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Original Article

SUPER Score Contributes to Warning and Management in Early-Stage COVID-19

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ABSTRACT

Background: Some COVID-19 patients deteriorate to severe cases with relatively higher case-fatality rates, which increases the medical burden. This necessitates identification of patients at risk of severe disease. Early assessment plays a crucial role in identifying patients at risk of severe disease. This study is to assess the effectiveness of SUPER score as a predictor of severe COVID-19 cases.

Methods: We consecutively enrolled COVID-19 patients admitted to a comprehensive medical center in Wuhan, China, and recorded clinical characteristics and laboratory indexes. The SUPER score was calculated using parameters including oxygen saturation, urine volume, pulse, emotional state, and respiratory rate. In addition, the area under the receiver operating characteristic curve (AUC), specificity, and sensitivity of the SUPER score for the diagnosis of severe COVID-19 were calculated and compared with the National Early Warning Score 2 (NEWS2).

Results: The SUPER score at admission, with a threshold of 4, exhibited good predictive performance for early identification of severe COVID-19 cases, yielding an AUC of 0.985 (95% confidence interval [CI] 0.897–1.000), sensitivity of 1.00 (95% CI 0.715–1.000), and specificity of 0.92 (95% CI 0.775–0.982), similar to NEWS2 (AUC 0.984; 95% CI 0.895–1.000, sensitivity 0.91; 95% CI 0.587–0.998, specificity 0.97; 95% CI 0.858–0.999). Compared with patients with a SUPER score<4, patients in the high-risk group exhibited lower lymphocyte counts, interleukin-2, interleukin-4 and higher fibrinogen, C-reactive protein, aspartate aminotransferase, and lactate dehydrogenase levels.

Conclusions: In conclusion, the SUPER score demonstrated equivalent accuracy to the NEWS2 score in predicting severe COVID-19. Its application in prognostic assessment therefore offers an effective early warning system for critical management and facilitating efficient allocation of health resources.

Abbreviations: ABG, arterial blood gas; AHF, acute heart failure; APTT, activated partial thromboplastin time; ALT, alanine aminotransferase; AST, aspartate aminotransferase; AUC, area under the receiver operating characteristic curve; BUN, blood urea nitrogen; COVID-19, Coronavirus disease 2019; CRP, C-reactive protein; CHA2DS2-VASc Scores, tool based on congestive heart failure, hypertension, age above 75 years, diabetes and prior stroke, age above 65, female sex and vascular disease.; CURB-65, tool based on confusion, urea level, respiratory rate, blood pressure, and age >or =65 years.; ECG, electrocardiogram; HEWS, Hamilton Early Warning Score; HFNC, high-flow nasal cannula; hs-CRP, high-sensitivity C-reactive protein; hs-TnI, hypersensitive troponin I; IL-4, interleukin-4; IPPV, intermittent positive pressure ventilation; LDH, lactate dehydrogenase; +LR, positive likelihood ratio; −LR, negative likelihood ratio; NEWS, National Early Warning Score; NEWS2, National Early Warning Score 2; NHS, National Health Service; NIPPV, non-invasive positive pressure ventilation; NPV, negative predictive value; PPV, positive predictive value; qSOFA, quick Sequential Organ Failure Assessment; ROC, receiver operating characteristic; ROX index, the ratio of SpO_2/FiO_2 (%) to Respiratory Rate (breaths/min); SD, standard deviation; SEWS, Standardized Early Warning Score; SpO_2, oxygen saturation; SMART-COP, tool based on systolic blood pressure, multilobar chest radiography involvement, albumin level, respiratory rate, tachycardia, confusion, oxygenation, and arterial pH; WHO, World Health Organization.

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1. Introduction

Coronavirus disease 2019 (COVID-19), caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was declared a pandemic by the World Health Organization (WHO) in March 2020. The number of confirmed COVID-19 cases rapidly increased owing to viral mutation and changes in pathogenicity, as well as variable epidemic prevention policies in different countries. By the end of July 2023, there had been approximately 768 million confirmed COVID-19 cases and more than 6.95 million deaths globally [1].

In May 2023, the WHO removed the Public Health Emergency of International Concern status of COVID-19, but COVID-19 still has a profound impact on public health and the medical system. Although most COVID-19 patients are classified as mild cases, approximately 15% of patients deteriorate to severe cases and have relatively higher case-fatality rates [2–4]. There is, therefore, an urgent need for innovative methods to predict COVID-19 deterioration.

Early assessment of disease severity is of vital importance for efficient triage, successful treatment, and optimal utilization of medical resources. The National Early Warning Score 2 (NEWS2) improves the assessment of acute-illness severity of patients in hospital and pre-hospital settings and is widely recommended by the WHO to assess the severity and predict prognosis of patients with COVID-19 [5]. However, the large increase in COVID-19 case complicates the practical application of the NEWS2 score. A simple scoring system that facilitates the prediction of serious disease by medical staff and even family members is required, especially when medical resources are limited.

The SUPER score, an early warning scoring system first developed in 2015 to identify patients at higher risk of acute heart failure (AHF) [6], involves comprehensive analysis of oxygen saturation (SpO_2), urine volume, pulse, emotional state, and respiratory rate (Table 1). Patients are stratified into low-, intermediate-, high-, and very high-risk groups, and patients with higher SUPER scores are at higher risk of AHF and mortality. The SUPER score has proven efficacy for AHF detection and can predict AHF 2 to 6 hours prior to onset, thereby enabling early risk stratification, prevention, and efficient intervention. Due to its demonstrated efficacy and feasibility, the SUPER score was recommended by the Chinese Guidelines on Nursing Practice of Acute Heart Failure in Adults in 2016 and the Consensus on Acute Chest Pain Emergency Management and Chinese Consensus on Construction and Management of Acute Heart Failure Unit in 2019.

As the SUPER score has demonstrated satisfactory performance in the assessment of AHF, which is closely related to pulmonary edema and effusion pathology, it is a candidate for a novel scoring system for COVID-19 evaluation. We aimed to evaluate the performance of the SUPER score as a predictor of severe COVID-19 cases to provide a novel tool for early warning and management of COVID-19.

2. Materials and methods

2.1. Patient selection and data collection

In this prospective study, we consecutively enrolled COVID-19 patients admitted to a comprehensive medical center in Wuhan, China, from 30 January to 2 March 2020. All patients over 18 years of age with confirmed COVID-19 were included. COVID-19 was confirmed by polymerase chain reaction detection of SARS-CoV-2 in throat or nasopharyngeal swabs.

Based on previous studies on prediction of COVID-19 severity [7,8], we set the estimated diagnostic test sensitivity and specificity at 80%, allowing for an error of 0.1, $\alpha = 0.05$ for bilateral testing, and a loss to follow-up rate of 0%. The estimated sample size was determined as 44 patients.

We recorded clinical characteristics and laboratory indexes, including age, sex, time from onset to hospitalization, comorbidities, temperature at admission, inflammatory factors (interleukins, tumor necrosis factor alpha, and interferon alpha), white blood cell count and differentials, platelet count, erythrocyte and hemoglobin levels, activated partial thromboplastin time, fibrinogen, transaminases, blood urea nitrogen, creatine, lactate dehydrogenase (LDH), myoglobin, and hypersensitive troponin I levels. Laboratory indexes were obtained from the first examination after hospitalization. All data were documented in electronic medical records. We recorded SpO_2, hourly urine volume, pulse, emotional state, and respiratory rate at admission to calculate the SUPER score. SpO2, respiratory rate, pulse, air or oxygen, systolic blood pressure, consciousness, and temperature recorded at admission were used to calculate the NEWS2 score. The

Table 1
The SUPER scoring system.

Points	SpO_2 (%)	Urine volume (mL/h)	Pulse (bpm)	Emotion	Respiratory (times/min)
0	99–100	>50	<90	0	<20
1	95–98	30–50	90–140	-/–	20–30
2	<95	<30	>140	+	>30

For patients without urethral catheterization, the urine volume was the mean value for normal urination over 24 hours. Emotion was indicated by restlessness, excitement, agitation or overstimulation, delirium (+), normal or sedation state (0), depression, apathy, unresponsive, lethargy (-), drowsiness, coma (–).

Table 2
Characteristics of patients hospitalized for COVID-19 and stratified by SUPER scores.

Variables	SUPER score < 4 (*N* = 33)	SUPER score ≥ 4 (*N* = 14)	*P* value
Age (years)	70 (58.5, 80)	66 (53.75, 69.25)	0.08
Male	19/33	10/14	0.37
Hypertension	13/33	4/14	0.48
Severe cases	0/33	11/14	<0.001
Temperature (°C)	37.56 ± 0.98	38.43 ± 1.22	0.01
SpO_2 (%)	97.00 (94.00, 98.00)	94.50 (88.75, 96.75)	0.10
Leukocytes (×10^9/L)	5.58 ± 2.24	4.87 ± 2.13	0.32
Neutrophils (×10^9/L)	3.34 (1.91, 5.18)	3.30 (2.29, 4.49)	0.96
Lymphocytes (×10^9/L)	1.00 (0.73, 1.51)	0.71 (0.55, 1.02)	0.02
Hemoglobin (g/L)	121.03 ± 17.52	123.07 ± 20.54	0.73
APTT (s)	27.82 ± 3.24	29.22 ± 3.64	0.20
Fibrinogen (g/L)	4.31 (2.63, 4.90)	5.24 (4.28, 5.98)	0.02
D-dimer (mg/L)	1.20 (0.60, 2.18)	1.51 (0.39, 7.17)	0.45
ALT (U/L)	30.00 (14.50, 39.00)	33.00 (17.75, 72.00)	0.27
AST (U/L)	27.00 (18.50, 33.50)	43.50 (36.00, 60.50)	0.004
BUN (mmol/L)	5.22 (4.11, 7.68)	4.97 (3.32, 7.06)	0.40
Creatine(umol/L)	65.00 (54.00, 76.00)	68.50 (57.25, 79.50)	0.58
LDH (U/L)	242 (214.00, 325.50)	407 (239.25, 540.50)	0.03
CK-MB (ng/mL)	0.99 (0.76, 1.65)	1.13 (0.72, 2.20)	0.79
Myoglobin (ug/L)	44.77 (35.42, 88.65)	47.72 (28.44, 96.11)	0.09
hs-cTnI (mg/mL)	0.00 (0.00, 0.02)	0.01 (0.00, 0.03)	0.60
IL-2 (pg/mL)	3.61 (3.40, 4.00) (N = 23)	3.17 (2.87, 3.81) (N = 13)	0.03
IL-4 (pg/mL)	3.44 (2.99, 3.85) (N = 23)	2.96 (2.71, 3.21) (N = 13)	0.004
TNF-α (pg/mL)	3.28 (2.61, 4.78) (N = 23)	3.47 (2.77, 5.08) (N = 13)	0.43
IFN-α (pg/mL)	3.01 (2.86, 3.56) (N = 23)	3.14 (2.61, 3.51) (N = 13)	0.70
CRP (mg/L)	25.30 (5.00, 51.85)	69.35 (26.00, 144.43)	0.01
hs-CRP (mg/L)	5.00 (1.59, 5.00)	5.00 (5.00, 5.00)	0.09

Data are represented as mean ± SD. SD, standard deviation; N, number; SpO_2, oxygen saturation; APTT, activated partial thromboplastin time; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; LDH, lactate dehydrogenase; CK-MB, creatine kinase-MB; hs-cTnI, high-sensitivity cardiac troponins I; IL-2, interleukin-2; IL-4: interleukin-4; TNF-α, tumor necrosis factor-alpha; IFN-α, type I interferon; CRP, C-reactive protein; hs-CRP, high-sensitivity C-reactive protein

study was approved by the ethics committee with waived informed consent (KYLL-2020-016).

Severe cases of COVID-19 were defined as patients who met at least one of the following criteria: (1) manifesting with dyspnea with respiratory rates ≥ 30 times per minute; (2) percutaneous $SpO_2 \leq 93\%$ on room air; (3) oxygenation index (PaO_2/FiO_2) ≤ 300 mm Hg.

2.2. Statistical analyses

Quantitative data with normal distribution were represented as means with standard deviation and analyzed using the Student's t test. Non normal distribution variables are represented by the median with an interquartile range [Q1–Q3] using Mann Whitney U independent sample rank test. Categorical data were represented as frequencies (percentage) and compared using the χ^2 or Fisher's exact test. A 2-tailed p value < 0.05 was considered statistically significant. Receiver operating characteristic (ROC) curves and the area under the ROC curve (AUC) were used to access the prognostic performance of the SUPER score in terms of sensitivity, specificity, and positive (+LR) and negative (−LR) likelihood ratios. The optimal threshold was determined using the Youden index. The sensitivity and specificity of the SUPER and NEWS2 scores were compared using the McNemar's test. AUC values were compared according to the method described by DeLong et al. (1988) [9]. Statistical analyses were performed with SPSS 25.0 and MedCalc 20.2.

3. Results

3.1. Baseline patient characteristics

We consecutively enrolled 47 patients who were hospitalized for COVID-19 during the study period. All the included patients were diagnosed with COVID-19 for the first time. At the time of admission, most of the cases (44/47, 93.62%) were non-severe and the patients did not require respiratory support. The baseline characteristics of the patients are summarized in Table 2. Twenty-nine (61.70%) patients were male. The median (interquartile range) age was 69 (55–74) years. The median (interquartile range) interval from symptom onset to hospital admission was 10 (8–15) days. The most common comorbidities were hypertension (17 patients), diabetes mellitus (7 patients), and coronary artery disease (6 patients). Eleven patients were diagnosed with severe COVID-19 during hospitalization, and no death was reported.

3.2. AUC, sensitivity, and specificity for predicting severe COVID-19 cases

The Youden index indicated a cut-off for optimal sensitivity and specificity for the NEWS2 score of 6 with sensitivity of 0.91 (95% CI 0.587–0.998) and specificity of 0.97 (95% CI 0.858–0.999). The positive predictive value (PPV) and negative predictive value (NPV) of the NEWS2 score were 0.91 and 0.97, respectively. The SUPER scores

Table 3
Sensitivity, specificity, positive and negative predictive values, and Youden index for the NEWS2 and SUPER scores at different cut-offs for severe COVID-19 cases.

NEWS2						SUPER score					
Cut point	Sensitivity	Specificity	PPV	NPV	Youden index	Cut point	Sensitivity	Specificity	PPV	NPV	Youden index
≥0	1.00	0.00	0.23	–	0.00	≥0	1.00	0.00	0.23	–	0.00
≥1	1.00	0.17	0.27	1.00	0.17	≥1	1.00	0.03	0.24	1.00	0.03
≥2	1.00	0.28	0.30	1.00	0.28	≥2	1.00	0.25	0.29	1.00	0.25
≥3	1.00	0.56	0.41	1.00	0.56	≥3	1.00	0.56	0.41	1.00	0.56
≥4	1.00	0.69	0.50	1.00	0.69	≥4	1.00	0.92	0.79	1.00	0.92
≥5	1.00	0.78	0.58	1.00	0.78	≥5	0.64	1.00	1.00	0.90	0.64
≥6	0.91	0.97	0.91	0.97	0.88	≥6	0.45	1.00	1.00	0.86	0.45
≥7	0.73	0.97	0.89	0.92	0.70	≥7	0.09	1.00	1.00	0.78	0.09
≥8	0.73	1.00	1.00	0.92	0.73	≥8	0.00	1.00	–	0.77	0.00
≥9	0.64	1.00	1.00	0.90	0.64						
≥10	0.55	1.00	1.00	0.88	0.55						
≥11	0.55	1.00	1.00	0.88	0.55						
≥12	0.55	1.00	1.00	0.88	0.55						
≥13	0.18	1.00	1.00	0.80	0.18						
≥14	0.09	1.00	1.00	0.78	0.09						
≥15	0.09	1.00	1.00	0.78	0.09						
≥16	0.00	1.00	–	0.77	0.00						

PPV, positive predictive value; NPV, negative predictive value.

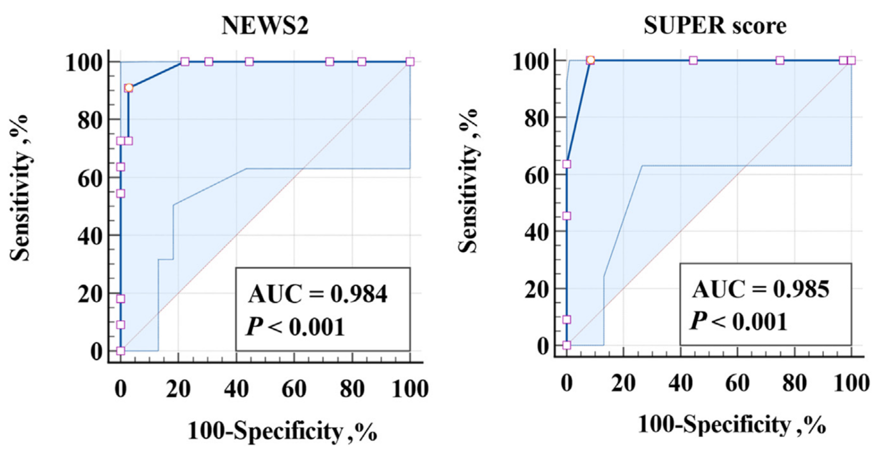

Fig. 1. Receiver operating characteristic (ROC) curves for the NEWS2 and SUPER scores at admission for predicting severe cases of COVID-19. NEWS2, National Early Warning Score 2; AUC, area under the receiver operating characteristic curve. The NEWS2 score at admission was capable of early detection of severe COVID-19 cases with an area under curve of 0.984 (95% CI 0.895–1.000). The SUPER score at admission was capable of early detection of severe COVID-19 cases with an area under curve of 0.985 (95% CI 0.897–1.000).

calculated at admission ranged from 0 to 8. The threshold for optimal sensitivity (1.00, 95% CI 0.715–1.000) and specificity (0.92, 95% CI 0.775–0.982) for detecting severe COVID-19 cases was 4, with a PPV of 0.79 and a NPV of 1.00 (Table 3). There was no significant difference in the sensitivity (difference of 9.09%, 95% CI 7.90–26.08) or specificity (difference of 5.56%, 95% CI 5.18–16.29) of the 2 scores. The ROC curve (Fig. 1.) indicated that the SUPER score at admission allows early detection of severe COVID-19 cases with AUC = 0.985, 95% CI 0.897–1.000), which is equivalent to that of the NEWS2 score (AUC = 0.984, 95% CI 0.895–1.000) (difference 0.00126, standard error = 0.0155, 95% CI 0.0291–0.0316). The +LR of the SUPER score was 12.00.

3.3. Risk characteristics of the SUPER score

The patients were divided into two groups according to the SUPER score cut-off of 4, with 14 categorized into the high-risk group (SUPER score ≥ 4 on admission). Of these 14 patients, 11 developed severe illness in hospital. Compared with patients with a SUPER score < 4, patients in the high-risk group exhibited lower lymphocyte counts (0.71 [0.55, 1.02] vs. 1.00 [0.73, 1.51], $p = 0.02$), interleukin-2 (IL-2) (3.17 [2.87, 3.81] vs. 3.61 [3.40, 4.00], $p = 0.03$], interleukin-4 (IL-4) (2.96 [2.71, 3.21] vs. 3.44 [2.99, 3.85], $p = 0.004$), and high level of fibrinogen (5.24 [4.28, 5.98] vs. 4.31 [2.63, 4.90], $p = 0.02$), C-reactive protein (CRP) (69.35 [26.00, 144.43] vs. 25.30 [5.00, 51.85], $p = 0.01$), aspartate aminotransferase (AST) (43.50 [36.00, 60.50] vs. 27.00 [18.50, 33.50], $p = 0.004$), and LDH (407 [239.25, 540.50] vs. 242 [214.00, 325.50], $p = 0.03$). No significant differences were seen between the age, sex, hypertension, and other laboratory indexes of the 2 groups.

4. Discussion

This study aimed to assess the performance of the SUPER score in predicting COVID-19 severity. The results indicated that the SUPER score has a good prognostic value with a satisfactory AUC of 0.985 (95% CI 0.897–1.000), comparable to that of the NEWS2 score (AUC, 0.984; 95% CI 0.895–1.000). When the diagnostic threshold was set as 4 points, the SUPER scoring system identified patients at high risk of severe COVID-19 with a sensitivity of 1.00 (95% CI 0.715–1.000) and specificity of 0.92 (95% CI 0.775–0.982), and the +LR was 12.00, demonstrating validity as an early warning system for severe COVID-19.

A previous study conducted in China reported that 14% of patients with COVID-19 exhibited severe manifestations, and 5% were critical cases experiencing respiratory failure, septic shock, and/or multiple organ dysfunction [2]. Sudden deterioration to severe and critical illness was reported in 6.5% of patients with COVID-19 and rapid progression can appear within 7–14 days of symptom onset [2,10]. As the case-fatality rate of patients admitted to the intensive care center can reach 40% [3], rapid evaluation of patients at high risk of severe illness is imperative for effective COVID-19 management and reducing mortality. Furthermore, as severe patients require intensive care and mechanical ventilation, early identification of high-risk cases can facilitate appropriate allocation of medical resources.

Although the SUPER score previously demonstrated efficiency in the prediction of AHF [6], this is the first study evaluating its application for prognostic prediction of COVID-19. In addition to the high efficacy of severity prediction, univariate analysis identified several risk factors associated with an elevated SUPER score. In our study, patients with a SUPER score $\geq$ 4 exhibited reduced lymphocyte, IL-2, IL-4 levels and increased levels of fibrinogen, CRP, AST, and LDH, indicating an inflammatory environment *in vivo* and multiorgan dysfunction.

Numerous studies have reported that lymphopenia in patients with COVID-19 is indicative of an unfavorable prognosis [11,12]. A decreased lymphocyte count may be caused by virus attachment, inflammatory factor-mediated immune damage, or infiltration of circulating lymphocytes into inflamed lung tissue [13–16]. Moreover, patients with low lymphocyte counts often present with anorexia and malnutrition, which may be linked to disease exacerbation [17]. Changed CRP, IL-2, and IL-4 levels in high-risk COVID-19 patients are indicative of systemic inflammatory disruption. Notably, elevated serum CRP is a key marker of disease progression and a risk factor for death of patients with severe COVID-19, indicating the occurrence of a cytokine storm [18,19]. IL-4 facilitates B cell proliferation and differentiation into plasma cells that produce neutralizing antibodies to clear SARS-CoV-2. Despite variations in earlier studies, a meta-analysis revealed significantly elevated IL-4 levels in patients with severe COVID-19 compared with non-severe cases [20], which may be attributed to a stronger immune response in severe COVID-19 cases.

A previous study reported abnormal liver function in 19% of patients upon COVID-19 diagnosis, and that patients with severe COVID-19 exhibit a more significant increase in ALT than non-severe cases [21]. Liver injury in COVID-19 cases may by a result of inflammation and cellular reactions during viral infection [22] or direct viral impact on hepatocytes [23], but the mechanisms remain unclear. Liver biochemical parameters should be closely monitored to evaluate disease progression. Fibrinogen levels were significantly higher in severe patients than in non-severe patients, that coagulation dysfunction is related to the severity of COVID-19 [20]. Therefore, prophylactic and therapeutic anticoagulant therapy regimes should be used in COVID-19 patients with a higher risk of thromboembolism. Elevated serum LDH levels have been widely reported in COVID-19 cases, mainly in severe cases [24,25], which corresponds with our results. LDH is therefore considered a valuable biomarker for severe and critical COVID-19, particularly in patients with cardiac injury, liver dysfunction, or severe inflammatory conditions [26–28].

In addition to deterioration of the respiratory system, the immune, urinary, and cardiovascular systems are related to COVID-19 progression and severity. Prower et al. [29] found that the fraction of inspired oxygen (FiO_2) changed significantly 12 hours before COVID-19 deterioration, while the respiratory rate did not increase until approximately 5 hours before progression. However, SpO_2 is generally maintained and cardiovascular observations remain relatively stable [29].

As COVID-19 progression is not only attributed to respiratory system damage but also to multiple system injury, it is necessary to monitor multiple systems in patients with COVID-19 suspected of deteriorating to severe disease. Numerous pre-existing scoring systems have been applied in COVID-19 risk assessment, including the NEWS, NEWS2, Standardized Early Warning Score, Hamilton Early Warning Score, qSOFA, CURB-65, SMART-COP, CHA2DS2-VASc Scores, and the ROX index [8,29–33]. The NEWS2 scoring system was developed by the National Health Service in the United Kingdom [34] and was recommended by WHO as an early warning and monitoring tool for patients with COVID-19 [5]. NEWS2 is based on a comprehensive score of the following parameters: respiratory rate, hypercapnic respiratory failure, supplemental oxygen, body temperature, systolic blood pressure, pulse rate, and consciousness level. Recent research indicated that NEWS2 can predict the deterioration of patients COVID-19 patients [30,35–37]. Myrstad et al. (2020) found that a NEWS2 score at admission of $\geq$6 exhibited 80.0% sensitivity and 84.3% specificity for predicting severe disease, with AUC = 0.822 (95% CI 0.690–0.953) [8]. In our study, the NEWS2 score at admission also showed good performance in predicting severe COVID-19. However, compared with the NEWS2

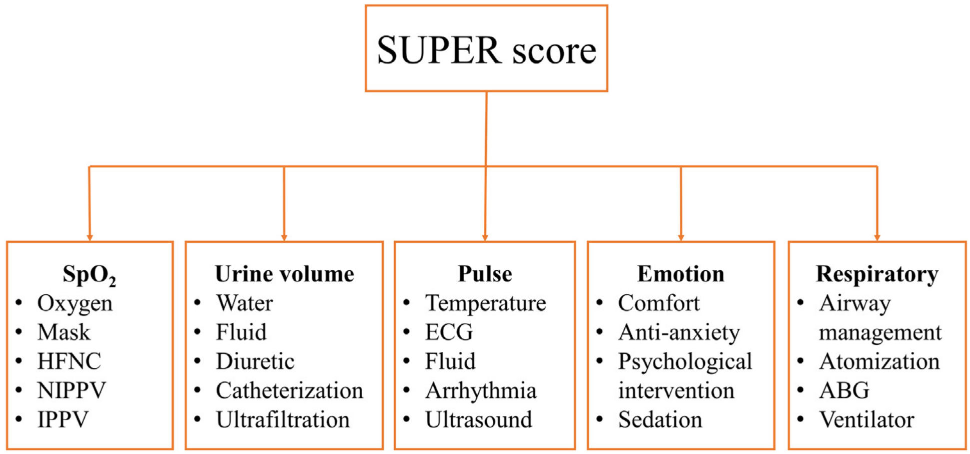

Fig. 2. Early management of patients with COVID-19 guided by the SUPER scoring system SpO2, oxygen saturation; HFNC, high-flow nasal cannula; NIPPV, non-invasive positive pressure ventilation; IPPV, intermittent positive pressure ventilation; ECG, electrocardiogram; ABG, arterial blood gas.

score, the SUPER score allows easier assessment of patients with COVID-19 by medical staff and even by family members. This flexibility will allow conservation of medical resources during COVID-19 outbreaks.

The SUPER scoring system may assist comprehensive COVID-19 management, thereby preventing deterioration and alleviating the severity of illness (Fig. 2). For the **S**pO_2 score, oxygen management should be taken seriously to determine whether additional respiratory support is required. For the **U**rine volume score, liquid management should be monitored. For the **P**ulse score, the cardiovascular system should be monitored to facilitate timely echocardiography. The **E**motional state of the patient should be considered, and sedation or psychological intervention should be initiated when necessary. Airway management is important for the **R**espiratory score.

The main limitation of this study is the small sample size, which does not allow for the development of a more detailed assessment system or large-scale validation. Furthermore, this study did not dynamically evaluate the efficacy of the SUPER score for predicting the time-line of disease progression.

5. Conclusion

In conclusion, the SUPER score of patients with COVID-19 at admission can predict the risk of severe disease with equivalent specificity and sensitivity to the NEWS2 score. A SUPER score $\geq$ 4 predicts severe cases with a sensitivity of 1.00 and specificity of 0.92. The application of the SUPER score for prognostic assessment of patients with COVID-19 is therefore valid and efficient, providing an early warning for effective critical management and facilitating efficient allocation of health resources.

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Author contributions

Contributions: Y.B.: Conceptualization, investigation, data curation, resources, and writing–review & editing. Q.H.: Data curation, visualization, writing–original draft. Y.Z.: Data curation, formal analysis, visualization, writing–review & editing. Y.Y.: Data curation. X.F.: Data curation. R.L.: Methodology, project administration, supervision. J.P.: Methodology, writing–review & editing. F.X.: Conceptualization, methodology, project administration, supervision, writing–review & editing. Y.C.: Conceptualization, methodology, project administration, supervision, writing–review & editing, and funding acquisition. All authors have read and approved the final version of the manuscript.

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None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Available Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

The study was approved by the Ethics Committee of Qilu Hospital of Shandong University (KYLL-2020-016).

Informed Consent

This was an observational study, which did not involve patient privacy information or affect patient diagnosis and treatment. Informed consent was therefore waived by the ethics committee.

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