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An investigation into the predictive capability for mortality and the trigger points of the National Early Warning Score 2 (NEWS2) in Emergency Department patients.

Abstract

Introduction: National Early Warning Score 2 (NEWS2) is widely used to monitor and trigger assessment throughout a patient's hospital journey. Since the development and roll out of NEWS2, its ability to predict mortality has been assessed in several settings, although to date not within the Emergency Department (ED).

Methods: we conducted a retrospective observational study of all adult ED attendees at two EDs in Northern England, between March and November 2019. Multilevel multiple logistic regression analyses were conducted on patient episode data (clustered within patient data) to assess the relationship between mortality at 2, 7 and 30 days from attendances; and maximum NEWS2, adjusting for age, sex, arrival mode and triage priority.

Results: Data were collected from 91,871 valid patient episodes associated with 64,760 patients. NEWS2 was a significant predictor of mortality at 2 days (odds ratio (OR) 1.75; 95% confidence interval (CI) 1.58-1.93); at 7 days (OR 1.69; 95% CI 1.59-1.80); at 30 days (OR 1.58; 95% CI 1.52-1.64). For the analyses of categorised NEWS2, NEWS2 of 2-20 was significantly associated with mortality at 2, 7 and 30 days compared with none-assigned: OR 3.54 (95% CI 2.15-5.85) at 2 days; OR 6.05 (95% CI 3.92-9.34) at 7 days; OR 12.4 (95% CI 7.91-19.3) at 30 days. Increasing age, male sex, arrival by ambulance and higher triage categories were also associated with significantly increased mortality. AUROC values of 0.963, 0.946 and 0.915 respectively were recorded for mortality outcomes, with optimum likelihood ratios associated with a trigger of 4 NEWS2 points.

Conclusions: NEWS2 is an effective predictor of mortality for patients presenting to the ED. Findings suggest that maximum NEWS2 of 4 and over may be the best trigger point for escalation of treatment. Findings also suggest a NEWS2 of 0-1 can identify a very low risk group within the ED.

What does this paper add?

What is already known on this subject?

- Since the development and roll out of NEWS2, its ability to predict mortality has been assessed in both inpatient and pre-hospital settings.
- However, to date the predictive capability of NEWS2 has not been assessed within the Emergency Department (ED).

What this study adds

- This study shows NEWS2 is an effective predictor of mortality for patients presenting to the ED.
- Findings suggest that a NEWS2 of 4 and over may be the best trigger point for escalation of treatment
- A NEWS2 of 0-1 can identify a very low risk group within the ED, which may be amenable to streaming.

Introduction

The National Early Warning Score (NEWS) was originally published by the Royal College of Physicians (RCP) in 2012. NEWS was developed as scoring system to predict mortality, which could be used as a

common monitoring system throughout the patient journey, and trigger clinical intervention in response to deterioration. NEWS was widely adopted in the National Health Service (NHS) and was validated across many clinical settings ¹.

In December 2017 the RCP published the National Early Warning Score 2 (NEWS2) as an update to the 2012 NEWS. The rationale for this change was to better predict deterioration in patients with hypercapnic respiratory failure ¹. In January 2019 NEWS2 was rolled out across the NHS in England, and is used throughout the patient journey from ambulance setting to inpatient. NEWS2 uses 6 physiological parameters (respiratory rate, pulse rate, systolic blood pressure, temperature, conscious level, and either of 2 levels of oxygen saturation scales dependent on a history of hypercapnic respiratory failure); each scored between 0 (least severe) and 3 (most severe) depending on the deviation from 'normal', with a further 2 points allocated for the use of supplemental oxygen. The score is then calculated as the total of the individual items. Hence a range of scores from 0 (least severe) to 20 (most severe) is possible.

The score is used to track patient progress, and trigger action at certain levels, with a key urgent response triggered at an aggregate score of 5 and above. The work done to derive this scoring system was performed by the RCP using inpatient data. NEWS2 has since been validated in various settings from pre-hospital to inpatient but generally looking at specific population ²⁻¹². However, to date, the capability of NEWS2 to predict mortality has not been assessed within an undifferentiated Emergency Department (ED) population. The objective of this study is to assess the predictive capability of NEWS2 as well as the use of trigger points within the ED setting.

Methods

We undertook a retrospective observational study reviewing the data of all adult (18 years old and over) ED attendances at both EDs within the Calderdale and Huddersfield NHS Foundation Trust (CHT) in the North of England between March and November 2019. Data was obtained from the Trust's electronic patient record (EPR), which is used to record all patient contacts during their stay in the ED, and links directly to NHS Spine (a national health database). Ethical approval for the study was granted by the Trust's research ethics committee. The following variables were recorded: age (years); sex; arrival mode (categorised as *Ambulance* or *Other*); triage priority level (recorded on a scale from 1 (most urgent) to 5 (least urgent)); maximum NEWS2 score; and patient status (recorded as surviving or died) at 2, 7 and 30 days after admission. Not all variables were recorded on all patients.

The sample was summarised descriptively. The extent of missing data was assessed. A small number of errors were identified, including patients whose dates of death had been erroneously recorded as occurring before date of attendance, or instances of the same death being recorded for the same patient on different dates. These items were checked individually and corrected where possible. Where correct values could not be established, cases were removed from the data set. Further exploratory procedures were conducted prior to the main analysis, including checking for collinearity between covariates.

A preliminary analysis was conducted to compare death rates at 7 days in those patients with no NEWS2 recorded and those patients with NEWS2 of 0 or 1 recorded using a Z-test for the comparison of 2 binomial proportions. Multilevel multiple logistic regression models were conducted on the subset of data for which one or more NEWS2 had been recorded, using outcomes of: death by 2 days from attendance; death by 7 days from attendance; death by 30 days from attendance. Analysis was conducted at the *episode* level. Maximum NEWS2 was considered as the predictor variable of primary

interest. In all models, patient age, sex, arrival mode and triage priority level were included as controlling variables. Patient age, arrival mode, triage priority level and maximum NEWS2 were considered as episode-level variables: patient status and sex were considered as patient-level variables. *P*-values, odds ratios (ORs) and 95% confidence intervals (CIs) in the multilevel models were reported in all models. CIs were calculated using clustered robust standard errors, clustered at the patient level.

ROC analyses were conducted using predicted probabilities as test variables against the outcomes of death by 2, 7 and 30 days from admission. For each model, the area under the ROC (AUROC) was derived for the test variable, to assess the overall discriminative capability of the maximum NEWS2 in conjunction with controlling variables, and to identify possible maximum NEWS2 thresholds as a predictor of death. Sensitivity, specificity and likelihood ratios (the ratio of the probability of death if the patient has a maximum NEWS2 over a given threshold to the probability of death if the patient has a maximum NEWS2 below that threshold) were calculated at each identified threshold.

After initial cross-tabulation a corresponding series of multilevel multiple logistic regression analyses, using the same set of outcomes and data structure, was conducted on all cases, with patient maximum NEWS2 categorised as follows: no NEWS2 recorded; maximum NEWS2 of 0 or 1 recorded; maximum NEWS2 of 2 or above recorded. Other predictor and outcome variables were included as in the models including the numerical version of the NEWS2.

For all multilevel models conducted, the data structures were assessed using χ^2 tests to compare log-likelihood statistics of multilevel and corresponding single-level models.

All statistical analyses were conducted using Stata statistical software (Version 14 I/C).¹³

Results

Descriptive and exploratory procedures

Data were collected from 91,871 valid patient episodes associated with 64,760 patients (48.8% male) of recorded ages from 18 to 109 years. Six cases were removed from the data set due to ambiguities in patient status and/or time of death. About 53.6% of patients were associated with a single attendance only. The number of attendances per patient ranged from 1 to 65; with 93.2% of all patients having 5 or fewer attendances. 24,881 patient attendance (27.1%) had no NEWS2 recorded.

The sample is summarised in Table 1 below. The denominator for sex and all patient death variables is the number of patients; for other variables, it is number of patient episodes.

Table 1: descriptive summary of sample data

Variable	Frequency (valid %)
Number of attendance per patient (<i>n</i> =91,871)	
1	49,252 (53.6%)
2	20,418 (22.2%)
3	8,991 (9.8%)
4	4,484 (4.9%)
5	2,500 (2.7%)
6 or more	6,226 (6.8%)
Maximum NEWS2 category	
Not recorded	24,881 (27.1%)
0-4	60,589 (66.0%)
5-6	3,362 (3.7%)

7-20	3,039 (3.3%)
Sex (n=64,760)	
Male	31,595 (48.8%)
Female	33,165 (51.2%)
Arrival mode (n=91,871)	
Ambulance	27,714 (30.2%)
Other	64,157 (69.8%)
Death by 2 days from attendance (n=64,760)	357 (0.55%)
Death by 7 days from attendance (n=64,760)	681 (1.05%)
Death by 30 days from attendance (n=64,760)	1356 (2.09%)
Variable	Mean (SD; range)
Age (years) (n=91,871)	50.1 (21.5; 18-109)
Maximum NEWS2 (n=66,990)	1.55 (2.17; 0-18)
Triage priority (n=90,951)	3.26 (0.822; 0-5)

47 patients with no NEWS2 recorded died within 7 days from attendance (0.19%). 46 patients with a NEWS2 of 0 or 1 recorded died within 7 days of attendance (0.10%). The difference in proportions was statistically significant at the 5% significance level ($Z=2.99$; $p=0.003$).

The numerical maximum NEWS2 was not strongly correlated with any other variable. Arrival mode was found to be strongly correlated with the categorised version of maximum NEWS2, with only 3.2% of patient episodes with no NEWS2 arriving by ambulance, compared to 31.0% of those with a maximum NEWS2 of 0 or 1; and 58.8% of those with a maximum NEWS2 of 2 or above. In view of the primary interest in NEWS2 as a predictor of death, the arrival mode variable was removed from this series of analyses, to avoid issues of collinearity.

A cross-tabulation of proportions of patient deaths by 2, 7 and 30 days revealed little substantive difference in proportions of deaths by 2 and 7 days from attendance in the categories corresponding to patients with no recorded NEWS2, and those with maximum NEWS2 of 0 or 1; but higher rates in patients with maximum NEWS2 of 2 or more. This categorisation was based on the practice of streaming patients on the basis of a NEWS2 of 0-1; and also on the basis of a preliminary analysis of death rates at 2, 7 and 30 days. This preliminary analysis suggested that there was little substantive distinction in rates experienced by those with NEWS2 scores of 0 or 1, or those with unrecorded NEWS2; however, a step change in rates was apparent between those with NEWS2 of 1 and those with NEWS2 of 2 or above. All categories were substantively distinct with respect to the outcome of death by 30 days from admission (Table 2).

Table 2: proportion of deaths by 2, 7 and 30 days in patients categorised by maximum NEWS2

NEWS2	Number of patients	Outcome		
		Death by 2 days	Death by 7 days	Death by 30 days
No NEWS2 recorded	24,880	42 (0.169%)	47 (0.189%)	63 (0.253%)
Maximum NEWS2 0-1	44,779	12 (0.0268%)	46 (0.103%)	288 (0.643%)
Maximum NEWS2 2-20	22,206	309 (1.39%)	620 (2.79%)	1275 (5.74%)
Maximum NEWS2: 0-4	60,586	53 (0.0875%)	168 (0.277%)	706 (1.17%)
Maximum NEWS2: 5-6	3,361	48 (1.43%)	118 (3.51%)	262 (7.80%)
Maximum NEWS2: 7-20	3,038	220 (7.24%)	380 (12.5%)	595 (19.6%)

Analysis of patients with valid maximum NEWS2

Parameters from the multiple multilevel logistic regression models conducted on the data using cases with valid maximum NEWS2 and considering NEWS2 as a continuous variable are summarised in Table 3.

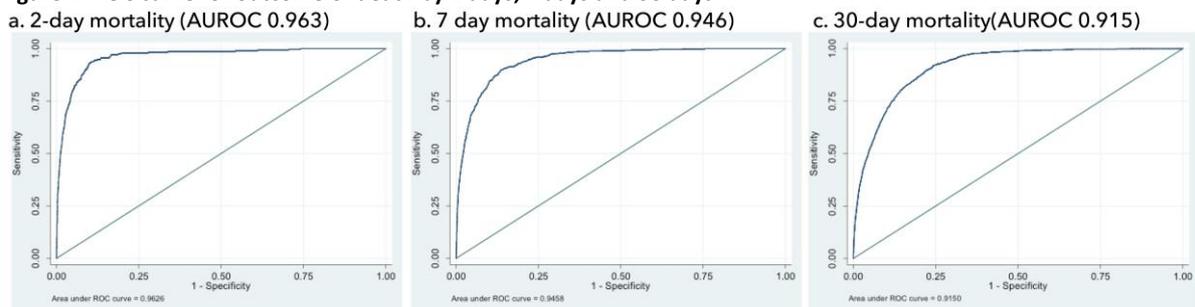
Table 3: multiple multilevel regression parameters

Outcome	Variable	p-value	OR	95% CI for OR
Death by 2 days	Maximum NEWS2	<0.001	1.75	(1.58, 1.93)
	Sex (reference: male)	0.731	0.941	(0.664, 1.33)
	Age (years)	<0.001	1.06	(1.05, 1.08)
	Triage priority	<0.001	0.395	(0.304, 0.512)
	Arrival method (reference: non-ambulance)	<0.001	3.06	(1.73, 5.41)
<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(1)}=43.2, p<0.001$</i>				
Death by 7 days	Maximum NEWS2	<0.001	1.69	(1.59, 1.80)
	Sex (reference: male)	0.002	0.674	(0.524, 0.867)
	Age (years)	<0.001	1.07	(1.06, 1.08)
	Triage	<0.001	0.552	(0.457, 0.666)
	Arrival method (reference: non-ambulance)	<0.001	4.10	(2.78, 6.05)
<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(1)}=116, p<0.001$</i>				
Death by 30 days	Maximum NEWS2	<0.001	1.58	(1.52, 1.64)
	Sex (reference: male)	<0.001	0.618	(0.505, 0.756)
	Age (years)	<0.001	1.09	(1.08, 1.10)
	Triage	<0.001	0.605	(0.529, 0.691)
	Arrival method (reference: non-ambulance)	<0.001	5.04	(3.82, 6.65)
<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(1)}=735, p<0.001$</i>				

For each model, the significance of the χ^2 test statistic justifies the assumption of the hierarchical data structure.

ROC curves based on predicted probabilities for each event of interest are illustrated in Figure 1(a)-(c). Associated AUROC values were in excess of 0.9 in each case (0.963 for 2 day, 0.946 at 7 day and 0.915 at 30 days mortality). Hence all models show good discriminative capability; with optimum discrimination shown in models of early death.

Figure 1: ROC curve for outcome of death by 2 days, 7 days and 30 days



Possible suitable maximum NEWS2 thresholds for each model, with associated sensitivity, specificity and likelihood ratios are summarised in Table 4. Higher likelihood ratios may be obtained only at a cost of reduced test sensitivity.

Table 4: NEWS2 threshold scores, sensitivity and specificity values

Model	NEWS2 threshold(s)	Optimum sensitivity	Optimum specificity	Likelihood ratio
Death by 2 days	3 and above	94.4%	79.3%	4.56
	4 and above	89.1%	86.7%	6.70
	5 and above	83.5%	90.8%	9.08
Death by 7 days	3 and above	87.5%	79.6%	4.29
	4 and above	80.8%	87.0%	6.23
	5 and above	74.8%	91.1%	8.40
Death by 30 days	3 and above	72.6%	81.2%	3.67
	4 and above	63.3%	87.6%	5.10
	5 and above	54.8%	91.5%	6.45

At a threshold of 2.5 (i.e. NEWS2 of 3 or above), action would be triggered in 15.3% of all patients (21.0% of patients with recorded NEWS2). At a threshold of 3.5 (i.e. NEWS2 of 4 or above), action would be triggered in 9.9% of all patients (13.6% of patients with recorded NEWS2). At a threshold of 4.5 (i.e. NEWS2 of 5 or above), action would be triggered in 7.0% of all patients (9.6% of patients with recorded NEWS2).

Analysis of all patients with and without recorded NEWS2

Parameters from the multiple multilevel logistic regression models conducted on the data using all cases and categorising NEWS2 as: not recorded; 0 or 1; 2 or above; are summarised in Table 5.

Table 5: multiple multilevel regression parameters (categorised NEWS2 variable)

Outcome	Variable	p-value	OR	95% CI for OR
Death by 2 days	NEWS2 category 0-1 (reference: none assigned)	<0.001	0.146	(0.0683, 0.314)
	NEWS2 category 2-20 (reference: none assigned)	<0.001	3.54	(2.15, 5.85)
	Sex (reference: male)	0.731	0.928	(0.706, 1.22)
	Age (years)	<0.001	1.07	(1.06, 1.08)
	Triage priority	<0.001	0.212	(0.179, 0.252)
	<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(2)}=463, p<0.001$</i>			
Death by 7 days	NEWS2 category 0-1 (reference: none assigned)	<0.001	0.390	(0.232, 0.653)
	NEWS2 category 2-20 (reference: none assigned)	<0.001	6.05	(3.92, 9.34)
	Sex (reference: male)	0.003	0.726	(0.588, 0.896)
	Age (years)	<0.001	1.08	(1.07, 1.08)
	Triage priority	<0.001	0.262	(0.229, 0.300)
	<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(2)}=636, p<0.001$</i>			
Death by 30 days	NEWS2 category 0-1 (reference: none assigned)	0.038	1.57	(1.02, 2.41)
	NEWS2 category 2-20 (reference: none assigned)	<0.001	12.4	(7.91, 19.3)
	Sex (reference: male)	<0.001	0.657	(0.546, 0.793)
	Age (years)	<0.001	1.11	(1.10, 1.12)
	Triage priority	<0.001	0.298	(0.265, 0.335)
	<i>Likelihood ratio test versus single level logistic model: $\chi^2_{(2)}=802, p<0.001$</i>			

Discussion

The work presented here demonstrates that NEWS2 is a valid mortality prediction tool for patients within the ED setting. With each increase of 1 point on the NEWS2 scale the odds of death increase by 75% in 2 day mortality, 69% for 7 day and 58% for 30 day mortality. The ROC analysis also shows that predicted probabilities based on a model including NEWS2 has excellent discriminative capability, although there is a slight reduction in performance with increasing time, with optimal performance for 2 day mortality AUROC 0.96, decreasing to 0.92 for 30 day mortality.

The majority of previously published studies on the performance of NEWS2 in predicting mortality are based on specific subgroups examining either 30 day or inpatient mortality. These subgroups include Sepsis^{2,3}, COPD⁴, Frailty⁵, ICU out-reach⁶. The results all report AUROC 0.7-0.75 for either 30 day or inpatient mortality. Recently several small studies examining NEWS2 and mortality in Covid-19 patients⁷⁻⁹ have been published reporting AUROC 0.67-0.82, for 30 day or in-hospital mortality.

Three studies examine the performance of NEWS2 in predicting 1-2 day mortality, reporting AUROC range of 0.86-0.89. This includes two pre-hospital studies^{10,11} conducted by an ambulance service examining 2 day mortality, and one inpatient study which examined mortality within 24 hours of a recorded NEWS2¹². The results of these studies indicate that NEWS2 has a higher predictive value over shorter time periods.

This study indicates that NEWS2 performs favourably in an undifferentiated ED population compared to the previously studied populations. When examining the performance of NEWS2 at predicting 30 day mortality this study demonstrates an AUROC of 0.92, compared to 0.7-0.75 in the previously reported studies, and 0.96 for 2-day mortality in comparison to 0.86-0.89^{2,4}. There are several potential reasons for the difference between the study outcomes. Firstly this study included substantially more patients, as well as all deaths within 30 days of ED attendance, rather than limiting the deaths to only those that occurred on that specific admission. If “death on that admission” is used, the time scale is potentially prolonged, and as demonstrated the AUROC diminishes slightly as the study period increases. Furthermore, deaths after discharge would not be identified within the study population. Another significant difference between this study and the other studies is that the ED population is undifferentiated, including those that do not require hospital admission and were able to “walk-in”, which may indicate that within ED NEWS2 is used on an overall lower risk group than in the other studies. In this study, 30-day mortality was 2.1%, where as mortality ranged from 2.7-36.1% mortality in the previously published studies. This was reflected in the Pimentel et al study¹² which examined 1-day mortality from a documented NEWS2. In the group with documented type 2 respiratory failure (T2RF) a mortality of 1.3% was recorded and an AUROC of 0.84, versus a mortality of 0.3% and AUROC of 0.89 for those without T2RF which represents a far broader category. It is also conceivable that the physiological state around the time of admission may be more a significant predictor of mortality in comparison to later on in the patient’s hospital stay.

A finding of particular note within this study is that the use of a NEWS2 of 4 or more may be the best trigger point to use, proving optimal with minimum distance and Youden’s index of the ROC, for 2 day and 7-day mortality. Currently the key trigger for action occurs at a NEWS2 of 5 or more¹. Using the trigger point of 4 or more would give sensitivity for 2-day mortality of 89.1% and specificity of 86.7%; versus sensitivity of 83.5% and specificity of 90.8% if the current key trigger point were used. However, this would represent 13.6% of the adult ED “Majors” population, compared to 9.6% with the use of the current trigger point. Using a trigger of NEWS2 4 and above leads to the highest overall test performance, as measured, although using a trigger of NEWS2 of 4 and above is statistically the optimal trigger point for action. This is at the cost of a significant increase in triggering by approximately 40%. The feasibility of such an increase in workload would need to be carefully considered before applying to the ED setting. Further study into the effect of changing the key trigger point from 5 to 4 on patient mortality is warranted before wholesale change is implemented.

Within the ED, a large proportion of patients are currently streamed to a co-located Minor Injuries Unit (MIU). Patients streamed to MIU will often have no observations taken depending on nursing gestalt. This group made up 27.1% of the study population. The 7-day mortality of this group was low (0.19%), suggesting triage-nursing gestalt is good. As navigation and streaming become more commonplace to areas outside the ED, safety is a particular concern. This study has demonstrated that using a NEWS2 of 0-1 identifies a particularly low risk group of patients. Mortality in the NEWS2 0-1 group is 0.1% at 7 days compared to 2.79% in the NEWS2 2-20 group (table 2). The data presented demonstrate the use of NEWS2 is superior to gestalt alone. If NEWS2 were combined with clinical assessment this would likely further reduce the mortality within the streaming group.

Several other findings of note were: increasing age, male sex, arrival by ambulance and higher triage categories; all indicating significantly increased mortality rates. The effect of age is obviously to be expected. CHT uses the Manchester triage tool, which has previously been shown to correlate with mortality¹⁴, echoing the result of this study. Ambulance arrival has also been shown to be an indicator of mortality¹⁵, as has male sex¹⁶.

There are several strengths to this study. These include a relatively large study sample, including all adult patients presenting to both EDs within CHT. Thus allowing access to patients with a wide variety of pathologies as all major specialties are covered across the two sites. Due to large sample size and the data available, a rigorous analysis of the data was possible. There were few missing data as all patient data is collected within the Trust's EPR. However, it must be acknowledged that as in any retrospective database review, some of the data will be missing or incorrect. It was decided to use only the data presented and not to attempt to generate any missing observations within NEWS2, as the intention was to study "real-life" i.e. using the data available to the clinician at the time. However, the use of incomplete observation sets, although pragmatically reflecting what happens on the ED 'shop floor', may artificially reduce the predictive value of this tool.

In conclusion, NEWS2 appears to be a valid mortality prediction tool in an undifferentiated ED population, with optimal performance for 2-day mortality. Enabling accurate risk assessment of ED patients and early escalation of treatment for those at higher risk of death. A NEWS2 of 0-1 can be used to select an ultra-low risk group for 7-day mortality, which may be amenable to ED streaming or navigation in combination with clinical assessment by a triage or streaming nurse. There is also a suggestion that using a cut off of NEWS2 of 4 and above may provide a better trigger than the current 5 and above, facilitating the identification and treatment of more patients at risk of early death. However, further work would need to be conducted to demonstrate any benefit of lowering the threshold as the implication of lowering this threshold could have a significant impact on the functioning of the ED when staffing is limited.

Competing interests

The authors declare no competing interests.

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