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Short Communication

Chest X-ray severity index as a predictor of in-hospital mortality in coronavirus disease 2019: A study of 302 patients from Italy

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ABSTRACT

Objectives: This study aimed to assess the usefulness of a new chest X-ray scoring system — the *Brixia* score — to predict the risk of in-hospital mortality in hospitalized patients with coronavirus disease 2019 (COVID-19).
Methods: Between March 4, 2020 and March 24, 2020, all CXR reports including the *Brixia* score were retrieved. We enrolled only hospitalized Caucasian patients with COVID-19 for whom the final outcome was available. For each patient, age, sex, underlying comorbidities, immunosuppressive therapies, and the CXR report containing the highest score were considered for analysis. These independent variables were analyzed using a multivariable logistic regression model to extract the predictive factors for in-hospital mortality.
Results: 302 Caucasian patients who were hospitalized for COVID-19 were enrolled. In the multivariable logistic regression model, only *Brixia* score, patient age, and conditions that induced immunosuppression were the significant predictive factors for in-hospital mortality. According to receiver operating characteristic curve analyses, the optimal cutoff values for *Brixia* score and patient age were 8 points and 71 years, respectively. Three different models that included the *Brixia* score showed excellent predictive power.
Conclusions: Patients with a high *Brixia* score and at least one other predictive factor had the highest risk of in-hospital death.

Introduction

Coronavirus disease 2019 (COVID-19), caused by a novel virus — the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) — has now become a pandemic. Currently, more than 200 countries, territories or areas are affected by this novel infectious disease (World Health Organization, 2020). On April 10, 2020, the overall number of confirmed COVID-19 cases was 1 521 252 worldwide, with a mortality rate of 6.1% (World Health Organization, 2020). Given the recent estimates of mortality rate for COVID-19 (Baud et al., 2020), clinicians should be aware of the risk factors associated with a fatal outcome. The literature reports that an older age, presence of underlying comorbidities (such as hypertension, diabetes, and cardiovascular disease), certain laboratory parameters, and severity of lung abnormalities are associated with an increased risk of mortality in patients with SARS-CoV-2 infection (Ruan et al., 2020; Wang et al., 2020; Yuan et al., 2020; Zhou et al., 2020). To improve the risk stratification for infected patients, we have introduced in clinical practice a new chest X-ray (CXR) scoring system for quantifying and monitoring the severity of lung abnormalities in patients with COVID-19 (Borghesi and Maroldi, 2020). This CXR scoring system (named the *Brixia* score) grades lung abnormalities due to COVID-19 on an 18-point severity scale (Borghesi and Maroldi, 2020). To the best of our knowledge, the predictive value of a CXR scoring system in patients with COVID-19 has not yet been studied. Therefore, this study aimed to investigate the usefulness of our CXR scoring system for predicting the risk of in-hospital mortality in patients with SARS-CoV-2 infection.

Materials and Methods

Through a retrospective search on the digital hospital archives between March 4, 2020 and March 24, 2020, all CXR reports including the new scoring system (the *Brixia* score) were retrieved.

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Table 1
Association between the final outcome and the selected independent variables.

Independent variables	Total (302)	Final outcome		*p*-Value*
		Recovery (237)	Death (65)	
Patient age, years	67.0 (57.0–77.0)	64.0 (54.0–73.3)	77.0 (70.5–81.0)	<0.0001
Patient sex				
Male	194 (64.2)	144 (47.7)	50 (16.6)	0.0162
Female	108 (35.8)	93 (30.8)	15 (5.0)	
Brixia score	8.0 (5.0–11.0)	7.0 (4.0–10.0)	11.0 (9–13.0)	<0.0001
Hypertension				
Yes	154 (51.0)	112 (37.1)	42 (13.9)	0.0133
No	148 (49.0)	125 (41.4)	23 (7.6)	
Cardiovascular disease				
Yes	126 (41.7)	84 (27.8)	42 (13.9)	<0.0001
No	176 (58.3)	153 (50.7)	23 (7.6)	
Diabetes				
Yes	38 (12.6)	25 (8.3)	13 (4.3)	0.0422
No	264 (87.4)	212 (70.2)	52 (17.2)	
Chronic obstructive/restrictive lung disease				
Yes	44 (14.6)	31 (10.3)	13 (4.3)	0.1620
No	258 (85.4)	206 (68.2)	52 (17.2)	
Oncological history within the past 5 years				
Yes	56 (18.5)	36 (11.9)	20 (6.6)	0.0043
No	246 (81.5)	201 (66.6)	45 (14.9)	
T/D inducing immunosupppresion				
Yes	98 (32.5)	62 (20.5)	36 (11.9)	<0.0001
No	204 (67.5)	175 (57.9)	29 (9.6)	

Data are presented as numbers (%) or medians (interquartile range); *p-values obtained by Mann–Whitney U test or chi-square test; T/D, therapy or disease.

We enrolled only hospitalized Caucasian patients with COVID-19 (confirmed by real-time polymerase chain reaction) for whom the final outcome (recovery or death) was available. Patients with incomplete information about the presence of underlying comorbidities and immunosuppressive therapies were excluded from the study. For each included patient, only the CXR report with the highest score was considered for analysis. Each frontal chest projection linked to these reports was independently reviewed by a thoracic radiologist (A.B.), with 15 years' experience of thoracic imaging, who reassigned the *Brixia* score. All chest X-rays were performed using portable digital radiography systems.

Notification of this retrospective study was presented to the Institutional Ethical Committee. Given the retrospective design of the study, the need for informed consent was waived.

To investigate significant differences between recovered and dead patients, we selected nine independent variables that were presumed to influence the final outcome (Table 1). These variables were analyzed using chi-square or Mann-Whitney U tests. The significant variables were subsequently included in a multivariable logistic regression model to extract the independent predictive factors for in-hospital mortality. In addition, the predictive power of the model was expressed as area under the curve. p-Values of <0.05 were considered statistically significant.

Results

We identified 302 Caucasian patients who were hospitalized for COVID-19 (Table 1). The relationships between the final outcome and the selected independent variables are summarized in Table 1. In the multivariable logistic regression model, only *Brixia* score, patient age, and conditions that induced immunosuppression were independent predictive factors for in-hospital mortality, and were therefore included in the predictive model (Table 2). With regard to immunosuppressive conditions, most patients had advanced renal failure (42%), hematological disorders (20%), or were treated with corticosteroids (18%).

According to receiver operating characteristic curve analyses, the optimal cutoff values for *Brixia* score and patient age were 8 points and 71 years, respectively. Three different models that included the *Brixia* score showed excellent predictive power (Figure 1).

Discussion

For our large study cohort, in-hospital mortality was 21.5%, and higher in men than in women. Multivariable analysis showed that only *Brixia* score, patient age, and immunosuppressive conditions were the risk factors strongly associated with in-hospital mortality.

In line with the findings of many authors, our study found that older age and severity of lung abnormalities were associated with poor prognosis in patients with COVID-19 (Ruan et al., 2020; Wang et al., 2020; Yuan et al., 2020; Zhou et al., 2020). In addition, as reported in another study (Zhou et al., 2020), our results did not confirm the predictive power of underlying comorbidities such as hypertension, cardiovascular disease, diabetes, chronic lung disease, and oncological history.

The currently available data on the impact of immunosuppressive status on mortality in COVID-19 are few, with a limited number of patients, and obtained almost exclusively from Asian patients (Minotti et al., 2020). In our large cohort of adult

Table 2
Multivariable logistic regression analysis.

Predictive factor	Coefficient	*p*-Value	Odds ratio	95% CI
Brixia score	0.283	<0.0001	1.327	1.200–1.472
Age	0.078	<0.0001	1.081	1.046–1.118
T/D inducing immunosupppresion	0.745	0.0278	2.106	1.085–4.087

T/D, therapy or disease; CI, confidence interval.

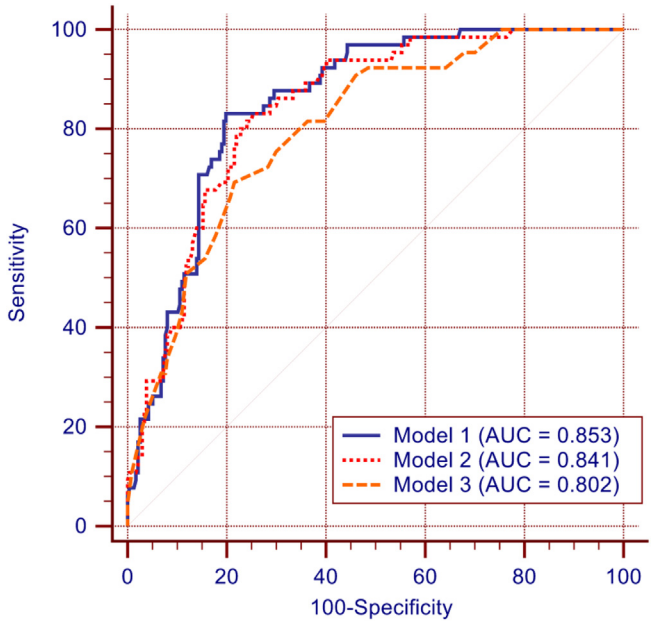

Figure 1. Comparison of receiver operating characteristic (ROC) curves generated using the three risk prediction models. Solid blue line (Model 1): ROC curve obtained using all three predictive factors. Dotted red line (Model 2): ROC curve obtained using *Brixia* score and patient age. Dashed orange line (Model 3): ROC curve obtained using *Brixia* score and immunosuppressive conditions.

Caucasian patients, we observed that immunosuppressive conditions significantly increased the risk of in-hospital mortality (Table 2). Therefore, we believe that our results will be of great importance and will help clinicians in determining appropriate clinical management by improving risk stratification in infected patients.

The major strength of this study is the large sample size, which comprised only Caucasian patients. Although several studies have investigated the role of CT score in patients with COVID-19 (Bernheim et al., 2020; Pan et al., 2020; Yuan et al., 2020), this is the first study to assess the effectiveness of a CXR scoring system for predicting in-hospital mortality in infected patients. The main limitations of this study include the retrospective study design and lack of laboratory parameters included in the predictive models (because these data were collected from a limited number of cases).

In conclusion, this study demonstrated for the first time that a high *Brixia* score and at least one other predictive factor — patient age and conditions that induced immunosuppression — conferred the highest risk of death due to COVID-19. This information may help clinicians with patient management and treatment planning, and would help them prepare for possible adverse outcomes.

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