed](#)]
9. Chen, T.-H.; Jeng, T.-H.; Lee, M.-Y.; Wang, H.-C.; Tsai, K.-F.; Chou, C.-K. Viral Mitochondriopathy in COVID-19. *Redox Biol.* **2025**, *85*, 103766. [[CrossRef](#)] [[PubMed](#)]
10. Ilyas, A. Decoding the Role of NF- κ B Signaling in COVID-19 Severity and Inflammation. *Prem. J. Sci.* **2025**, *13*, 100097. [[CrossRef](#)]
11. Jing, H.; Wu, X.; Xiang, M.; Liu, L.; Novakovic, V.A.; Shi, J. Pathophysiological Mechanisms of Thrombosis in Acute and Long COVID-19. *Front. Immunol.* **2022**, *13*, 992384. [[CrossRef](#)] [[PubMed](#)]
12. Ambrosino, P.; Calcaterra, I.; Molino, A.; Moretta, P.; Lupoli, R.; Spedicato, G.A.; Papa, A.; Motta, A.; Maniscalco, M.; Di Minno, M.N.D. Persistent Endothelial Dysfunction in Post-Acute COVID-19 Syndrome: A Case-Control Study. *Biomedicines* **2021**, *9*, 957. [[CrossRef](#)] [[PubMed](#)]
13. Dennis, A.; Wamil, M.; Alberts, J.; Oben, J.; Cuthbertson, D.J.; Wootton, D.; Crooks, M.; Gabbay, M.; Brady, M.; Hishmeh, L.; et al. Multiorgan Impairment in Low-Risk Individuals with Post-COVID-19 Syndrome: A Prospective, Community-Based Study. *BMJ Open* **2021**, *11*, e048391. [[CrossRef](#)] [[PubMed](#)]
14. Karakasis, P.; Nasoufidou, A.; Sagris, M.; Fragakis, N.; Tsioufis, K. Vascular Alterations Following COVID-19 Infection: A Comprehensive Literature Review. *Life* **2024**, *14*, 545. [[CrossRef](#)] [[PubMed](#)]
15. Rus, M.; Ardelean, A.I.; Andronie-Cioara, F.L.; Filimon, G.C. Acute Myocardial Infarction During the COVID-19 Pandemic: Long-Term Outcomes and Prognosis—A Systematic Review. *Life* **2024**, *14*, 202. [[CrossRef](#)] [[PubMed](#)]
16. Conte, C.; Cipponeri, E.; Roden, M. Diabetes Mellitus, Energy Metabolism, and COVID-19. *Endocr. Rev.* **2024**, *45*, 281–308. [[CrossRef](#)] [[PubMed](#)]
17. Goswami, J.; MacArthur, T.A.; Sridharan, M.; Pruthi, R.K.; McBane, R.D.I.; Witzig, T.E.; Park, M.S. A Review of Pathophysiology, Clinical Features, and Management Options of COVID-19 Associated Coagulopathy. *Shock* **2021**, *55*, 700–716. [[CrossRef](#)] [[PubMed](#)]
18. László, S.-A.; Ianoşi, E.-S.; Văsieşiu, A.-M.; Szathmáry, M.; Ianoşi, M.B.; Rachis, D.-L.; Nistor, G.; Jimborean, G. COVID-19 and Lung Cancer Interactions: A Literature Review. *Med. Sci.* **2025**, *13*, 295. [[CrossRef](#)] [[PubMed](#)]
19. Budin, C.E.; Cocuz, I.G.; Enache, L.S.; Renţa, I.A.; Cazacu, C.; Pătrîntaşu, D.E.; Olteanu, M.; Răjnoveanu, R.-M.; Ianoşi, E.S.; Răjnoveanu, A.; et al. Neutrophil-to-Lymphocyte and Platelet-to-Lymphocyte Ratio: Side by Side with Molecular Mutations in Patients with Non-Small Cell Lung Cancer—The INOLUNG Study. *Cancers* **2024**, *16*, 2903. [[CrossRef](#)] [[PubMed](#)]
20. Szathmáry, M.; Gîrbovan, E.-C.; Sárközi, H.-K.; Gáll, Z.; Vultur, M.A.; Nemeş, A.F.; Ianoşi, E.S.; Jimborean, G. Exacerbation of Obstructive Pulmonary Diseases by SARS-CoV-2 Infection in Patients Treated in the Pulmonology Clinic of Târgu Mureş. *Orvosi Hetil.* **2023**, *164*, 43–50. [[CrossRef](#)] [[PubMed](#)]
21. Ianoşi, E.S.; Dantes, E.; Csipor, A.; Szathmáry, M.; Socaci, A.; Rusu, E.; Nemes, R.M. Enhancing Education for Smoking Prevention and Smoking Cessation in Medical Personnel: A Measure for Better Health. *Rev. Chim.* **2018**, *69*, 2725–2727. [[CrossRef](#)]
22. Szathmáry, M.; Ianoşi, E.S.; Gáll, Z.; Dogar, C.M.; Jimborean, G. Smoking Habits among Adolescents in Târgu Mureş. *Orvosi Hetil.* **2024**, *165*, 1669–1675. [[CrossRef](#)] [[PubMed](#)]
23. Kitano, T.; Toyota, T.; Sano, M.; Morimoto, T.; Azumi, Y.; Hayashi, H.; Murai, R.; Ooka, J.; Sasaki, Y.; Taniguchi, T.; et al. Combination of High-Sensitive Troponin I and NT-proBNP for Mortality Risk Stratification in Hospitalized COVID-19 Across Pandemic Waves: Pooled Analysis from COVID-MI Registry Cohort-1 and Cohort-2. *Circulation* **2025**, *152*, A4367239. [[CrossRef](#)]
24. Xu, S.; Ilyas, I.; Weng, J. Endothelial Dysfunction in COVID-19: An Overview of Evidence, Biomarkers, Mechanisms and Potential Therapies. *Acta Pharmacol. Sin.* **2023**, *44*, 695–709. [[CrossRef](#)] [[PubMed](#)]
25. Patrascu, R.; Dumitru, C.S. Advances in Understanding Inflammation and Tissue Damage: Markers of Persistent Sequelae in COVID-19 Patients. *J. Clin. Med.* **2025**, *14*, 1475. [[CrossRef](#)] [[PubMed](#)]
26. Lee, S.; Hwang, S.H.; Park, S.; Son, Y.; Kim, S.; Kim, H.J.; Park, J.; Jo, H.; Lee, K.; Oh, J.; et al. Burden of Cardiovascular Outcomes After SARS-CoV-2 Infection in South Korea and Japan: A Binational Population-Based Cohort Study. *Circulation* **2025**, *152*, 11–23. [[CrossRef](#)] [[PubMed](#)]
27. Zhang, T.; Li, Z.; Mei, Q.; Walline, J.H.; Zhang, Z.; Liu, Y.; Zhu, H.; Du, B. Cardiovascular Outcomes After SARS-CoV-2 Infection: A Systematic Review and Meta-Analysis. *Front. Cardiovasc. Med.* **2025**, *12*, 1450470. [[CrossRef](#)] [[PubMed](#)]
28. Ribeiro, A.; Wallraven, T.; Lech, M.; Adorjan, K.; Stubbe, H.C.; Seifert, M.; Wöhl, A.; Kessler, V.; Negele, J.; Schmaderer, C. SARS-CoV-2 Spike S1-Mediated HIF-2 α Activation in Retinal Endothelial Cells Suggests a Mechanism Contributing to Post-COVID Endothelial Dysfunction. *Front. Immunol.* **2026**, *17*, 1770758. [[CrossRef](#)] [[PubMed](#)]

29. Curtiaud, A.; Trimaille, A.; Severac, F.; Granier, A.; Demiselle, J.; Lakehal, R.; Helms, J.; Morel, O.; Meziani, F.; Merdji, H. Long-Term Cardiovascular Complications in COVID-19 Survivors According to Disease Severity. *Sci. Rep.* **2025**, *15*, 37900. [\[CrossRef\]](#)
30. Othman, H.Y.; Zaki, I.A.H.; Isa, M.R.; Ming, L.C.; Zulkifly, H.H. A Systematic Review of Thromboembolic Complications and Outcomes in Hospitalized COVID-19 Patients. *BMC Infect. Dis.* **2024**, *24*, 484. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Briciu, V.; Leucuta, D.-C.; Muntean, M.; Radulescu, A.; Cismaru, C.; Topan, A.; Herbel, L.; Horvat, M.; Flonta, M.; Calin, M.; et al. Differences in the Inflammatory Response and Outcome Among Hospitalized Patients During Different Waves of the COVID-19 Pandemic. *Front. Immunol.* **2025**, *16*, 1545181. [\[CrossRef\]](#) [\[PubMed\]](#)
32. Al-Badri, H.A.M. Comparison of BNP and NT-proBNP Levels Between Heart Failure Patients and Heart Failure Patients with COVID-19. *Samarra J. Pure Appl. Sci.* **2025**, *7*, 26–33. [\[CrossRef\]](#)
33. Cercel, R.A.; Buibaş, F.I.; Şerbănescu, M.-S.; Mirea, A.A.; Dumitrescu, F.; Pirici, I.; Badea-Voiculescu, O.; Mogoantă, L.; Botezat, M.-M. COVID-19—Multisystem Disease. *Rom. J. Morphol. Embryol.* **2025**, *66*, 61–67. [\[CrossRef\]](#) [\[PubMed\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.