

Article

Characteristics, Associated Factors, and Outcomes of Cardiac Arrest in Critically Ill COVID-19 Patients in the Intensive Care Unit: A Single-Center Retrospective Study

Danijela Jakovljević ^{1,2,*} , Aleksandar Pavlović ^{1,3}, Aleksandra Ilić ¹, Slađana Trpković ^{1,3} , Nebojša Videnović ^{1,3}, Milan Filipović ^{1,3}, Snežana Đukić ^{1,2}, Ranko Zdravković ^{4,5} , Marija Milanović ² and Aleksandar Jakovljević ^{1,2} 

¹ Faculty of Medicine, University of Pristina, 38220 Kosovska Mitrovica, Serbia; milan.filipovic1967@gmail.com (M.F.); a.jakovljevic@outlook.com (A.J.)

² Clinical Hospital Center Kosovska Mitrovica, 38220 Kosovska Mitrovica, Serbia

³ Clinical Hospital Center Pristina, 38205 Gracanica, Serbia

⁴ Faculty of Medicine, University of Novi Sad, 21000 Novi Sad, Serbia

⁵ Institute of Cardiovascular Diseases of Vojvodina, 21208 Sremska Kamenica, Serbia

* Correspondence: danijelavicentijevic94@hotmail.com; Tel.: +381-64-1267575

Abstract

Background and Objectives: In-hospital cardiac arrest (IHCA) in critically ill patients with COVID-19 is among the most severe clinical outcomes, associated with high mortality and a significant risk to healthcare workers during cardiopulmonary resuscitation (CPR). The aim of this study was to evaluate the incidence, characteristics, associated factors, and outcomes of IHCA among COVID-19 patients treated in the intensive care unit (ICU), with particular emphasis on resuscitation outcomes and survival. **Materials and Methods:** A retrospective cohort study was conducted including critically ill patients with confirmed SARS-CoV-2 infection treated in the ICU of the Clinical-Hospital Center (KBC) in Kosovska Mitrovica between March 2020 and December 2022. Patients were categorized into two groups: (1) CA group—patients who experienced CA in the ICU, and (2) non-CA group—patients who did not experience CA during ICU treatment. **Results:** A total of 222 patients were analyzed, of whom 114 (51.4%) experienced IHCA. Patients with IHCA were significantly older, more frequently obese, and had a higher burden of comorbidities. They also exhibited more pronounced hematological and inflammatory abnormalities, including lower erythrocyte and hemoglobin levels, thrombocytopenia, and elevated leukocyte counts, fibrinogen, C-reactive protein, and procalcitonin levels. In addition, higher lactate and D-dimer concentrations were observed, along with a more frequent occurrence of hyperkalemia and hypernatremia. The predominant cause of IHCA was respiratory failure, most commonly associated with severe hypoxemia (59.6%), while non-shockable initial rhythms (asystole and pulseless electrical activity (PEA)) were most common (76.3%). Among patients with IHCA, return of spontaneous circulation (ROSC) was achieved in 11 patients (9.6%), and 3 patients (2.6%) survived to hospital discharge. **Conclusions:** Despite rapid response and CPR in the ICU setting, outcomes remained poor. More favorable outcomes were observed mainly in cases with potentially reversible etiologies (such as myocardial infarction and pulmonary embolism (PE)), in contrast to hypoxia-mediated CA.

Keywords: in-hospital cardiac arrest; COVID-19; intensive care unit; cardiopulmonary resuscitation



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1. Introduction

The COVID-19 pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and responsible for more than 7 million deaths worldwide, has posed a major challenge to healthcare systems globally. Patients infected with SARS-CoV-2 present with a wide spectrum of clinical manifestations, ranging from asymptomatic infection and mild to moderate disease (mild pneumonia) to severe disease (dyspnea and hypoxemia) and critical illness, including acute respiratory distress syndrome (ARDS), sepsis, respiratory failure, shock, multiple organ dysfunction syndrome (MODS), and other extrapulmonary manifestations, as well as pulmonary embolism (PE). Among the most severe outcomes are cardiac arrest (CA) and death [1–3].

Previous studies have identified older age, male sex, and chronic comorbidities, including diabetes mellitus, hypertension, obesity, coronary artery disease, and heart failure, as factors associated with poorer outcomes [1,4]. Respiratory failure is the leading reason for admission to the intensive care unit (ICU). It is estimated that approximately 14% of patients with COVID-19 require hospitalization, while about 2% require ICU admission. Many patients with COVID-19 develop severe acute respiratory failure requiring mechanical ventilation (MV) [4].

Laboratory parameters associated with poor outcomes include lymphocytopenia and elevated levels of inflammatory biomarkers such as C-reactive protein (CRP), lactate dehydrogenase (LDH), and interleukin-6 (IL-6) [5].

Given the novel nature of COVID-19, clinicians faced numerous uncertainties and dilemmas in the management of these patients, particularly during the early stages of the pandemic. Between 2020 and 2023, the World Health Organization (WHO) issued as many as 14 versions of clinical guidelines for the management of COVID-19 [6].

A large multicenter study reported that the incidence of in-hospital cardiac arrest (IHCA) among patients with COVID-19 is approximately 14% [7]. Several studies have indicated that IHCA in patients with COVID-19 is associated with poor survival outcomes [8].

One meta-analysis demonstrated that IHCA in patients with COVID-19 is associated with lower rates of return of spontaneous circulation (ROSC) and higher mortality compared with non-COVID-19 IHCA and that COVID-19 represents an independent risk factor for poor outcomes in patients with IHCA [9].

Available studies indicate that the success rate of cardiopulmonary resuscitation (CPR) in patients with IHCA and COVID-19 ranges from as low as 0% [10–12] to 12.3% [13]. These findings highlight the poor prognosis associated with IHCA in patients with COVID-19 and have prompted discussion regarding resuscitation practices during the pandemic, particularly in patients with advanced critical illness [14].

The COVID-19 pandemic had direct, indirect, psychosocial, and ethical impacts on the CA chain of survival [15]. CPR in patients with COVID-19 initially required a modified approach compared with conventional resuscitation because of the significant risk to healthcare workers related to increased aerosol generation [16]. These circumstances raised important ethical considerations regarding the use of CPR in patients with COVID-19, particularly in the context of limited healthcare resources and increased hospital burden during the pandemic [17].

For this reason, several international organizations, including the European Resuscitation Council (ERC) and the American Heart Association (AHA), proposed modifications to CPR guidelines during the SARS-CoV-2 pandemic in order to ensure safe and effective resuscitation [18,19]. However, as the pandemic evolved and healthcare systems adapted to improved infection control measures, vaccination, and resource availability, several healthcare organizations and resuscitation councils gradually withdrew or modified COVID-19-specific CPR recommendations, although the timing and implementation

of these changes varied across different healthcare systems and regions. Consequently, patients with COVID-19 are currently managed similarly to other critically ill patients, and specific CPR modifications are generally no longer required [20].

Although previous studies have consistently demonstrated poor outcomes after IHCA in patients with COVID-19, most have focused primarily on survival or included heterogeneous populations of hospitalized patients. Despite previous studies, data providing a comprehensive evaluation of clinical characteristics, laboratory abnormalities, respiratory support, resuscitation characteristics, and factors independently associated with IHCA in exclusively critically ill ICU patients remain limited, particularly in Southeast Europe [21]. Therefore, the aim of this study was to comprehensively evaluate the incidence, characteristics, associated factors, and outcomes of IHCA in critically ill patients with COVID-19 treated in the ICU. By integrating clinical, laboratory, respiratory, and resuscitation-related variables in a single cohort, this study contributes additional data on IHCA in critically ill patients with COVID-19.

2. Materials and Methods

We conducted a retrospective study of consecutive adult patients with severe or critical COVID-19 treated in the ICU at the Clinical-Hospital Center (KBC) in Kosovska Mitrovica between 1 March 2020 and 31 December 2022. Disease severity was classified according to the World Health Organization (WHO) clinical severity classification. Severe COVID-19 was defined as clinical signs of pneumonia associated with severe respiratory distress, respiratory rate >30 breaths/min, or oxygen saturation (SpO_2) $<90\%$ on room air. Critical COVID-19 was defined as the presence of acute respiratory distress syndrome (ARDS), sepsis, septic shock, or other life-threatening conditions requiring life-sustaining therapies, including invasive mechanical ventilation and intensive care management. The severity classification was assigned retrospectively based on the clinical findings documented in the patients' medical records. During the study period, ICU admission was reserved for patients with severe or critical COVID-19 requiring intensive monitoring and advanced organ support, including severe hypoxemic respiratory failure, invasive mechanical ventilation (IMV), vasopressor therapy, or other manifestations of multiorgan dysfunction. Patients with milder disease were managed in dedicated COVID-19 hospital wards and were not included in this study. All patients were positive for SARS-CoV-2 by polymerase chain reaction (PCR) testing using nasopharyngeal swab samples. Patients with out-of-hospital CA were excluded, while ICU readmissions during the same hospitalization were not analyzed separately, and only the first ICU admission was included. During the study period, no formal DNACPR policy existed, and all patients who developed IHCA underwent CPR attempts. Missing data were addressed through retrospective review of electronic and paper medical records, and cases with substantial missing information relevant to the primary outcomes were excluded from the analysis. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Clinical-Hospital Center Kosovska Mitrovica (No. 2293, 9 May 2022), in accordance with ethical principles of privacy protection for studies involving humans.

Epidemiological and clinical data were obtained from medical records and recorded in a standardized case report form that included demographic characteristics (age and sex), risk factors (obesity), lifestyle habits (tobacco and alcohol use), and previous medical conditions (comorbidities). Body weight and height were obtained retrospectively from the medical records, and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Patients were classified according to the World Health Organization (WHO) BMI categories as underweight, normal weight, overweight, obese, or class III obese. Complications occurring within 24 h prior to IHCA

were assessed in the CA group, while in the non-CA group complications during ICU stay were recorded, including respiratory failure, ARDS, pneumonia, hypotension, sepsis, acute kidney injury (AKI), acute liver failure (ALF), and coagulation disorders.

In addition, chest radiographs, electrocardiography (ECG), and laboratory parameters obtained at admission and during hospitalization were analyzed, including complete blood count (CBC), metabolic disturbances (acidosis/alkalosis), electrolyte abnormalities (potassium and sodium levels), and arterial blood gas (ABG) parameters, including the $\text{PaO}_2/\text{FiO}_2$ ratio and lactate concentration. In patients with CA, laboratory and ABG parameters were analyzed using the last available measurements obtained within 24 h prior to the arrest event, whereas in patients without CA, laboratory and ABG parameters were obtained from the period of greatest clinical severity during the ICU stay, based on the available medical records. Because this was a retrospective study, standardized serial measurements at predefined time points were not available for all patients.

Inflammatory biomarkers were additionally assessed, including CRP, fibrinogen, D-dimer, and procalcitonin. The need for oxygen therapy, MV, vasopressor therapy, and dialysis in the period prior to the occurrence of CA was also analyzed. Furthermore, CPR characteristics were recorded, including the personnel initiating resuscitation (nurse, physician, or hospital resuscitation team), initial cardiac rhythm (asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], and pulseless ventricular tachycardia [pVT]), and interventions during IHCA, such as airway management, ventilation during CPR, and medications administered during resuscitation. In addition, no-flow time, time to ROSC, and survival to hospital discharge were documented.

In our healthcare system, the “Do Not Attempt Cardiopulmonary Resuscitation” (DNACPR) order has not yet been incorporated into national healthcare regulations; therefore, CPR was performed in all patients who experienced IHCA.

All patients were divided into two groups: Group I, the CA group, consisting of COVID-19 patients who experienced CA in the ICU; and Group II, the non-CA group, consisting of COVID-19 patients who did not experience CA during ICU treatment.

During the COVID-19 pandemic, CPR procedures in our hospital were performed with all necessary measures for the protection of healthcare personnel from aerosol transmission, in accordance with national and local protocols, as well as ERC guidelines for resuscitation in patients with COVID-19.

Statistical Analysis

Descriptive statistical methods and statistical hypothesis testing were used for data analysis. Continuous variables were presented as mean $\pm$ standard deviation (SD) or medians with interquartile range (Q1–Q3), depending on distribution normality, which was assessed using the Shapiro–Wilk test, while categorical variables were expressed as absolute numbers and percentages.

For hypothesis testing, Student’s *t*-test or the Mann–Whitney U test (rank-sum test) was used for continuous variables, while the chi-square (χ^2) test or Fisher’s exact test was applied for categorical variables.

Variables showing statistical significance in univariate analysis were considered for inclusion in the multivariable logistic regression models. A stricter significance threshold ($p < 0.001$) was initially applied in order to reduce the number of predictors, improve model stability, and decrease the risk of type I error and overfitting, given the relatively limited sample size and the large number of analyzed variables.

Because 114 patients experienced the outcome of interest (cardiac arrest), inclusion of all eligible predictors in a single multivariable model would have exceeded the recommended events-per-variable (EPV) ratio. Therefore, two conceptually distinct domain-

specific multivariable logistic regression models were initially constructed. The Multivariable Clinical Model included sociodemographic characteristics, lifestyle habits, comorbidities, respiratory support, and treatment-related variables, whereas the Multivariable Laboratory Model included hematological, biochemical, inflammatory, coagulation, and arterial blood gas parameters.

Before model construction, predictors were evaluated for multicollinearity and singularity. Variables demonstrating complete or quasi-complete separation were excluded to improve model stability. Forward selection was used for model building. Multicollinearity was assessed using variance inflation factors (VIF). Predictors that remained statistically significant in the domain-specific models were subsequently evaluated together in a final combined multivariable logistic regression model to identify factors independently associated with cardiac arrest after mutual adjustment.

Missing data were handled using available-case analysis, while cases with substantial missing information relevant to the primary outcome were excluded from the analysis.

Given the exploratory nature of the study, no formal adjustment for multiple comparisons was performed. Therefore, the findings should be interpreted as hypothesis-generating rather than confirmatory.

Statistical hypotheses were tested at a significance level (α) of 0.05. All analyses were performed using SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA).

3. Results

A total of 222 critically ill patients with SARS-CoV-2 infection treated in the ICU during the study period were included in the analysis. The patients were aged 32 to 91 years, with a mean age of 64.6 ± 11.4 years.

Baseline characteristics of critically ill patients with COVID-19 according to the occurrence of CA in the ICU are presented in Table 1. Overall, 119 patients (53.6%) were male and 103 (46.4%) were female. The mean age was 63.2 ± 11.4 years among male patients and 64.9 ± 11.3 years among female patients. Overall, 114 patients (51.4%) experienced CA during their ICU stay. There was no significant difference in sex distribution between the CA and non-CA groups ($p = 0.610$). However, patients in the CA group were significantly older than those in the non-CA group (70.3 ± 9.8 vs. 57.3 ± 8.9 years, $p < 0.001$).

Body mass index (BMI) was calculated using body weight and height obtained from the medical records, and patients were classified according to the WHO BMI categories. Normal body weight was significantly more common in the non-CA group than in the CA group (74.1% vs. 45.6%, $p < 0.001$). Conversely, obesity was significantly more prevalent in the CA group ($p = 0.004$). In the CA group, 16.7% of patients were overweight, 26.3% were obese, and 8.8% had class III obesity, indicating that more than half of the patients (51.8%) had excess body weight or obesity.

The prevalence of cigarette smoking was higher among patients who experienced CA than among those without CA (44.7% vs. 35.2%), although this difference did not reach statistical significance ($p = 0.147$). Similarly, alcohol consumption did not differ significantly between the groups (17.5% vs. 16.7%, $p = 0.884$).

The prevalence of comorbidities differed significantly between the CA and non-CA groups ($p < 0.001$). Compared with the non-CA group, patients in the CA group more frequently had hypertension (83.3%), valvular heart disease (23.7%), cardiac arrhythmias (42.1%), and congestive heart failure (30.7%) (all $p < 0.001$). Previous myocardial infarction (17.5%) and cerebrovascular disease (15.8%) were also more common in the CA group (both $p = 0.010$), as were bronchial asthma (13.2%, $p = 0.012$), acute kidney injury (12.3%, $p = 0.008$), hyperlipidemia (42.1%, $p = 0.011$), and malignancy (3.5%, $p = 0.049$).

Table 1. Baseline characteristics of critically ill patients with COVID-19 according to the occurrence of CA in the ICU.

Variable	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
Sex			
Male, <i>n</i> (%)	56 (51.9)	63 (55.3)	0.610
Female, <i>n</i> (%)	52 (48.1)	51 (44.7)	
Age	57.3 ± 8.9	70.3 ± 9.8	<0.001
Obesity (overall), <i>n</i> (%)	28 (25.9)	59 (51.8)	<i>p</i> < 0.001
Body mass index (BMI) category, <i>n</i> (%)			
Underweight (<18.5)	0 (0.0)	3 (2.6)	<0.001
Normal weight (18.5–24.9)	80 (74.1)	52 (45.6)	
Overweight (25–29.9)	16 (14.8)	19 (16.7)	
Obesity (≥30)	12 (11.1)	30 (26.3)	
Class III obesity (≥40)	0 (0.0)	10 (8.8)	
Smoking, <i>n</i> (%)	38 (35.2)	51 (44.7)	0.147
Alcohol use, <i>n</i> (%)	18 (16.7)	20 (17.5)	0.884
Comorbidities, <i>n</i> (%)	59 (54.6)	107 (93.9)	<0.001
Hypertension, <i>n</i> (%)	41 (38.0)	95 (83.3)	<0.001
Valvular heart disease, <i>n</i> (%)	5 (4.6)	27 (23.7)	<0.001
Cardiac arrhythmia, <i>n</i> (%)	19 (17.6)	48 (42.1)	<0.001
Previous myocardial infarction, <i>n</i> (%)	4 (3.7)	20 (17.5)	0.001
Congestive heart failure, <i>n</i> (%)	3 (2.8)	35 (30.7)	<0.001
Cerebrovascular diseases, <i>n</i> (%)	3 (2.8)	18 (15.8)	0.001
Varicose veins, <i>n</i> (%)	12 (11.1)	21 (18.4)	0.126
COPD, <i>n</i> (%)	8 (7.4)	18 (15.8)	0.052
Bronchial asthma, <i>n</i> (%)	4 (3.7)	15 (13.2)	0.012
AKI, <i>n</i> (%)	3 (2.8)	14 (12.3)	0.008
Liver diseases, <i>n</i> (%)	1 (0.9)	3 (2.6)	0.340
Hyperlipidemia, <i>n</i> (%)	28 (25.9)	48 (42.1)	0.011
Diabetes mellitus, <i>n</i> (%)	26 (24.1)	41 (36.0)	0.054
Malignancy, <i>n</i> (%)	0 (0.0)	4 (3.5)	0.049
Immunosuppressive diseases, <i>n</i> (%)	2 (1.9)	2 (1.8)	0.956

Abbreviations: CA—cardiac arrest; ICU—intensive care unit; BMI—body mass index; AKI—acute kidney injury; COPD—chronic obstructive pulmonary disease. Data are presented as mean ± standard deviation or number (%). Bold indicates statistical significance (*p* < 0.05).

The frequency of complications in critically ill patients during treatment for COVID-19 infection in the ICU, according to the occurrence of CA, is presented in Table 2. Complications that were statistically significant in the CA group included respiratory complications, namely respiratory failure (99.1%), severe pneumonia (93.0%), and severe ARDS (87.7%), AKI (63.2%), ALF (23.7%), disseminated intravascular coagulation (DIC) (17.5%), for all *p* < 0.001, as well as hypotension (50%); *p* = 0.003, despite the use of inotropic agents in these patients (44.7%), and PE (5.3%); *p* = 0.016.

Patients in the CA group exhibited significantly lower erythrocyte counts (*p* < 0.001), hemoglobin levels (*p* < 0.001), and thrombocytopenia (*U* = 4554.0; *p* = 0.001) compared with the non-CA group. Patients who developed CA demonstrated a more pronounced inflammatory response, reflected in significantly higher levels of leukocytes (*p* < 0.001), fibrinogen (*p* < 0.001), CRP (*p* = 0.008), and procalcitonin (*p* < 0.001). In addition, these patients had significantly higher lactate levels (*p* < 0.001) as well as D-dimer levels (*p* < 0.001). Furthermore, hyperkalemia (28.9% vs. 5.6%) and hypernatremia (22.8% vs. 10.2%) were also more frequent in the CA group (*p* < 0.05 for both abnormalities) (Table 3).

Table 2. Frequency of complications in patients with COVID-19 treated in the ICU according to the occurrence of CA.

Variables	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
Respiratory failure, <i>n</i> (%)	59 (54.6)	113 (99.1)	<0.001
Pneumonia, <i>n</i> (%)	106 (98.1)	114 (100.0)	0.144
Severe pneumonia, <i>n</i> (%)	79 (73.1)	106 (93.0)	<0.001
ARDS, <i>n</i> (%)			
Yes, mild, <i>n</i> (%)	12 (11.1)	2 (1.8)	<0.001
Yes, moderate, <i>n</i> (%)	37 (34.3)	11 (9.6)	
Yes, severe, <i>n</i> (%)	46 (42.6)	100 (87.7)	
No, <i>n</i> (%)	13 (12.0)	1 (0.9)	
Hypotension, <i>n</i> (%)	33 (30.6)	57 (50.0)	0.003
Septic shock, MODS, <i>n</i> (%)	34 (31.5)	44 (38.6)	0.267
AKI, <i>n</i> (%)	7 (6.5)	72 (63.2)	<0.001
ALF, <i>n</i> (%)	0 (0.0)	27 (23.7)	<0.001
Coagulation disorder, <i>n</i> (%)	39 (36.1)	40 (35.1)	0.874
PE, <i>n</i> (%)	0 (0.0)	6 (5.3)	0.016
DIC, <i>n</i> (%)	0 (0.0)	20 (17.5)	<0.001

Abbreviations: ARDS—acute respiratory distress syndrome; AKI—acute kidney injury; ALF—acute liver failure; MODS—multiple organ dysfunction syndrome; PE—pulmonary embolism; DIC—disseminated intravascular coagulation; CA—cardiac arrest. Data are presented as numbers (%). Bold indicates statistical significance ($p < 0.05$).

Table 3. Laboratory parameters in critically ill patients with COVID-19 treated in the ICU according to the occurrence of CA.

Laboratory Parameters	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
Hematological parameters			
Leukocytes, 10^9 /L	12.1 (11.0–14.1)	15.0 (11.2–21.3)	<0.001
Erythrocytes, 10^{12} /L	4.3 (4.2–4.5)	3.9 (3.3–4.4)	<0.001
Hemoglobin, g/L	123.0 (114.2–133.8)	113.2 (96.4–127.2)	<0.001
Platelets, 10^9 /L	222.3 (165.2–292.0)	180.0 (131.2–246.3)	0.001
Hematocrit, %	34.0 (32.0–35.0)	34.0 (29.8–37.9)	0.285
Electrolyte parameters			
Potassium, mmol/L	4.2 (3.4–4.5)	4.0 (3.2–5.0)	0.937
Inflammatory and coagulation markers			
Fibrinogen, g/L	3.9 (3.5–4.5)	5.0 (4.0–6.0)	<0.001
CRP, mg/L	56.0 (34.1–89.7)	89.4 (29.9–155.9)	0.008
Lactate, mmol/L	1.4 (0.8–2.0)	2.0 (1.1–3.2)	<0.001
Procalcitonin, ng/mL	0.1 (0.04–0.09)	0.2 (0.03–1.2)	<0.001
D-dimer, ng/mL	365.0 (230.0–600.0)	990.0 (501.5–1699.0)	<0.001
Liver function parameters			
AST, U/L	47.0 (31.0–65.0)	41.5 (24.0–91.0)	0.700
ALT, U/L	53.0 (41.0–62.8)	35.0 (22.0–55.2)	<0.001
Direct bilirubin, μ mol/L	3.6 (2.4–4.8)	3.2 (2.0–5.2)	0.256
Total bilirubin, μ mol/L	12.0 (6.6–14.0)	11.1 (6.8–17.8)	0.394

Data are presented as median (interquartile range). Bold indicates statistical significance ($p < 0.05$). Abbreviations: CRP—C-reactive protein; AST—aspartate aminotransferase; ALT—alanine aminotransferase; CA—cardiac arrest.

The partial pressure of oxygen in arterial blood (PaO_2) was significantly lower in the CA group (43.0–62.0 mmHg) compared with the non-CA group (59.2–79.0 mmHg; $p < 0.001$), indicating a more severe degree of respiratory failure. In the same group, significantly lower pH values (7.1–7.5 vs. 7.4–7.5; $p < 0.001$) and lower bicarbonate (HCO_3^-) concentrations (16.2–24.7 mmol/L vs. 23.0–27.3 mmol/L; $p < 0.001$) were also observed, suggesting the presence of significant metabolic acidosis (Table 4).

Table 4. ABG parameters in patients with COVID-19 treated in the ICU according to the occurrence of CA.

Parameters	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
PaO ₂ , mmHg	70.0 (59.2–79.0)	50.0 (43.0–62.0)	<0.001
PaCO ₂ , mmHg	38.0 (33.0–40.0)	40.0 (30.0–50.0)	0.127
pH	7.4 (7.4–7.5)	7.3 (7.1–7.5)	<0.001
HCO ₃ [−] , mmol/L	24.5 (23.0–27.3)	19.8 (16.2–24.7)	<0.001
SaO ₂ , %	80.0 (76.0–85.0)	80.0 (72.0–89.0)	0.689
PaO ₂ /FiO ₂ ratio	200.0 (160.0–245.2)	53.0 (44.8–67.0)	<0.001

Data are presented as median (interquartile range). Bold indicates statistical significance ($p < 0.05$). Abbreviations: PaO₂—partial pressure of oxygen; PaCO₂—partial pressure of carbon dioxide; HCO₃[−]—bicarbonate; SaO₂—arterial oxygen saturation; PaO₂/FiO₂—arterial oxygen partial pressure to fractional inspired oxygen ratio; CA—cardiac arrest.

Differences in arterial partial pressure of carbon dioxide (PaCO₂) and hemoglobin oxygen saturation (SaO₂) between the groups did not reach statistical significance ($p = 0.127$ and $p = 0.689$, respectively).

In addition, the PaO₂/FiO₂ ratio in the CA group indicated severe hypoxemia, with a median of only 53 (IQR 44.8–67.0), compared with the non-CA group (median 200, IQR 160–245.2). This finding further supports the significant role of respiratory failure as a key factor in the pathophysiology of CA in patients with COVID-19 ($p < 0.001$).

Conventional oxygen therapy (without MV), including the use of a nasal cannula and conventional O₂ face mask, was more commonly used in the non-CA group (83.3%; $p = 0.010$). Non-invasive respiratory support in the form of high-flow nasal oxygen therapy (HFNO) was applied in a high proportion of patients in both groups (96.5% in the CA group and 97.2% in the non-CA group), with no statistically significant difference in its use between groups ($p = 0.755$). However, FiO₂ values during HFNO therapy were higher in the CA group ($p < 0.001$), indicating a more severe degree of respiratory failure in these patients.

IMV was substantially more frequent in the CA group. IMV support was used in 67.5% of patients in the CA group compared with 9.3% in the non-CA group, representing a highly statistically significant difference ($p < 0.001$) (Table 5). This finding most likely reflects greater disease severity and advanced respiratory failure among patients who developed cardiac arrest.

Norepinephrine was administered in both groups (35.1% in the CA group vs. 24.1% in the non-CA group), whereas epinephrine (alone or in combination with norepinephrine) was more commonly used in the CA group (6.1% vs. 2.9%; $p = 0.037$). Amiodarone use in the pre-arrest period was more frequent in the CA group compared with the non-CA group (62.3% vs. 33.3%; $p < 0.001$). This finding may reflect greater disease severity and arrhythmic burden among patients who experienced CA. Diuretic therapy was also more common in the CA group compared with the non-CA group (65.8% vs. 52.8%; $p = 0.048$). Renal replacement therapy (RRT) was more frequently administered in the CA group (11.4% vs. 4.6%), although this difference did not reach statistical significance ($p = 0.065$) (Table 6).

Table 5. Respiratory support in ICU patients with COVID-19 according to the occurrence of CA.

Respiratory Support	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
Conventional oxygen therapy (no MV)			
Spontaneous breathing, <i>n</i> (%)	2 (1.9)	0 (0.0)	
Oxygen mask, <i>n</i> (%)	12 (11.1)	19 (16.7)	
Nasal cannula, <i>n</i> (%)	4 (3.7)	15 (13.2)	
Nasal cannula + mask, <i>n</i> (%)	90 (83.3)	78 (68.4)	
Non-invasive respiratory support			
HFNO, <i>n</i> (%)	105 (97.2)	110 (96.5)	0.755
HFNO flow, L/min	60.0 (50.0–60.0)	60.0 (60.0–60.0)	0.335
HFNO FiO ₂ , %	95.0 (90.0–100.0)	100.0 (98.75–100.0)	0.001
Non-invasive ventilation (NIV) via oronasal mask			
NIV flow, L/min	50.0 (40.0–60.0)	40.0 (0.0–60.0)	0.038
NIV FiO ₂ , %	90.0 (80.0–100.0)	85.0 (0.0–100.0)	0.129
NIV PEEP, cmH ₂ O	6.0 (5.5–7.0)	5.0 (0.0–8.0)	0.004
Invasive mechanical ventilation (IMV)			
Invasive mechanical ventilation, <i>n</i> (%)	10 (9.3)	77 (67.5)	<0.001

Data are presented as median (interquartile range) or number (%). Bold indicates statistical significance ($p < 0.05$). Abbreviations: HFNO—high-flow nasal oxygen; NIV—non-invasive ventilation; PEEP—positive end-expiratory pressure; IMV—invasive mechanical ventilation; CA—cardiac arrest.

Table 6. Frequency of administered pharmacological therapy in patients with COVID-19 treated in the ICU according to the occurrence of CA.

Medications	Non-CA Group (n = 108)	CA Group (n = 114)	<i>p</i>
Amiodarone	36 (33.3)	71 (62.3)	<0.001
Norepinephrine	26 (24.1)	40 (35.1)	0.073
Epinephrine	1 (2.9)	7 (6.1)	0.037
Dobutamine	13 (12.0)	8 (7.0)	0.201
Diuretic therapy	57 (52.8)	75 (65.8)	0.048

Data are presented as numbers (%). Bold indicates statistical significance ($p < 0.05$).

The final multivariable logistic regression model included 8 predictors and was statistically significant ($p < 0.001$). Older age ($B = 0.15$; $p = 0.001$), higher fibrinogen levels ($B = 1.38$; $p < 0.001$), higher lactate levels ($B = 0.94$; $p = 0.034$), higher D-dimer levels ($B = 0.002$; $p = 0.009$), lower PaO₂ values ($B = -0.09$; $p < 0.001$), and the use of IMV ($B = 3.49$; $p < 0.001$) were independently associated with the occurrence of cardiac arrest (Table 7).

Respiratory failure was present in the vast majority of patients and represented the leading underlying mechanism of IHCA and also represented the most common cause of CA (59.6%). Other causes of CA were less frequent and included DIC (10.5%), sepsis with MODS (8.8%), myocardial infarction and AKI (6.1%), primary arrhythmias (4.4%), as well as PE (2.6%).

Analysis of the initial cardiac rhythm showed that non-shockable rhythms predominated, occurring in 76.3% of patients, with asystole being the most common (70.0%). Shockable rhythms were less frequent (23.7%), among which VF was more prevalent (74.1%). The no-flow time, defined as the interval from the onset of CA to the initiation of CPR, was relatively short, with a median of 16.5 s (IQR 10.0–32.5).

CPR was performed in all patients who experienced CA ($n = 114$; 51.4%). In the majority of cases, resuscitation was performed by the hospital resuscitation team (90.4%), while it was less frequently initiated by ward physicians (7.9%) and nurses (1.8%), after which it was taken over by the resuscitation team. Defibrillation was performed in 23.7% of patients, consistent with the frequency of shockable rhythms.

Table 7. Sequential multivariable logistic regression analysis of factors associated with cardiac arrest. The left columns present the domain-specific multivariable models (Clinical and Laboratory models), whereas the right columns present the final combined multivariable model.

Independent Variables	Parameters					
	B	p	OR (95%CI)	B	p	OR (95%CI)
Multivariable Clinical Model						
Age	0.10	<0.001	1.11 (1.05–1.16)	0.15	0.001	1.17 (1.06–1.28)
Obesity	0.89	0.054	2.44 (0.99–6.03)			
Hypertension	0.82	0.095	2.27 (0.87–5.95)			
Valvular heart disease	0.84	0.246	2.30 (0.56–9.43)			
Cardiac arrhythmia	0.06	0.907	1.06 (0.37–3.03)			
Congestive heart failure	0.36	0.657	1.43 (0.30–6.85)			
ARDS						
Yes, mild		Reference category				
Yes, moderate	−0.15	0.896	0.86 (0.09–8.13)			
Yes, severe	1.60	0.129	4.94 (0.63–38.92)			
No	−1.72	0.376	0.18 (0.004–8.06)			
AKI	2.38	<0.001	10.82 (3.58–32.68)	0.60	0.543	1.81 (0.27–12.39)
Multivariable Laboratory Model						
Leukocytes	0.10	0.089	1.11 (0.98–1.25)			
Hemoglobin	−0.04	0.021	0.96 (0.93–0.99)	−0.04	0.054	0.96 (0.92–1.00)
Fibrinogen	1.53	<0.001	4.64 (2.40–8.98)	1.38	<0.001	3.96 (1.94–8.08)
ALT	−0.01	0.103	1.00 (0.99–1.00)			
Lactate	0.93	0.003	2.53 (1.36–4.68)	0.94	0.034	2.55 (1.07–6.06)
Procalcitonin	0.19	0.287	1.21 (0.86–1.70)			
D-dimer	0.002	0.001	1.002 (1.001–1.003)	0.002	0.009	1.002 (1.001–1.003)
PaO ₂	−0.06	<0.001	0.94 (0.91–0.97)	−0.09	<0.001	0.91 (0.88–0.95)
pH	−2.93	0.280	0.05 (0.00–10.89)			
HCO ₃ [−]	−0.02	0.724	0.98 (0.89–1.08)			
Invasive mechanical ventilation	3.37	<0.001	29.10 (6.66–127.10)	3.49	<0.001	32.70 (5.62–190.19)

Bolded—statistically significant predictor ($p < 0.05$), B—beta coefficient, OR—odds ratio, CI—confidence interval. Abbreviations: ARDS—acute respiratory distress syndrome; AKI—acute kidney injury; ALT—alanine aminotransferase; PaO₂—partial pressure of oxygen; HCO₃[−]—bicarbonate. The left columns present the domain-specific multivariable models (Clinical and Laboratory models), whereas the right columns present the final combined multivariable logistic regression model including predictors retained from the domain-specific analyses.

Regarding airway management, the majority of patients were already endotracheally intubated at the time of CA (16.7%), reflecting the severity of their clinical condition and the prior need for invasive respiratory support. In 65.8% of patients, tracheal intubation was performed during CPR, while in 1.8% of patients, CPR was conducted using bag-valve-mask (BVM) ventilation. Accordingly, MV during CPR was applied in the majority of patients (71.1%), whereas BVM ventilation was used in 28.9% of patients, most commonly in the initial phase of resuscitation.

During CPR, in addition to epinephrine administration, amiodarone was administered in 28.1% of patients, primarily in cases of shockable rhythms. Lidocaine was used rarely (1.8%). The median total dose of epinephrine was 5.0 mg (IQR 4.0–7.0), and the median duration of CPR was 28 min (IQR 20–40). Among the 114 patients with IHCA, ROSC was achieved in 11 patients (9.6%), and 3 patients (2.6%) survived to hospital discharge. In two patients, the cause of CA was myocardial infarction, while in one patient, PE was identified as the underlying etiology (Table 8).

Table 8. Characteristics of CA and CPR in patients with COVID-19 in the ICU.

IHCA Characteristics	CA Group (n = 114)
Primary cause of IHCA	
Respiratory failure, <i>n</i> (%)	68 (59.6)
Sepsis, MODS, <i>n</i> (%)	10 (8.8)
Myocardial infarction, <i>n</i> (%)	7 (6.1)
Primary arrhythmia, <i>n</i> (%)	5 (4.4)
PE, <i>n</i> (%)	3 (2.6)
AKI, <i>n</i> (%)	7 (6.1)
DIC, <i>n</i> (%)	12 (10.5)
Other, <i>n</i> (%)	2 (1.8)
Initial cardiac rhythm in CA	
Shockable, <i>n</i> (%)	27 (23.7)
Non-shockable, <i>n</i> (%)	87 (76.3)
Shockable rhythm	
VF, <i>n</i> (%)	20/27 (74.1)
pVT, <i>n</i> (%)	7/27 (25.9)
Non-shockable rhythm	
Asystole, <i>n</i> (%)	60/87 (70.0)
PEA, <i>n</i> (%)	27/87 (30.0)
No-flow time (sec)	16.5 (10.0–32.5)
Resuscitation initiated by	
Ward nurse, <i>n</i> (%)	2 (1.8)
Ward physician, <i>n</i> (%)	9 (7.9)
Hospital resuscitation team, <i>n</i> (%)	103 (90.4)
Resuscitation performed until outcome	
Ward physician, <i>n</i> (%)	1 (0.9)
Hospital resuscitation team, <i>n</i> (%)	113 (99.1)
Pre-arrest airway status	
Unsecured airway, <i>n</i> (%)	2 (1.8)
Endotracheal intubation performed during CPR, <i>n</i> (%)	75 (65.8)
Endotracheally intubated in the pre-arrest period, <i>n</i> (%)	37 (16.7)
CPR measures	
BVM ventilation, <i>n</i> (%)	33 (28.9)
MV, <i>n</i> (%)	81 (71.1)
Chest compressions, <i>n</i> (%)	114 (100.0)
Defibrillation, <i>n</i> (%)	27 (23.7)
Drugs in CPR	
Epinephrine, <i>n</i> (%)	114 (100.0)
Lidocaine, <i>n</i> (%)	2 (1.8)
Amiodarone, <i>n</i> (%)	32 (28.1)
Total epinephrine dose, mg	5.0 (4.0–7.0)
Total duration of CPR, min	28.0 (20.0–40.0)
ROSC achieved, <i>n</i> (%)	11 (9.6)
30-day survival, <i>n</i> (%)	3 (2.6)

Data are presented as numbers (%) or medians (interquartile range). Percentages were calculated using the 114 patients with IHCA as the denominator. Abbreviations: CA—cardiac arrest; VF—ventricular fibrillation; pVT—pulseless ventricular tachycardia; PEA—pulseless electrical activity; PE—pulmonary embolism; AKI—acute kidney injury; DIC—disseminated intravascular coagulation; MODS—multiple organ dysfunction syndrome; CPR—cardiopulmonary resuscitation; BVM—bag-valve-mask; ROSC—return of spontaneous circulation.

4. Discussion

We investigated the occurrence, characteristics, outcomes, and associated factors of ICU CA in critically ill patients with COVID-19. During the COVID-19 pandemic, an increase in the incidence of IHCA was observed compared with the pre-pandemic period [14,22–25]. In our study, the incidence of IHCA among critically ill patients with

COVID-19 was 51.4%. The high incidence of IHCA observed in our cohort may be explained by the fact that our ICU predominantly treated critically ill patients with advanced COVID-19, severe hypoxemia, ARDS, and hemodynamic instability. In addition, our institution served as a referral center for critically ill patients with COVID-19 from the surrounding region. During the pandemic, ICU capacity was limited, and admission was prioritized for patients requiring advanced organ support because of severe respiratory failure, ARDS, or multiorgan dysfunction. Consequently, our cohort does not represent the general population of hospitalized patients with COVID-19 but rather a highly selected group of the most severely ill patients, which should be considered when comparing our findings with previous studies. Patients with mild or moderate disease were managed in dedicated COVID-19 wards, whereas only patients with severe or critical COVID-19 were admitted to the ICU. Delayed hospital presentation and the considerable burden placed on the healthcare system may have further contributed to the severity of illness and the high incidence of IHCA observed in our cohort. Reported IHCA incidence varies considerably across studies, ranging from 8.0% to 15.4% in most cohorts [2,3]. Refs. [7,14], although substantially higher rates have also been reported in populations with more severe disease, such as the 45.5% incidence reported in a Sri Lankan ICU cohort [26]. These differences should be interpreted in the context of variations in ICU admission criteria, healthcare organization, patient selection, and pandemic burden across healthcare systems.

In our study, no significant difference in sex distribution was observed between patients with and without IHCA. This finding differs from most previous studies, which reported a predominance of male patients among critically ill individuals with COVID-19 who experienced IHCA [7,13,26–29]. Male sex has consistently been associated with more severe COVID-19 and poorer outcomes, potentially because of a combination of biological factors, including differences in immune and hormonal responses, as well as a higher prevalence of cardiovascular risk factors and unhealthy behaviors such as smoking [1,5,16,26–28,30–33]. The absence of a significant sex difference in our cohort may reflect the uniformly high severity of illness among ICU patients, where the impact of sex may have been outweighed by advanced respiratory failure and multiorgan dysfunction.

Older age was strongly associated with IHCA, consistent with previous studies identifying advanced age as one of the strongest predictors of severe COVID-19 and poor clinical outcomes [13,26,34]. Age-related immune dysregulation, frailty, and the higher burden of chronic comorbidities likely contribute to this increased vulnerability.

Obesity was significantly more prevalent among patients who experienced IHCA, suggesting that increased BMI may contribute to a more severe clinical course in critically ill patients with COVID-19. This finding is consistent with previous studies demonstrating that obesity is associated with increased in-hospital mortality, a higher risk of CA, and poorer clinical outcomes [28,29,35–38]. The adverse impact of obesity is likely mediated by impaired respiratory mechanics, chronic low-grade inflammation, endothelial dysfunction, and the high prevalence of associated cardiometabolic comorbidities.

Smoking and alcohol consumption were not significantly associated with IHCA in our cohort, although previous studies have linked both factors with more severe COVID-19 and poorer outcomes [39–42].

Patients who experienced IHCA had a substantially higher burden of comorbidities, with more than 90% having at least one underlying disease. Cardiovascular comorbidities, particularly hypertension, cardiac arrhythmias, heart failure, valvular heart disease, and previous myocardial infarction, predominated in the IHCA group, underscoring the importance of pre-existing cardiovascular disease as a determinant of poor outcomes in critically ill patients with COVID-19 [11,13,36,43]. Respiratory disease, chronic kidney disease, hyperlipidemia, and malignancy were also more common among patients with IHCA,

suggesting that multiple chronic conditions may increase vulnerability to cardiorespiratory deterioration during severe COVID-19. These findings are consistent with previous studies demonstrating that a high comorbidity burden is associated with an increased risk of ICU admission, CA, and mortality [44–46].

Patients who experienced IHCA had a substantially higher incidence of organ dysfunction and complications, reflecting a more severe clinical course and progression to multiorgan dysfunction syndrome. Respiratory complications, including respiratory failure, severe pneumonia, and ARDS, predominated in the IHCA group, emphasizing the central role of advanced respiratory dysfunction in the development of CA [47,48]. Hemodynamic instability was also more pronounced, as reflected by the higher incidence of hypotension despite more frequent use of vasoactive agents [11,44]. In addition, AKI, ALF, DIC, and PE were more common among patients with IHCA, supporting the concept that CA in severe COVID-19 is often preceded by progressive multiorgan dysfunction and COVID-19-associated coagulopathy [44,49–52]. Although ALF was more frequent in the IHCA group, ALT values were paradoxically lower. This discrepancy may reflect the timing of laboratory measurements, heterogeneous patterns of hepatic injury, and the fact that the diagnosis of ALF was based on the overall clinical assessment rather than ALT elevation alone.

Patients who experienced IHCA exhibited laboratory evidence of more advanced systemic illness, including anemia, thrombocytopenia, a more pronounced inflammatory response, and biochemical markers of tissue hypoperfusion and coagulopathy. Lower hemoglobin and platelet counts have previously been associated with poor outcomes in COVID-19, whereas elevated inflammatory markers reflect greater disease severity and systemic inflammation [11,45,53–57]. In addition, higher lactate and D-dimer levels in the IHCA group indicate impaired tissue perfusion and activation of coagulation pathways, both of which are well-established predictors of multiorgan dysfunction and mortality in critically ill patients with COVID-19 [58–62].

ABG analysis demonstrated more severe hypoxemia and metabolic acidosis in patients who experienced IHCA, as reflected by lower PaO₂, pH, bicarbonate, and PaO₂/FiO₂ values. These findings emphasize the central role of advanced respiratory failure in the pathophysiology of CA in critically ill patients with COVID-19. Severe hypoxemia and acid-base disturbances may impair myocardial oxygen delivery and electrical stability, thereby increasing the risk of CA, and have consistently been associated with poor outcomes following in-hospital resuscitation [5,12,14,63]. In addition, hyperkalemia and hypernatremia were more common in the IHCA group, supporting the contribution of electrolyte disturbances to cardiac electrical instability and adverse outcomes [64].

The observed differences in respiratory support reflect substantial differences in disease severity between the two groups. Patients who experienced IHCA required more intensive respiratory support, as evidenced by higher FiO₂ requirements during HFNO and, most notably, a markedly higher use of IMV. These findings indicate that progressive respiratory failure was the principal driver of clinical deterioration preceding CA. In contrast, patients without IHCA were more frequently managed with conventional oxygen therapy and non-invasive respiratory support, suggesting less severe respiratory compromise. Our findings are consistent with previous studies showing that increasing oxygen requirements and IMV are strong indicators of disease progression and are associated with a higher risk of IHCA and poor outcomes in critically ill patients with COVID-19 [11,48,65–69].

Differences in pharmacological management between the two groups also reflected greater disease severity among patients who experienced IHCA. Although norepinephrine was used with similar frequency in both groups, indicating that hemodynamic instability was common in critically ill patients with COVID-19, the more frequent use of epinephrine in the IHCA group suggests refractory shock and advanced circulatory failure requiring

escalation of vasopressor support [70–72]. Likewise, amiodarone was administered more often before CA, most likely reflecting a greater burden of severe arrhythmias and cardiovascular instability rather than a causal association with IHCA [73]. Overall, these findings indicate that the intensity of pharmacological support primarily reflects progression of multiorgan dysfunction and hemodynamic deterioration preceding CA.

Diuretic therapy was more frequently used in the IHCA group, likely reflecting greater cardiorenal dysfunction, volume overload, and progression of multiorgan dysfunction. This finding is consistent with previous reports showing that patients who develop IHCA commonly require escalating organ support, including MV, vasopressors, and renal replacement therapy, before CA [13,74,75]. Together, these findings support the concept that IHCA in critically ill patients with COVID-19 most often represents the terminal manifestation of progressive multiorgan failure rather than an isolated event.

Respiratory failure was the leading cause of IHCA in our cohort, accounting for 59.6% of cases, emphasizing the central role of progressive hypoxemia and severe pulmonary dysfunction in the pathogenesis of CA among critically ill patients with COVID-19. This finding is consistent with previous studies identifying hypoxemia as the most common clinical deterioration preceding IHCA and respiratory failure as the predominant mechanism of CA in this population [8,75–78].

Non-shockable rhythms, PEA, predominated in our cohort, supporting the concept that COVID-19-related IHCA is primarily driven by progressive hypoxemia rather than primary cardiac events. Because these rhythms are associated with substantially lower rates of successful resuscitation, their predominance likely contributed to the poor outcomes observed in our study. This finding is consistent with previous reports demonstrating that respiratory causes account for most IHCA events in patients with COVID-19 and are typically associated with non-shockable rhythms [79,80].

In our setting, DNACPR has not yet been incorporated into healthcare regulations; therefore, CPR was attempted in all patients who experienced IHCA. The extremely low rates of ROSC (5.0%) and survival to hospital discharge (2.6%) observed in our cohort highlight important ethical considerations regarding the potential benefit of prolonged resuscitation in patients with advanced multiorgan failure and limited reversibility of the underlying disease. Nevertheless, decisions regarding CPR should remain individualized and based on the patient's clinical condition, prognosis, comorbidities, ethical principles, and available healthcare resources. Similar ethical challenges have been recognized during the COVID-19 pandemic, leading some institutions to introduce DNACPR policies or recommendations against initiating CPR when resuscitation was considered medically futile [81–83].

Despite rapid recognition of CA, prompt initiation of CPR by the hospital resuscitation team, and short no-flow times, outcomes remained extremely poor. Most patients were already receiving IMV at the time of IHCA, reflecting advanced disease severity, a finding consistent with previous reports [13,21]. The predominance of non-shockable rhythms and respiratory causes of CA likely explains the limited success of resuscitation despite prolonged CPR efforts.

Among the three patients who survived to hospital discharge, CA resulted from acute myocardial infarction in two patients and PE in one, suggesting that outcomes were more favorable when IHCA was caused by potentially reversible conditions rather than progressive respiratory failure. In contrast, hypoxia-related CA usually occurred in the setting of advanced multiorgan dysfunction, where the underlying disease was largely irreversible and the likelihood of successful resuscitation was extremely low. Accordingly, the very low ROSC (9.6%) and survival to hospital discharge (2.6%) observed in our cohort are consistent with previous studies reporting poor outcomes after COVID-19-related

IHCA, despite occasional variability in reported survival rates [7,10–14,22,80,81,84,85]. In addition to the severity of illness, organizational challenges during peak pandemic periods, including the use of personal protective equipment, high ICU workload, limited resources, and the complexity of airway management, may also have adversely affected resuscitation outcomes.

Overall, our findings are consistent with previous reports demonstrating that COVID-19-related IHCA is characterized by progressive respiratory failure, predominance of non-shockable rhythms, low rates of ROSC, and extremely poor survival. Beyond confirming these observations, our study provides a comprehensive evaluation of demographic characteristics, comorbidities, laboratory and ABG abnormalities, respiratory support, resuscitation characteristics, and independent factors associated with IHCA in a homogeneous cohort of critically ill ICU patients. In addition, it provides data from a Southeast European tertiary care center, a region that remains underrepresented in the current literature, thereby improving the generalizability of existing evidence across different healthcare settings. These findings may facilitate earlier identification of critically ill patients at high risk of IHCA and support timely optimization of intensive care management, potentially improving preventive strategies and clinical decision-making.

Limitations

This study has several limitations. First, its retrospective single-center design may limit the generalizability of the findings to other healthcare settings and patient populations. In addition, the study was conducted over different phases of the COVID-19 pandemic, during which viral variants, treatment protocols, ICU admission criteria, and healthcare resource availability evolved, potentially influencing patient characteristics and outcomes.

Second, laboratory and ABG parameters were not collected at identical time points in the two study groups. In patients with IHCA, the last available measurements obtained within 24 h before cardiac arrest were analyzed, whereas laboratory and ABG parameters obtained during the period of greatest clinical severity during the ICU stay were used for patients without IHCA. Because of the retrospective study design and the lack of standardized serial measurements at predefined time points, temporal changes in these parameters could not be assessed and may have influenced the observed associations.

Finally, although the regression strategy was specifically designed to minimize the risk of overfitting by using domain-specific multivariable models followed by a final combined model, the relatively limited sample size inherent to this single-center study may still have affected the precision and stability of some estimated associations. Therefore, the identified predictors should be interpreted with appropriate caution and validated in larger multicenter prospective studies. Furthermore, comprehensive illness severity scores, such as APACHE II and SOFA, were not included in the final multivariable models because of incomplete availability of the variables required for consistent score calculation across all patients. In addition, because multiple statistical comparisons were performed without formal adjustment for multiple testing, the findings should be considered exploratory and interpreted as hypothesis-generating until confirmed in larger prospective cohorts.

5. Conclusions

IHCA in critically ill patients with COVID-19 was characterized by a high incidence, predominance of respiratory failure as the underlying cause, frequent non-shockable initial rhythms, and extremely poor survival outcomes. Older age, elevated fibrinogen, lactate, and D-dimer levels, lower PaO₂ values, and the need for IMV were independently associated with the occurrence of IHCA. Despite rapid recognition and timely initiation of

CPR in the ICU setting, ROSC and survival rates remained very low, reflecting the severity of respiratory failure and multiorgan dysfunction in this population.

Our findings are consistent with previous reports indicating that COVID-19-related IHCA represents a manifestation of advanced critical illness rather than an isolated cardiac event. More favorable outcomes were observed in the small number of patients whose CA resulted from potentially reversible causes, such as myocardial infarction and PE. These findings provide additional evidence regarding the clinical characteristics, associated factors, and outcomes of IHCA in critically ill patients with COVID-19 and contribute data from a Southeast European tertiary care center.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

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