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ORIGINAL RESEARCH

Physiologic Scoring Systems in Predicting the COVID-19 Patients' one-month Mortality; a Prognostic Accuracy Study

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Abstract: **Introduction:** It is critical to quickly and easily identify severe coronavirus disease 2019 (COVID-19) patients and predict their mortality. This study aimed to determine the accuracy of the physiologic scoring systems in predicting the mortality of COVID-19 patients. **Methods:** This prospective cross-sectional study was performed on COVID-19 patients admitted to the emergency department (ED). The clinical characteristics of the participants were collected by the emergency physicians and the accuracy of the Quick Sequential Failure Assessment (qSOFA), Coronavirus Clinical Characterization Consortium (4C) Mortality, National Early Warning Score-2 (NEWS2), and Pandemic Respiratory Infection Emergency System Triage (PRIEST) scores for mortality prediction was evaluated. **Results:** Nine hundred and twenty-one subjects were included. Of whom, 745 (80.9%) patients survived after 30 days of admission. The mean age of patients was 59.13 ± 17.52 years, and 550 (61.6%) subjects were male. Non-Survived patients were significantly older (66.02 ± 17.80 vs. 57.45 ± 17.07, P< 0.001) and had more comorbidities (diabetes mellitus, respiratory, cardiovascular, and cerebrovascular disease) in comparison with survived patients. For COVID-19 mortality prediction, the AUROCs of PRIEST, qSOFA, NEWS2, and 4C Mortality score were 0.846 (95% CI [0.821-0.868]), 0.788 (95% CI [0.760-0.814]), 0.843 (95% CI [0.818-0.866]), and 0.804 (95% CI [0.776-0.829]), respectively. All scores were good predictors of COVID-19 mortality. **Conclusion:** All studied physiologic scores were good predictors of COVID-19 mortality and could be a useful screening tool for identifying high-risk patients. The NEWS2 and PRIEST scores predicted mortality in COVID-19 patients significantly better than qSOFA.

Keywords: COVID-19; Clinical Decision Rules; Mortality; Emergency service, hospital

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1. Introduction

The coronavirus disease 2019 (COVID-19), a respiratory disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has unfolded globally with unheard-of rapidity (1). COVID-19 has had a devastating impact on health care, internationally (1, 2). 6 to 20% of sufferers need to be hospitalized (2, 3). The incidence of critical disorder

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amongst hospitalized patients is about 5-20%, and intensive care treatment may also be required in >25% of them (4, 5). The mortality rate amongst hospitalized subjects is estimated to be 11-28% (2, 6).

Therefore, it is essential to identify subjects that emerge as severely or even critically ill quickly and without problems, which can help in allocation of the limited medical and monitoring resources. Using scoring systems to estimate a patient's risk of unfavorable outcome can decrease unnecessary use of the limited available resources (1, 2, 5). Several medical scoring tools have been used For risk stratification regarding sepsis and community-acquired pneumonia (CAP) (2, 5). There are several valid scoring systems for predicting pneumonia mortality. The Quick Sequential Failure Assessment (qSOFA) criteria were developed in 2016 (2, 5) to predict mortality in septic patients. Still, recent research has recommended that qSOFA is an effective tool to evaluate mortality risk in seriously ill subjects with a variety of diseases, especially in resource-constrained eventualities (7, 8).

The Coronavirus Clinical Characterization Consortium (4C) Mortality Score was developed by the International Severe Acute Respiratory and emerging Infections Consortium (ISARIC). It was used on adult hospitalized COVID-19 patients in England, Wales, and Scotland to predict 30-day mortality (9, 10).

In studies conducted on emergency department (ED) patients, the National Early Warning Score (NEWS) was the most accurate in predicting in-hospital mortality (11). In 2017, NEWS was updated to NEWS2 by adding new oxygen saturation (SpO2) scoring scale. NEWS2 is recommended by the Royal College of Physicians for use in COVID-19 patients (11) and is a standardized scoring tool developed to improve the detection of deterioration in acutely ill patients (12). NEWS2 has shown good ability in prediction of adverse outcomes in patients attending the ED with suspected COVID-19.

In 2021, Pandemic Respiratory Infection Emergency System Triage (PRIEST) tool was developed and validated among adult patients with suspected COVID-19 in ED to address any pandemic respiratory infection, including COVID-19. It was created by adding age, sex, and performance status to NEWS2 (13).

The present study was performed at the time of the circulation of the Delta variant. Previous studies have suggested that physiologic scoring systems are practical tools to assess mortality risk in critically ill patients (9-14).

Therefore, these scores can assist emergency physicians in predicting the mortality of COVID-19 hospitalized patients.

This study was conducted to estimate and compare the accuracy of the qSOFA, 4C Mortality, NEWS2, and PRIEST scores in predicting the mortality of COVID-19 patients in the emergency department setting.

2. Methods

2.1. Study setting and design

This prospective cross-sectional study was conducted at Al-Zahra hospital (a university-affiliated, COVID-19 referral hospital) in Isfahan, Iran, between June 22, 2021, and November 21, 2021 (at the time of circulation of the Delta variant of the coronavirus). The clinical characteristics of the participants were collected by the emergency physicians and the accuracy of the Quick Sequential Failure Assessment (qSOFA), Coronavirus Clinical Characterization Consortium (4C) Mortality, National Early Warning Score-2 (NEWS2), and Pandemic Respiratory Infection Emergency System Triage (PRIEST) scores in prediction of one-month mortality was evaluated.

This study was approved by the ethics committee of Isfahan University of Medical Sciences (code: IR.MUI.MED.REC.1399.932), and the study participants signed the informed consent.

2.2. Participants

Adult subjects (over 18 years of age) with confirmed COVID-19 infection, who were admitted to the emergency department (ED) of Al-Zahra hospital were eligible for study participation. COVID-19 infection was established according to the WHO interim guidance (15). Pregnant patients, those who disagreed to participate in the study, those hospitalized for other medical conditions unrelated to COVID-19, and patients transferred from other hospitals were excluded.

2.3. Data collection

The emergency medicine residents evaluated and managed the patients in the ED based on the standard protocol at Al-Zahra Hospital. The patients' demographic information (gender and age), baseline variables, and clinical and laboratory data were collected on ED admission. Clinical data including signs and symptoms, blood pressure (BP), respiratory rate (RR), heart rate (HR), AVPU ('Alert', 'Voice', 'Pain', 'Unresponsive'), temperature, O2 saturation (SpO2), laboratory findings, and triage level based on Emergency Severity Index (ESI) version 4, and chest computed tomography (CT) scans were recorded. These data were extracted to calculate the qSOFA, 4C Mortality, NEWS2, and PRIEST scores. The primary outcome was mortality within 30 days after admission to the ED.

The qSOFA consists of three parameters. One point is allotted to each variable: SBP ≤100 mm Hg, RR ≥22 breaths/minute, and altered mental status (GCS<15). The score ranges from 0 to 3 (7).

The NEWS2 tool comprises six physiological variables (RR, SpO2, SBP, HR, level of consciousness or new confusion, and temperature). Each variable is scored from 0 to 3. Finally, two

points are added for patients requiring supplementary oxygen treatment (11) (Appendix 1). The NEWS-2 assessment categorizes patients into low risk (0–4), medium risk (5–6), and high risk (≥7).

The PRIEST score can be calculated by adding age and gender, and performance status to the parameters of the NEWS2 score (Appendix 1). The score ranges from zero to 29 points (13).

The 4C Mortality Score includes eight variables (age, sex, number of comorbidities, RR, SpO2, GCS, BUN level, and C-reactive protein level) (Appendix 2). The total score ranges between 0 and 21 points (9).

2.4. Statistical analysis

Based on similar studies (2), assuming specificity of 80%, the mortality rate of 20%, the estimation accuracy of 95%, and type-1 error of 3%, the minimum required sample size was 853 people. SPSS software version 25.0 (IBM, Armonk, NY) was applied to analyze the variables. Categorical data were described as frequency (%), and continuous data were expressed as mean and standard deviation (SD) or 95% confidence interval (CI). Chi-square test and Student's t-test, or the Mann-Whitney U test were performed to compare variables. The area under a receiver operating characteristic (AUROC) curve was calculated to evaluate and compare the effectiveness of the qSOFA, 4C Mortality, NEWS2, and PRIEST scores in predicting mortality. P-value less than 0.05 in two-tailed tests was considered significant.

3. Results

3.1. Patients' baseline characteristics

Nine hundred and twenty-one subjects were included in this study. Of them, 745 (80.9%) patients had survived 30 days after admission. The mean age of patients was 59.13 ± 17.52 years, and 550 (61.6%) subjects were male. The mean length of hospital stay was 8.69 ± 8.91 days. The most common underlying diseases were hypertension (32.6%) and diabetes (32.2%). The most common symptoms on admission were dyspnea (72.6%) and fever (65.1%). The baseline characteristics and laboratory parameters of survived and non-survived patients are compared in table 1 and 2.

Non-Survived patients were significantly older (66.02 ± 17.80 vs. 57.45 ± 17.07, P< 0.001) and had more comorbidities (diabetes mellitus, respiratory, cardiovascular, and cerebrovascular disease) in comparison with survived patients. Among vital parameters on ED admission, SpO2, RR and HR significantly differed between survived and non-survived patients. There were significant differences between survivor and non-survivor patients regarding GCS, length of hospital stay, qSOFA, PRIEST, NEWS2, and 4C Mortality scores.

The lymphocyte counts and hemoglobin in non-survived patients were significantly lower than survived patients (P < 0.001). The d-Dimer, blood sugar, and Lactate Dehydrogenase levels in non-survived patients were significantly higher than those who survived.

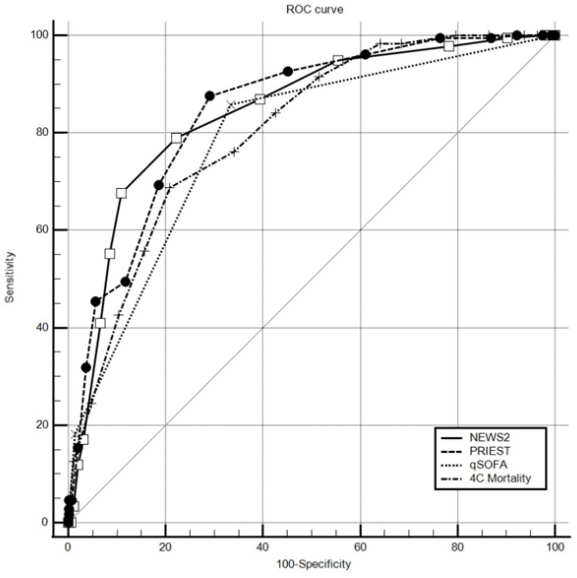

Figure 1: Area under the receiver operating characteristic curve of different scoring systems in predicting the 30-day mortality of COVID-19 patients.

3.2. Comparing the Accuracy of scoring systems

ROC curves were drawn to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and cut-off values of scores to predict COVID-19 mortality. The optimal cut-off values of ≥2 for the qSOFA, ≥8 for PRIEST, ≥6 for NEWS2, and ≥13 for the 4C Mortality score were established. The NPV of the PRIEST, qSOFA, NEWS2, and 4C Mortality scores for mortality were 96.0%, 95.2%, 94.0%, and 91.5%, respectively (Table 3).

For COVID-19 mortality prediction, the AUROCs of PRIEST, qSOFA, NEWS2, and 4C Mortality score were 0.846 (95% CI [0.821-0.868]), 0.788 (95% CI [0.760-0.814]), 0.843 (95% CI [0.818-0.866]), and 0.804 (95% CI [0.776-0.829]), respectively. All scores were good predictors of COVID-19 mortality (Figure 1). The AUROC analysis showed that the NEWS2 and PRIEST scores were more successful than qSOFA (P=0.004 and P=0.001) in predicting mortality for COVID-19 patients (Table 4).

4. Discussion

Due to the limitations of medical resources during the COVID-19 outbreak, it is essential to initially assess COVID-19 patients in terms of disease severity to ensure primary medical management and interventions. Therefore, one of

Table 1: Comparison of demographic and clinical characteristics of COVID-19 patients based on 30-day mortality

Characteristics	Total (n=921)	Survived (n=745)	Non-Survived (n=176)	P
Age (year)	59.13 ± 17.52	57.45 ± 17.07	66.02 ± 17.80	0.001
Gender				
Male	550 (61.6)	436 (58.5)	114 (64.8)	0.128
Female	371 (38.4)	309 (41.5)	62 (35.2)	
Comorbidities				
Respiratory disease	127 (13.8)	82 (11.0)	45 (25.6)	<0.001
Cardiovascular disease	164 (17.8)	122 (16.4)	42 (23.9)	0.032
Diabetes mellitus	294 (32.2)	219 (29.8)	75 (42.6)	0.001
Hypertension	300 (32.6)	236 (31.7)	64 (36.4)	0.357
Cerebrovascular disease	84 (9.1)	54 (7.2)	30 (17.0)	0.001
Chronic kidney disease	98 (10.6)	77 (10.3)	21 (11.9)	0.413
Chronic liver disease	27 (2.9)	21 (2.8)	6 (3.4)	0.452
Malignancy	76 (8.3)	55 (7.4)	21 (11.9)	0.053
Signs and symptoms				
Fever	600 (65.1)	499 (67.0)	101 (57.4)	0.041
Cough	549 (59.6)	448 (60.1)	101 (57.4)	0.537
Dyspnea	669 (72.6)	542 (72.8)	127 (72.2)	0.874
Fatigue	497 (54.0)	412 (55.3)	85 (48.3)	0.093
Sore throat	84 (9.12)	67 (8.99)	17 (9.66)	0.388
Myalgia	208 (22.6)	178 (23.9)	30 (17.0)	0.051
Diarrhea	215 (23.3)	188 (25.2)	27 (15.3)	0.005
Opioid				
Yes	91 (9.9)	70 (9.4)	21 (11.9)	0.593
Glasgow coma scale				
Mean ± SD	11.61± 2.03	12.32 ± 6.92	10.02 ± 2.67	<0.001
Length of stay (day)				
Mean ± SD	8.68± 8.91	8.06 ± 7.39	11.23 ±13.26	0.003
Vital parameters				
HR; bpm	88.04±12.41	87.25±11.91	91.31±13.92	0.043
SBP; mmHg	23.53±17.64	23.95±17.87	21.81±16.71	0.463
DBP; mmHg	75.71± 11.56	75.84±11.71	75.19±11.04	0.864
RR; bpm	20.59±3.09	20.31±2.88	21.76±3.65	0.001
Temp; °c	37.34 ± 0.61	37.33±0.63	37.37±0.51	0.312
SpO2;%	88.99± 6.06	91.40±6.03	80.31±5.95	0.001
Scores				
qSOFA	1.46± 0.61	1.33±0.53	2.04±0.57	<0.001
PRIEST	7.15±2.92	6.61±2.72	9.42±2.66	<0.001
4C Mortality	10.42±3.70	9.67±3.52	13.58±2.63	<0.001
NEWS2	4.81±2.70	4.17±2.34	7.54±2.40	<0.001

Data are presented as mean ± standard deviation (SD) or frequency (%). HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; RR: respiratory rate; temp: temperature; SpO2: oxygen saturation.

the most critical tasks of emergency physicians is rapid and accurate screening of subjects at risk of death in severe or critically ill COVID-19 patients to provide them with additional monitoring, intervention, or intensive care (16). In such situations, scoring systems can help overcome limitations. Each scoring tool has its advantages and disadvantages.

The 30-day mortality in the current study was high (19.1%). It was in line with previous studies (ranging from 19.2% to 20.9%) (2, 6, 10). Consistent with the current study, previous studies have shown that non-survived COVID-19 patients were significantly older, had a higher respiratory rate, a lower SpO2 on ED arrival, and had more underlying diseases than those who survived (2, 5, 8, 11).

Most patients presented with respiratory tract symptoms such as dyspnea and cough, fever, and fatigue. Previous studies reported that the most common symptoms include cough (60–86%), dyspnea (53–80%), and taste or smell disturbance (64–80%) (10, 17-19). These results are similar to the present study.

The current study has compared the performance of four different scoring systems in predicting COVID-19 mortality. The NEWS2 and PRIEST, with AUROC of 0.843 and 0.846 in predicting mortality of COVID-19 patients, are significantly

Table 2: Comparing the laboratory parameters of the COVID-19 patients at the time of admission between survived and non-survived

Characteristics	Total (n=921)	Survived (n=745)	Non-Survived (n=176)	P
White blood cells, $\times10^9$ /ml	7.096± 4.279	6.964 ± 4.089	7.656±5.010	0.125
Lymphocytes, $\times10^9$ /ml	1.59±0.91	1.71 ± 0.88	1.09 ± 0.87	<0.001
Hemoglobin, g/L	13.41±2.13	13.03 ±1.86	15.00 ± 2.46	<0.001
Platelets, $\times10^9$ /ml	182.6 ±81.8	183.2±82.5	179.8±79.5	0.721
PaO 2, mmHg	45.60±23.03	46.60±23.70	41.48±19.72	0.012
PH	7.32±0.10	7.31 ±0.09	7.37±0.10	<0.001
PaCO2	41.50±12.10	41.72±11.69	40.61±13.71	0.260
HCO3	21.29±4.85	21.29±4.79	21.27±5.12	0.803
ALT, U/L	44.45±27.31	45.20 ±27.17	41.33 ±27.91	0.352
AST, U/L	55.16±23.38	54.26±22.97	58.79±24.81	0.185
BUN, mmol/L	20.13±12.69	19.74±12.38	21.79±13.95	0.476
Creatinine, umol/L	1.59±1.44	1.59±1.17	1.61±0.98	0.973
Potassium, mmol/L	4.68±1.23	4.69±1.32	4.64±0.79	0.985
Sodium, mmol/L	137.14±7.86	137.26±8.35	136.65±5.47	0.130
Ferritin,	528.1±380.2	519.3±391.0	579.5±311.8	0.235
d-Dimer	910.5±841.0	881.5±851.7	1018.6±798.2	<0.001
Blood sugar	130.28±57.26	127.59±59.71	141.50±44.38	<0.001
Creatine kinase	308.1±411.3	303.9±405.6	326.9±440.1	0.929
Lactate Dehydrogenase	672.6±310.0	646.5±280.4	776.9±393.3	0.019
C-reactive protein	68.15±44.11	67.88±44.85	69.28±41.23	0.880
ESR	48.87±25.94	49.20±25.56	47.54±23.41	0.696

Data are presented as mean ± standard deviation (SD). ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; BUN: Blood Urea Nitrogen; ESR: erythrocyte sedimentation rate.

Table 3: Screening performance characteristics of physiologic scoring systems in predicting the 30-day mortality of COVID-19 patients

Variables	4C Mortality	NEWS2	qSOFA	PRIEST
Cut-off	≥13	≥6	≥2	≥8
Sensitivity	68.75 (61.3 - 75.5)	78.98 (72.2 – 84.7)	85.80 (79.7 -90.6)	87.50 (81.7 – 92.0)
Specificity	79.19 (76.1 – 82.1)	77.76 (74.6 -80.7)	66.87 (63.3 – 70.2)	71.05 (67.6 – 74.3)
PPV	43.8 (39.7 - 48.1)	45.7 (41.9 – 49.6)	37.9 (35.2 – 40.8)	41.6 (38.6 – 44.7)
NPV	91.5 (89.6 – 93.1)	94.0 (92.1 – 95.4)	95.2 (93.2 – 96.6)	96.0 (94.2– 97.3)
PLR	3.30 (2.78 - 3.92)	3.55 (3.04 – 4.15)	2.59 (2.30 – 2.91)	3.02 (2.67 – 3.43)
NLR	0.39 (0.32 - 0.49)	0.27 (0.20 - 0.36)	0.21 (0.15 - 0.31)	0.18 0.12 - 0.26)
AUC	0.804 (0.776-0.829)	0.843 (0.818-0.866)	0.788 (0.760-0.814)	0.846 (0.821-0.868)

Data are presented with 95% confidence intervals. PPV: Positive predictive value; NPV: Negative predictive value; PLR: Positive Likelihood Ratio; NLR: Negative Likelihood Ratio; and AUC: Area Under the receiver operating characteristic Curve.

Table 4: Comparison of the area under the receiver operating characteristic curve of different scoring systems in predicting the 30-day mortality of COVID-19 patients

	qSOFA	PRIEST	4C	NEWS2
qSOFA	–	0.001	0.357	0.004
PRIEST		–	0.021	0.870
4C			–	0.073
NEWS2				–

superior to qSOFA (AUROC = 0.778). PRIEST score did not perform significantly better than the NEWS2 score. Covino et al. demonstrated that NEWS2 predicted death within 48 hours from ED admission with AUROC of 0.753 [95% CI 0.703 -0.798], with 72.7% [95% CI 39.0 - 94.0] sensitivity and 72.7% [95% CI 67.6 - 77.5] specificity (11). In another study, NEWS2 demonstrated an AUROC of 0.78 for in-hospital mortality (4). Previous studies reported that NEWS-2 had an excellent performance (AUC = 0.842–0.894) (13, 20, 21). They showed that NEWS-2 was the best tool for evaluating the prognosis of COVID-19 patients compared to several other tools (12, 20). These findings were in line with the present study. NEWS2

can be used as a triage tool to predict the mortality of COVID-19 patients and allocate the limited resources.

The diagnostic ability of qSOFA for the prediction of hospital mortality in the current study (AUROC=0.788) was comparable to Liu et al. (AUROC=0.742), Wilfong et al. (AUROC=0.801), and Jang et al. (AUROC=0.779) in COVID-19 patients (16, 22, 23). These findings showed that qSOFA is quite a good tool for predicting hospital mortality in COVID-19 patients.

The PRIEST study examined 20891 suspected COVID-19 patients in 70 emergency departments. Triage scores provided good but not excellent discrimination with good sensitivity at the expense of specificity in patients with suspected COVID-19 (24). This study did not suggest any cut-off point to apply for decision-making in COVID-19 patients. Goodacre et al. demonstrated that PRIEST scores ≥5 predicted 30-day mortality with 98% sensitivity (13). Marincowitz et al. reported that the NEWS2 and PRIEST scores achieved high estimated sensitivities concerning 30-day mortality (14). In the present study, the additional components of the PRIEST score improved sensitivity and NPV.

The 4C Mortality score has been validated in over 57,000 patients in previous studies in several settings (4, 9, 10, 25, 26). The AUROC of the 4C Mortality score in the present study (0.804 [95% CI, 0.776-0.829]) is consistent with the results of previous studies in other countries. The AUROC of the 4C Mortality score was 0.84 (95% CI, 0.79-0.88) in a Dutch population (25), 0.78 (95% CI, 0.75-0.81) in a Brazilian and Spanish population (26), and 0.85 (95% CI, 0.79-0.89) in a United States population (27).

Citu et al. showed that the NEWS with an AUROC of 0.861 predicted mortality in COVID-19 patients and was significantly superior to the 4C Mortality score (AUROC = 0.818) (28). Ocho et al. demonstrated that for mortality prediction, AUROC of the 4C Mortality score (0.84 [95% CI, 0.76–0.92]) was higher than qSOFA (0.66 [95% CI, 0.53–0.78]) (29). These results were similar to the present study. Therefore, the 4C Mortality score is a useful tool to assess mortality risk in COVID-19 patients.

The NPV of the PRIEST, qSOFA, NEWS2, and 4C Mortality scores for in-hospital mortality were 96.0%, 95.2%, 94.0%, and 91.5%, respectively. The high NPV acts as a gatekeeper accurately identifying low-risk patients. The PRIEST had the highest sensitivity and NPV for mortality prediction. Thus, it is particularly well in identifying COVID-19 patients who were at low risk of death. For triaging patients in the ED, it is important to have a high NPV for predicting severe COVID-19 to avoid inappropriately admitting patients at risk of deterioration to a non-critical care area.

The PRIEST, qSOFA, and NEWS2 scores are calculated without laboratory tests or diagnostic imaging, while the 4C Mortality score needs laboratory tests. Therefore, the 4C Mortality score is more time-consuming than others. The PRIEST, qSOFA, and NEWS2 scores can predict patient deterioration quickly and simply in COVID-19 patients who need immediate treatment to minimize mortality in COVID-19 patients. Although a single evaluation on hospital admission has limited predictive ability, these scores could be a helpful screening tool to evaluate COVID-19 patients at the time of ED arrival. However, these should only supplement and not replace clinical judgment.

Due to silent hypoxemia in severe COVID-19, the accuracy of the qSOFA score in predicting hospital mortality decreases. These patients appear to breathe comfortably even at low SPO2. This score only counts the respiratory rate and does not consider SpO2. Therefore, it has limitations in predicting mortality in COVID-19 patients. An advantage of other scores compared to the qSOFA is that both hypoxemia and respiratory rate are included as scoring parameters.

5. Limitations

Our study has some limitations. A convenience sampling method was used, and the researcher was present in the ED, which may have caused selection bias. This study was a single-center study with limited generalizability, and the findings may not apply to other environments with different populations or healthcare systems. Additionally, the value of a single evaluation is limited, and patients admitted to the hospital should be reassessed frequently for signs of deterioration.

6. Conclusion

All studied physiologic scores were good predictors of COVID-19 mortality and these can be considered a useful screening tool to identify the high-risk patients. The NEWS2 and PRIEST scores predicted mortality in COVID-19 patients significantly better than qSOFA.

7. Declarations

7.1. Acknowledgments

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7.2. Authors' contributions

All authors; Contributed to conception, study design, and data collection and evaluation. F.H. and M.Z.; Contributed to statistical analysis and interpretation of data. F.H. and M.Z.; Drafted the manuscript, which was revised by S.A., K.S., and S.M. All authors read and approved the final manuscript.

7.3. Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

7.4. Ethics approval and consent to participate

This study was approved by the ethics committee of Isfahan University of Medical Sciences (code: IR.MUI.MED.REC.1399.932), and the study participants signed the informed consent.

7.5. Funding

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7.6. Competing interests

The authors declare no conflict of interest.

References

1. Azizkhani R, Heydari F, Sadeghi A, Ahmadi O, Meibody AA. Professional quality of life and emotional well-being among healthcare workers during the COVID-19 pandemic in Iran. Front Emerg Med. 2022;6(1):e2.
2. Artero A, Madrazo M, Fernández-Garcés M, Muiño Miguez A, González García A, Crestelo Vieitez A, et al. Severity scores in COVID-19 pneumonia: a multicenter, retrospective, cohort study. J Gen Intern Med. 2021;36(5):1338-45.
3. Rosenberg ES, Dufort EM, Blog DS, Hall EW, Hoefer D, Backenson BP, et al. COVID-19 testing, epidemic features, hospital outcomes, and household prevalence, New York State—March 2020. Clin Infect Dis. 2020;71(8):1953-9.
4. Gupta RK, Marks M, Samuels TH, Luintel A, Rampling T, Chowdhury H, et al. Systematic evaluation and external validation of 22 prognostic models among hospitalised adults with COVID-19: an observational cohort study. Eur Respir J. 2020;56(6):2003498.
5. Holten AR, Nore KG, Tveiten CEVWK, Olasveengen TM, Tonby K. Predicting severe COVID-19 in the Emergency Department. Resusc Plus. 2020;4:100042.
6. Bhargava A, Sharma M, Akagi E, Szpunar SM, Saravolatz L. Predictors for in-hospital mortality from coronavirus disease 2019 (COVID-19) infection among adults aged 18–65 years. Infect Control Hosp Epidemiol. 2021;42(6):772-5.
7. Saberian P, Tavakoli N, Hasani-Sharamin P, Modabber M, Jamshididana M, Baratloo A. Accuracy of the prehospital triage tools (qSOFA, NEWS, and PRESEP) in predicting probable COVID-19 patients' outcomes transferred by Emergency Medical Services. Casp J Intern Med 2020;11:536–43.
8. Guo W, Ran L-y, Zhu J-h, Ge Q-g, Du Z, Wang F-l, et al. Identifying critically ill patients at risk of death from coronavirus disease. World J Emergency Med. 2021;12(1):18.
9. Knight SR, Ho A, Pius R, Buchan I, Carson G, Drake TM, et al. Risk stratification of patients admitted to hospital with covid-19 using the ISARIC WHO Clinical Characterisation Protocol: development and validation of the 4C Mortality Score. BMJ. 2020;370:m3339.
10. Long B, Carius BM, Liang SY, Chavez S, Brady WJ, Koyfman A, et al. Clinical update on COVID-19 for the emergency clinician: Presentation and evaluation. Am J Emerg Med. 2022;54:46–57.
11. Covino M, Sandroni C, Santoro M, Sabia L, Simeoni B, Bocci MG, et al. Predicting intensive care unit admission and death for COVID-19 patients in the emergency department using early warning scores. Resuscitation. 2020;156:84-91.
12. Myrstad M, Ihle-Hansen H, Tveita AA, Andersen EL, Nygård S, Tveit A, et al. National Early Warning Score 2 (NEWS2) on admission predicts severe disease and in-hospital mortality from Covid-19–a prospective cohort study. Scand J Trauma Resusc Emerg Med. 2020;28(1):1-8.
13. Goodacre S, Thomas B, Sutton L, Burnsall M, Lee E, Bradburn M, et al. Derivation and validation of a clinical severity score for acutely ill adults with suspected COVID-19: the Priest observational cohort study. PloS one. 2021;16(1):e0245840.
14. Marincowitz C, Sutton L, Stone T, Pilbery R, Campbell R, Thomas B, et al. Prognostic accuracy of triage tools for adults with suspected COVID-19 in a prehospital setting: an observational cohort study. Emerg Med J. 2022;39(4):317-24.
15. Organization WH. Public health surveillance for COVID-19: interim guidance, 16 December 2020. World Health Organization; 2020.
16. Liu S, Yao N, Qiu Y, He C. Predictive performance of SOFA and qSOFA for in-hospital mortality in severe novel coronavirus disease. Am J Emerg Med. 2020;38(10):2074-80.
17. Peyrony O, Marbeuf-Gueye C, Truong V, Giroud M, Rivière C, Khenissi K, et al. Accuracy of emergency department clinical findings for diagnosis of coronavirus disease 2019. Ann Emerg Med. 2020;76(4):405-12.
18. Kornitzer J, Johnson J, Yang M, Pecor KW, Cohen N, Jiang C, et al. A systematic review of characteristics associated with COVID-19 in children with typical presentation and with multisystem inflammatory syndrome. Int J Environ Res Public Health. 2021;18(16):8269.
19. Carpenter CR, Mudd PA, West CP, Wilber E, Wilber ST.

Diagnosing COVID-19 in the emergency department: a scoping review of clinical examinations, laboratory tests, imaging accuracy, and biases. Acad Emerg Med. 2020;27(8):653-70.
20. Wibisono E, Hadi U, Arfijanto MV, Rusli M, Rahman BE, Asmarawati TP, et al. National early warning score (NEWS) 2 predicts hospital mortality from COVID-19 patients. Ann Med Surg. 2022;76:103462.
21. Kostakis I, Smith GB, Prytherch D, Meredith P, Price C, Chauhan A, et al. The performance of the National Early Warning Score and National Early Warning Score 2 in hospitalised patients infected by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Resuscitation. 2021;159:150-7.
22. Wilfong EM, Lovly CM, Gillaspie EA, Huang L-C, Shyr Y, Casey JD, et al. Severity of illness scores at presentation predict ICU admission and mortality in COVID-19. J Emerg Crit Care Med. 2021;5:7.
23. Jang JG, Hur J, Hong KS, Lee W, Ahn JH. Prognostic accuracy of the SIRS, qSOFA, and NEWS for early detection of clinical deterioration in SARS-CoV-2 infected patients. J Korean Med Sci 2020;35(25):e234.
24. Thomas B, Goodacre S, Lee E, Sutton L, Bursnall M, Loban A, et al. Prognostic accuracy of emergency department triage tools for adults with suspected COVID-19: the Priest observational cohort study. Emerg Med J 2021;38(8):587-93.
25. van Dam PM, Zelis N, van Kuijk SM, Linkens AE, Brüggemann RA, Spaetgens B, et al. Performance of prediction models for short-term outcome in COVID-19 patients in the emergency department: a retrospective study. Ann Med. 2021;53(1):402-9.
26. Neto FL, Marino LO, Torres A, Cilloniz C, Marchini JFM, de Alencar JCG, et al. Community-acquired pneumonia severity assessment tools in patients hospitalized with COVID-19: a validation and clinical applicability study. Clin Microbiol Infect. 2021;27(7):1037. e1-. e8.
27. Riley JM, Moeller PJ, Crawford AG, Schaefer JW, Cheney-Peters DR, Venkataraman CM, et al. External validation of the COVID-19 4C Mortality Score in an urban United States cohort. Am J Med Sci. 2022;364(4):409-13.
28. Citu C, Gorun F, Motoc A, Ratiu A, Gorun OM, Burlea B, et al. Evaluation and Comparison of the Predictive Value of 4C Mortality Score, NEWS, and CURB-65 in Poor Outcomes in COVID-19 Patients: A Retrospective Study from a Single Center in Romania. Diagnostics. 2022;12(3):703.
29. Ocho K, Hagiya H, Hasegawa K, Fujita K, Otsuka F. Clinical Utility of 4C Mortality Scores among Japanese COVID-19 Patients: A Multicenter Study. J Clin Med. 2022;11(3):821.

Appendix 1: National Early Warning Score-2 (NEWS2) and Pandemic Respiratory Infection Emergency System Triage (PRIEST)

Variable	Categories	Points
Respiratory rate, breaths per minute	≤8	3
	9–11	1
	12–20	0
	21–24	2
	≥25	3
SpO2 (on room air or supplemental)	≤91%	3
	92–93%	2
	94–95%	1
	≥96%	0
Oxygen	Supplemental oxygen	2
	Room air	0
Temperature	≤35.0 °C	3
	35.1–36.0 °C	1
	36.1–38.0 °C	0
	38.1–39.0 °C	1
	≥39.1 °C	2
Systolic Blood Pressure, mm Hg	≤90	3
	91–100	2
	101–110	1
	111–219	0
	≥220	3
Pulse Rate, beats per minute	≤40	3
	41–50	1
	51–90	0
	91–110	1
	111–130	2
	≥131	3
Consciousness	Alert	0
	Confused or not alert	3
Age in years*	16–49	0
	50–65	2
	66–80	3
	>80	4
Sex*	Female	0
	Male	1
Performance status*	Unrestricted normal activity	0
	Limited strenuous activity, can do light activity	1
	Limited activity, can self-care	2
	Limited self-care	3
	Bed/chair bound, no self-care	4

*It is only used in the PRIEST score.

Appendix 2: Coronavirus Clinical Characterization Consortium (4C) Mortality Score

Variable		Points
Age in years	< 50	0
	50–59	2
	60–69	4
	70–79	6
	≥80	7
Sex at birth	Female	0
	Male	1
Number of comorbidities	0	0
	1	1
	≥2	2
Respiratory rate (/minute)	<20	0
	20–29	1
	≥30	2
Peripheral oxygen saturation on room air	≥92%	0
	<92%	2
Glasgow coma scale	15	0
	<15	2
Urea/ Blood Urea Nitrogen	Urea <7 mmol/L or BUN <19.6 mg/dL	0
	Urea 7–14 mmol/L or BUN 19.6–39.2 mg/dL	1
	Urea >140 mmol/L or BUN >39.2 mg/dL	3
C-reactive protein	< 50 mg/L	0
	50–99 mg/L	1
	≥100 mg/L	2