


# The ROX index can be a useful tool for the triage evaluation of COVID-19 patients with dyspnoea

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## Abstract

**Aim:** To assess whether the application of a non-invasive tool, such as ratio of oxygen saturation (ROX) index, during triage can identify patients with COVID-19 at high risk of developing acute respiratory distress syndrome (ARDS).

**Design:** A multi-centre, observational, retrospective study.

**Methods:** Only COVID-19 positive patients who required an emergency department evaluation for dyspnoea were considered. The primary objective of the study was to compare the ROX value obtained during triage with the medical diagnosis of ARDS and intubation in 72 h of the triage evaluation. The ROX index value was also compared with objective outcomes, such as the pressure of arterial O<sub>2</sub> (PaO<sub>2</sub>)/fraction of inspired oxygen (FiO<sub>2</sub>) ratio and the lung parenchyma volume involved in COVID-19-related inflammatory processes, based on 3D reconstructions of chest computed tomography (CT).

**Results:** During the study period, from 20 March 2020 until 31 May 2020, a total of 273 patients with confirmed SARS-CoV-2 infection were enrolled. The predictive ability of ROX for the risk of developing ARDS in 72 h after triage evaluation was associated with an area under the receiver operating characteristic (AUROC) of 0.845 (0.797–0.892,  $p < 0.001$ ), whereas the AUROC value was 0.727 (0.634–0.821,  $p < 0.001$ ) for the risk of intubation. ROX values were strongly correlated with PaO<sub>2</sub>/FiO<sub>2</sub> values ( $r = 0.650$ ,  $p < 0.001$ ), decreased ROX values were associated with increased percentages of lung involvement based on 3D CT reconstruction ( $r = -0.371$ ,  $p < 0.001$ ).

**Conclusion:** The ROX index showed a good ability to identify triage patients at high evolutionary risk. Correlations with objective but more invasive indicators (PaO<sub>2</sub>/FiO<sub>2</sub> and CT) confirmed the important role of ROX in identifying COVID-19 patients with extensive pathological processes.

**Impact:** During the difficult triage evaluation of COVID-19 patients, the ROX index can help the nurse to identify the real severity of the patient. The triage systems could integrate the ROX in the rapid patient assessment to stratify patients more accurately.

## KEYWORDS

COVID-19, emergency department, emergency medicine, emergency nursing, nursing, pandemic, ROX, ROX index, SARS-CoV-2, triage

## 1 | INTRODUCTION

During the first phase of the coronavirus disease 2019 (COVID-19) pandemic, which occurred between February and April 2020 in Italy, emergency departments (EDs) were exposed to extraordinary pressures due to the continuous inflow of patients with symptoms that were potentially associated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection (Hartnett et al., 2020).

In addition to patients who presented with respiratory distress syndrome on ED arrival, patients infected with COVID-19 presented a wide range of symptoms, ranging from flu-like symptoms to signs of severe pulmonary involvement (Hartnett et al., 2020; Paules et al., 2020; Yuki et al., 2020). Moreover, a significant proportion of patients who presented to the ED with non-severe symptoms developed sudden, unexpected and apparently unpredictable worsening of symptoms in hours after ED admission, which often required rapid life-saving interventions (Chavez et al., 2020; Guo et al., 2020; Paules et al., 2020). Good pulmonary compliance, which was maintained even in cases with severe inflammatory pulmonary involvement, may have masked the true severity of many COVID-19 patients on ED arrival (Grasselli et al., 2020). These unexpected respiratory deteriorations, which often occurred in hours after ED arrival, highlighted the difficulties associated with the early identification of patients at high evolutionary risk (Kilaru et al., 2020; Somani et al., 2020).

Although some anamnestic, clinical and laboratory features have been recently proposed to support the prognostic evaluation of COVID-19 patients who present to the ED, no information is currently available for the risk stratification of COVID-19 patients according to their potential evolutionary risks (Du et al., 2020; Guan et al., 2019).

### 1.1 | Background

The triage evaluation of patients with respiratory or suspected infection symptoms is complex (Ausserhofer et al., 2020; Zaboli et al., 2020). Vital sign alterations (such as respiratory rate, oxygen saturation and temperature) that are recorded on ED admission do not always correlate with severe prognosis, and apparent conditions that suggest stable compensation may actually indicate very serious pulmonary involvement effectively compensated by large pulmonary functional reserves (Du et al., 2020). These challenges have been widely observed among COVID-19 patients, for whom the absence of solid predictive instruments has limited the role of triage (Gandhi et al., 2020; Manning, 2020).

To assess the progress or worsening of patients with pneumonia who were treated with a high-flow nasal cannula (HFNC), Roca et al.

for a non-delayed intubation introduced a simple clinical index, the ratio of oxygen saturation (ROX) index (Roca et al., 2016). The ROX index represents a ratio of oxygen saturation, measured as the ratio between pulse oximetry ( $SpO_2$ )/fraction of inspired oxygen ( $FiO_2$ ) and the respiratory rate, demonstrated the excellent ability to differentiate non-invasively ventilated patients (HFNC) who appeared well-compensated from those who would benefit from more invasive and earlier airway management strategies (Roca et al., 2016, 2019). Because patients with COVID-19 who appear to be paucisymptomatic may present advanced pulmonary involvement patterns, the introduction of a similar index during triage could improve the early detection of patients who appear uncompromised but are associated with high evolutionary risk (Du et al., 2020; Gandhi et al., 2020; Manning, 2020).

## 2 | THE STUDY

### 2.1 | Aim

The aim of this study was to compare the ROX values obtained in triage against the incidence of medical acute respiratory distress syndrome (ARDS) diagnosis and the risk of intubation in 72 h of triage evaluation. The predictive capacity of the ROX index was also analysed with regard to arterial blood gas (ABG) test values, and the percentage of pulmonary parenchyma involved in the COVID-19-related inflammatory process.

### 2.2 | Design

This study was performed as a retrospective, multi-centre, observational study, evaluating all patients who were consecutively assessed for SARS-CoV-2 infections and acute respiratory symptoms at three EDs in Northern Italy between 20 March 2020 and 31 May 2020. The departments involved included: the ED of the General Hospital of Merano (70,000 ED visits per year), the ED of the General Hospital of Bressanone (40,000 ED visits per year), and the ED of the General Hospital of Silandro (20,000 ED visits per year).

### 2.3 | Study protocol

Starting 20 March 2020, the three departments involved in this study began sharing a clinical protocol for the management of patients with suspected SARS-CoV-2 infections that required ED evaluations. All patients who were evaluated in the ED and complained of COVID-19-like symptoms (fever, cough, dyspnoea,

tachypnoea, shortness of breath, asthenia, diarrhoea, vomiting, conjunctivitis, anosmia) were admitted to the ED infected area, where triage evaluations and nasopharyngeal swabs were performed to confirm SARS-CoV-2 infection using polymerase chain reaction (PCR) tests.

Triage evaluated each patient's priority according to the Manchester Triage System (MTS) methodology, which has been adopted and standardized across all three departments since 2014.

During triage operations, all symptoms (symptom type, onset and duration) were recorded, and a detailed overall history of the primary comorbidities presented by each patient (ischemic heart disease, chronic heart failure, hypertension, diabetes, chronic obstructive pulmonary disease, chronic renal failure, stroke, and dementia) was collected. All vital signs were collected (heart rate, peripheral oxygen saturation, blood pressure, respiratory rate, and temperature), and general clinical conditions (altered mental state, reactivity and need for oxygen therapy) were evaluated. All patients underwent an ABG test (regardless of respiratory condition and, if possible, in room air). All data collected during this protocol were recorded in the patient's electronic record and were saved in the electronic database of the ED.

## 2.4 | Sample

The present study involved all patients who were consecutively evaluated for dyspnoea with confirmed SARS-CoV-2 infection during triage at all three EDs participating in this study. Dyspnoea was defined as: "a subjective experience of breathing discomfort that consist of a quality distinct sensation that varies in intensity and includes the physician's perception of laboured breathing and the patient's reaction to this sensation" and was marked on the patient chart at the time of triage (Parshall et al., 2012). The presence of at least one positive PCR swab for SARS-CoV-2 was used to confirm the presence of COVID-19 infection.

Patients under 18 years of age, pregnant patients, patients transferred from other hospitals, and those who arrived at the ED already intubated were excluded from the study.

## 2.5 | Data collection

All demographic, anamnestic, and clinical characteristics collected at the time of triage were recorded. In all patients, the ABG test was performed in accordance with the operating protocol, and all respiratory and metabolic function values were collected.

The ROX index was calculated, using the formula  $ROX = \frac{(SpO_2/FiO_2)}{RR}$ , for every patient based on the vital signs obtained at the time of triage (Roca et al., 2016, 2019).

The predictive ability of ROX was primarily assessed with regard to the risk of developing ARDS in 72 h after triage evaluation. ARDS was defined according to the Berlin criteria as the presence of bilateral pulmonary infiltration on pulmonary radiological examination (chest computed tomography [CT] or X-ray), the absence of heart

failure, and the presence of the partial pressure of  $O_2$  ( $PaO_2$ )/ $FiO_2$  index  $\leq 300$  (Ranieri et al., 2012; Roca et al., 2016).

The predictive capacity of the ROX index was also analysed with regard to the risk of orotracheal intubation (OTI) in 72 h of triage evaluation, ABG values (especially the  $PaO_2$ / $FiO_2$  value), and, for a subgroup of patients (Merano Hospital), the percentage of pulmonary parenchyma involved in the COVID-19-related inflammatory process, as calculated using the three-dimensional (3D) software reconstruction of chest CT. Pulmo3D software (Siemens Healthineers) was used to obtain the percentage of lung involved in the SARS-CoV-2 infection.

## 2.6 | Ethical consideration

The study was approved by the Local Ethics Committee (Comitato etico per la sperimentazione clinica, Azienda Sanitaria dell'Alto Adige, Bolzano, Italia, approval number 57-2020) and was conducted according to the Declaration of Helsinki regarding the Ethical Principles for Medical Research Involving Human Subjects.

## 2.7 | Data analysis

All continuous variables are expressed as the median and interquartile range, reporting the 25th and 75th percentile, whereas all categorical variables are reported as the number and percentage. Comparisons were made using the Mann-Whitney *U* test and the Kruskal-Wallis test or Fisher's exact test and the Chi-square test, as appropriate.

The predictive ability of the ROX index with regard to ARDS and OTI incidence was analysed according to the discriminatory ability obtained through the evaluation of the area under the receiver operating characteristic (AUROC). The associations between the ROX index and  $PaO_2$ / $FiO_2$  values and the percentage of the lung affected by the COVID-19 infection, as assessed by the 3D CT reconstruction, were evaluated by reporting Pearson's correlation coefficient (*r*).

Multivariate association between the risk of ARDS and the ROX index value, dichotomized by the median value, was evaluated through a logistic regression model adjusted for the demographic, anamnestic, and clinical characteristics that were recorded in triage and were previously identified as significantly associated with ARDS by univariate analysis. Associations are reported in terms of odds ratios (ORs) and 95% confidence intervals (95% CIs). To evaluate the ROX index as a continuous variable, an analysis model using generalized estimation equations (GEEs) for the correct diagnosis of ARDS and all anamnestic and clinical confounding factors was performed. Statistical analyses were performed using STATA 13.0 software (StataCorp).

## 2.8 | Validity and reliability

A manual review of the patient charts was conducted for each patient considered for the study. The lack of any data required for the

study in the patient charts has led to their exclusion. Other exclusion criteria included the lack of triage for any reason, the necessity of immediate airway management by the emergency physician due to symptom severity, the lack of complete adherence to the study protocol, the direct activation of the shock room by the physician of the extra-hospital service (resulting in the bypassing of triage), and the absence of ABG test results.

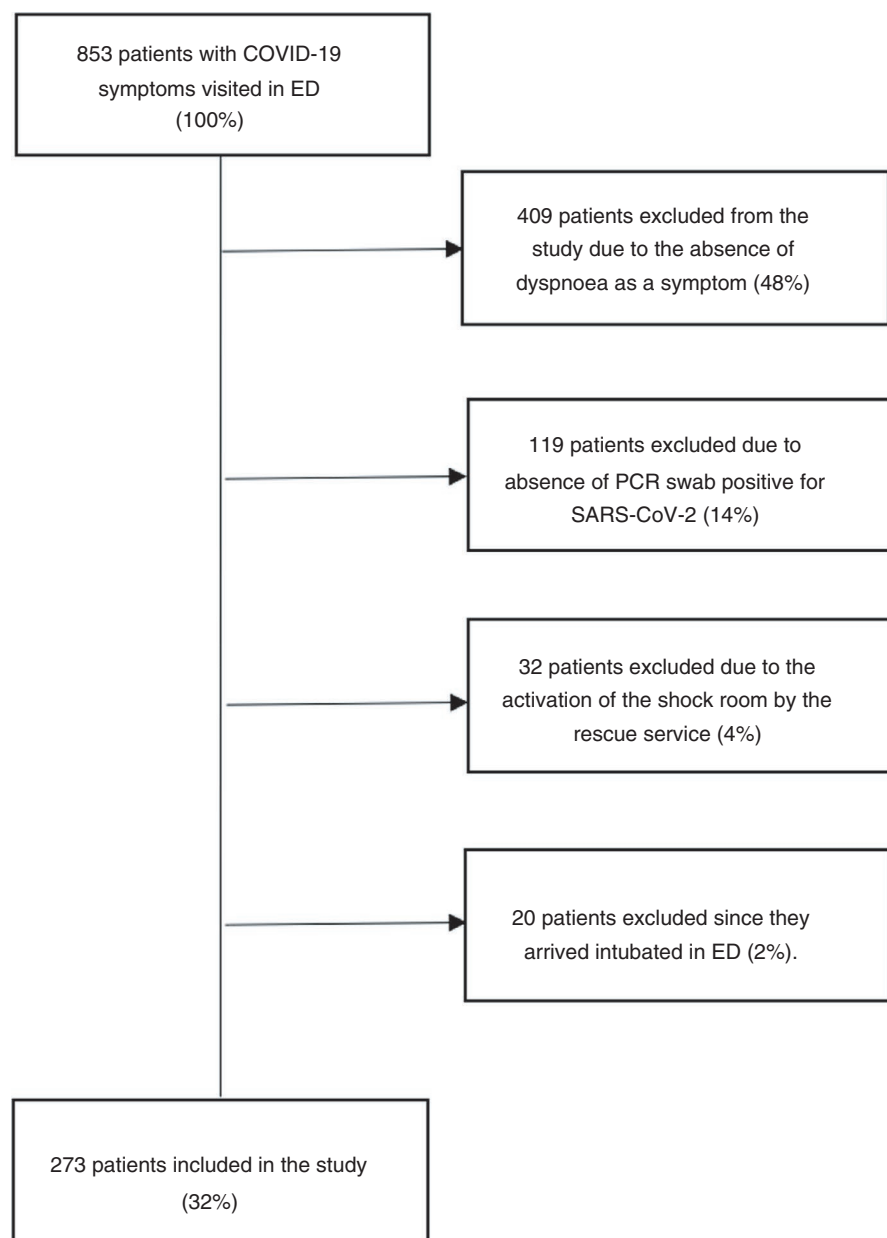
### 3 | RESULTS

#### 3.1 | Patients

A total of 273 patients with confirmed SARS-CoV-2 infections who were evaluated for dyspnoea were enrolled in this study; 580 patients were excluded (Figure 1).

The baseline characteristics of the study population at the time of triage evaluation are described in Table 1. A diagnosis of ARDS in 72 h after the triage evaluation occurred in 36.3% of patients (99/273), whereas 9.5% of patients (26/273) required intubation in 72 h after the triage evaluation.

Patients who developed ARDS were older, the majority were male, and presented comorbidities including chronic respiratory disease (22.2% vs. 9.8%,  $p = 0.007$ ), hypertension (73.7% vs. 58.0%,  $p = 0.013$ ), obesity (26.3% vs. 13.8%,  $p = 0.014$ ), and a previous episode of stroke (14.1% vs. 5.2%,  $p = 0.013$ ) compared to patients who did not develop ARDS. Patients who developed ARDS were associated with altered vital signs and higher quick sequential organ failure assessment scores than those that did not develop ARDS. After triage was performed using the MTS method, a higher severity code was assigned to patients who eventually developed ARDS than for those who did not ( $<0.001$ ).



**FIGURE 1** Flow-chart of patients enrolled in the study.

**TABLE 1** Patients characteristics according to the medical diagnosis of acute respiratory distress syndrome (ARDS) within 72 h of triage

Variables	Not ARDS	ARDS	<i>p</i>
Patients, <i>n</i> (%)	174 (63.7)	99 (36.3)	
Gender, <i>n</i> (%)			0.025 <sup>a</sup>
Male	104 (59.8)	73 (73.7)	
Female	70 (40.2)	26 (26.3)	
Age, median (IQR)	64 (53–79)	76 (67–83)	<0.001 <sup>a</sup>
Symptoms in ED, <i>n</i> (%)			
Fever	133 (76.4)	76 (76.8)	1.000 <sup>a</sup>
Cough	88 (50.6)	55 (55.6)	0.452 <sup>a</sup>
Dyspnea	74 (42.5)	64 (64.6)	0.001 <sup>a</sup>
Gastroenterological	18 (10.3)	5 (5.1)	0.174 <sup>a</sup>
Cognitive deterioration	12 (6.9)	28 (28.3)	<0.001 <sup>a</sup>
Respiratory difficulties	37 (21.3)	61 (61.6)	<0.001 <sup>a</sup>
Triage priority level, <i>n</i> (%)			<0.001 <sup>b</sup>
Red-Orange	40 (23.0)	58 (58.6)	
Yellow	58 (33.3)	29 (29.3)	
Blue-Green	76 (40.7)	12 (12.1)	
Previous clinical history, <i>n</i> (%)			
Chronic obstructive pulmonary disease	17 (9.8)	22 (22.2)	0.007 <sup>a</sup>
Ischemic heart disease	17 (9.8)	9 (9.1)	1.000 <sup>a</sup>
Kidney disease	15 (8.6)	15 (15.2)	0.110 <sup>a</sup>
Chronic heart failure	20 (11.5)	14 (14.1)	0.569 <sup>a</sup>
Stroke	9 (5.2)	14 (14.1)	0.013 <sup>a</sup>
Hypertension	101 (58.0)	73 (73.7)	0.013 <sup>a</sup>
Obesity	24 (13.8)	26 (26.3)	0.014 <sup>a</sup>
Diabetes	19 (10.9)	16 (16.2)	0.259 <sup>a</sup>
Cancer	9 (5.2)	8 (8.2)	0.435 <sup>a</sup>
Vital signs, median (IQR)			
Hazard ratio (bpm)	84 (72–99)	90 (77–105)	0.013 <sup>c</sup>
Oxygen saturation (%)	95 (93–97)	90 (86–93)	<0.001 <sup>c</sup>
RR (breaths per minute)	18 (16–22)	25 (20–30)	<0.001 <sup>c</sup>
Systolic BP (mmHg)	130 (120–144)	138 (120–150)	0.176 <sup>c</sup>
Temperature (°C)	37.2 (36.3–38.0)	37.1 (36.4–38.2)	0.562 <sup>c</sup>
qSOFA, <i>n</i> (%)			
≥1	54 (31.0)	68 (68.7)	<0.001 <sup>a</sup>
≥2	7 (4.0)	27 (27.3)	<0.001 <sup>a</sup>
Orotracheal intubation, <i>n</i> (%)	7 (4.0)	19 (19.2)	<0.001 <sup>a</sup>

<sup>a</sup>Fisher's exact test;; <sup>b</sup>Chi-square test;; <sup>c</sup>Mann–Whitney *U* test.

### 3.2 | ROX value

The median (IQR) ROX value recorded at the time of triage evaluation was 21.4 (13.6–27.9). The distributions of the characteristics recorded at the time of triage, according to ROX values, are reported in Table 2.

Patients diagnosed with ARDS had a median ROX value at triage of 13.1 (7.7–19.4), whereas patients without ARDS had a median ROX value of 25.2 (19.2–29.2,  $p < 0.001$ ). A ROX value lower than the median (21.4) at triage was identified in 79.8% (79/99) of patients who were subsequently diagnosed with ARDS (OR: 3979, 95% CI: 2590–6113). The risk of ARDS increases as ROX values decrease, with almost two-thirds of patients who received subsequent diagnoses of ARDS associated with the lower tertile (<16.2).

In patients who required intubation in 72 h of triage, the median ROX value was 15.3 (8.4–18.2), whereas, in non-intubated patients, the median ROX value was 22.2 (14.2–28.1,  $p < 0.001$ ). Among patients intubated in 72 h of triage, 84.6% (22/26) had ROX values were recorded in triage lower than the group median (21.4,  $p < 0.001$ ).

### 3.3 | Performance of ROX

In all patients, an ABG test was performed immediately after triage. ROX values presented a moderately positive correlation with PaO<sub>2</sub>/FiO<sub>2</sub> values ( $r = 0.650$ ,  $p < 0.001$ ), indicating that low ROX values at triage were associated with low PaO<sub>2</sub>/FiO<sub>2</sub> values found using invasive ABG tests. The predictive ability of the ROX index with regard to the risk of developing ARDS in 72 h after triage evaluation resulted in an AUROC value of 0.845 (0.797–0.892,  $p < 0.001$ ; Figure 2) whereas the AUROC value was 0.727 (0.634–0.821,  $p < 0.001$ ) for the risk of intubation (Figure 3).

The logistic regression model revealed that a ROX value lower than the median recorded during triage was an independent risk factor for the ARDS development, with an adjusted OR for clinical confounders of 4,442 (95% CI: 2224–8873,  $p < 0.001$ ). The GEE model found that each one-point decrease in the ROX index value (expressed continuously) was an independent risk factor for ARDS, with an adjusted OR of 1,184 (95% CI: 1121–1249).

### 3.4 | ROX and CT volumetry

In 71 patients, the percentage of pulmonary involvement associated with COVID-19 was assessed by 3D software reconstruction using ED chest CT data. The median percentage of the lungs that were compromised in patients diagnosed with ARDS was 19.6% (13.9%–37.3%), whereas in patients without an ARDS diagnosis, this percentage was 10.9% (5.4%–19.2%,  $p = 0.003$ ). A decrease in the ROX value recorded at the time of triage was associated with a moderate increase in the percentage of lung involvement ( $r = -0.371$ ,  $p < 0.001$ ).

## 4 | DISCUSSION

The present study examined a cohort of 273 patients with confirmed SARS-CoV-2 infections who presented to the ED for dyspnoea and

Variables	ROX < 16.2	>16.2 ROX < 25.4	ROX > 25.4	p
Patients, n (%)	90 (33.0)	92 (33.7)	91 (33.3)	
Gender, n (%)				0.015 <sup>a</sup>
Male	66 (73.3)	60 (65.2)	51 (56.0)	
Female	24 (26.7)	32 (34.8)	40 (44.0)	
Age, median (IQR)	77 (65–84)	70 (55–81)	62 (51–75)	<0.001 <sup>b</sup>
Previous clinical history, n (%)				
Chronic obstructive pulmonary disease	21 (23.3)	8 (8.7)	10 (11.0)	0.018 <sup>a</sup>
Ischemic heart disease	12 (13.3)	8 (8.7)	6 (6.6)	0.123 <sup>a</sup>
Kidney disease	14 (15.6)	7 (7.6)	9 (9.9)	0.225 <sup>a</sup>
Chronic heart failure	14 (15.6)	9 (9.8)	11 (12.1)	0.483 <sup>a</sup>
Stroke	10 (11.1)	9 (9.8)	4 (4.4)	0.104 <sup>a</sup>
Hypertension	65 (72.2)	55 (59.8)	54 (59.3)	0.073 <sup>a</sup>
Obesity	22 (24.4)	16 (17.4)	12 (13.2)	0.050 <sup>a</sup>
Diabetes	11 (12.2)	13 (14.1)	11 (12.1)	0.977 <sup>a</sup>
Vital parameter, median (IQR)				
Oxygen saturation (%)	88 (83–92)	94 (92–95)	96 (95–98)	<0.001 <sup>b</sup>
Fraction of inspired oxygen (%)	0.28 (0.21–0.50)	0.21 (0.21–0.21)	0.21 (0.21–0.21)	<0.001 <sup>b</sup>
RR (breaths per minute)	30 (26–32)	20 (18–23)	16 (15–18)	<0.001 <sup>b</sup>
Emogas analysis				
PaO <sub>2</sub> (mmHg)	62.8 (52.1–80.0)	68.5 (60.3–80.4)	72.1 (64.2–81.7)	0.009 <sup>b</sup>
PaCO <sub>2</sub> (mmHg)	32.7 (28.1–38.2)	33.0 (28.0–37.8)	34.0 (30.1–37.4)	0.841 <sup>b</sup>
Bicarbonate (mEq/L)	23.6 (21.7–25.3)	24.7 (22.4–26.6)	24.6 (23.3–26.3)	0.034 <sup>b</sup>
Lactate (mmol/L)	1.4 (1.0–1.8)	1.1 (0.9–1.4)	1.1 (0.8–1.3)	0.002 <sup>b</sup>
qSOFA ≥ 2 points, n (%)	26 (28.9)	6 (6.5)	2 (2.2)	<0.001 <sup>a</sup>
ARDS, n (%)	65 (72.2)	25 (27.2)	9 (9.9)	<0.001 <sup>a</sup>
Orotracheal intubation, n (%)	14 (15.6)	10 (10.9)	2 (2.2)	0.002 <sup>a</sup>

<sup>a</sup>Chi-square test;; <sup>b</sup>Kruskal–Wallis test.

**TABLE 2** Clinical, anamnestic, and demographic characteristics, according to ratio of oxygen saturation (ROX) tertiles

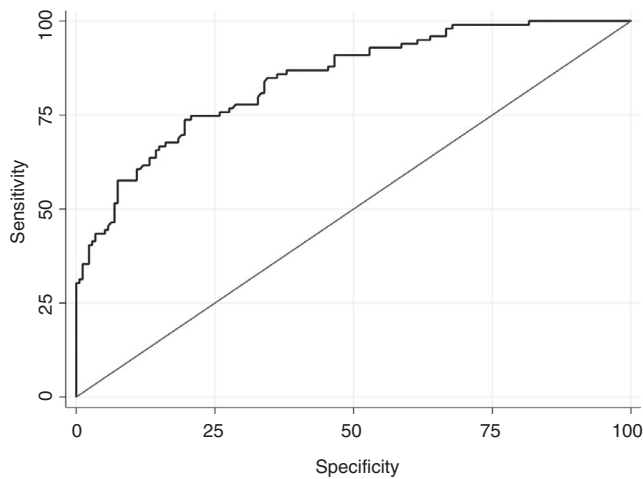
revealed that assessing the ROX index at triage could improve the assessment of COVID-19 patients at risk of developing ARDS.

Acute respiratory distress syndrome is the most severe complication associated with SARS-CoV-2 infection. Among symptomatic patients with COVID-19, 15% developed severe respiratory disease and 5% developed a severe illness (Weiss & Murdoch, 2020). High mortality rates are related to ARDS and COVID-19, among both the multi-pathological elderly population and the younger ventilated population (Camporota et al., 2020; Weiss & Murdoch, 2020). Some distinctive characteristics have been highlighted for COVID-19 ARDS compared with other forms of ARDS (Camporota et al., 2020; Gattinoni et al., 2020; Grasselli et al., 2020; Li & Ma, 2020), including the maintenance of good pulmonary compliance, even when significant pulmonary involvement might explain the apparent clinical compensation observed at first ED contact in patients who later presented with rapid and unexpected respiratory failure (Camporota et al., 2020; Gattinoni et al., 2020; Grasselli et al., 2020; Weiss &

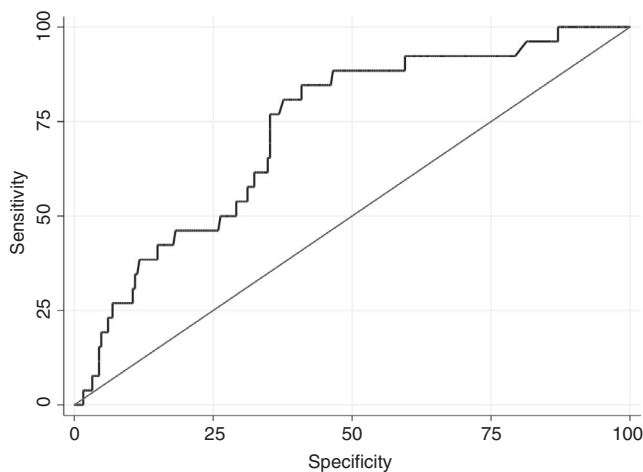
Murdoch, 2020). The invasive assessment of these patients on ED arrival was able to confirm the presence of extensive pulmonary involvement (chest CT) or gas exchange deregulation (PaO<sub>2</sub>/FiO<sub>2</sub>), despite the lack of clear clinical signs of respiratory distress (Colombi et al., 2020; Salinas et al., 2020). The evolutionary risk assessment on first medical contact in the ED among COVID-19 patients who do not present clear signs of respiratory failure can be extremely complex.

In this complicated situation, the ROX index appears to be an implementable tool for triage practice. The ROX index is non-invasive, fast, easily reproducible, and appears to be suitable for the rapid assessment of evolutionary risk for COVID-19 patients with dyspnoea during triage. Roca et al. demonstrated that the ROX index could be a useful predictive tool for preventing intubation delays among patients with pneumonia who, despite HFNC therapy and apparent compensation, experienced severe respiratory failure (Roca et al., 2016, 2019). According to their study, an





**FIGURE 2** Receiver operating characteristic (ROC) curve of the ratio of oxygen saturation (ROX) value relative to the risk of medical diagnosis of acute respiratory distress syndrome in 72 h



**FIGURE 3** Receiver operating characteristic (ROC) curve of the ratio of oxygen saturation (ROX) value relative to the risk of intubation in 72 h

AUROC of 0.87 was observed for the risk of ventilation failure with HFNC, and a ROX value greater than 4.88 was associated with a reduced risk of invasive mechanical ventilation (Roca et al., 2016). In the study by Roca et al., the ROX index was used over the hours to detect patients at risk of sudden respiratory deterioration in a population who appeared to be manageable with HFNC (Roca et al., 2016). Similarly, the present study attempted to evaluate a population of COVID-19 patients who were admitted to the ED without evidence of respiratory distress to determine whether ROX values could identify those at higher evolutionary risk. The ROX values presented by Roca et al. appeared to be significantly lower than those found in this study, which is likely due to the high  $\text{FiO}_2$  levels associated with HFNC. Panadero et al. also suggested that even among COVID-19 patients undergoing HFNC, ROX index values below 4.94 were associated with increased risk of intubation (Panadero et al., 2020). Although the decision to perform intubation was based on medical decisions, and the ROX index was

retrospectively reassessed, the results reported by Panadero et al. appear to confirm the usefulness of the index and the potential to make correct prognostic decisions based on the ROX index values (Panadero et al., 2020). Winearls et al. used the ROX index to evaluate the clinical performance of pronated patients treated with continuous positive airway pressure, suggesting that ROX index evaluations could serve as a target for effective ventilation (Winearls et al., 2020).

In an ED setting, more similar to the present study, Lee et al. applied the ROX index to the evaluation of septic patients (Lee et al., 2020). Although the ROX index did not present globally exciting predictive abilities (AUROC: 0.641), ROX values that were recorded below 10 during triage were independent risk factors for 28-days mortality (hazard ratio [HR]: 1.41, 95% CI: 1.13–1.76; Lee et al., 2020).

The current study presents some additional details regarding the effectiveness of the ROX index. Although previous studies compared the ROX index with intubation, which is an outcome that sometimes can also depend from clinical practice, in this study the ROX was evaluated in comparison with relatively objective criteria, including the development of ARDS in 72 h of triage and the presence of pulmonary impairment (Panadero et al., 2020; Roca et al., 2016; Winearls et al., 2020). The 3D reconstruction of pulmonary CT scans has been proposed to be able to provide accurate information regarding the extent of the ongoing inflammatory processes in COVID-19 patients (Colombi et al., 2020). Although chest CT can be predictive for short-term mortality risk, the extensive use of chest CT in all COVID-19 patients is not currently recommended (Colombi et al., 2020). ABG data, which is more accessible than chest CT in clinical practice, demonstrated a strong correlation with the severity of the inflammatory process as estimated by 3D CT reconstruction, and low  $\text{PaO}_2/\text{FiO}_2$  values were identified in cases of extensive parenchymal involvement during COVID-19-related inflammatory processes and were associated with severe outcomes (Turcato, Panebianco, et al., 2020). Therefore, the simple and immediately assessable ROX index, which has been associated with both CT volumetry and ABG values, can serve as a non-invasive surrogate to improve prognostic definition and optimize the stratification of evolutionary risk as early as triage. This indicates that patients with a ROX value of less than 21.4 in triage are at high risk of being diagnosed with ARDS and at high risk of intubation.

Even during this pandemic, the role of triage has been central to the effective management of ED patients. The early detection of patients at high evolutionary risk is essential to improving the outcomes of time-dependent diseases and to effectively organize limited resources by focusing them on the most severe patients (Camporota et al., 2020). To perform these functions optimally, triage should implement tools that are accurate, reproducible, and rapidly executed.

#### 4.1 | Limitations

The present study has some limitations. First, the size of the cohort appears to be limited for several reasons: (1) the study period was

delayed relative to the beginning of the pandemic in Italy (February 2020); (2) we observed the potential effects of the imposed lockdown on virus diffusion; (3) the available PCR swabs during the first phase of the pandemic had low sensitivity; (4) the triage-out performed on patients without any parametric alterations (Turcato et al., 2020). Second, the study inclusion and exclusion criteria may have limited the sample. However, these criteria allowed this study to focus on a population that was less immediately critical but associated with a high evolutionary risk, for which a specific tool would provide benefit for the entire organization. Third, the decision to use the 72-h time frame was made arbitrarily. A longer time frame could limit the influence of triage on the outcome.

## 5 | CONCLUSIONS

The ROX index, when applied to patients infected with SARS-CoV-2, revealed a good ability to identify patients at higher evolutionary risk as early as triage. The correlations between the ROX index values and objective but more invasive indicators (ABG and CT) confirmed the potentially important role for the ROX index in the identification of patients with more extensive pathological processes. Further studies remain necessary to confirm the implementation of the ROX index during the initial evaluation of the patient on ED arrival; however, the non-invasiveness nature of the ROX index, its ease of use, and its good predictive ability for identifying patients at risk of ARDS appear to suggest a potential role for this tool during crucial triage evaluations.

## CONFLICT OF INTEREST

There is no conflict of interests.

## PEER REVIEW

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## DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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