Investigation into the predictive capability for mortality and the trigger points of the National Early Warning Score 2 (NEWS2) in emergency department patients

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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 role out of NEWS2, its ability to predict mortality has been assessed in several settings, although to date not within an undifferentiated ED population.

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 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 (OR 1.75; 95% CI 1.58 to 1.93); at 7 days (OR 1.69; 95% CI 1.59 to 1.80); at 30 days (OR 1.58; 95% CI 1.52 to 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 to 5.85) at 2 days; OR 6.05 (95% CI 3.92 to 9.34) at 7 days; OR 12.4 (95% CI 7.91 to 19.3) at 30 days. Increasing age, male sex, arrival by ambulance and higher triage categories were also associated with significantly increased mortality. Area under the receiver operating characteristic curve values of 0.963, 0.946 and 0.915, respectively, were recorded for mortality at 2, 7 and 30 days from attendances; and 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.

INTRODUCTION

The National Early Warning Score (NEWS) was originally published by the Royal College of Physicians (RCP) in 2012. NEWS was developed as a 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 NHS and was validated across many clinical settings.

What is already known on this subject

► Since the development and roll out of National Early Warning Score 2 (NEWS2), its ability to predict mortality has been assessed in both inpatient and prehospital settings.

► However, to date the predictive capability of NEWS2 has not been assessed within an undifferentiated ED population.

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.

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. 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 six physiological parameters (RR, pulse rate, systolic BP, temperature, conscious level, and either of two 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 prehospital to inpatient but generally looking at specific population groups. However, to
date, the capability of NEWS2 to predict mortality has not been assessed within an undifferentiated 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 (CHFT) in the North of England between March and November 2019. Data were 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). 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, ORs and 95% CIs in the multilevel models were reported in all models. CIs were calculated using clustered robust SEs, clustered at the patient level.

Receiver operating characteristic curve (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 chi-squared tests to compare log-likelihood statistics of multilevel and corresponding single-level models.

**RESULTS**

**Descriptive and exploratory procedures**

Data were collected from 91 871 valid patient episodes associated with 64 760 patients (48.8% men) 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 five or fewer attendances. A total of 24 881 patient attendances (27.1%) had no NEWS2 recorded. Forty-seven patients with no NEWS2 recorded died within 2 days from attendance, death by 7 days from attendance; death by 30 days from attendance. 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 the number of patient episodes.

Table 1: Descriptive summary of sample data

| Variable                        | Frequency (valid %) |
|---------------------------------|---------------------|
| Number of attendance per patient (n=91 871) |                      |
| 1                               | 49 252 (53.6)       |
| 2                               | 20 418 (22.2)       |
| 3                               | 8991 (9.8)          |
| 4                               | 4484 (4.9)          |
| 5                               | 2500 (2.7)          |
| 6 or more                       | 6226 (6.8)          |
| Maximum NEWS2 category          |                     |
| Not recorded                    | 24 881 (27.1)       |
| 0–4                             | 60 589 (66.0)       |
| 5–6                             | 3362 (3.7)          |
| 7–20                            | 3039 (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)   |

NEWS2, National Early Warning Score 2.
by ambulance, compared with 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). 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.

**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 (0.268%) | 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 (0.875%) | 168 (0.277%) | 706 (1.17%) |
| Maximum NEWS2: 5–6 | 3361 | 48 (1.43%) | 118 (3.51%) | 262 (7.80%) |
| Maximum NEWS2: 7–20 | 3038 | 220 (7.24%) | 380 (12.5%) | 595 (19.6%) |

NEWS2, National Early Warning Score 2.

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.

For each model, the significance of the χ² 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 1A–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-day mortality). Hence, all models show good discriminative capability, with optimum discrimination shown in models of early death.

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.

At a threshold of 2.5 (ie, 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 (ie, 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 (ie, 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 2.

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

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, chronic obstructive pulmonary disease, frailty and intensive care unit outreach. 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 patients with COVID-19 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 mortality 1–2 days, reporting AUROC range of 0.86–0.89. This includes two prehospital studies conducted by an ambulance service examining 2-day mortality, and one inpatient study which examined mortality within 24 hours of a recorded ambulance service examining 2-day mortality, and one inpatient study which examined mortality within 24 hours of a recorded admission.' If 'death on that admission' is used, the time scale is potentially prolonged, as demonstrated the AUROC diminishes 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%, whereas mortality ranged from 2.7% to 36.1% mortality in the previously published studies. This was reflected in the Pimentel et al study, 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, vs 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 with 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 more. Using the trigger point of 4 or more would give sensitivity for 2-day mortality of 89.1% and specificity of 86.7%, vs 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 with 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 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 with 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.

![Figure 1](image)

**Figure 1** ROC curve for outcome of death by (A) 2 days, (B) 7 days and (C) 30 days. ROC, receiver operating characteristic.

| 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            |

Table 4 NEWS2 threshold scores, sensitivity and specificity values

NEWS2, National Early Warning Score 2.
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 mortality,\(^{14}\) echoing the result of this study. Ambulance arrival has also been shown to be an indicator of mortality, as has male sex.\(^{15}\)

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 are collected within the Trust’s EPR system, hence not for public access.

Data availability statement

All data were taken from the Trust EPR system, hence not for public access. No data are available. All data were taken from the Trust EPR system hence not for public access.

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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 to 0.314 |
|         | NEWS2 category 2–20 (reference: none assigned) | <0.001 | 3.54  | 2.15 to 5.85  |
|         | Sex (reference: male) | 0.731 | 0.928 | 0.706 to 1.22 |
|         | Age (years) | <0.001 | 1.07  | 1.06 to 1.08  |
|         | Triage priority | <0.001 | 0.212 | 0.179 to 0.252 |
| Likelihood ratio test versus single-level logistic model: χ²=463, p<0.001

Death by 7 days | NEWS2 category 0–1 (reference: none assigned) | <0.001 | 0.390 | 0.232 to 0.653 |
|         | NEWS2 category 2–20 (reference: none assigned) | <0.001 | 6.05  | 3.92 to 9.34  |
|         | Sex (reference: male) | 0.003 | 0.726 | 0.588 to 0.896 |
|         | Age (years) | <0.001 | 1.08  | 1.07 to 1.08  |
|         | Triage priority | <0.001 | 0.262 | 0.229 to 0.300 |
| Likelihood ratio test versus single-level logistic model: χ²=636, p<0.001

Death by 30 days | NEWS2 category 0–1 (reference: none assigned) | 0.038 | 1.57  | 1.02 to 2.41  |
|         | NEWS2 category 2–20 (reference: none assigned) | <0.001 | 12.4  | 7.91 to 19.3  |
|         | Sex (reference: male) | <0.001 | 0.657 | 0.546 to 0.793 |
|         | Age (years) | <0.001 | 1.11  | 1.10 to 1.12  |
|         | Triage priority | <0.001 | 0.298 | 0.265 to 0.335 |
| Likelihood ratio test versus single-level logistic model: χ²=802, p<0.001

NEWS2, National Early Warning Score 2.
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