

## The Prognostic Value Of Early Warning Scores In Predicting Mortality Among Stroke Patients: A Systematic Review

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### ABSTRACT

Stroke remains a leading global cause of mortality and disability, necessitating effective tools for early risk stratification. This systematic review evaluates the prognostic performance of Early Warning Scores (EWS)—MEWS, NEWS, and NEWS2—in predicting in-hospital mortality among stroke patients. Five studies published between 2021 and 2025 were included, encompassing diverse stroke subtypes and care settings. Across studies, higher EWS values were consistently associated with increased mortality risk, with odds ratios ranging from 2.44 to 3.21 and AUROC values between 0.69 and 0.79. NEWS2 generally outperformed MEWS and NEWS. Importantly, models incorporating neurological assessments, particularly the Glasgow Coma Scale (GCS), significantly improved predictive accuracy (AUROC 0.87). While EWS are valuable for early detection of deterioration, their performance in stroke is enhanced by integrating neurological parameters. These findings support the development of combined scoring systems and digital integration to optimize early intervention strategies in acute stroke care across varied healthcare settings.

**Keywords:** Stroke, Mortality Prediction, Early Warning Score, NEWS2, In-Hospital Mortality

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### INTRODUCTION

Stroke continues to pose a significant global public health concern, with approximately 12 million new cases reported annually and over 100 million individuals experiencing long-term stroke-related disabilities worldwide (Knoery et al., 2021; Valburg et al., 2025). As one of the leading causes of death and persistent disability, stroke exerts a heavy economic toll on healthcare systems and communities (Covino et al., 2023). The acute management of stroke is particularly challenging due to the broad variability in clinical presentation, making early risk assessment complex. Rapid and accurate identification of patients at elevated risk for in-hospital mortality is essential for guiding timely interventions and optimizing the use of critical care resources (Erdi, 2022; Kim et al., 2025)

Early Warning Scores (EWS), including the Modified Early Warning Score (MEWS), the National Early Warning Score (NEWS), and its updated version NEWS2, have gained

widespread adoption in emergency and critical care settings to aid in the prompt recognition of clinical deterioration (Covino et al., 2023; Mahmoodpoor et al., 2022). These tools aggregate vital signs and other clinical indicators into composite scores that assist clinicians in making informed decisions. Numerous studies have supported the effectiveness of EWS in forecasting adverse events such as ICU admission and mortality in general hospital populations (Loisa et al., 2022; Naylor et al., 2025). However, the specific utility of EWS in stroke cohorts remains inadequately examined, with available evidence being limited and often inconsistent, likely due to differences in study methodologies, population characteristics, and stroke subtypes (Knoery et al., 2021; Valburg et al., 2025). Furthermore, many scoring systems do not incorporate key neurological assessments like the Glasgow Coma Scale (GCS), which could be vital for accurate prognosis in stroke patients. (Mahmoodpoor et al., 2022; Shang et al., 2024)

This systematic review seeks to assess and compare the prognostic accuracy of MEWS, NEWS, and NEWS2 in predicting in-hospital mortality among individuals diagnosed with stroke. Emphasis is placed on both discriminative metrics such as the area under the receiver operating characteristic curve (AUC) and on effect measures including odds ratios (OR), relative risks (RR), and hazard ratios (HR). Additionally, the review explores whether incorporating neurological indicators such as GCS enhances the predictive performance of these scoring systems within the stroke context.

To the best of our knowledge, this is the first systematic review to synthesize evidence from 2021 to 2025 comparing the prognostic value of EWS tools specifically for mortality prediction in stroke. The findings aim to elucidate the comparative strengths of these tools in stroke care and offer recommendations for integrating multi-parameter scoring systems into clinical workflows. These insights could have practical implications for healthcare professionals operating in emergency departments, intensive care units, and dedicated stroke centers, while also supporting the development of smart hospital systems and early intervention frameworks. Moreover, the conclusions of this review are likely to be applicable across both resource-rich and resource-limited settings, potentially enhancing global stroke outcomes.

## **METHOD**

This study employed a systematic review design with a quantitative descriptive evidence-based approach. The primary objective was to evaluate the prognostic value of various Early Warning Scores (EWS), including NEWS, NEWS2, and MEWS, in predicting mortality among patients with acute and sub-acute stroke. The population of interest comprised primary research articles investigating stroke patients—both ischemic and hemorrhagic types—with mortality as the outcome measure and involving the application and assessment of EWS (NEWS, NEWS2 and MEWS). Inclusion criteria encompassed quantitative observational studies (cohort, cross-sectional, case-control) designs published in English between 2021 and 2025. Eligible studies had to be peer-reviewed and provide full-text access. Exclusion criteria included non-original articles such as editorials, narrative reviews, systematic review and studies lacking specific data on the association between

EWS and mortality in stroke patients. Article selection was conducted purposively through systematic database searches.

A comprehensive literature search was performed across multiple electronic databases: PubMed, Scopus, Web of Science and ScienceDirect. The search strategy combined keywords and boolean operators as follows: ("early warning score" OR "EWS" OR "NEWS" OR "MEWS") AND ("stroke" OR "ischemic stroke" OR "hemorrhagic stroke") AND ("mortality" OR "death" OR "outcome"). Two independent reviewers screened titles and abstracts for relevance, followed by full-text assessments of potentially eligible articles. Data extraction utilized a standardized form capturing details such as EWS type, study population characteristics, study design, and key prognostic outcomes (e.g., odds ratios, hazard ratios, area under the curve).

## FINDING AND DISCUSSION

### RESEARCH RESULT

**Table 1 : Prognostic Performance of EWS in Stroke Mortality Prediction**

Author, Year	Study Design	Stroke Type	EWS Used	Outcome Measure	Effect Size (OR/HR)	AUC / AUROC	Clinical Conclusion
<b>Erdi, 2022</b>	Retrospective observational study	Ischemic and hemorrhagic stroke in ICU patients	NEWS	In-hospital mortality	OR: 3.21 (95% CI: 1.89–5.46) per unit increase in NEWS $\geq 7$	AUC: 0.802	The NEWS was found to be a reliable predictor of in-hospital mortality among stroke patients admitted to ICU. Scores $\geq 7$ were associated with significantly higher risk. However, the lack of

							neurological parameters limited its stroke specificity.
<b>Kim et al., 2025</b>	Data mining-based retrospective cohort using smart clinical data warehouse	General in-hospital stroke incidence (including TIA)	MEWS, NEWS, NEWS2	Stroke occurrence and mortality	NEWS2 : HR 2.74 (95% CI: 1.64–4.12); MEWS: HR 2.10	NEWS2: AUC 0.77; MEWS: AUC 0.69	Among hospitalized patients, NEWS2 outperformed MEWS in predicting stroke events and adverse outcomes. Integration with real-time electronic systems supports automation in smart hospitals. The absence of GCS limits neurological sensitivity.
<b>Knoery et al., 2021</b>	Multicenter cohort study (UK-based stroke registry)	Acute ischemic stroke	MEWS	30-day mortality	OR 2.98 for MEWS $\geq 5$ (adjusted)	AUROC: 0.71 (95% CI: 0.67–0.75)	MEWS showed moderate discrimination in predicting post-stroke mortality.

							Performance improved when combined with NIHSS. Recommended as adjunctive rather than stand-alone tool.
<b>Shanget al., 2024</b>	Multicenter retrospective study	Stroke and traumatic brain injury (TBI)	NEWS2, GCS, Combined NEWS2+ GCS	In-hospital mortality	Combined model: OR 4.11 (p < 0.001); NEWS2 alone: OR 2.78	NEWS2: AUC 0.79; Combined NEWS2+ GCS: AUC 0.87	Combining NEWS2 with GCS significantly enhanced mortality prediction. Suggests the critical need for neurological assessment integration in EWS for neurocritical care. Proposed combined model as a superior prognostic tool.
<b>Valburg</b>	Prospective observational	Acute stroke (hospitali	NEWS	In-hospital deteriora	OR 2.44 for	AUROC: 0.75 (95% CI:	NEWS was moderately

<b>et al., 2025</b>	onal study	zed cases)	tion and mortality	NEWS ≥6	0.71– 0.79)	predictive of deteriorati on and short-term mortality. Utility limited in patients with atypical presentati ons (e.g., pure aphasia). Recomme nds cautious interpretat ion and supplemen t with neurologic al scores.
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This systematic review synthesized findings from five peer-reviewed studies published between 2021 and 2025, evaluating the prognostic performance of early warning scoring systems (MEWS, NEWS, and NEWS2) in predicting in-hospital mortality among patients with stroke. The studies employed a range of designs, including three retrospective cohort studies and two prospective observational studies, and were conducted across diverse hospital settings. Stroke types varied, with the majority of studies focusing on acute ischemic and hemorrhagic stroke, although not all provided stratified analysis by subtype.

The prognostic tools assessed included MEWS (n = 2), NEWS (n = 3), and NEWS2 (n = 3). One notable study (Shang et al., 2024) evaluated the combined utility of NEWS2 with the Glasgow Coma Scale (GCS), introducing a neurological dimension that is often missing in standard EWS frameworks. Across all studies, elevated EWS scores were consistently associated with an increased risk of in-hospital mortality. Reported effect sizes were substantial, with odds ratios (ORs) ranging from 2.44 to 3.21 for NEWS and MEWS thresholds ≥5–7. Kim et al., (2025) reported a hazard ratio (HR) of 2.74 for NEWS2 in predicting stroke-related deterioration, whereas Shang et al. (2024) demonstrated that combining NEWS2 with GCS significantly improved predictive power, yielding an OR of 4.11 and an area under the curve (AUC) of 0.87— the highest among all included studies.

AUC values for standalone EWS tools ranged from 0.69 (MEWS) to 0.79 (NEWS2), indicating moderate to good discriminatory ability. NEWS2 generally outperformed MEWS and NEWS in most scenarios, particularly in settings where real-time monitoring and smart data integration were utilized. However, the absence of neurologic-specific parameters in standard EWS was a common limitation, particularly for stroke patients with atypical presentations such as aphasia or decreased consciousness. This limitation was underscored in studies by Knoery et al. (2021) and Valburg et al. (2025), which concluded that the clinical utility of EWS is maximized when used alongside neurological assessments such as the NIH Stroke Scale (NIHSS) or GCS.

Overall, the results indicate that while MEWS, NEWS, and NEWS2 offer valuable prognostic insights for stroke mortality, their predictive performance is significantly enhanced when neurological variables are incorporated. The integration of GCS, in particular, yielded superior accuracy and discriminative power, supporting its routine use in acute stroke settings. These findings underscore the importance of multimodal scoring systems and highlight the potential of incorporating EWS into digital clinical decision support tools to optimize early intervention strategies for stroke patients.

## **DISCUSSION**

The findings of this review highlight the prognostic utility of Early Warning Scores (EWS), particularly NEWS, NEWS2, and MEWS, in predicting adverse outcomes in stroke patients. The reviewed studies consistently reported moderate to strong predictive performance, with area under the receiver operating characteristic (AUROC) values ranging from 0.71 to 0.87. These results demonstrate that EWS can serve as reliable tools for early identification of clinical deterioration and mortality risk in stroke populations, especially when integrated with neurological assessment tools. For example, Shang et al. (2024) reported a significantly higher predictive accuracy when combining NEWS2 with the Glasgow Coma Scale (GCS), yielding an AUROC of 0.87 compared to 0.79 for NEWS2 alone, emphasizing the importance of integrating neurological parameters into EWS frameworks.

Effect sizes further reinforce the utility of EWS. Erdi (2022) showed that a NEWS  $\geq 7$  increased the odds of in-hospital mortality by more than threefold (OR = 3.21), while Kim et al. (2025) demonstrated a hazard ratio (HR) of 2.74 for stroke-related adverse events using NEWS2. Similarly, Knoery et al. (2021) and Valburg et al. (2025) confirmed that elevated MEWS and NEWS scores were associated with higher short-term mortality and clinical deterioration, though with slightly lower discrimination (AUROC 0.71–0.75). Despite their strengths, most of these tools lack stroke-specific neurological inputs, which may limit their sensitivity in detecting deterioration in patients with isolated neurologic deficits such as aphasia or hemineglect.

When compared with prior literature, these findings are in line with the broader body of evidence supporting EWS implementation in acute care. Covino et al. (2023) found NEWS and NEWS2 to outperform other EWS models in emergency departments, while Mahmoodpoor et al. (2022) and Jacob et al. (2024) validated their prognostic value in ICU and postoperative cardiac surgery settings. Loisa et al. (2022) also demonstrated that

upward trends in NEWS correlated significantly with subsequent hospital mortality. These observations support the application of EWS not only in real-time monitoring but also as part of dynamic, trend-based risk stratification protocols.

Nonetheless, certain limitations merit consideration. A predominant reliance on retrospective study designs introduces the possibility of selection bias and restricts causal inference. While multicenter cohorts, as used by Knoery et al. (2021) and Shang et al. (2024), enhance external validity, differences in patient selection, scoring thresholds, and outcome definitions reduce comparability. Moreover, stroke heterogeneity, including underrepresentation of subtypes such as subarachnoid hemorrhage or posterior circulation strokes, presents a challenge for generalizing EWS performance across all stroke cases. The lack of neurologic specificity in traditional EWS may explain their limited performance in such atypical presentations, as noted by Valburg et al. (2025) and echoed in previous meta-analyses (Ling et al., 2024).

Another key limitation lies in the underutilization of digital health infrastructures. Although Kim et al. (2025) demonstrated the benefit of smart clinical data warehouses for EWS automation, such systems remain uncommon in low-resource settings. Similarly, while Hammoud et al. (2021) proposed EventScore for real-time EWS monitoring, the practical implementation of these models remains limited, suggesting a gap between theoretical frameworks and bedside application.

The clinical implications of these findings are multifaceted. Integrating neurological assessments—such as the GCS or National Institutes of Health Stroke Scale (NIHSS)—into EWS algorithms could significantly enhance predictive accuracy. Ritonga et al. (2024) have already called for updates to current EWS models to address this need. Future research should focus on prospective, multicenter validations of combined scoring systems, particularly in emergency and prehospital environments, as emphasized by Naylor et al. (2025). Additionally, incorporating EWS into electronic health records with automated alerts may facilitate timely intervention, improving outcomes in acute stroke care (Maharani et al., 2025; Nielsen et al., 2022).

In conclusion, while existing EWS such as NEWS, NEWS2, and MEWS are valuable tools for early risk identification in stroke patients, their limitations—particularly the lack of neurological specificity—necessitate further refinement. The path forward lies in developing integrated, multimodal scoring systems that combine physiologic, neurologic, and dynamic trend data to improve prognostication and support clinical decision-making in stroke care.

## **CONCLUSION**

This review underscores the moderate to strong prognostic utility of Early Warning Scores (EWS), particularly NEWS, NEWS2, and MEWS, in identifying clinical deterioration and mortality risk among stroke patients. Across diverse clinical settings and stroke subtypes, these tools demonstrated consistent predictive performance, with AUROC values ranging from 0.71 to 0.87 and significant effect sizes (e.g., OR > 2.0 for high-risk thresholds). While NEWS2 outperformed MEWS in most settings and showed enhanced accuracy when

combined with neurological assessments such as the Glasgow Coma Scale (GCS), traditional EWS remain limited by their lack of stroke-specific neurological input.

The findings advocate for the refinement of current EWS frameworks by integrating neurological parameters to improve sensitivity and specificity in neurocritical populations. Furthermore, real-time digital integration of EWS into hospital information systems could support more timely and accurate clinical decision-making. Future prospective studies are essential to validate these enhanced models and assess their impact on patient outcomes in both high- and low-resource environments. In sum, while EWS tools are not stroke-specific, their careful application—particularly in combination with neurologic assessments—can play a pivotal role in improving acute stroke care and reducing preventable mortality.

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