
Scoring systems for early detection of sepsis on the ward

ORIGINAL ARTICLE

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BACKGROUND

Sepsis is one of the most common causes of death in Norwegian hospitals. The condition is often overlooked with treatment being delayed. Scoring systems to detect patients with sepsis have mostly been studied in emergency departments and more rarely on wards. The objective of this study was to investigate the ability of various clinical scoring systems to identify sepsis in patients on wards.

MATERIAL AND METHOD

The ability of the scoring systems SIRS (Systemic Inflammatory Response Syndrome), qSOFA (quick Sequential Organ Failure Assessment) and NEWS2 (National Early Warning Score 2) to identify patients with sepsis was compared in a study of adult patients with clinically suspected severe infection on wards at Haukeland University Hospital in the period March–December 2019. The diagnosis of sepsis was made based on an increase in SOFA (Sequential Organ Failure Assessment) score of 2 or more in the first 24 hours after inclusion.

RESULTS

89 patients with suspected new onset of severe infection were identified. Sepsis was diagnosed in 55 of these patients. SIRS had a sensitivity of 82 % and a specificity of 6 % in diagnosing sepsis, qSOFA had a sensitivity of 20 % and a specificity of 97 %, while NEWS2 with a threshold of an aggregate score ≥ 5 and/or 3 in a single parameter had a sensitivity of 96 % and a specificity of 59 %. Oxygen saturation with a threshold of 95 % was the most sensitive measurement for sepsis.

INTERPRETATION

NEWS2 was better suited than qSOFA and SIRS for early detection of sepsis on wards.

Main findings

The scoring system NEWS2 is suitable for detecting sepsis in ward patients. Respiratory dysfunction led to a diagnosis of sepsis in most patients.

Sepsis is one of the most common causes of death in hospital, and at least one in eight patient deaths in hospital in Norway are from sepsis [\(1\)](#). Incidence increases with advancing age, and more cases of sepsis are expected in coming years due to the ageing population [\(2, 3\)](#). Rapid diagnosis and initiation of antibiotic treatment are the most important steps in severe infections [\(4\)](#). Early detection of sepsis has been a key area of focus for the Norwegian Board of Health Supervision, which conducted a nationwide inspection in 2016–2018 into the management of patients with sepsis in emergency departments [\(5\)](#). The inspection revealed a lack of prioritisation of resources for sepsis patients and delayed initiation of antibiotic treatment. However, the Board did not investigate the management of ward patients. It is also likely that nosocomial sepsis represents a considerable proportion of all cases of sepsis in hospitals, although data are sparse in this regard both at a national and international level [\(1, 3, 6\)](#).

Several scoring systems use vital signs to identify patients with sepsis or other causes of deterioration in a patient's condition. The SIRS (Systemic Inflammatory Response Syndrome) scoring system is a measure of the degree of inflammation and has been used in Norwegian hospitals since the late 1990s [\(7\)](#). The main weakness of the SIRS score is very low specificity in identifying sepsis [\(8, 9\)](#). Following the change in international guidelines in 2016, sepsis was defined as a dysregulated host response to infection leading to organ failure, and more specifically a rise in the SOFA (Sequential Organ Failure Assessment) score of 2 or more. SOFA is a comprehensive scoring system for the assessment of organ failure in six organs and was primarily developed for use in intensive care units. SOFA consists of a comprehensive evaluation of blood samples and clinical parameters, which is time-consuming and relatively

resource-intensive, and it is less suitable for clinical use in emergency departments and on wards (8). Therefore, the qSOFA (quick Sequential Organ Failure Assessment) scoring system was launched at the same time to identify patients with sepsis outside intensive care units. This scoring system has high specificity, but low sensitivity (9–12). The Norwegian Directorate of Health has recommended that NEWS (National Early Warning Score) be used on wards in Norwegian hospitals for the detection of deterioration and sepsis (13). NEWS is not a scoring system specifically for infection, but rather a tool for the systematic monitoring of a patient's vital signs in order to detect changes in their condition (9). NEWS was updated in 2017 to take account of prior respiratory failure, among other things, and now the updated NEWS2 is mainly used. This scoring system has been reported to be better suited for the detection of sepsis than qSOFA and SIRS (9–11, 14). As far as we know, there has been no previous publication of a comparison of the scoring systems for sepsis diagnosis on wards in Norwegian hospitals, although international data are available (15).

The objective of this study was to investigate which of the scoring systems SIRS, qSOFA and NEWS2 were best suited for the early detection of sepsis on wards.

Material and method

The project was a quality study conducted at Haukeland University Hospital in the period March–December 2019. The study was assessed by the Regional Committees for Medical and Health Research Ethics as a quality assurance project (REC West 2018/2535) and was notified to the data protection officer for Bergen Hospital Trust (PVO 00288), with no objections being raised. No data were collected other than data recorded routinely as part of workup and treatment, and therefore patient consent was not obtained. Adult patients over the age of 18 years from five medical and four surgical wards with a total of 146 beds were included. The Medical Division at Haukeland University Hospital has approximately 5,500 bed occupancy days per year, while the Surgical Division has approximately 8,500 per year.

Inclusion criteria were the clinical suspicion by a doctor treating an inpatient on the ward that the patient had new onset of severe infection (Figure 1). We included predominantly nosocomial infections discovered on the ward and not diagnosed on arrival at hospital. Patients with primarily community-acquired infection with deterioration after admission were also included. These patients had infection without sepsis on admission, but subsequently developed sepsis on the ward. The inclusion criteria were that the patient had an initial infection without sepsis for the first 24 hours and developed secondary deterioration more than 24 hours after admission. Identification of patients was carried out by two of the authors reviewing lists of inpatients on individual wards with a doctor or nurse, as well as mandatory review of medical documentation in electronic patient medical records. Identification of patients with suspected sepsis was supported if the attending doctor initiated or changed antibiotic

treatment in addition to ordering new microbiological diagnostic tests, which is recommended in the latest sepsis definition for the identification of sepsis patients in studies (8). Comorbidities, age and sex were recorded based on electronic patient medical records. The suspected focus of infection was recorded from medical record notes and additional investigations for suspected severe infection, and verified in consultation with the departmental staff treating the patients.

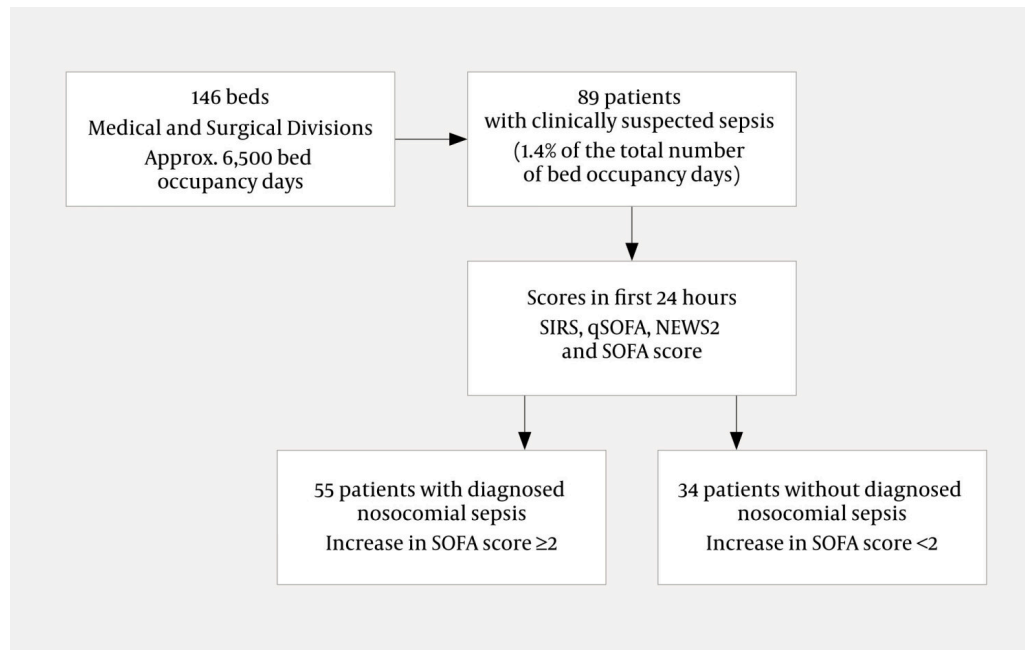


Figure 1 Inclusion of patients in the study.

Data from the electronic medical records system DIPS and the charting system Meona were recorded for 24 hours from the first moment that severe infection was suspected. Values that were recorded at the closest possible time to the suspicion of severe infection were used to score the patients in SIRS, qSOFA and NEWS2. For scoring in SOFA, values prior to suspicion of severe infection were compared with the worst single values measured in the next 24 hours (7, 8, 11). The SIRS criteria include two or more of the variables of temperature ($> 38^{\circ}\text{C}$ or $< 36^{\circ}\text{C}$), pulse rate (> 90 bpm), respiratory rate (> 20 breaths per minute) and leukocyte count ($> 12 \times 10^9/\text{L}$ or $< 4 \times 10^9/\text{L}$). The qSOFA test was defined as positive if at least two of the following criteria were fulfilled: systolic blood pressure ≤ 100 mmHg, respiratory rate ≥ 22 breaths per minute and altered mental status. NEWS2 includes a number of parameters and is presented in Table 1. A NEWS2 score of ≥ 5 is considered the threshold, in addition to a value of 3 in any single vital parameter category (14).

Table 1

NEWS2 (National Early Warning Score 2). Scoring system based on six physiological parameters. The system takes account of pre-existing respiratory failure. Based on (14).

Parameter	Score						
	3	2	1	0	1	2	3
Respiratory rate (breaths per minute)	≤ 8		9–11	12–20		21–24	≥ 25

Parameter	Score						
	3	2	1	0	1	2	3
SpO ₂ , scale 1 (%) ¹	≤ 91	92-93	94-95	≥ 96			
SpO ₂ , scale 2 (%) ¹	≤ 83	84-85	86-87	88-92 ≥ 93 on room air	93-94 on O ₂	95-96 on O ₂	≥ 97 on O ₂
Room air or oxygen		oxygen		room air			
Systolic blood pressure (mmHg)	≤ 90	91-100	101-110	111-219			≥ 220
Pulse rate (bpm)	≤ 40		41-50	51-90	91-110	111-130	≥ 131
Level of consciousness ²				A			C, V, P, U
Temperature (°C)	≤ 35.0		35.1- 36.0	36.1- 38.0	38.1- 39.0	≥ 39.1	

¹SpO₂ scale 2 should be reserved for patients with known hypercapnic respiratory failure with target SpO₂ of 88–92 %, verified by blood gas analysis. The doctor should document in the medical records when scale 2 should be used. Scale 1 should be used in all other cases.

²Level of consciousness: A = alert, C = new confusion, V = responds to verbal stimulus, P = responds to pain stimulus, U = unresponsive to verbal or pain stimulus.

Sepsis was defined as infection and an increase in SOFA score of ≥ 2 in the first 24 hours after severe infection was suspected (8). The various parameters included in the SOFA score are presented in Table 2 (16). For 58 patients, the fraction of O₂ was known in their treatment, but data from arterial blood gas analysis and thus arterial pressure of oxygen (PaO₂) were missing. These patients' SOFA score for the respiratory system was estimated by using a published conversion table (17). The table was missing a threshold for a SOFA score of 1. We decided to use > 90 % oxygen saturation on room air as a threshold for a SOFA score of 1 based on previous practice at Haukeland University Hospital and other Norwegian hospitals (18). Bilirubin was the marker with most missing data (32 patients), which might result in underestimation of the SOFA score. Since previous studies have demonstrated a low incidence of hepatic failure with sepsis (2.4 %), the effect of this will probably be low (1). Medical records were reviewed two months after the end of the inclusion period to record 30-day mortality.

Table 2

SOFA (Sequential Organ Failure Assessment). Scoring system based on parameters from six organ systems (16). MAP = mean arterial pressure, GCS = Glasgow Coma Scale, DA = dopamine ($\mu\text{g}/\text{kg}/\text{min}$), DB = dobutamine ($\mu\text{g}/\text{kg}/\text{min}$), A = adrenaline ($\mu\text{g}/\text{kg}/\text{min}$), NA = noradrenaline ($\mu\text{g}/\text{kg}/\text{min}$).

Organ system	Parameter	Score				
		0	1	2	3	4
Respiration	PaO ₂ /FiO ₂ (kPa)	> 53.3	<53.3	<40	<26.7 ¹	<13.3 ¹
Circulation	MAP (mmHg)	> 70	<70	DA <5 or DB	DA 5.1-15 A ≤ 0.1 NA ≤ 0.1	DA > 15 A > 0.1 NA > 0.1
Central nervous system	GCS	15	13-14	10-12	6-9	<6
Renal	Urine production (mL/24 hours)				<500	<200
	Creatinine (μmol/L)	<110	110-170	171-299	300-440	> 440
Coagulation	Platelets (× 10 ³ /μL)	≥ 150	<150	<100	<50	<20
Hepatic	Bilirubin (μmol/L)	<20	20-32	33-101	102-204	> 204

¹With mechanical ventilation.

Statistics

Sensitivity, specificity, positive predictive value and negative predictive value for sepsis were calculated for each test. Statistical analysis included the Mann-Whitney test for comparison of continuous non-parametric data and the chi-squared test for comparison of categorical variables. A ROC (receiver operating characteristic) curve was plotted for each test, including Youden's index, using GraphPad Prism 8 (GraphPad Software, San Diego, California, USA). MedCalc version 20.109 (MedCalc Software bv, Ostend, Belgium) was used for pairwise comparison of the area under the ROC curve with DeLong's test. Calculation of statistical power for mortality prediction found that 200 patients needed to be included to provide sufficient power to be able to demonstrate the scoring systems' ability to predict mortality. Unfortunately, resources were not available for further patient inclusion in this project, but we have nevertheless decided to publish the data.

Results

A total of 89 patients with suspected sepsis were included in the study. The most common suspected focus of infection was the abdomen (28 patients, 31 %), respiratory tract (21 patients, 24 %) and urinary tract (9 patients, 10 %). No definite focus of infection was detected in 24 patients (28 %). The main clinical data are presented in Table 3. The criteria for sepsis with an increase in

SOFA score of ≥ 2 were fulfilled in 55 patients (62 %). Respiratory dysfunction led to the diagnosis of sepsis in most of the patients, and 51 (93 %) of the 55 patients with an increase in SOFA score of ≥ 2 were allocated points in this category. The next most common organ failure was circulatory failure, which was recorded in 26 patients (47 %). All of the 9 patients who died within 30 days of inclusion had been diagnosed with sepsis, which corresponds to a mortality rate in the sepsis group of 16 % (9 out of 55).

Table 3

Data for 89 patients with clinical suspicion of sepsis at Haukeland University Hospital. In the 'Sepsis' and 'Not sepsis' columns, the figures state the number (%) unless otherwise specified. Significant *p*-values are shown in bold. qSOFA = quick Sequential Organ Failure Assessment, SIRS = Systemic Inflammatory Response Syndrome, NEWS2 = National Early Warning Score 2.

Variable	Sepsis (<i>n</i> = 55)	Not sepsis (<i>n</i> = 34)	<i>p</i> -value
Age in years, median (distribution)	67 (21–75)	60 (20–91)	0.066
Female	23 (42)	13 (38)	0.738
Comorbidities			
At least one comorbidity	38 (69)	28 (82)	0.165
Hypertension	19 (35)	5 (15)	0.040
Cardiovascular disease	20 (36)	5 (15)	0.027
Chronic pulmonary disease	3 (5)	2 (6)	0.932
Chronic kidney disease	5 (9)	3 (9)	0.965
Hepatic failure	3 (5)	0 (0)	0.166
Diabetes	12 (22)	5 (15)	0.407
Immunosuppression	7 (13)	15 (35)	0.001
Malignancy	16 (29)	20 (59)	0.006
Suspected focus of infection			
Abdomen	19 (35)	9 (26)	0.425
Respiratory tract	11 (20)	10 (29)	0.310
Urinary tract	7 (13)	2 (6)	0.298
Soft tissue	5 (9)	2 (6)	0.585
Unknown	13 (24)	11 (32)	0.368
Ward			
Medical	21 (38)	26 (76)	<0.001
Surgical	34 (62)	8 (24)	<0.001
Bacteraemia	14 (25)	6 (11)	0.391

Variable	Sepsis (n = 55)	Not sepsis (n = 34)	p-value
Clinical variables, median (distribution)			
Respiratory rate, breaths per minute	22 (12–44)	24 (15–37)	0.452
SpO ₂ , %	93 (62–98)	94 (90–100)	0.002
Systolic blood pressure, mmHg	125 (65–185)	133 (92–202)	0.076
Pulse rate, bpm	102 (60–142)	109 (71–147)	0.094
Temperature, °C	38.1 (35.9–40.9)	38.4 (37.3–39.5)	0.023
Leukocytes, × 10 ⁹ /L	10.5 (0.2–94.4)	8.9 (0.2–19.9)	0.319
Scoring system, median (distribution) ¹			
qSOFA	1 (0–2)	0 (0–2)	<0.001
SIRS	3 (0–4)	3 (1–4)	0.141
NEWS2	7 (2–12)	4 (1–10)	<0.001
SOFA	3 (2–10)	1 (0–5)	<0.001
Mortality	9 (16)	0	0.013

¹Values recorded as close as possible to the time that severe infection was suspected were used to score the patients on qSOFA, SIRS and NEWS2. For scoring on SOFA, values prior to suspicion of severe infection were compared with the worst single values measured in the following 24 hours.

The three scoring systems are presented in Table 4. System characteristics in the detection of sepsis are presented in Table 5. ROC analysis was performed to investigate the ability of the various scoring systems to identify patients with sepsis (Figure 2). Increasing area under the curve (AUC) represents the test's increasing ability to diagnose the condition – an ideal test would have an area of 1.0. For NEWS2, we found an AUC value of 0.79 (95 % CI 0.69 to 0.87), while it was lower for both qSOFA and SIRS, which had AUC values of 0.74 (95 % CI 0.63 to 0.82) and 0.59 (95 % CI 0.48 to 0.69) respectively. There was a significant difference between the AUC value for NEWS2 and SIRS ($p = 0.03$), while the AUC value for qSOFA was not significantly different from the values for NEWS2 and SIRS.

Table 4

Results for the various scoring systems for patients with and without sepsis at Haukeland University Hospital, stated as number of patients (%) in each group. qSOFA = quick Sequential Organ Failure Assessment, SIRS = Systemic Inflammatory Response Syndrome, NEWS2 = National Early Warning Score 2.

Scoring system	Sepsis (n = 55)	Not sepsis (n = 34)	Total (n = 89)
qSOFA			

Scoring system	Sepsis (n = 55)	Not sepsis (n = 34)	Total (n = 89)
≥ 2	11 (20)	1 (3)	12 (13)
<2	44 (80)	33 (97)	77 (87)
SIRS			
≥ 2	45 (82)	32 (94)	77 (87)
<2	10 (18)	2 (6)	12 (13)
NEWS2			
≥ 5 in total and/or 3 in a single parameter	53 (96)	14 (41)	67 (75)
<5 in total and/or < 3 in all parameters	2 (4)	20 (59)	22 (25)
≥ 5	51 (93)	13 (38)	64 (72)
<5	4 (7)	21 (62)	25 (28)

Table 5

Test characteristics in the detection of sepsis with established thresholds for qSOFA, SIRS and NEWS2 in patients with clinically suspected sepsis at Haukeland University Hospital. Values are stated as percentages with 95 % confidence interval (CI). Please note that NEWS2 can also be used with an alert threshold of a score of 3 in a single parameter. qSOFA = quick Sequential Organ Failure Assessment, SIRS = Systemic Inflammatory Response Syndrome, NEWS2 = National Early Warning Score 2.

Variable	qSOFA ≥ 2 (95 % CI)	SIRS ≥ 2 (95 % CI)	NEWS2 ≥ 5 in total and/or 3 in a single parameter (95 % CI)	NEWS2 ≥ 5 (95 % CI)
Sensitivity	20 (12 to 32)	82 (70 to 90)	96 (88 to 99)	93 (83 to 97)
Specificity	97 (85 to 100)	6 (1 to 19)	59 (42 to 74)	62 (45 to 76)
Positive predictive value	92 (65 to 100)	58 (47 to 69)	79 (68 to 87)	80 (68 to 88)
Negative predictive value	43 (32 to 54)	17 (3 to 45)	91 (72 to 98)	84 (65 to 94)
Mortality rate	8	8	13	14

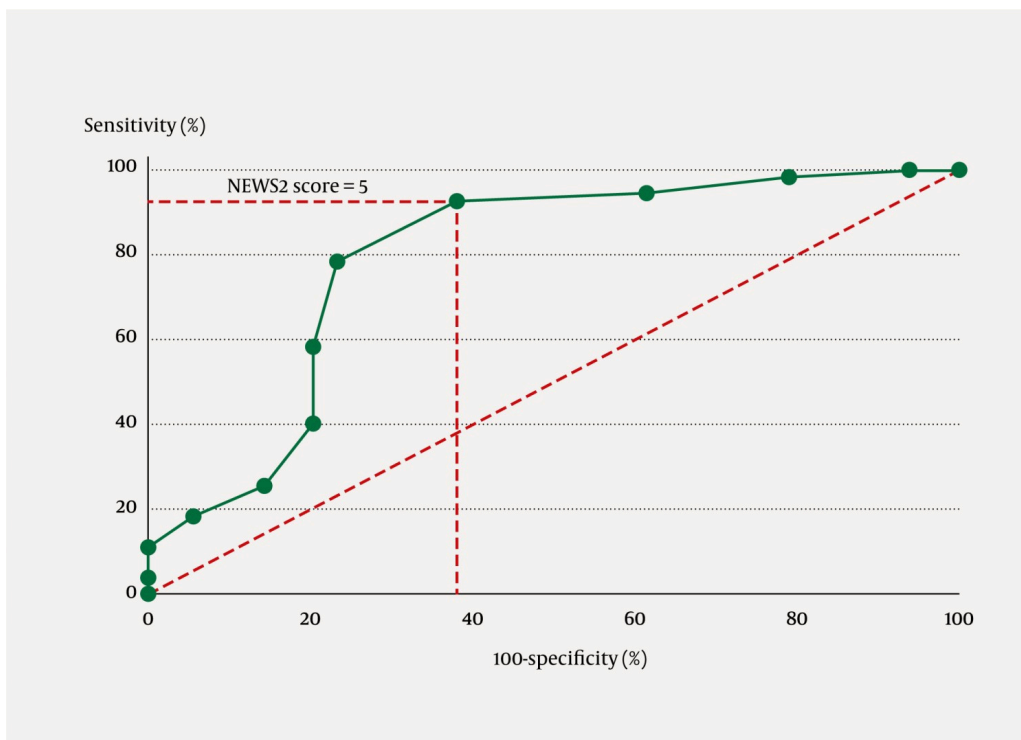


Figure 2 ROC (receiver operating characteristic) curve showing how well the NEWS2 aggregate score can distinguish between patients with and without sepsis. A NEWS2 score of 5, which is the recommended alert threshold, is indicated.

The best threshold for detection of sepsis with the various tests was investigated with Youden's index, which tests for the best statistical threshold regardless of its clinical relevance because high sensitivity and negative predictive value are often more important. The results differed somewhat from established thresholds, with a best threshold of 6 for NEWS2 with a sensitivity of 78 % and specificity of 76 %, and ≥ 2 for qSOFA with a sensitivity of 20 % and specificity of 97 %. The best threshold for SIRS was difficult to evaluate since more of the patients without sepsis fulfilled four SIRS criteria, so there is little clinical relevance in presenting Youden's index values for SIRS.

To establish the possible reason for the differences in detection of sepsis by the various scoring systems, we evaluated the test characteristics for the individual parameters. Out of the parameters recorded, the most sensitive measure of sepsis was oxygen saturation with a threshold of 95 % (85 %). We also found a correlation between respiratory rate and decreasing oxygen saturation ($r = -0.30$, $p = 0.017$). Pulse rate > 100 bpm had a sensitivity of 71 %. The remaining parameters had a sensitivity of between 18 % and 55 %, with the GCS (Glasgow Coma Scale) parameter having the lowest. We recorded ten patients with altered mental status, all of whom were diagnosed with sepsis. The most specific parameters were altered mental status (measured with GCS score) and decreased systolic blood pressure, followed by oxygen saturation.

Discussion

NEWS2 was the most sensitive scoring system in identifying patients with sepsis on wards, while qSOFA had the highest specificity. The AUC values were acceptable for both NEWS2 and qSOFA, but the low sensitivity of qSOFA entails a high risk of missing most cases of sepsis if this system is used alone.

Although few of the ward patients with sepsis were included in this study, the results are consistent with previous studies conducted in emergency departments (9–11). It has largely been demonstrated that NEWS2 is able to predict mortality and need for intensive care treatment for both patients in emergency departments and those on wards (15, 19), but the statistical power of our study was too low to draw any conclusions about whether NEWS2 predicts mortality. Two Norwegian studies have found that NEWS2 was also useful in predicting outcomes in COVID-19 patients (20, 21).

In the Norwegian Board of Health Supervision's assessment of sepsis treatment, the main concern was a lack of prioritisation of resources for sepsis patients in emergency departments (5). A lack of specificity of SIRS and hence an inability to prioritise was also the reason for international guidelines recommending a move away from the SIRS criteria in the sepsis definition in 2016 (8). In 2021, the Surviving Sepsis Campaign (SSC) published updated guidelines warning against the use of qSOFA alone as a scoring system to detect sepsis because its sensitivity is too low, which is in line with our results (22).

The best thresholds for detection of sepsis in our study according to statistical analysis with Youden's index were 6 for NEWS2 and 4 for SIRS. This differs from the established thresholds of 5 and 2 respectively. Our assessment is that the established thresholds provide better sensitivity, but that NEWS2 with a threshold of 5 still has acceptable specificity. Tables 4 and 5 show little difference in sensitivity and specificity with NEWS2 if a score of 3 in a single parameter is included in addition to an aggregate score of 5 as a threshold, which was the initial recommendation for NEWS2 (14). There are similar findings in a study, i.e. that it would be sufficient to keep an aggregate score of 5 alone as the threshold for NEWS2 because the addition of one single parameter of 3 would create an increased burden of work without any great improvement in sensitivity (23). Therefore, in the latest version of NEWS2, the National Health Service (NHS) recommends giving patients with a single parameter score of 3 closer monitoring and assessment on the ward, but not the same alerting of doctors as a total NEWS2 score of 5 or more (14).

There are several weaknesses with the study. The inclusion criterion was a clinical suspicion on the part of clinical staff treating a ward inpatient that the patient had a severe infection. However, we did not record data from all inpatients on wards in the inclusion period because our electronic medical records systems were not equipped for that type of data collection. Although inpatients were assessed for all days in the inclusion period, we cannot rule out the fact that individual patients with suspected severe infection were not included in the study. An important weakness is that the assessment of the

focus of infection was based on the subjective diagnosis of the clinician treating the patient, and that no post-hoc assessment of the probability of infection was performed (24). However, the main weakness was that too few patients were included in the study to be able to assess the scoring systems' ability to predict mortality since it has previously been demonstrated that NEWS2 can be used for this purpose (15).

Clinical parameters were recorded in cases of clinical suspicion of infection. Since the study was partly based on a retrospective review of data collected from patient medical records, it has been challenging to obtain complete data, and data are missing for several patients. Oxygen saturation was the most sensitive single parameter for sepsis, while at the same time it was also the most problematic to interpret. The most challenging aspect of calculating the total SOFA score was calculating the SOFA score for respiration in patients for whom arterial blood gas analysis results were missing. We identified the best estimated value using a table to impute a ratio calculated from oxygen saturation, but discovered early on that this had its limitations (9, 17). The table does not give definite values for a SOFA score of 1, and the fact that we had to use thresholds previously used for respiratory failure in sepsis resulted in uncertainty in the recording of respiratory failure. If we only recorded those patients for whom arterial blood gas results were available, the proportion with recorded respiratory failure would have been underestimated. If we had followed the table without correction, the proportion with respiratory failure would have been overestimated. Another option for calculating a SOFA score based on peripheral oxygen saturation may be to use oxygen saturation of 94 % and 91 % on room air as thresholds for SOFA scores of 1 and 2 respectively, which has recently been proposed and validated in a larger patient cohort (25).

The assessment of mental status is also challenging. A large proportion of altered mental status in this study was recorded by nurses who used NEWS2 for scoring. However, there is a risk that this value is underestimated because a systematic screening tool, for example 4AT, was not used to record altered mental status (26).

Prompt antibiotic treatment is the single measure that has greatest impact for the prognosis of sepsis patients (5). Data from Norway demonstrate that early detection of sepsis on the ward results in reduced mortality (27). Deterioration in a patient's condition often occurs gradually, and it is important to detect changes early enough to prevent the development of sepsis and organ failure. In this study, we found that reduced oxygen saturation was more sensitive than other parameters such as mental status, which may help explain differences between the various scoring systems.

Conclusion

Our data indicate that NEWS2 is better suited than qSOFA and SIRS to detect sepsis in patients on the wards.

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