Retrospective Study to Identify Risk Factors for Severe Disease and Mortality Using the Modified Early Warning Score in 5127 Patients with COVID-19 Admitted to an Emergency Department in Poland Between March 2020 and April 2021

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Background: COVID-19, a disease caused by SARS-CoV-2, has posed a threat to global public health. This retrospective study of 5127 patients with COVID-19 admitted to an Emergency Department in Poland between March 2020 and April 2021 aimed to identify risk factors for severe disease and mortality using the modified early warning score (MEWS).

Material/Methods: The study was based on a retrospective analysis of patients with SARS-CoV-2 infection admitted to the Emergency Department between March 2020 and April 2021. A total of 5127 cases were included in the final analysis. Identifying the group of high-risk patients with COVID-19 was determined based on the MEWS score.

Results: Most of the patients studied were male (53.38%). The in-hospital mortality rate among the patients was 21.53%. The factors associated with the risk of in-hospital mortality from COVID-19 were age (>60 years, hazard ratio [HR]=2.27, \( P < 0.001 \)), comorbidities (cancer, HR=1.39, \( P = 0.005 \); heart failure, HR=1.31, \( P = 0.009 \); renal failure, HR=1.37, \( P = 0.004 \)), higher MEWS score (MEWS \( \geq 5 \), HR=1.43, \( P < 0.001 \)), higher percentage of lung parenchyma affected (\( > 50\% \), HR=2.10, \( P = 0.001 \)), and higher respiratory rate (>24 breaths per min, HR=2.10, \( P < 0.001 \)).

Conclusions: This study produced real-world data of risk factors for mortality from COVID-19 and the use of the MEWS for a faster identification of patients with COVID-19 requiring more intensive medical care.

Keywords: COVID-19 • Critical Care Outcomes • Risk Factors • SARS-CoV-2 • Hospital Mortality

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Background

The global emergence of a new pathogen SARS-CoV-2, which in humans causes COVID-19, has presented a major problem and challenge for public health and health systems worldwide [1-3]. Since the coronavirus outbreak was identified as a pandemic by the World Health Organization on March 11, 2020, more than 539 million people have been infected and more than 6.3 million have died from COVID-19 [4].

Infection with SARS-CoV-2 can be symptomatic or asymptomatic. In symptomatic individuals, illness severity can range from mild to severe and critical [5-7]. It is estimated that one-third of infected individuals do not develop any noticeable clinical symptoms [8]. Furthermore, clinical manifestations of SARS-CoV-2 infection include a diverse range of symptoms. The most commonly reported clinical symptoms of COVID-19 include fever, cough, dyspnea, fatigue, muscle pain, headache, loss of taste and/or smell, sore throat, vomiting, and diarrhea [9,10]. Most individuals with SARS-CoV-2 infection (approximately 81%) have a mild course of illness. In 14% of cases, COVID-19 presents with severe symptoms, such as dyspnea, hypoxemia, and lung infiltrates greater than 50% on radiological imaging. Five percent of patients, representing the smallest proportion of all cases of SARS-CoV-2 infection, develop complications such as severe acute respiratory failure, shock, and multiple organ failure [5]. These patients require Intensive Care Unit (ICU) admission and have the highest mortality rate [11].

The COVID-19 mortality rate varies between countries. It is estimated that the global COVID-19 mortality rate is 2.2% [12,13]. The results of research to date indicate that there are several risk factors that predispose a patient to severe COVID-19 disease and mortality. These include older age [14-16], male sex [17,18], and the presence of comorbidities, including cardiovascular disease, diabetes, chronic obstructive pulmonary disease (COPD), cancer [19-22], obesity, and hypertension [22-24]. Severe illness from the novel coronavirus is associated with many complications, which are not restricted to the respiratory system. Indeed, apart from acute respiratory distress syndrome, other complications reported in COVID-19 patients include cardiac arrhythmias, myocardial damage, heart failure, venous thromboembolism, extensive deep vein thrombosis, pulmonary embolism, encephalopathy, motor and sensory deficits, and seizures [25-28].

The above observations underscore the scale of the problem and the dangers faced today by health care systems [13]. Therefore, this retrospective study of 5127 patients with COVID-19 admitted to an Emergency Department (ED) in Poland between March 2020 and April 2021 aimed to identify risk factors for severe disease and mortality using the modified early warning score (MEWS).

Material and Methods

Ethics

The study was limited to the retrospective review of medical records and was conducted in accordance with the principles of the Declaration of Helsinki. Reports with data were anonymous and did not permit identification of individual patients at any stage of the study. The study protocol was submitted to the Bioethics Committee at the Medical University of Warsaw, which confirmed that the study did not require consent due to its retrospective nature (AKBE/13/2022).

Data Collection and Variables

The present study was based on a retrospective analysis of the discharge medical records of patients with SARS-CoV-2 infection admitted to the ED of the Central Clinical Hospital of the Ministry of Interior and Administration in Warsaw between March 2020 and April 2021. In the study period, there were 2 pandemic waves in Poland: the first (spring) wave of the pandemic (March-June 2020) and the second (autumn) wave of the pandemic (September-December 2020). The pandemic waves in Poland were defined based on 2 parameters: the R number, namely the basic reproduction rate of the virus, and the actual infection growth rate. What is considered the beginning of a wave is the moment when the R number exceeds 1 and continues to increase. This is when the number of infections starts increasing as well. When the R value is <1, the epidemic slows down, which signals the end of a wave.

The data were prepared by the hospital’s Information Technology Department. The population was composed of patients admitted to the ED of the Central Clinical Hospital of the Ministry of Interior and Administration in Warsaw who were diagnosed with SARS-CoV-2 infection. SARS-CoV-2 infection was confirmed by laboratory testing by reverse transcription-polymerase chain reaction tests, which were performed in a laboratory in accordance with guidelines developed by the National Institute of Public Health-National Institute of Hygiene [29]. The exclusion criteria included gaps in the medical records of data required for the analysis (n=273), lack of laboratory-confirmed COVID-19 (n=5147), pediatric patients (n=155), and other diagnoses (n=2205). A total of 5127 patients meeting the established criteria were included in the final analysis (Figure 1). At the beginning of the pandemic, owing to limited accessibility of COVID-19 laboratory testing, the decision to perform the test was made by the doctor on duty based on the medical history, symptoms, and general condition of the patient.

The discharge medical records of the patients were analyzed to obtain the following information: independent variables of...
age, sex, and place of residence of the patients, admission and discharge information, duration of hospital stay, main vital signs, laboratory test results, medical procedures performed, clinical symptoms, comorbidities; and the dependent variables of mortality and admission to the ICU.

**COVID-19 Outcome**

In our analysis, the primary aspect used to determine the treatment outcome of the COVID-19 patients studied was the outcome of hospitalization: survival or mortality. Another aspect was whether or not the patient had to be admitted to the ICU.

The other issue we tried to address was identifying the group of high-risk patients based on the MEWS scale. Every patient included in the study was assessed using the MEWS scale in accordance with the hospital protocol. The MEWS scale was incorporated in standard care in our hospital at the beginning of the pandemic. Calculations of the MEWS values were based on the system by Subbe et al [30]. The score measurements were registered in the patients’ medical files by the nursing staff. A MEWS score of ≥5 denotes critical clinical condition (*Table 1*).

Moreover, a high-resolution computed tomography (HRCT) scan of the chest was performed in the patients to assess the percentage of lung parenchyma affected.

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*Table 1.* Calculation of the modified early warning score (MEWS) [30].

|                      | 3     | 2-3  | 1     | 0     | 1     | 2     | 3     |
|----------------------|-------|------|-------|-------|-------|-------|-------|
| Heart rate           | <40   | 40-50| 51-100| 101-110| 111-130| >130  |
| Systolic blood pressure | <70   | 70-80| 81-100| 101-200| >200  |
| Respiratory rate     | <9    | 9-14 | 15-20 | 21-30 | >30   |
| Temperature (°C)     | <35   | 35-38.4| ≥38.5|
| AVPU score           | Alert | Reacting to Voice| Reacting to Pain| Unresponsive|
| Worried about patient’s condition: 1 point | |
| Urine production <75 ml during previous 4 hours: 1 point | |
| Oxygen saturation <90% despite adequate oxygen therapy: 3 points | |

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*Figure 1.* Flow chart of patients included in the study.
were analyzed by a radiologist. Various lesions, such as the presence of ground glass opacities, consolidations, reticulations, traction bronchiectasis, cystic changes, nodules, lymphadenopathy, pleural thickening, pleural effusion, and pneumomediastinum, were assessed. An HRCT score was calculated based on the extent of lobar involvement [31].

The number of COVID-19 signs was assessed on the basis of a set of 16 symptoms (fever, cough, dyspnea, respiratory effort, sore throat, myalgia, weakness, rhinorrhea, headache, loss/change in sense of taste, loss/change in sense of smell, diarrhea, conjunctivitis, skin rash, chest/back pain), whose frequency in the covered analysis period exceeded 5%.

The decision to admit a patient with COVID-19 to the ICU was made by the ICU doctors on duty in accordance with the criteria of the National Consultant on Anaesthesiology and Intensive Therapy [32].

Statistical Analysis

The data obtained were analyzed using STATISTICA software, version 13.2 (Tibco Software Inc., Palo Alto, CA, USA). Categorical variables were presented using frequencies (n) and percentages (%), while numerical variables using medians (Me) and interquartile ranges (IQR). The normality of distribution of variables was tested using the Kolmogorov-Smirnov test and the Lilliefors test. An initial bivariate analysis was performed using the Mann-Whitney U test for numerical variables and chi-square test for categorical ones. We used univariate logistic regression analyses to determine the association of variables with ICU admission. Variables with \( P < 0.05 \) in the univariate logistic analyses were included in multivariable logistic regression. We used forward selection of variables in the logistic regression model and determined adjusted odds ratios and their 95% confidence intervals (CIs). To evaluate the association of an independent variable with mortality, Cox regression was performed to find the crude and adjusted hazard ratios (HR) with their respective 95% CIs of those variables that had been found significant in the bivariate analysis (\( P < 0.05 \)). The multivariable Cox regression model included those variables that had been found significant in bivariate analysis except those considered possibly collinear. Furthermore, power and sample size analysis was performed, indicating that with a power of 0.9 (90%) the minimum sample size should be 3126. A significance level of \( P < 0.05 \) was used in the study.

Results

Study Group Characteristics

In the period analyzed, from March 2020 to April 2021, a total of 5127 patients with COVID-19 were admitted to the ED of the Central Clinical Hospital of the Ministry of Interior and Administration in Warsaw. Of those patients, 1104 (21.53%) died. The largest number of patients (1002) were admitted in March 2021. The highest case mortality rate (31.96%) was among patients admitted in May 2020. During the first (spring) wave of the pandemic (March-June 2020), 453 patients with
COVID-19 were admitted to the hospital, of whom 118 died. Thus, the case mortality rate among those patients was 26.05%. During the second (autumn) wave of the pandemic (September-December 2020), 1842 COVID-19 patients were admitted to the hospital; 394 (case mortality rate of 21.39%) of those patients died. Details are shown in Figure 2.

Most of the patients studied were male (53.38%) and they accounted for a higher proportion of patients who died, compared with female patients (58.88% vs 41.12%). The median age of the patients studied was 64 years. However, it should be noted that patients who did not survive were older by a median of 15 years. The most commonly reported symptoms were fever (25.61%), cough (24.13%), and dyspnea (20.73%). Among the symptoms, the presence of fever, cough, muscle pain, diarrhea, chest/back pain, loss/change in sense of taste, loss/change in sense of smell, and headache were associated with lower mortality. The most common comorbidities in both groups of patients were hypertension (21.10%), diabetes (10.24%), and heart failure (6.94%). All of the comorbidities identified were more common among patients who did not survive. Most of the patients admitted to the ED were in a stable condition, as determined by the MEWS score (Me=3). Furthermore, patients with MEWS score ≥5 died significantly more often than the other patients (37.14% vs 15.26%) (P<0.001; Table 2).

Of the patients studied, 15.10% required nasal high-flow therapy, 5.52% required mechanical ventilation, and 8.82% had to be transferred to the ICU. The aforementioned medical procedures were more commonly performed in patients who did not survive (P<0.001). Regarding the findings on the physical examination, mortality was found to be associated with a higher percentage of lung parenchyma affected (>50%; P<0.001), higher heart rate (>125 beats per min; P<0.001), higher respiratory rate (>24 breaths per min; P<0.001), lower oxygen saturation (<92%; P<0.001), systolic blood pressure <90 mmHg (P<0.005), and lower platelet count (<150000/µL; P=0.002).

Prediction of Mortality in Patients with COVID-19

A multivariate Cox proportional hazards model was used to identify variables independently associated with mortality in COVID-19 patients. The adjusted analysis found that older age (>60 years, HR=2.27, P<0.001), comorbidities (cancer, HR=1.39, P=0.005; heart failure, HR=1.31, P=0.009; renal failure, HR=1.37, P=0.004), higher MEWS score (MEWS ≥5, HR=1.43, P<0.001), higher level of neutrophil (neutrophil >8, HR=2.29, P<0.001), higher percentage of lung parenchyma affected (>50%, HR=2.10, P=0.001), and higher respiratory rate (>24, HR=2.10, P<0.001) were significant factors associated with an increased risk of mortality in COVID-19 patients. Lower oxygen saturation (<92, HR=2.65, P<0.001) and MAP (<70, HR=2.17, P=0.013) and lower level red blood cells (RBC <4, HR=3.17, P<0.001) and lymphocyte (<1.1, HR=2.05, P<0.001) were also found to be associated with a higher risk of mortality from COVID-19. Treatment with ventilator therapy (HR=1.23, P 0.013) and ICU admission (HR=2.33, P<0.001) were associated with higher mortality (Table 4).

Discussion

In our study, we provide an analysis of all patients diagnosed with SARS-CoV-2 infection who were admitted to the ED of one of the largest COVID-19 hospitals in Poland between March 2020 and April 2021. The results of our study showed that patients with confirmed SARS-CoV-2 infection varied in terms of demographic characteristics, incidence of symptoms of infection, presence of comorbidities, laboratory test results, and vital signs. Furthermore, it was found that these variables and the MEWS were significant prognostic factors for ICU admission and in-hospital mortality from COVID-19.

The COVID-19 pandemic has prompted a large number of studies investigating the characteristics of patients with SARS-CoV-2 infection, risk factors for severe COVID-19 disease, and risk factors for in-hospital mortality from COVID-19 [33-36]. The analysis performed in our study showed that, during the period covered by the study, most patients were admitted in March 2021. The highest mortality rate (31.96%) was among patients admitted in May 2020. At that time, the dominant COVID-19 variant in Poland and internationally was the Alpha variant (B.1.1.7) [37]. Since the outbreak of the SARS-CoV-2 pandemic, many variants of the virus have emerged, including the Alpha, Beta, Gamma, and Delta variants. However, the results of studies on the severity of disease caused by particular variants are not consistent. According to a study by Funk et al (2021), the Alpha variant is associated with a significantly...
Table 2. Characteristics of the study population and a comparative analysis between the surviving and non-surviving groups of patients (from March 1, 2020, to April 30, 2021).

| Variables                        | Total (n=5,127) | Survivors (n=4,023) | Non-survivors (n=1,104) | p-value |
|----------------------------------|-----------------|---------------------|-------------------------|---------|
| Age [years] – Me (IQR)           |                 |                     |                         |         |
| >60 – n (%)                      | 3016 (58.8)     | 2028 (50.41)        | 988 (89.49)             | <0.001  |
| Sex – n (%)                      |                 |                     |                         |         |
| Female                           | 2390 (46.62)    | 1936 (48.12)        | 454 (41.12)             | <0.001  |
| Male                             | 2737 (53.38)    | 2087 (51.88)        | 650 (58.88)             |         |
| Fever – n (%)                    |                 |                     |                         |         |
| Yes                              | 1313 (25.61)    | 1106 (27.49)        | 207 (18.75)             | <0.001  |
| No                               | 3814 (74.39)    | 2917 (72.51)        | 897 (81.25)             |         |
| Cough – n (%)                    |                 |                     |                         |         |
| Yes                              | 1237 (24.13)    | 1046 (26.00)        | 191 (17.30)             | <0.001  |
| No                               | 3890 (75.87)    | 2977 (74.00)        | 913 (82.70)             |         |
| Respiratory effort – n (%)       |                 |                     |                         |         |
| Yes                              | 642 (12.52)     | 493 (12.25)         | 149 (13.50)             | 0.269   |
| No                               | 4485 (87.48)    | 3530 (87.75)        | 955 (86.50)             |         |
| Dyspnea – n (%)                  |                 |                     |                         |         |
| Yes                              | 1063 (20.73)    | 822 (20.43)         | 241 (21.83)             | 0.310   |
| No                               | 4064 (79.27)    | 3201 (79.57)        | 863 (78.17)             |         |
| Muscle pain – n (%)              |                 |                     |                         |         |
| Yes                              | 449 (8.76)      | 413 (10.27)         | 36 (3.26)               | <0.001  |
| No                               | 4678 (91.24)    | 3610 (93.61)        | 1068 (96.74)            |         |
| Diarrhea – n (%)                 |                 |                     |                         |         |
| Yes                              | 310 (6.05)      | 257 (6.39)          | 53 (4.80)               | 0.045   |
| No                               | 4817 (93.95)    | 3766 (93.61)        | 1051 (95.20)            |         |
| Chest/back pain – n (%)          |                 |                     |                         |         |
| Yes                              | 299 (5.83)      | 260 (6.64)          | 39 (3.53)               | <0.001  |
| No                               | 4828 (94.17)    | 3763 (93.54)        | 1065 (96.47)            |         |
| Loss/change in sense of taste – n (%) |           |                     |                         |         |
| Yes                              | 326 (6.36)      | 300 (7.46)          | 26 (2.36)               | <0.001  |
| No                               | 4801 (93.64)    | 3723 (92.54)        | 1078 (97.64)            |         |
| Loss/change in sense of smell – n (%) |           |                     |                         |         |
| Yes                              | 363 (7.08)      | 334 (8.30)          | 29 (2.63)               | <0.001  |
| No                               | 4764 (92.92)    | 3689 (91.70)        | 1075 (97.37)            |         |
| Headache – n (%)                 |                 |                     |                         |         |
| Yes                              | 446 (8.70)      | 410 (10.19)         | 36 (3.26)               | <0.001  |
| No                               | 4681 (91.30)    | 3613 (89.81)        | 1068 (96.74)            |         |
Table 2 continued. Characteristics of the study population and a comparative analysis between the surviving and non-surviving groups of patients (from March 1, 2020, to April 30, 2021).

| Variables                                | Total (n=5,127) | Survivors (n=4,023) | Non-survivors (n=1,104) | p-value |
|-------------------------------------------|-----------------|---------------------|-------------------------|---------|
| Diabetes – n (%)                          |                 |                     |                         |         |
| Yes                                       | 525 (10.24)     | 363 (9.02)          | 162 (14.67)             | <0.001  |
| No                                        | 4602 (89.76)    | 3660 (90.98)        | 942 (85.33)             |         |
| Hypertension – n (%)                      |                 |                     |                         |         |
| Yes                                       | 1082 (21.10)    | 803 (19.96)         | 279 (25.27)             | <0.001  |
| No                                        | 4045 (78.90)    | 3220 (80.04)        | 825 (74.73)             |         |
| Acute coronary syndromes – n (%)          |                 |                     |                         |         |
| Yes                                       | 296 (5.77)      | 206 (5.12)          | 90 (8.15)               | <0.001  |
| No                                        | 4831 (94.23)    | 3817 (94.88)        | 1014 (91.85)            |         |
| Stroke history – n (%)                    |                 |                     |                         |         |
| Yes                                       | 250 (4.88)      | 168 (4.18)          | 82 (7.43)               | <0.001  |
| No                                        | 4877 (95.12)    | 3855 (95.82)        | 1022 (92.57)            |         |
| Cancer – n (%)                            |                 |                     |                         |         |
| Yes                                       | 192 (3.74)      | 119 (2.96)          | 73 (6.61)               | <0.001  |
| No                                        | 4935 (96.26)    | 3904 (97.04)        | 1031 (93.39)            |         |
| Heart failure – n (%)                     |                 |                     |                         |         |
| Yes                                       | 356 (6.94)      | 220 (5.47)          | 136 (12.32)             | <0.001  |
| No                                        | 4771 (93.06)    | 3803 (94.53)        | 968 (87.68)             |         |
| Chronic obstructive pulmonary disease – n (%) |           |                     |                         |         |
| Yes                                       | 112 (2.18)      | 74 (1.84)           | 38 (3.44)               | 0.001   |
| No                                        | 5015 (97.82)    | 3949 (98.16)        | 1066 (96.56)            |         |
| Renal failure – n (%)                     |                 |                     |                         |         |
| Yes                                       | 314 (6.12)      | 195 (4.85)          | 119 (10.78)             | <0.001  |
| No                                        | 4813 (93.88)    | 3828 (95.15)        | 985 (89.22)             |         |
| Smoking – n (%)                           |                 |                     |                         |         |
| Yes                                       | 282 (5.50)      | 211 (5.24)          | 71 (6.43)               | 0.126   |
| No                                        | 4845 (94.50)    | 3812 (94.76)        | 1033 (93.57)            |         |
| Ventilator therapy – n (%)                |                 |                     |                         |         |
| Yes                                       | 283 (5.52)      | 178 (4.42)          | 105 (9.51)              | <0.001  |
| No                                        | 4844 (94.48)    | 3845 (95.58)        | 999 (90.49)             |         |
| Nasal high-flow therapy – n (%)           |                 |                     |                         |         |
| Yes                                       | 774 (15.10)     | 546 (13.57)         | 228 (20.65)             | <0.001  |
| No                                        | 4353 (84.90)    | 3477 (86.43)        | 876 (79.35)             |         |
Table 2 continued. Characteristics of the study population and a comparative analysis between the surviving and non-surviving groups of patients (from March 1, 2020, to April 30, 2021).

| Variables                                                      | Total (n=5,127) | Survivors (n=4,023) | Non-survivors (n=1,104) | p-value |
|---------------------------------------------------------------|----------------|---------------------|-------------------------|---------|
| Intensive Care Unit admission – n (%)                         |                |                     |                         |         |
| Yes                                                           | 452 (8.82)     | 131 (3.26)          | 321 (29.08)             | <0.001  |
| No                                                            | 4675 (91.18)   | 3892 (96.74)        | 783 (70.92)             |         |
| Duration of hospital stay [days] – Me (IQR)                   |                |                     |                         | 0.092   |
| MEWS – Me (IQR)                                               | 3 (0-3)        | 2 (0-3)             | 3 (3-5)                 | <0.001  |
| ≥5 – n (%)                                                    | 1024 (19.97)   | 614 (15.26)         | 410 (37.14)             | <0.001  |
| WBC count [thousand/µl] – Me (IQR)                            | 7 (5-9)        | 6 (5-9)             | 10 (7-16)               | <0.001  |
| >10 – n (%)                                                   | 1030 (20.10)   | 527 (13.09)         | 504 (45.64)             | <0.001  |
| RBC count [million/µl] – Me (IQR)                             |                |                     |                         |         |
| ≤4 – n (%)                                                    | 682 (13.30)    | 343 (8.53)          | 339 (30.67)             | <0.001  |
| Hemoglobin [g/dl] – Me (IQR)                                  |                |                     |                         |         |
| <7 – n (%)                                                    | 45 (0.88)      | 13 (3.2)            | 32 (2.94)               | <0.001  |
| Platelet count [thousand/µl] – Me (IQR)                       |                |                     |                         |         |
| ≥150 [thousand/µl] – n (%)                                    | 1029 (20.07)   | 667 (16.59)         | 362 (32.77)             | <0.001  |
| Neutrophil count [thousand/µl] – Me (IQR)                     |                |                     |                         |         |
| >8 [thousand/µl] – n (%)                                      | 920 (17.95)    | 425 (10.57)         | 495 (44.83)             | <0.001  |
| Percentage of lung parenchyma affected based on HRCT [%] – Me (IQR) |                |                     |                         |         |
| >50 [%] – n (%)                                               | 417 (8.12)     | 204 (5.08)          | 212 (19.22)             | <0.001  |
| Systolic blood pressure [mmHg] – Me (IQR)                     |                |                     |                         |         |
| ≥90 [mmHg] – n (%)                                            | 134 (2.62)     | 37 (0.93)           | 97 (8.76)               | <0.001  |
| Diastolic blood pressure [mmHg] – Me (IQR)                    |                |                     |                         |         |
| ≥60 [mmHg] – n (%)                                            | 351 (6.84)     | 163 (4.05)          | 188 (17.01)             | <0.001  |
| MAP – Me (IQR)                                                |                |                     |                         |         |
| ≥70 [mmHg] – n (%)                                            | 150 (2.92)     | 58 (1.44)           | 92 (8.33)               | <0.001  |
| Heart rate [beats per minute] – Me (IQR) – n (%)              |                |                     |                         |         |
| ≥125 [beats per minute]                                       | 239 (4.67)     | 119 (2.96)          | 120 (10.88)             | <0.001  |
Table 2 continued. Characteristics of the study population and a comparative analysis between the surviving and non-surviving groups of patients (from March 1, 2020, to April 30, 2021).

| Variables                                                                 | Total (n=5,127) | Survivors (n=4,023) | Non-survivors (n=1,104) | p-value |
|---------------------------------------------------------------------------|-----------------|---------------------|-------------------------|---------|
| Respiratory rate [breaths per minute] – Me (IQR) – n (%)                 | 18 (15-20)      | 17 (15-19)          | 20 (18-25)              | <0.001  |
| >24 [breaths per minute]                                                 | 442 (8.63)      | 111 (2.76)          | 331 (30.00)             | <0.001  |
| Oxygen saturation [%] – Me (IQR)                                        | 97 (94-99)      | 97 (95-99)          | 92 (85-95)              | <0.001  |
| <92 [%] – n (%)                                                          | 967 (18.87)     | (9.27)              | (53.85)                 | <0.001  |

Me – median; IQR , interquartile range; MEWS – modified early warning score; WBC – white blood cells; RBC – red blood cells; HRCT – high-resolution computed tomography; MAP – mean arterial pressure.

Table 3. Logistic regression analysis evaluating the impact of selected factors on the risk of Intensive Care Unit (ICU) admission in patients hospitalized with COVID-19 (from March 1, 2020, to April 30, 2021).

| Variable                                | ORc    | 95% CI      | p-value | ORa    | 95% CI      | p-value |
|-----------------------------------------|--------|-------------|---------|--------|-------------|---------|
| Age >60                                 | 1.14   | 0.93-1.40   | 0.217   |        |             |         |
| Sex (Male)                              | 1.96   | 1.59-2.40   | <0.001  | 1.68   | 1.40-2.01   | <0.001  |
| Fever (>38°C)                           | 1.12   | 0.90-1.39   | <0.001  |        |             |         |
| Cough                                   | 1.11   | 0.89-1.38   | 0.361   |        |             |         |
| Respiratory effort                      | 1.60   | 1.24-2.07   | <0.001  |        |             |         |
| Dyspnoy                                 | 1.93   | 1.57-2.39   | <0.001  | 1.89   | 1.50-2.40   | <0.001  |
| Muscle pain                             | 0.64   | 0.43-0.96   | 0.030   |        |             |         |
| Diarrhea                                | 1.16   | 0.79-1.70   | 0.449   |        |             |         |
| Chest/back pain                         | 0.86   | 0.55-1.32   | 0.480   |        |             |         |
| Loss/change in sense of taste           | 0.85   | 0.56-1.30   | 0.451   |        |             |         |
| Loss/change in sense of smell           | 0.86   | 0.47-1.27   | 0.443   |        |             |         |
| Headache                                | 0.87   | 0.61-1.25   | 0.451   |        |             |         |
| Diabetes                                | 1.70   | 1.29-2.23   | <0.001  | 1.40   | 1.05-1.87   | 0.020   |
| Hypertension                            | 1.41   | 1.13-1.76   | 0.002   |        |             |         |
| Acute coronary syndromes                | 1.09   | 0.73-1.62   | 0.688   |        |             |         |
| Stroke history                          | 0.75   | 0.45-1.23   | 0.251   |        |             |         |
| Cancer                                  | 1.01   | 0.61-1.67   | 0.985   |        |             |         |
| Heart failure                           | 1.34   | 0.95-1.89   | 0.096   |        |             |         |
| Chronic obstructive pulmonary disease   | 2.76   | 1.73-4.42   | <0.001  | 1.75   | 1.07-2.87   | 0.027   |
| Renal failure                           | 1.56   | 1.10-2.21   | 0.012   |        |             |         |
| Smoking                                 | 1.72   | 1.21-2.45   | 0.003   |        |             |         |
| Ventilator therapy                      | 3.51   | 2.62-4.72   | <0.001  | 3.63   | 2.81-4.69   | 0.001   |
| Nasal high-flow therapy                 | 2.60   | 2.06-3.19   | <0.001  | 3.03   | 2.42-3.80   | <0.001  |
| Duration of hospital stay               | 1.06   | 1.05-1.06   | <0.001  |        |             |         |
Table 3 continued. Logistic regression analysis evaluating the impact of selected factors on the risk of Intensive Care Unit (ICU) admission in patients hospitalized with COVID-19 (from March 1, 2020, to April 30, 2021).

| Variable                                      | ORc     | 95% CI       | p-value | ORa     | 95% CI       | p-value |
|-----------------------------------------------|---------|--------------|---------|---------|--------------|---------|
| MEWS ≥ 5                                      | 16.99   | 14.15-20.40  | <0.001  | 26.16   | 11.69-58.52  | <0.001  |
| WBC count >10                                 | 5.37    | 3.27-8.82    | <0.001  |        |              |         |
| RBC count <4                                   | 1.80    | 0.75-4.35    | 0.190   |        |              |         |
| Hemoglobin <7                                  | 4.72    | 0.0-4.69     | 0.469   |        |              |         |
| Hematocrit <40% (male) 37% (female)           | 1.98    | 0.98-4.01    | 0.057   |        |              |         |
| Platelet count <150                           | 2.52    | 1.26-5.03    | 0.009   | 6.71    | 1.97-22.90   | 0.002   |
| Neutrophil count >8                           | 14.55   | 7.02-30.18   | <0.001  | 17.04   | 4.77-60.83   | <0.001  |
| Lymphocyte count <1.0                         | 8.83    | 4.42-17.61   | <0.001  |        |              |         |
| Monocyte count 3.0-0.1                         | 6.75    | 2.89-15.75   | <0.001  |        |              |         |
| Percentage of lung parenchyma affected >50%   | 3.69    | 2.76-4.94    | <0.001  | 4.13    | 1.12-15.22   | 0.033   |
| Systolic blood pressure <90                   | 12.25   | 7.12-21.07   | <0.001  | 4.07    | 1.53-10.81   | 0.005   |
| Diastolic blood pressure <60                  | 5.66    | 3.90-8.23    | <0.001  |        |              |         |
| MAP <70                                       | 0.04    | 3.16-11.54   | <0.001  |        |              |         |
| Heart rate >125                               | 5.09    | 3.28-7.87    | <0.001  |        |              |         |
| Respiratory rate >24                          | 16.14   | 10.63-24.51  | <0.001  | 2.79    | 1.60-4.86    | <0.001  |
| Oxygen saturation <92%                        | 17.54   | 13.02-23.63  | <0.001  | 2.90    | 1.75-4.80    | <0.001  |

ORc – crude odds ratio; ORa – adjusted odds ratio; 95% CI – 95% confidence interval; MEWS – modified early warning score; WBC – white blood cells; RBC – red blood cells; MAP – mean arterial pressure.

Table 4. Results of the multivariate Cox proportional hazards model to predict mortality in patients with COVID-19 (from March 1, 2020, to April 30, 2021).

| Variable                        | HRc     | 95% CI       | p-value | HRa     | 95% CI       | p-value |
|---------------------------------|---------|--------------|---------|---------|--------------|---------|
| Age >60                         | 2.47    | 2.11-2.90    | <0.001  | 2.27    | 1.94-2.67    | <0.001  |
| Sex (Male)                      | 1.13    | 1.00-1.27    | 0.052   |        |              |         |
| Fever (>38°C)                   | 0.57    | 0.49-0.66    | <0.001  |        |              |         |
| Cough                           | 0.52    | 0.45-0.61    | <0.001  | 0.72    | 0.62-0.85    | <0.001  |
| Muscle pain                     | 0.33    | 0.23-0.45    | <0.001  | 0.60    | 0.43-0.86    | 0.005   |
| Diarrhea                        | 0.65    | 0.49-0.86    | 0.002   |        |              |         |
| Chest/back pain                 | 0.50    | 0.37-0.69    | <0.001  |        |              |         |
| Loss/change in sense of taste   | 0.34    | 0.23-0.51    | <0.001  |        |              |         |
| Loss/change in sense of smell   | 0.84    | 0.24-0.49    | <0.001  | 0.59    | 0.41-0.83    | 0.005   |
| Headache                        | 0.32    | 0.23-0.45    | <0.001  | 0.58    | 0.41-0.83    | 0.003   |
| Diabetes                        | 1.09    | 0.93-1.29    | 0.296   |        |              |         |
| Hypertension                    | 0.84    | 0.73-0.96    | 0.010   | 0.72    | 0.62-0.84    | <0.001  |
Table 4 continued. Results of the multivariate Cox proportional hazards model to predict mortality in patients with COVID-19 (from March 1, 2020, to April 30, 2021).

| Variable                              | HRc  | 95% CI        | p-value | HRa  | 95% CI        | p-value |
|---------------------------------------|------|---------------|---------|------|---------------|---------|
| Acute coronary syndromes             | 1.02 | 0.82-1.27     | 0.844   | –    | –             | –       |
| Stroke history                       | 1.05 | 0.84-1.31     | 0.682   | –    | –             | –       |
| Cancer                                | 1.27 | 1.00-1.61     | 0.049   | 1.39 | 1.10-1.76     | 0.005   |
| Heart failure                         | 1.24 | 1.03-1.48     | 0.021   | 1.31 | 1.07-0.61     | 0.009   |
| Chronic obstructive pulmonary disease | 1.06 | 0.77-1.46     | 0.728   | –    | –             | –       |
| Renal failure                         | 1.22 | 1.01-1.48     | 0.040   | 1.37 | 1.11-1.69     | 0.004   |
| Ventilator therapy                    | 1.53 | 1.25-1.84     | <0.001  | 1.23 | 1.01-1.49     | 0.036   |
| Nasal high-flow therapy               | 0.93 | 0.80-1.08     | 0.333   | –    | –             | –       |
| Intensive care unit admission        | 2.26 | 1.98-2.58     | <0.001  | 2.33 | 2.05-2.65     | <0.001  |
| MEWS >5                              | 1.61 | 1.44-1.81     | <0.001  | 1.43 | 1.18-1.73     | <0.001  |
| WBC count >10                         | 2.88 | 2.34-3.54     | <0.001  | –    | –             | –       |
| RBC count <4                          | 2.30 | 1.80-2.95     | <0.001  | 3.17 | 2.22-4.53     | <0.001  |
| Hemoglobin <7                         | 3.65 | 1.88-7.08     | <0.001  | –    | –             | –       |
| Hematocrit <40% (male) 37% (female)  | 1.38 | 1.06-1.81     | 0.017   | –    | –             | –       |
| Platelet count <150                   | 1.88 | 1.47-2.39     | <0.001  | –    | –             | –       |
| Neutrophil count >8                   | 3.64 | 2.89-4.56     | <0.001  | 2.29 | 1.57-3.35     | <0.001  |
| Lymphocyte count <1.1                 | 3.76 | 2.90-4.88     | <0.001  | 2.05 | 1.55-2.71     | <0.001  |
| Monocyte count <0.1                   | 4.88 | 3.66-6.51     | <0.001  | –    | –             | –       |
| Percentage of lung parenchyma affected >50% | 2.02 | 1.69-2.40     | <0.001  | 2.10 | 1.36-3.24     | 0.001   |
| Diastolic blood pressure <60          | 2.52 | 1.86-3.41     | <0.001  | –    | –             | –       |
| MAP <70                               | 3.56 | 2.25-5.63     | <0.001  | 2.17 | 1.18-3.98     | 0.013   |
| Heart rate >125                       | 2.65 | 1.85-3.79     | <0.001  | –    | –             | –       |
| Respiratory rate >24                  | 3.60 | 2.60-4.99     | <0.001  | 2.10 | 1.39-3.15     | <0.001  |
| Oxygen saturation <92                 | 3.27 | 2.58-4.15     | <0.001  | 2.65 | 1.83-3.84     | <0.001  |

HRc – crude hazard ratio; HRa – adjusted hazard ratio; 95% CI – 95% confidence interval; MEWS – modified early warning score; WBC – white blood cells; RBC – red blood cells; MAP – mean arterial pressure.

higher risk of hospitalization and ICU admission and a lower risk of mortality compared with that of the wildtype variant [38]. In their study from France, Hoang et al (2021) compared the risk of hospitalization and transfer to ICU between the Beta, Gamma, and Alpha variants. They found that the Beta variant is associated with a significantly higher risk of hospitalization and ICU transfer than the Alpha variant and that the Alpha variant presents a similar risk as the Gamma variant [39]. In a study by Cueto-Manzano et al (2021), the mortality rate of ICU and ward patients with COVID-19 was 38% [40].
were in a stable condition, as determined by the MEWS score. The results of the present study are consistent with those from earlier studies on patients with COVID-19, including a study by Gray et al (2021) concerning COVID-19 patients in England [24] and studies by Wang et al (2021) [15], Huang et al (2020) [41], and Guan et al (2020) [42] conducted on patients in China. Our findings are also consistent with the results of a meta-analysis by Zheng et al (2020), which included 13 studies from China [34].

Our study showed that male sex, dyspnea, diabetes, COPD, ventilator therapy, nasal high-flow therapy, MEWS score ≥5, higher neutrophil count, higher percentage of lung parenchyma affected, higher respiratory rate, lower oxygen saturation, lower systolic blood pressure, and lower platelet count were factors associated with an increased risk of ICU admission in patients with COVID-19. The results of a meta-analysis by Pijls et al (2021) showed that men and patients aged 70 years or over have a higher risk of COVID-19 infection, severe COVID-19 disease, ICU admission, and mortality [43]. A multicenter observational study concerning patients hospitalized with COVID-19 in Brazil found that the most common symptoms among COVID-19 patients admitted to the ICU were dyspnea, fever, dry cough, and myalgia [44]. Jain and Yuan (2020) found in their study that dyspnea was the only symptom predictive of severe COVID-19 disease and ICU admission in the COVID-19 patients studied [45]. In a study conducted by Ahlström et al (2020) in Sweden, hypertension, type 2 diabetes, chronic renal failure, asthma, obesity, being a recipient of a solid organ transplant, and immunosuppressant medications were found to be independent risk factors for ICU admission, whereas oral anticoagulants were found to be protective [23]. In a study conducted by Zhao et al (2020) in the United States, the following 5 significant variables predicting ICU admission in COVID-19 patients were identified: lactate dehydrogenase level, procalcitonin level, pulse oxygen saturation, smoking history, and lymphocyte count [46]. Kim et al (2021), in their study from the United States including 2491 adults hospitalized with laboratory confirmed COVID-19, found that older age, male sex, obesity, immunosuppression, and diabetes were independent factors associated with ICU admission in COVID-19 patients [47].

A study by Larsson et al (2020) concerning patients with COVID-19 admitted to the ICU in a tertiary hospital in Stockholm, Sweden, showed that older patients and those admitted from an ED had a higher mortality rate [48]. In our study, significant factors affecting the risk of in-hospital mortality from COVID-19 in the patients studied included age and sex, which is consistent with the findings from other studies around the world on the issue concerned [47,49-54]. In a study from Iran conducted by Alizadehsani et al (2020), such symptoms of COVID-19 as dry cough, ageusia, fever, and anosmia were found to be associated with increased mortality [55]. The results of our study also showed that clinical manifestations of COVID-19, namely symptoms such as fever, dyspnea, and respiratory effort, were unfavorable variables that were associated with ICU admission. However, the presence of these symptoms was also found to be a favorable variable associated with survival. One hypothesis which may explain these results is that the occurrence of these symptoms might have been associated with a risk of ICU admission of patients whose condition had already been severe, but not necessarily with mortality in patients from the general population studied. Keeley et al (2020) also emphasized that cough, breathlessness, fatigue, and myalgia are significant symptoms in hospitalized patients, whereas the most important symptom in patients dying with COVID-19 is dyspnea [56].

In the present study, the results of multivariate Cox proportional hazards analysis showed that cancer, heart failure, and renal failure were factors associated with an increased risk of in-hospital mortality from COVID-19. It should be stressed that, according to the literature on the subject, the presence of comorbidities is a significant risk factor for in-hospital mortality from COVID-19. Many authors emphasize that patients with diabetes, renal failure, heart failure, COPD, and history of stroke or cancer have a higher risk of mortality [47,52-60].

Stachura et al (2021) showed that along with older age, a higher body mass index, MEWS grade, D-dimer value, and lactate dehydrogenase concentration are related to a more severe course of COVID-19 [60]. Moreover, based on the multi-factor analysis, Gani et al (2022) stated that comorbidities, continuous fever, and MEWS score >3 were factors that led to severe COVID-19 [61]. It is important to note the important role of early warning scores (eg, MEWS [62-66]) in the assessment and prediction of ICU admission or in-hospital mortality of COVID-19 patients. Wang et al (2020) stated that MEWS is a useful tool for a quick assessment of elderly patients with COVID-19. Furthermore, it gives promising results in predicting the in-hospital mortality rate and identifying high-risk elderly COVID-19 patients [62]. In their research, Aygun and Eraybar (2022) also showed that MEWS and the real-time early warning score (TREWS) calculated during the emergency service are effective in 28-day mortality rate predictions of COVID-19 patients who require hospitalization [63]. On the other hand, Hu et al (2020) highlighted that both MEWS and the rapid emergency medicine score (REMS) are acceptable scales for the assessment and prediction of in-hospital mortality rate of critically ill COVID-19 patients. However, in the case of COVID-19 patients below the age of 65 years, REMS is more precise, which may be the result of the lack of oxygen saturation parameter in MEWS [64]. Covino et al (2020) stated that the ICU admission rate and mortality rate due to COVID-19 were higher in the cases of patients with a higher
MEWS score. However, this result was not claimed to be statistically significant [65]. However, a study by Na et al. (2022) showed that MEWS scores were higher for patients who died than for patients who survived [66]. The above mentioned results correspond with our research, which demonstrated that a MEWS score ≥5 is associated with a higher risk of ICU admission and in-hospital mortality. Furthermore, the results of our study demonstrated that the use of the MEWS in an ED is an effective tool for predicting disease severity and mortality in the case of COVID-19 patients. Our findings have been corroborated by Veldhuis et al. (2021), who found that the National Early Warning Score 2 (NEWS2) score and the Quick COVID-19 Severity Index (qCSI) score presented good diagnostic performance in predicting ICU admissions [67]. Myrstad et al. (2020), on the other hand, found that NEWS2 was superior to the sequential organ failure assessment (qSOFA) when assessing patients with COVID-19 [68].

The present study reports comprehensive characteristics of patients with SARS-CoV-2 infection admitted to the ED of the Central Clinical Hospital of the Ministry of Interior and Administration in Warsaw. In addition, it complements our previous study concerning COVID-19 patients hospitalized at the temporary hospital in Warsaw [69]. The findings from the present study can be used for international comparisons aimed at developing the best strategies for the management of patients with COVID-19. The data reported in the present study concerning risk factors for ICU admission and in-hospital mortality in COVID-19 patients can be used by decision makers responsible for organizing health systems to prepare the systems for a growing number of COVID-19 patients and thus improve the quality of the medical services provided during the pandemic. Moreover, the present findings enable prompt identification of patients at high risk from COVID-19 and allow for the selection of appropriate medical treatment for COVID-19 patients.

We would like to stress that the present study had certain limitations. First, the data used in the study were from only a single hospital and only just over 5000 cases were analyzed. Second, as the study was retrospective in nature, it included only an analysis of hospital records, which had data gaps and were not completed in a uniform manner. Third, we analyzed cases of patients in whom SARS-CoV-2 infection was confirmed with laboratory testing. At the initial stage of the pandemic, hospitals struggled with a very limited accessibility of diagnostic tests. As a result, it was the doctor on duty who had to make the decision whether or not to perform the test. This situation is also a limitation of this study, as many very mildly symptomatic patients might have been excluded from the analysis. We made every effort to ensure that the limitations do not undermine the quality of the study.

Conclusions

This study, which included patients admitted to the ED of the Central Clinical Hospital of the Ministry of Interior and Administration in Warsaw between March 2020 and April 2021 with COVID-19, produced real-world data of risk factors for mortality from COVID-19 and the use of the MEWS for a faster identification of COVID-19 patients requiring more intensive medical care. Our findings concerning differences between the surviving and non-surviving patients, and especially the findings related to the independent risk factors for in-hospital mortality from COVID-19, are of tremendous importance for the improved management of patients at risk. Moreover, they will enable the implementation of preventive measures in COVID-19 patients during their hospitalization to limit the impact of this pandemic on vulnerable populations.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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