RESEARCH LETTER

Severity of inflammatory lung lesions in COVID-19 based on computed tomography examination as a prognostic factor for respiratory failure and death

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Introduction The ongoing COVID-19 epidemic is posing an extraordinary threat to public health worldwide.[1] Clinical manifestations of patients infected with SARS-CoV-2 include both asymptomatic or mild cases and those with symptoms of severe hypoxemia and characteristic pulmonary infiltrates that may develop into acute respiratory distress syndrome.[2] Apart from the pulmonary symptoms related to the inflammatory process, it was also observed that COVID-19 is associated with a higher risk of exacerbation of anxiety, depression, and sleep disorders in patients with systemic lupus erythematosus which can also result from the inflammatory process.[3]

Computed tomography (CT) plays a key role in the diagnosis and treatment of COVID-19 pneumonia.[4] The main feature of this disease on CT images is ground glass opacity, usually with a subpleural predilection. The foci of ground glass may be accompanied by consolidations and a crazy paving pattern.[5,6] Computed tomography scans usually show the lesions characteristic of COVID-19 pneumonia. Most importantly, this modality enables a precise assessment of the extent of lung involvement using various tools and scales that can have a prognostic value.

The aim of the study was to assess the extent of lung inflammation in the course of COVID-19 relative to 3 endpoints, that is, the need for hospitalization in the intensive care unit (ICU), need for mechanical ventilation, and risk of death.

Patients and methods The study included 128 patients (38 women; mean age, 67.25 years) hospitalized in the ICU and other departments of the Upper Silesian Medical Center in Katowice between October 1 and November, 2020. In all patients, SARS-CoV-2 infection was confirmed using a reverse transcriptase–polymerase chain reaction test of nasopharyngeal swab specimens. Chest CT scans were obtained as part of an assessment of pulmonary inflammatory lesions. The demographic data, results of the COVID-19 test, and information on the clinical outcomes of hospitalized patients were obtained from the internal electronic system of the hospital. A group of critically ill patients was distinguished based on the following clinical outcome criteria: 1) ICU hospitalization, 2) need for mechanical ventilation, or 3) death.

The examinations were performed using a third-generation, dual-source CT system (Somatom Force, Siemens Healthineers, Forchheim, Germany) with the following scan and reconstruction parameters: tube voltage, 120 kV; tube current automatically optimized to the patient's body size and shape using the CARE Dose system and reference tube current-time product, 100 mAs; pitch, 1.2; rotation time, 0.5 s, which resulted in a scan time of 2.2 s. The lung series were reconstructed with a 0.75-mm slice thickness and an increment of 0.5 mm (overlapping) with an additional soft series that was reconstructed with a 1-mm slice thickness.

The percentage changes in the amount of the affected lung tissue with a division into individual lobes of both lungs were calculated using automatic postprocessing with the artificial intelligence–powered SyngoVia VB30A CT Pneumonia Analysis software (Siemens Healthcare).[7] Based on the obtained results, the values of the chest CT score[8] and total opacity score (by Siemens

TABLE 1 Multivariable logistic regression analysis (adjusted for age and sex)

Variable	OR	95% CI	*P* value	Nagelkerke R^2
Percentage of affected lung tissue				
Death	1.03	1.02–1.05	<0.001	0.2462
Hospitalization in ICU	1.04	1.02–1.06	<0.001	0.2374
Need for artificial ventilation	1.04	1.02–1.06	<0.001	0.2945
Chest CT score				
Death	1.16	1.08–1.24	<0.001	0.2374
Hospitalization in ICU	1.22	1.12–1.32	<0.001	0.3747
Need for mechanical ventilation	1.23	1.13–1.34	<0.001	0.3272
Total opacity score				
Death	1.20	1.10–1.29	<0.001	0.2407
Hospitalization in ICU	1.25	1.14–1.37	<0.001	0.3170
Need for artificial ventilation	1.27	1.16–1.39	<0.001	0.3412

Abbreviations: CT, computed tomography; ICU, intensive care unit; OR, odds ratio

Healthcare) were calculated. Both of these are modern semi-quantitative scales that can evaluate the volume of the affected lung tissue as well as the distribution of any inflammatory lesions.

Statistical analysis All data were entered into the internal clinical database. Due to nonnormal distribution of data, variables were presented as medians and interquartile ranges (IQRs). Multivariable logistic regression model (adjusted for age and sex) was used to predict the factors associated with ICU hospitalization, need for mechanical ventilation, and death in the included patients.

A receiver operating characteristic curve analysis was performed to evaluate the diagnostic utility of 3 CT-based parameters, namely, the percentage of the affected lung tissue, total opacity score, and chest CT score. The area under the curve was calculated to reflect and compare the predictive values of these parameters to identify patients at risk of any of the endpoints mentioned above. The results were considered significant at *P* values of less than 0.05. The presented analyses were performed using the advanced analytics software package Statistica 13 (TIBCO Statistica, Palo Alto, California, United States).

Ethics This study was approved by our Institutional Review Board and the requirement for informed consent was waived (IRB No. PCN/CBN/0022/KB1/113/21).

Results Overall, 26.5% of the included patients required hospitalization in the ICU, a similar percentage of patients (27.3%) required mechanical ventilation, and 30.5% died during the study period. The median (IQR) percentage of the affected lung tissue was 30.5% (9.5%–61%) and the median (IQR) values for the total opacity and chest CT scores were 9 (5–14) and 14 (8–19), respectively.

In the logistic regression analysis adjusted for age and sex, the percentage of lung tissue involvement, chest CT score and total opacity score were found to be independent predictors of hospitalization in the ICU, need for artificial ventilation, and death. All of these associations were highly significant; details are presented in the **TABLE 1**.

The cutoff value for the percentage of the affected lung tissue associated with the risk of achieving any of the clinical outcomes was over 32%. The cutoff values for the chest CT score were over 12 points for the risk of ICU hospitalization / need for artificial ventilation and over 15 points for death. For the total opacity score, the cutoff value associated with the risk of ICU hospitalization, need for mechanical ventilation, and death was more than 8 points.

Discussion Traditionally, viral pneumonia has been considered a disease that mainly affects the very young, the elderly, and those at risk of influenza. In the era of the COVID-19 pandemic, pneumonia caused by the SARS-CoV-2 virus has become a leading health problem worldwide. In the first stage of COVID-19, flu-like symptoms can develop, primarily from the viral infection itself. The second stage is characterized by pneumonia and coagulopathy, which may develop sequentially but which often overlap.[6] Increased levels of the inflammatory biomarkers such as C-reactive protein, ferritin, interleukin 6, interleukin 1, and D-dimer are associated with acute respiratory distress syndrome, which results in an unfavorable clinical course.[6] The third stage of the disease is characterized by fibrosis.[6] The clinical course of COVID-19 is unpredictable due to the diversity of symptoms.[8] Determining the prognostic factors of mortality using CT imaging in individuals with COVID-19 pneumonia may help to identify the most vulnerable patients and thus change their therapy,[9,10] including the form of oxygen therapy that needs to be administered.

The inflammatory changes in the course of COVID-19 are bilateral and diffuse.[11,12] To assess the extent of inflammatory infiltrates, we estimated the percentage of lung involvement and used semi-quantitative scales. The results showed that the degree of lung involvement was an independent predictor of hospitalization in the ICU, need for mechanical ventilation, and death. The cutoff value of more than 15 points in the chest CT score, as identified in our study, is noteworthy in terms of assessing the risk of death. By contrast, Francone et al[8] found a cutoff CT score of more than 18 points relative to the risk of death. The discrepancy between the results could be due to the fact that the studies were performed at different periods during the pandemic. Data analyzed by Francone et al[8] were collected early during the first wave of the pandemic in Italy, while we examined patients 6 months later, during the second wave. We believe that the virus already started mutating in the meantime. Of course, the differences in the obtained results are multifactorial. A cutoff

value of more than 32% for lung involvement in the inflammatory process predicts the unfavorable course of COVID-19 pneumonia. That is why identification of the prognostic factors is so important for further management.

Conclusions The degree of lung involvement in the inflammatory process that was evaluated using CT is an independent predictor of hospitalization in the ICU, need for mechanical ventilation, and death in patients with COVID-19.

ARTICLE INFORMATION

CONFLICT OF INTEREST None declared.

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