Clinical paper

Predicting severe COVID-19 in the Emergency Department

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Abstract

Background: COVID-19 may lead to severe disease, requiring intensive care treatment and challenging the capacity of health care systems. The aim of this study was to compare the ability of commonly used scoring systems for sepsis and pneumonia to predict severe COVID-19 in the emergency department.

Methods: Prospective, observational, single centre study in a secondary/tertiary care hospital in Oslo, Norway. Patients were assessed upon hospital admission using the following scoring systems: quick Sequential Failure Assessment (qSOFA), Systemic Inflammatory Response Syndrome criteria (SIRS), National Early Warning Score 2 (NEWS2), CURB-65 and Pneumonia Severity index (PSI). The ratio of arterial oxygen tension to inspiratory oxygen fraction (P/F-ratio) was also calculated. The area under the receiver operating characteristics curve (AUROC) for each scoring system was calculated, along with sensitivity and specificity for the most commonly used cut-offs. Severe disease was defined as death or treatment in ICU within 14 days.

Results: 38 of 175 study participants developed severe disease, 13 (7%) died and 29 (17%) had a stay at an intensive care unit (ICU). NEWS2 displayed an AUROC of 0.80 (95% confidence interval 0.72–0.88), CURB-65 0.75 (0.65–0.84), PSI 0.75 (0.65–0.84), SIRS 0.70 (0.61–0.80) and qSOFA 0.70 (0.61–0.79). NEWS2 was significantly better than SIRS and qSOFA in predicting severe disease, and with a cut-off of 5 points, had a sensitivity and specificity of 82% and 60%, respectively.

Conclusion: NEWS2 predicted severe COVID-19 disease more accurately than SIRS and qSOFA, but not significantly better than CURB65 and PSI. NEWS2 may be a useful screening tool in evaluating COVID-19 patients during hospital admission.

Trial registration: ClinicalTrials.gov Identifier: NCT04345536. (https://clinicaltrials.gov/ct2/show/NCT04345536).

Keywords: COVID-19, National Early Warning Score2 (NEWS2), qSOFA, Systemic Inflammatory Response Syndrome (SIRS), CURB-65, Pneumonia Severity Index (PSI)
Introduction

COVID-19 was first discovered in Wuhan, China, in December 2019 and has since spread to every continent. The pandemic caused by SARS-CoV-2 has had a devastating impact on healthcare worldwide, exceeding local health-care capacity in many regions of the world. It is estimated that about 5% of COVID-19 patients develop critical disease. Viral pneumonia is the most common organ manifestation, and many patients need respiratory support. Although the majority of patients with COVID-19 admitted to hospital can be managed on general wards with supplemental oxygen, there is limited knowledge on how to identify patients that will ultimately need invasive ventilatory support. A reliable screening tool to identify patients at risk would help allocate limited monitoring resources.

Several tools have been developed for risk stratification in patients with sepsis and pneumonia. Sepsis and pneumonia scoring systems have been evaluated separately in COVID-19, but few comprehensive, prospective comparison of these tools in COVID-19 have been published. The accuracy of sepsis and pneumonia scoring systems in COVID-19 is therefore still uncertain.

Commonly applied scoring systems for sepsis in the emergency department (ED) include; a) the Quick Sequential Failure Assessment (qSOFA) score, b) Systemic Inflammatory Response Syndrome criteria (SIRS), and c) National Early Warning Score 2 (NEWS2). For pneumonia, the two most commonly used scoring systems are CURB-65 and Pneumonia Severity Index (PSI). Both have been prospectively validated to predict mortality. PSI is far more comprehensive and time consuming than CURB-65, though currently not strictly a characteristic. If the score is >70 the patient is assigned to risk class II, 71–90 to risk class III, 91–130 to risk class IV and >130 to risk class V.

In this prospective observational study, we have evaluated and compared the predictive characteristics of commonly used scoring systems for sepsis and pneumonia applied to a cohort of consecutive COVID-19 patients admitted to our hospital. Our aim was to evaluate their accuracy in the ED in predicting the development of severe COVID-19 infection within 14 days after hospital admittance, in order to assist initial triage and allocation of limited monitoring resources.

**Quick Sequential Organ Failure Assessment (qSOFA) (1 point each; score range, 0–3 points)**
- Altered mental state
- Systolic blood pressure <100 mmHg
- Respiratory rate >22 breaths/min

**Systemic Inflammatory Response Syndrome (SIRS) (1 point each; score range, 0–4 points)**
- Temperature >38 °C or <36 °C
- Heart rate >90 beats/min
- Respiratory rate >20 breaths/min or PaCO2 <4.3 kPa
- White blood cell count >12,000 cells/mm³ or <4,000 cells/mm³

**CURB-65 (1 point each; score range, 0–5 points)**
- Confusion
- Urea >7 mmol/l

**Pneumonia severity index (risk class I–V)**

Step 1. If any, assign patient to risk class II–V according to step 2. If none, assign patient to risk class I

**Methods**

All SARS-CoV2-positive patients >18 years old, admitted to the OEH during the period from 01.03.20 to 30.06.20 were evaluated for study participation. Patients transferred from other hospitals, and patients electively hospitalized for medical conditions unrelated to...
SARS-CoV-2, were excluded. Since the aim of this study was to evaluate the value of the scoring systems in the ED, only the calculation of qSOFA, SIRS-criteria, CURB-65, PSI, NEWS2 and P/F-ratio from the patient’s first assessment at the hospital were included. Severe disease was defined as death or treatment in ICU within 14 days after admittance. There were no established criteria for ICU admission. The decision to transfer a patient to ICU was taken by experienced intensivist on duty.

The included patients were included in the quality registry “Covid19 OUS”, at Oslo University Hospital (OUH). The quality registry was approved by the data protection officer at OUH on March 13th 2020 (Reference number 20/08822). Informed consent was waived in accordance with the data protection officer. Patients were included prospectively, but before March 13th, due to the acute onset of the pandemic in Norway, the first eight patients were included retrospectively. The register contains all patients hospitalized with confirmed SARS-CoV-2 (positive reverse transcriptase polymerase chain reaction (RT-PCR)) regardless of symptoms and clinical findings. Identification of COVID-19 positive patients admitted to OUH has been done by cross-checking results of positive SARS-CoV-2 RT-PCR provided by the Department of Microbiology at OUH, and by use of the diagnose coding system “International Classification of Diseases” (ICD10) by identifying the diagnosis codes J12.8 (other viral pneumonia) in combination with U07.1 (COVID-19 identified). The clinicians who assessed the patients were otherwise unrelated to the study. Data were extracted from patient journals and recorded electronically by register staff in the Medinsight registration tool. The records were controlled by two of the authors (ARH, TMO).

Fig. 1 – Flow chart over study participants.
This paper has been developed according to the STARD-guidelines for reporting diagnostic accuracy studies.26

**Statistical analysis**

The area under the receiver operating characteristics curve (AUROC) for severe disease was calculated for each scoring system. Sensitivity, specificity, positive and negative predicative values of the most commonly used cut-off values for SIRS-criteria (2/4), qSOFA (2/3), CURB-65 (2/5), PSI (3/5) and NEWS (5), together with a P/F-ratio less than 300mmHg (40KPa), were determined. Patients with missing data were excluded from the individual calculation.

Continuous variables are given in median and interquartile ranges, and compared using the independent Student’s t test. Categorical variables are given in numbers and percentages, and were compared with the chi-square test. Statistical analyses were calculated using the IBM SPSS Statistics (version 26) and GraphPad Prism (version 8). 95% confidence intervals for sensitivity, specificity and positive and negative predicative values were calculated by Medcalc (https://www.medcalc.org/). P-values less than 0.05 were considered significant.

**Results**

**Patient characteristics**

A total of 207 adult patients with confirmed COVID-19 were admitted to the hospital from March to June 30th. 19 patients transferred from other hospitals and 13 patients electively admitted for nonCOVID related conditions were excluded (Fig. 1), leaving 175 for further analysis. 169 patients had sufficient data from the first assessment to calculate qSOFA, SIRS, CURB-65, PSI and NEWS2. P/F-ratio could be calculated in 136 patients. Within the first two weeks after admittance, 13 patients (7%) died and 29 (17%) were transferred to the hospital from March to June 30th. 19 patients transferred from other hospitals and 13 patients electively admitted for nonCOVID related conditions were excluded (Fig. 1), leaving 175 for further analysis. 169 patients had sufficient data from the first assessment to calculate qSOFA, SIRS, CURB-65, PSI and NEWS2. P/F-ratio could be calculated in 136 patients. Within the first two weeks after admittance, 13 patients (7%) died and 29 (17%) were transferred to one of four ICUs treating patients with COVID-19. 38 patients had severe disease according to the definition of the study protocol. All ICU-patients were admitted to the ICU within 7 days and 83% within the first 3 days. The surge capacity of the hospital was never exceeded. 21 of 29 (72%) ICU-patients were mechanically ventilated.

The patients who developed severe disease were older, had more comorbidity, frailty and limitation of treatment. Baseline characteristics, see Table 1.

**Main outcome**

NEWS2 displayed an AUROC of 0.80 (95% confidence interval 0.71 – 0.88), CURB-65 0.76 (0.67 – 0.84), PSI 0.74 (0.64 – 0.84), SIRS 0.70 (0.61 – 0.80) and qSOFA 0.70 (0.62 – 0.78). NEWS2 were significantly better than qSOFA and SIRS (Fig. 2 and Table 2), and comparable with CURB-65 and PSI. NEWS2 cut-off set to five points demonstrated a sensitivity of 82% and a specificity of 60% in detecting severe COVID-19 (Table 3). QSOFA had a sensitivity of 26% and a specificity of 95%. SIRS displayed a sensitivity of 79% and a specificity of 52%. The pneumonia prediction scores CURB-65 and PSI had sensitivities of 58% and 71% and specificities of 80% and 70%, respectively. The positive predicative values (PPV) of the scoring systems were generally low. NEWS2 ≥ 5 showed the highest negative predicative value (NPV) of 92%, only significantly higher than qSOFA ≥ 2.

The AUROC for P/F-ratio for predicting severe disease was 0.81, which is comparable with NEWS2, CURB-65 and PSI. The sensitivity and specificity for the P/F-ratio with cut-off ≤ 300mmHg (≤40kPa) were 70% and 73%, respectively.

**Discussion**

This prospective observational study of five different scoring systems applied on COVID-19 patients at admittance to hospital found that NEWS2 predicts severe disease in COVID-19 patients significantly better than the sepsis scoring systems qSOFA and SIRS. The

| Variable | All (n=175) | Severe disease (n=38) | Non-severe disease (n=137) | p-value (severe VS non-severe) |
|----------|-------------|-----------------------|-----------------------------|-------------------------------|
| Age, median (IQR), y | 59 (26) | 65 (27) | 54 (25) | 0.002 |
| Male sex, No (%) | 102 (58%) | 27 (71%) | 75 (55%) | 0.071 |
| Limitation of treatment, No (%) | 32 (18%) | 13 (34%) | 19 (14%) | 0.004 |
| Charlson Comorbidity Index, median (IQR) | 1 (2) | 1 (4) | 0 (2) | 0.001 |
| Clinical Frailty Index, median (IQR) | 3 (1) | 3 (2) | 2 (1) | 0.001 |
| Duration of symptoms before admittance, median (IQR), days | 8 (7) | 7 (5) | 8 (7) | 0.40 |

| Variable | All (n=169) | Severe disease (n=38) | Non-severe disease (n=131) | p-value (severe VS non-severe) |
|----------|-------------|-----------------------|-----------------------------|-------------------------------|
| qSOFA ≥ 2, No (%) | 17 (10%) | 10 (26%) | 7 (5%) | <0.001 |
| SIRS ≥ 2, No (%) | 93 (55%) | 30 (79%) | 63 (48%) | 0.001 |
| CURB-65 ≥ 2, No (%) | 49 (29%) | 22 (58%) | 27 (21%) | <0.001 |
| PSI ≥ 3, No (%) | 66 (39%) | 27 (71%) | 39 (30%) | <0.001 |
| NEWS ≥ 5, No (%) | 83 (49%) | 31 (82%) | 52 (40%) | <0.001 |
| NEWS ≥ 6, No (%) | 66 (39%) | 29 (76%) | 37 (28%) | <0.001 |
| NEWS ≥ 7, No (%) | 47 (29%) | 25 (66%) | 22 (17%) | <0.001 |

| Variable | All (n=136) | Severe disease (n=37) | Non-severe disease (n=99) | p-value (severe VS non-severe) |
|----------|-------------|-----------------------|-----------------------------|-------------------------------|
| PaO2/FiO2 ≤ 300mmHg (≤40kPa), No (%) | 53 (39%) | 26 (70%) | 27 (27%) | <0.001 |
AUROC was not significantly higher for NEWS2 than for CURB-65 and PSI.

With a cut-off of NEWS2 set to five, the sensitivity of 82% and the NPV of 92% are moderately good. However, the specificity of 60% and PPV of only 37% makes it challenging to use in clinical practice. When the NEWS2 cut-off value is increased, both the specificity and the PPV increase, but at the expense of sensitivity. NEWS2 is currently used in assessing patients with suspected severe infections in several EDs around the world.\textsuperscript{27,28} Even though a single assessment during hospital admission obviously has limited predictive capability, NEWS2...
might still be useful as a clinical decision tool also in COVID-19. Reliable identification of patients at high risk of developing severe COVID-19 could have important implications. A predictive tool would be helpful in selecting the patients most likely to benefit from additional monitoring, inclusion in interventional trials or receiving intensive care.

There have been several attempts at developing new tools to predict development of severe COVID-19. Liang and colleagues developed a prognostic scoring system consisting of ten factors including X-ray abnormalities, age, symptoms, comorbid conditions and biomarkers. The score is validated in four additional cohorts and obtained an AUROC of 0.88 both in the development cohort and the validation cohorts. It is even launched as a freely available online risk calculator. While promising, the score is demanding in use and requires several diagnostic tests before the score can be calculated.

In contrast to sepsis, which commonly presents with multiorgan failure, COVID-19 is often characterized by solitary respiratory failure. In contrast to the other sepsis scoring tools, three of seven parameters in the NEWS2 score relate to degree of respiratory failure, and this could explain its relatively high performance compared to the other scoring systems we evaluated. However, maximal scores in NEWS2 are reached at respiratory rate \( \geq 25 \), oxygen saturation \( \leq 91\% \) and the need for any supplemental oxygen – parameters often far exceeded in COVID-19 patients at time of admission. It is possible that the prognostic accuracy of the NEWS2 score could be improved by modifying the score. For instance, respiratory rate \( \geq 40 \) breaths per minute, oxygen saturation \( \leq 80\% \) and need for \( \geq 10 \) L of oxygen might further add to the total score. Novel predictive strategies, whether based on new artificial intelligence technology or modifications of existing scores, need to be prospectively tested in adequately sized training and validation cohorts.

Of the 175 hospitalized COVID-19 patients included in our study, 38 were defined as severe disease; non-survivors or by need of intensive care treatment. Thus, adequate clinical observations are of utmost importance. This is hindered by a multitude of infection control measures such as time-consuming donning and doffing of personal protective equipment. It is therefore important that the routines for observations are simple and well documented. Serial assessments using NEWS2 is a reasonable practical approach, and may possibly identify deteriorating patients. While NEWS2 did not perform significantly better than CURB65 and PSI, it is simple to use, include only easily accessible clinical parameters, while CURB-65 and PSI both include laboratory analyses. P/F-ratio assessment require blood gas analysis, and may therefore be difficult to perform outside of the ICU.

It must be emphasized that COVID-19 is mainly a pulmonary disease. We suggest that the NEWS2 score in COVID-19 patients is supplemented with monitoring the degree of oxygen requirement and more detailed grading of respiratory rate and signs of patient exhaustion, as well as the P/F- ratio if feasible.

This study has some limitations. It is a single centre study which may limit the generalizability, and the relatively small number of participants limits the certainty of our analysis. The study was conducted in the early phase of the pandemic, and there may have been changes in clinical practice and routines during the study period. However, we do not think this affected data collection. Notable strengths are that all participants are well characterized in a large prospective quality register that comprise a complete consecutive patient set, including the first COVID-19 patients admitted to our hospital.

In conclusion, our study revealed that NEWS2 was equivalent to CURB65, PSI and P/F-ratio, but more accurate than SIRS and qSOFA, in predicting severe disease among patients hospitalized for COVID-19. However, the value of single assessments is limited, and hospitalized patients must be adequately monitored for signs of deterioration.

Funding

The study was funded by Oslo University Hospital. It did not receive any external funding.

Registration

The study was registered as an observational study in ClinicalTrials.gov. The ClinicalTrials.gov Identifier is NCT04345536.

Conflicts of interest

Dr Olasveengen has received research grants from Zoll Foundation and Laerdal Foundation. No other disclosures were reported.

Ethics approval

Informed consent was waived in accordance with the data protection officer (case number 20/07119) due to the status as a quality register with reporting of aggregated patient data with no risk of identification of personal sensitive information.

Consent for publication

The publication was approved by data protection officer at Oslo University Hospital (case number 20/08822, April 04, 2020).

Availability of data and material (data transparency)

Due to the nature of this research, with data from a quality register with waived consent, data is not available do to ethical and legal restrictions.

Code availability

Not applicable.

CRediT authorship contribution statement

Aleksander Rygh Holten: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing, Supervision. Kristin Grotle Nore: Formal analysis, Investigation, Writing - review & editing. Caroline Emilie Van Woensel Kooy Tveiten: Formal analysis, Investigation, Writing - review & editing. Theresa Mariero
Olasveenge: Methodology, Formal analysis, Investigation, Writing - review & editing, Resources. Kristian Tonby: Methodology, Formal analysis, Investigation, Writing - review & editing, Resources, Supervision.

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REFERENCES

1. Lu H, Stratton CW, Tang YW. Outbreak of pneumonia of unknown etiology in Wuhan, China: the mystery and the miracle. J Med Virol 2020;92(4):401–2.
2. Tanne JH, Hayasaki E, Zastrow M, Pulla P, Smith P, Rada AG. Covid-19: how doctors and healthcare systems are tackling coronavirus worldwide. BMJ (Clin Res Ed) 2020;368:m1090.
3. Ji Y, Ma Z, Peppelenbosch MP, Pan Q. Potential association between COVID-19 mortality and health-care resource availability. Lancet Glob Health 2020;8(4):e480.
4. Maves RC, Downar J, Dichter JR, et al. Triage of scarce critical care resources in COVID-19: an implementation guide for regional allocation: an expert panel report of the Task Force for Mass Critical Care and the American College of Chest Physicians. Chest 2020;158(1):212–25.
5. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese center for disease control and prevention. JAMA 2020;323(12):1239–42.
6. Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. JAMA 2020;323(16):1574–81.
7. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City Area. JAMA 2020;323(20):2022–9.
8. Ferreira M, Bijn T, Collercandy N, et al. Critically ill SARS-CoV-2-infected patients are not stratified as sepsis by the qSOFA. Ann Intensive Care 2020;10(1):43.
9. Ihle-Hansen H, Berge T, Tveita A, et al. COVID-19: symptoms, course of illness and use of clinical scoring systems for the first 42 patients admitted to a Norwegian local hospital. Tidsskr Nor Laegeforen 2020140(7).
10. Gidari A, De Socio GV, Sabbatini S, Francisci D. Predictive value of National Early Warning Score 2 (NEWS2) for intensive care unit admission in patients with SARS-CoV-2 infection. Infect Dis (Lond) 2020;1–7.
11. Jiang JG, Hur J, Hong KS, Lee W, Ahn JH. Prognostic accuracy of the SciRS, qSOFA, and NEWS for early detection of clinical deterioration in SARS-CoV-2 infected patients. J Korean Med Sci 2020;35(25):e234.
12. Su Y, Tu GW, Ju MJ, et al. Comparison of CRB-65 and quick sepsis-related organ failure assessment for predicting the need for intensive respiratory or vasopressor support in patients with COVID-19. J Infect 2020;81(4):647–79.
13. Nguyen Y, Corre F, Honsel V, et al. Applicability of the CURB-65 pneumonia severity score for outpatient treatment of COVID-19. J Infect 2020;81(3):e96–8.
14. Satici C, Demirkol MA, Altunok ES, et al. Performance of Pneumonia Severity Index and CURB-65 in predicting 30-day mortality in patients with COVID-19. Int J Infect Dis 2020;98:84–9.
15. Myrstad M, Ihle-Hansen H, Tveita AA, 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):66.
16. Xie J, Tong Z, Guan X, Du B, Qiu H, Slutsky AS. Critical care crisis and some recommendations during the COVID-19 epidemic in China. Intensive Care Med 2020;46(5):837–40.
17. Seymour CW, Liu VX, Iwashyna TJ, et al. Assessment of clinical criteria for sepsis: For the third international consensus definitions for sepsis and septic shock (sepsis-3). JAMA 2016;315(8):762–74.
18. Bone RC, Balk RA, Cerra FB, et al. Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. The ACCP/SCCM Consensus Conference Committee. American College of Chest Physicians/Society of Critical Care Medicine. Chest 1992;101(6):1644–55.
19. Physicians RCo. National Early Warning Score (NEWS 2): Standardising the assessment of acute illness severity in the NHS. Updated report of a working party, 2017.
20. Lim WS, van der Eerden MM, Laing R, et al. Defining community acquired pneumonia severity on presentation to hospital: an international derivation and validation study. Thorax 2003;58(5):377–82.
21. Bauer TT, Ewig S, Marre R, Suttorp N, Welte T. CRB-65 predicts death from community-acquired pneumonia. J Intern Med 2006;260(1):93–101.
22. Fine MJ, Auble TE, Yealy DM, et al. A prediction rule to identify low-risk patients with community-acquired pneumonia. N Engl J Med 1997;336(4):243–50.
23. Metlay JP, Waterer GW, Long AC, et al. Diagnosis and treatment of adults with community-acquired pneumonia. An official clinical practice guideline of the American thoracic society and infectious diseases society of america. Am J Respir Crit Care Med 2019;200(7):e45–67.
24. Ranieri VM, Rubenfeld GD, Thompson BT, et al. Acute respiratory distress syndrome: the Berlin Definition. JAMA 2012;307(23):2526–33.
25. Vincent JL, Moreno R, Takala J, et al. The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/ failure. Intensive Care Med 1996;22(7):707–10.
26. Cohen JF, Korevaar DA, Altman DG, et al. STARD 2015 guidelines for reporting diagnostic accuracy studies: explanation and elaboration. BMJ Open 2016;6(11):e012799.
27. Bellmammar L, Linder A, Tverring J, et al. NEWS2 is superior to qSOFA in detecting sepsis with organ dysfunction in the emergency department. J Clin Med 2019(8).
28. Churpek MM, Snyder A, Han X, et al. Quick sepsis-related organ failure assessment, systemic inflammatory response syndrome, and early warning scores for detecting clinical deterioration in infected patients outside the intensive care unit. Am J Respir Crit Care Med 2017;195(7):906–11.
29. Wynants L, Van Calster B, Collins GS, et al. Prediction models for diagnosis and prognosis of covid-19 infection: Systematic review and critical appraisal. BMJ 2020;369:m1328.
30. Liang W, Liang H, Ou L, et al. Development and validation of a clinical risk score to predict the occurrence of critical illness in hospitalized patients with COVID-19. JAMA Intern Med 2020;180(8):1081–9.
31. Wu C, Chen X, Cai Y, et al. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan, China. JAMA Intern Med 2020;180(7):934–43.
32. Jiang X, Coffee M, Bari A, et al. Towards an artificial intelligence framework for data-driven prediction of coronavirus clinical severity. Comput Mater Continua 2020;63(1):537–51.