

ORIGINAL RESEARCH

National Early Warning Score in Predicting Adverse Outcomes for Patients Admitted to Emergency Department; a Prognostic Accuracy Study

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Abstract: **Introduction:** Overcrowding in emergency departments (ED) is a global concern, emphasizing the need for effective resource allocation. Triage plays a crucial role in prioritizing patients based on medical needs. This study aimed to evaluate the accuracy of National Early Warning Score (NEWS) in predicting the ED patients' outcomes. **Methods:** A cross-sectional study was conducted in two tertiary hospitals in Tehran, Iran, from June to July 2023. Adult patients presenting to ED were included. Data for calculating the NEWS and emergency severity index (ESI), as well as outcomes were recorded by trained nurses, and then the accuracy of each score in predicting the outcomes was evaluated. **Results:** A total of 2,085 patients were analyzed. The majority were male (57%) with a mean age of 54.4 years. The primary outcome, cardiopulmonary resuscitation (CPR) within 24 hours of admission, occurred in 1.9% of patients, while the need for intensive care unit (ICU) care and/or mechanical ventilation happened in 3.4%, and CPR or need for ICU care and/or mechanical ventilation was observed in 4.3% of studied cases. Each one-point increase in NEWS was associated with a 52% higher likelihood of CPR (95% confidence interval (CI): 1.41 to 1.65, $p < 0.001$). Receiver operating characteristic curve analyses for the NEWS yielded the optimum cut-off value to be 6 for all three outcomes, with an overall area under the curve (AUC) of 0.856 (95% CI: 0.840 to 0.871), 0.834 (95% CI: 0.817 to 0.850), and 0.854 (95% CI: 0.838 to 0.869) for the primary, secondary, and tertiary outcomes, respectively. **Conclusion:** NEWS 6 was associated with a higher incidence of adverse outcomes, including ICU admission and need for CPR. The good predictive validity of NEWS highlights its value in identifying patients at higher risk of adverse outcomes.

Keywords: Triage; Emergency service, hospital; Outcome assessment, health care; Predictive value of tests

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1. Introduction

Overcrowding in emergency departments (EDs) has emerged as a global concern (1, 2), emphasizing the critical need to prioritize and allocate resources effectively (3). As the first

point of patient contact in the ED, the triage unit plays a pivotal role in making accurate decisions to prioritize patients based on their medical needs, reducing waiting times, and ultimately mitigating mortality and morbidity rates (4). In this context, various triage systems are employed in EDs to facilitate patient allocation and optimize the utilization of limited medical resources (2).

In Iran, since 2011, the emergency severity index (ESI) has been universally implemented in hospitals following the recommendation of Iran's Ministry of Health (5). The ESI system is a well-validated approach to assess patients' conditions (6-9), utilizing a five-level scale ranging from one (most urgent) to five (least urgent) (10). Despite the availability of

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alternative triage methods, the National Early Warning Score (NEWS) has gained significant recognition among clinicians since its introduction by the Royal College of Physicians in England in 2012 (11, 12). NEWS encompasses six physiological measurements, including heart rate (HR), respiratory rate (RR), body temperature, oxygen saturation, and level of consciousness (13). NEWS has demonstrated superior reproducibility as a triage system compared to the ESI (14). Notably, ESI has shown relatively lower reproducibility, especially in situations where the medical staff lack regular education and training (15-17). These findings underscore the potential of NEWS as an effective and reliable approach in the triage setting.

Healthcare resources are limited and the overcrowding in EDs of public hospitals is a growing concern, which requires more efficient ways of managing resources (18). Additionally, the accurate identification of high-urgency patients is crucial for patient safety, as misclassifying them as low-urgency can result in delays in diagnosis and treatment, potentially leading to adverse health outcomes and increased mortality rates. Conversely, appropriately categorizing low-urgency patients enhances ED efficiency and reduces waiting times for those with high-urgency ED visits. By conducting a comprehensive evaluation, we aim to determine the effectiveness of NEWS as a triage system and provide insights into its potential advantages and limitations compared to ESI. This study is to assess the efficacy of the NEWS in predicting adverse outcomes among ED patients and to compare its performance with the established ESI.

2. Methods

2.1. Study design and setting

This cross-sectional study was conducted from June to July 2023 on adult patients admitted to the emergency department of Shohada-e Tajrish or Vali-e-Asr Hospitals, which are tertiary centers located in Tehran, Iran. The variables of ESI and NEWS scores, as well as outcomes were gathered and screening performance of scores in predicting the outcomes were compared. The study protocol was approved by the ethics committee of Shahid Beheshti university of medical sciences with the approval number IR.SBMU.TEB.POLICE.REC.1402.044. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki, ensuring ethical considerations were addressed.

2.2. Participants

Patients below the age of 18 years; patients readmitted to the ED within a 24-hour period; patients with inadequate data collection; patients who left the hospital against medical advice; patients transferred to other healthcare facilities; pa-

tients who were declared to be deceased upon arrival at the ED; patients who were pregnant; patients with an ESI score of four or five; and patients who had a cardiac arrest outside the hospital were excluded.

2.3. Data collection

During triage in the ED, vital signs including HR, RR, O₂ saturation, body temperature, blood pressure, level of consciousness, and ESI score for each admitted patient were measured and recorded. Demographic data including age, sex, history of hypertension (HTN), cardiovascular diseases (CVDs), diabetes mellitus (DM), chronic kidney disease (CKD), pulmonary disease, and body mass index (BMI), as well as patients' outcome were also recorded. Data collection was performed by two members of the research team who entered the collected data into an Excel spreadsheet. Subsequently, the NEWS scale was calculated based on the entered data. To minimize selection bias, efforts were made to include patients across the entire spectrum of severity. Furthermore, to mitigate information bias, data collection was conducted by trained personnel and subsequently verified by the research team.

2.4. Outcomes

We identified three distinct outcomes for the participants in our study. The primary outcome was defined as the occurrence of cardiopulmonary resuscitation (CPR). The secondary outcome encompassed the need for intensive care unit (ICU) care and/or mechanical ventilation. Lastly, the tertiary outcome was characterized by either the requirement for CPR or the need for ICU care and/or mechanical ventilation. The follow-up period spanned 24 hours from the time of admission.

2.5. Statistical analysis

According to data from the Keep study (19), the required sample size was determined. For an expected mortality of 10%, a confidence level of 95%, and a precision of 5%, it needed a minimum of 562 patients, with a sensitivity of 92.6% and specificity of 77% reported for a cutoff point of 3.

Statistical analyses were performed using SPSS (version 26.0, SPSS Inc., Armonk, NY), and Vassarstats software (clinical calculator).

Continuous variables were described using mean and standard deviation (SD), while categorical variables were presented as frequency and percentage. The normality of the data was assessed using the Kolmogorov-Smirnov test. To compare means between groups, independent samples t-test was employed. In cases where the data did not follow a normal distribution, non-parametric counterparts were utilized instead. Youden's index was used to determine the optimal cut-off point for outcomes, and Mann-Whitney-U test was

Table 1: Baseline characteristics of study participants

Variables	Values	Variables	Values
Age (years)		Baseline Characteristics	
Mean ± SD	54.4±18.8	BMI (kg/m ²)	28.30±4.63
Sex		Heart rate (/minute)	81.40±16.59
Male	1207 (57.9)	Respiratory rate (/minute)	18.50±5.11
Female	878 (42.1)	Body temperature (°C)	37.59±0.53
Medical history		SBP (mmHg)	137.33±28.80
Diabetes mellitus	208 (10.0)	DBP (mmHg)	87.95±20.55
Cardiovascular diseases	90 (4.3)	O2 saturation (percent)	95.86±3.02
Hypertension	294 (14.1)	Supplementary O2	55 (2.6)
Cerebrovascular accident	16 (0.8)	Full consciousness	1967 (94.3)
Pulmonary diseases	54 (2.6)	Trauma type	
Chronic kidney disease	65 (3.1)	Blunt	52 (38.2)
Hepatic diseases	17 (0.8)	Sharp	50 (36.7)
Malignancy	34 (1.6)	Mix	34 (25.0)
Admission diagnosis		Trauma location	
Medical illness	1651 (79.1)	Head	12 (8.9)
Surgical diseases	298 (14.3)	Neck	4 (2.9)
Traumatic injuries	136 (6.5)	Chest	26 (19.1)
Outcomes		Abdomen	29 (21.3)
Need for CPR	40 (1.9)	Limb	65 (47.8)
Need for ICU care and/or MV	71 (3.4)		
Need for CPR or ICU and/or MV	91 (4.3)		

Data are presented as mean ± standard deviation (SD) or frequency (%). NEWS: National Early Warning Score; BMI: Body mass index; MV: mechanical ventilation; CPR: cardiopulmonary resuscitation; ICU: intensive care unit; SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

Table 2: Screening performance characteristics of National Early Warning Score (NEWS) for predicting the outcomes of emergency department patients in cut-off point of 6

Characteristics	CPR	ICU or MV	CPR or ICU and/or MV
False positive	238	222	206
False negative	11	26	30
True positive	29	45	61
True negative	1807	1792	1788
Sensitivity	72.5% (55.86-84.85)	63.38% (51.04-74.25)	67.03% (56.29-76.31)
Specificity	88.36% (86.87-89.70)	88.97% (87.50-90.29)	89.66% (88.22-90.95)
PPV	10.86% (7.51-15.37)	16.85% (12.67-22.01)	22.84% (18.04-28.44)
NPV	99.39% (98.88-99.68)	98.56% (97.88-99.04)	98.34% (97.62-98.86)
PLR (weighted)	0.121 (0.086-0.172)	0.202 (0.154-0.266)	0.296 (0.235-0.372)
NLR (weighted)	0.006 (0.003-0.010)	0.014 (0.009-0.021)	0.016 (0.011-0.023)
Total accuracy	0.856 (0.840-0.871)	0.834 (0.817-0.850)	0.854 (0.838-0.869)

All measures are reported with 95% confidence interval (CI). CPR: Cardiopulmonary resuscitation; ICU: Intensive Care Unit; MV: mechanical ventilation; PPV: Positive Predictive Value; NPV: Negative Predictive Value; PLR: positive likelihood ratio, NLR: negative likelihood ratio.

utilized to compare the area under curves (AUC) for different methods of triage. Furthermore, Cox proportional hazards regression analysis was conducted to calculate the hazard ratio for the study variables. The significance level was set at $p < 0.05$.

3. Results

3.1. Baseline characteristics of study participants

Initially, a total of 3,203 patients were enrolled in our study. However, 78 patients were excluded due to their age being less than 18, while an additional 18 patients were excluded based on their pregnancy status. Moreover, 94 patients were excluded as a result of readmission within 24 hours of their

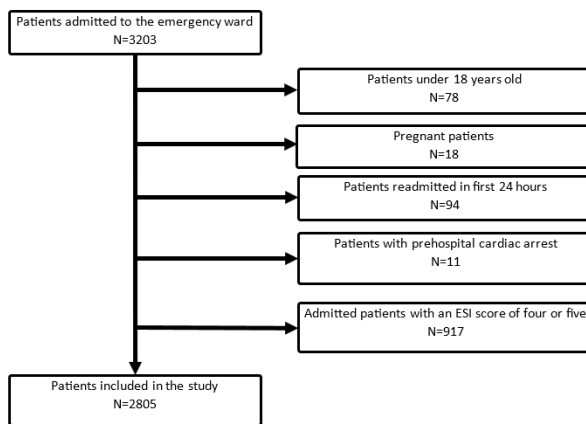


Figure 1: Flowchart of selection of study participant. ESI: emergency severity index.

previous discharge, 11 patients due to pre-hospital cardiac arrest, and 917 admitted patients with an ESI score higher than three were also excluded. Consequently, 2,085 patients remained for analysis (Figure 1).

Table 1 shows the baseline characteristics of studied cases. Of the participants, 57.9% were male, and the mean age was 54.4 ± 18.8 years. The most prevalent disease among the participants was hypertension (HTN) (14.1%), followed by diabetes mellitus (DM) (10%) and cardiovascular diseases (CVD) (4.3%). The majority of presented cases were admitted due to medical illnesses (79.1%), also 14.3% and 6.5% of patients were admitted due to non-traumatic surgical diseases and traumatic injuries, respectively. Regarding the outcomes, the primary outcome, defined as the need for CPR occurring within the first 24 hours of admission, was observed in 40 (1.9%) patients. The secondary outcome occurred in 71 (3.4%) patients, while the tertiary outcome was experienced by 91 (4.3%) patients.

3.2. Screening performance of NEWS in predicting the ED patients' outcomes

Receiver operating characteristic curve analyses for the NEWS yielded the optimum cut-off value of 6 for all three outcomes, with an overall area under the curve (AUC) of 0.856 (95% CI: 0.840 to 0.871), 0.834 (95% CI: 0.817 to 0.850), and 0.854 (95% CI: 0.838 to 0.869) for the primary, secondary, and tertiary outcomes, respectively (Figure 2).

Table 2 summarizes the screening performance characteristics of NEWS in predicting the ED patients' outcomes in cut-off point 6. NEWS had sensitivity of 72.5%, 63.38%, and 67.03% regarding primary, secondary, and tertiary outcomes. Specificity of NEWS was 88.36%, 88.97%, and 89.66%, respectively. Additionally, our analysis also demonstrated that NEWS had negative predictive values of 99.39% for CPR, 98.56% for ICU care and/or mechanical ventilation, and

98.34% for need for CPR or need for ICU care and/or mechanical ventilation.

3.3. Association between NEWS and outcomes

To examine the association between an increase in the NEWS and the likelihood of adverse outcomes, we conducted hazard ratio calculations using three different models. Model one was an unadjusted risk prediction model, model two was adjusted for age and sex, and model three was further adjusted for past medical history (PMH), including a history of DM, CVD, HTN, and CKD.

Our findings revealed that for each one-point increase in the NEWS, the likelihood of patients requiring CPR increased by 52% (95% CI: 1.41 to 1.65, P-value < 0.001). After adjusting for age and sex, increase in the chance of CPR for each one-point increase in NEWS was 54% (95% CI: 1.42 to 1.68, P-value < 0.001). Furthermore, after further adjustment for PMH, the increase in the chance was 53% (95% CI: 1.40 to 1.69, P-value < 0.001). Additionally, an increase in the NEWS was associated with the increased chances of need for ICU care and/or mechanical ventilation (HR: 1.44, 95% CI: 1.36 to 1.53, P-value < 0.001). Even after adjusting for age, sex, and further adjustment for PMH, the association remained significant (HR: 1.45, 95% CI: 1.36 to 1.54, P-value < 0.001, and HR: 1.47, 95% CI: 1.35 to 1.59, P-value < 0.001, respectively). Moreover, regarding the tertiary outcome (the need for CPR or the need for ICU care and/or mechanical ventilation), each one-point increase in the NEWS was associated with a 53% increased risk of the outcome (95% CI: 1.44 to 1.62, P-value < 0.001). After adjustment for age and sex, the increase in the chance of the outcome was 55% (95% CI: 1.46 to 1.64, P-value < 0.001). Even after further adjustment for PMH, the association remained significant (HR: 1.56, 95% CI: 1.46 to 1.68, P-value < 0.001).

3.4. Comparison of area under curve between NEWS and ESI

The AUC for the ESI regarding our outcomes was 0.781 (95% CI: 0.763 to 0.799), 0.749 (95% CI: 0.730 to 0.768), and 0.774 (95% CI: 0.756 to 0.792), respectively. We observed a significant difference comparing AUCs for NEWS and ESI regarding the need for CPR ($p < 0.001$), need for ICU care and/or mechanical ventilation ($p < 0.01$), and need for CPR or need for ICU care and/or mechanical ventilation ($p < 0.001$).

4. Discussion

Triage systems play a crucial role in healthcare by aiding healthcare providers in recognizing the urgency of patients' conditions and determining the appropriate timing for interventions to reduce the incidence of adverse effects (20). However, accurate patient triage relies on the experience of

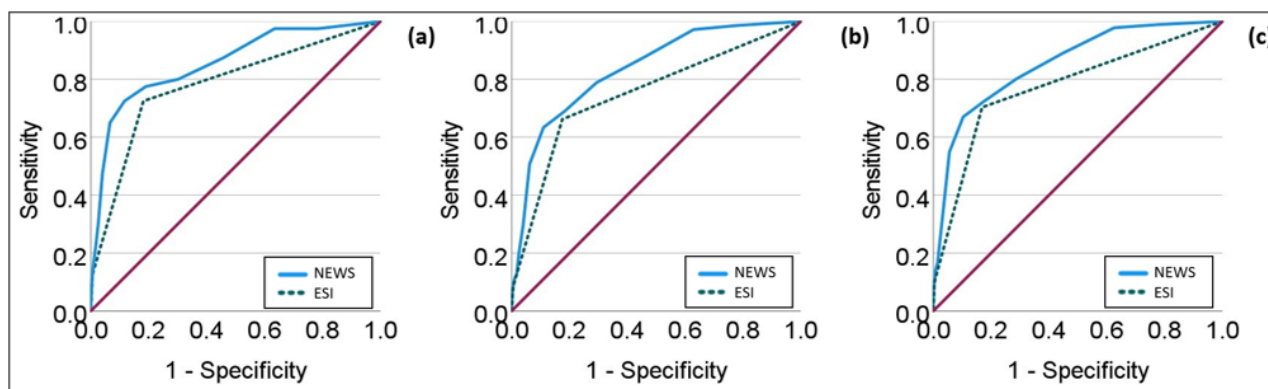


Figure 2: The area under the ROC curve of National Early Warning Score (NEWS) and Emergency Severity Index (ESI) in predicting the need for CPR (a), ICU care and/or mechanical ventilation (b), CPR or ICU care and/or mechanical ventilation (C). $P < 0.01$ for all three measured outcomes.

healthcare providers and can be influenced by interobserver reliability (21). To ensure patient safety and minimize the risk of adverse outcomes, it is essential to continually discuss and improve in-hospital early warning systems (EWS).

Numerous studies have been conducted to assess the value of EWS in identifying patients at risk of deterioration (22, 23), as well as their impact on clinical outcomes (24-27). These studies have also examined the predictive abilities of EWSs for clinical outcomes. The collective body of research in this field has provided valuable insights into the usefulness and effectiveness of EWSs in healthcare settings.

Currently, hospitals in Iran utilize the ESI as a valid EWS, which is also employed by the US healthcare system (15). However, since 2012, the United Kingdom has adopted the National Early Warning Score (NEWS) in their EDs. An updated version of NEWS was introduced in 2017, incorporating additional parameters such as modifications to oxygen saturation in patients with hypercapnic respiratory failure and changes in mental status. These modifications were made to enhance the precision of the scoring system (28, 29). The true value of any EWS lies not solely in its ability to predict specific outcomes for patients but also in its capacity to identify at-risk individuals who are experiencing deterioration. Timely recognition of these patients allows for interventions to be implemented promptly, including critical care measures (30). Our findings indicated that patients with a higher NEWS exhibited significant differences in various clinical parameters and had a higher incidence of adverse outcomes.

Furthermore, our study demonstrated a significant association between NEWS and adverse outcomes, even after adjusting for age and comorbidities. These results provide strong support for the routine implementation of NEWS in EDs. By incorporating NEWS into clinical practice, healthcare providers can efficiently assess and monitor patients,

enabling early identification of those at higher risk of deterioration and the need for urgent interventions. Previous studies have shown that NEWS can predict patients' outcome accurately. Previous studies have also shown the accurate predictive ability of the NEWS score for patients' outcomes. Abbott et al. found that pre-hospital assessment of NEWS predicted deterioration in patients in the ICU or death within 48 hours of admission. Patients with a NEWS score of seven or higher had an eight-fold increase in the odds of status deterioration or mortality (31). Other studies also demonstrated the superiority of NEWS over other scoring systems in predicting mortality, sepsis outcomes, and the need for ICU admission in different patient populations (32-35).

An intriguing finding of the current study was the significant difference in the admission-to-adverse outcomes time between patients with higher NEWS compared to those with lower NEWS. This observation is consistent with previous studies that have reported shorter survival times among patients with higher NEWS (29, 36, 37), indicating the potential of NEWS as a tool for long-term risk stratification.

Furthermore, our ROC curve analysis demonstrated excellent validity of NEWS in predicting adverse outcomes, including the need for CPR, ICU care and/or mechanical ventilation, and the combined outcome of CPR or ICU care and/or mechanical ventilation. The area under the curve (AUC) for these outcomes was 0.856, 0.834, and 0.854, respectively. Our findings were in line with previous studies where a good validity of NEWS was observed regarding different outcomes and found that NEWS outperformed other scoring systems, with AUC values of 0.722, 0.857, 0.894, and 0.873 for cardiac arrests, unanticipated ICU admission, death, and any of the outcomes, respectively (38). Another study by Jo et al. focused on general ED patients and reported AUC values of 0.84 and 0.78 for in-hospital mortality and the need for critical care, respectively (39).

Moreover, we observed that NEWS is a more accurate way of predicting adverse outcomes in more critical cases when compared to ESI. ESI system, Relies more on healthcare provider's clinical judgement (10). NEWS relies on a set of physiological parameters, which can be measured easily, with a better inter- and intra-observer variability (14). A recent meta-analysis by Wei et al. demonstrated that NEWS2 was a better predictor of early mortality compared with other EWSs, including ESI (40). Other studies also reported a higher AUC for NEWS compared with ESI, regarding mortality prediction in general emergency patients (17), as well as patients suspected with sepsis (41, 42). These consistent findings across different studies highlight the robustness and predictive accuracy of NEWS in assessing patient outcomes. The high AUC values indicate the strong discriminative ability of NEWS in identifying patients at risk of adverse events, enabling healthcare providers to intervene promptly and optimize patient care.

5. Limitations

While our study provides valuable insights into the association between the NEWS and adverse outcomes in hospitalized patients, it is important to acknowledge several limitations. First, our study was conducted in a specific healthcare setting and may not be generalizable to other populations or healthcare systems. The characteristics and management of the study population may differ from those in other settings, potentially impacting the external validity of our findings. Additionally, the use of NEWS as a predictive tool has inherent limitations. NEWS is based on physiological parameters that may be influenced by various factors, including medications and underlying comorbidities. The generalizability of NEWS thresholds and their predictive performance may vary across different patient populations and settings. Furthermore, our study focused on short-term outcomes (within the first 24 hours of admission) in a subgroup of patients with more critical status and did not capture long-term outcomes or evaluate the impact of interventions based on NEWS. Future studies should consider assessing the long-term implications of NEWS and its potential for guiding interventions and improving patient outcomes.

6. Conclusion

Based on our study findings, NEWS demonstrated a significant association with adverse outcomes in hospitalized patients. Patients with higher NEWS exhibited an increased likelihood of requiring CPR and the need for ICU care and/or mechanical ventilation. The ROC curve analyses also demonstrated satisfactory discriminatory ability for NEWS in predicting primary, secondary, and tertiary outcomes. These findings emphasize the importance of incorporating NEWS

into clinical practice to enhance risk stratification and optimize patient management.

7. Declarations

7.1. Acknowledgments

None.

7.2. Conflict of interest

The authors declared no conflicts of interest.

7.3. Funding and support

None.

7.4. Authors' contribution

The authors confirm contribution to the paper as follows: study conception and design: Setareh Asgharzadeh, Ali Saberi Shahrabaki, and Saeed Safari; Methodology: Setareh Asgharzadeh, Abbas Ebadi, and Shayan Sadeghi; data collection: Setareh Asgharzadeh, Abbas Ebadi, Ali Saberi Shahrabaki, Seyed Hadi Aghili, Mehri Farhang Ranjbar; analysis and interpretation of results: Saeed Safari, Abbas Ebadi, Ali Saberi Shahrabaki, and Shayan Sadeghi; draft manuscript preparation: Setareh Asgharzadeh, Abbas Ebadi, Ali Saberi Shahrabaki, Seyed Hadi Aghili, Mehri Farhang Ranjbar. All authors reviewed the results and approved the final version of the manuscript.

7.5. Using artificial intelligence chatbots

None.

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