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Review Article

Functional Prognostic Scores Following Stroke in Intubated and Mechanically Ventilated Patients: A Narrative Review

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Abstract

Stroke is a leading cause of mortality and long-term disability worldwide, and a significant proportion of patients with severe acute stroke require intensive care and invasive mechanical ventilation due to impaired consciousness, airway compromise, or respiratory failure. In this high-risk population, accurate prediction of functional outcomes is essential to guide clinical decisions, rehabilitation planning, and family counseling. Several prognostic scores are used for ischemic stroke (NIHSS, ASTRAL, DRAGON, THRIVE, iScore), hemorrhagic stroke (ICH Score, Hunt and Hess scale), and critically ill patients (APACHE II, SOFA, SAPS II). However, their reliability decreases in ventilated stroke patients because sedation and critical illness limit neurological assessment and introduce confounders. This review critically examines these classical and hybrid prognostic tools, highlighting their limitations in intubated patients, including underestimation of neurological deficits and poor validation in intensive care settings. Emerging hybrid models integrating neurological, systemic, and ventilatory parameters may allow accurate and individualized functional prognostication.

Keywords: ***Functional Independence; Intensive Care Units; Mechanical Ventilation; Prognostic Scores; Stroke.***

Introduction

Stroke is a leading cause of death and long-term disability worldwide, affecting people of all ages. Every year, well over 12 million people have strokes, and about six million of them die as a result [1]. In addition to death, many survivors suffer from long-term motor, cognitive, and functional impairments that greatly reduce their independence and quality of life.

Most stroke patients are cared for in specialized stroke units or general neurology wards, but a large number of them develop complications that are life-threatening and need intensive care. These complications encompass severe neurological injury, diminished consciousness, impaired airway protection, respiratory failure, and systemic issues such as aspiration pneumonia or sepsis [2-4]. Population-based studies indicate that approximately 10-20% of patients with severe acute stroke require invasive mechanical ventilation, identifying a clinically distinct subgroup with high morbidity and mortality. The SPICE multicenter prospective observational study by Sonneville et al. (2020) specifically investigates outcomes in this population, aiming to provide standardized data on functional prognosis, complications, and mortality [5-7].

Patients necessitating mechanical ventilation constitute a specific subgroup characterized by adverse functional outcomes. Although survival rates have improved marginally due to progress in critical care and stroke management, a considerable proportion of survivors remain dependent or severely disabled [6-8]. This group of people makes it challenging to use standard prognostic scores. Sedation, diminished consciousness, and lack of cooperation often compromise the reliability of standard neurological assessments, including language and fine motor testing. Intensive care severity scores like APACHE II or SOFA give us useful information about systemic physiology, but they don't give us specific information about neurological severity or future functional independence.

Functional prognostication in ventilated stroke patients encompasses more than mere survival. Accurate early prediction is

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essential for informing clinical decisions, such as the timing and suitability of tracheostomy, the formulation of rehabilitation strategies based on anticipated recovery, and the assessment of whether to pursue continued intensive care or adopt a palliative approach. These choices have a big effect on patients, their families, and how care is organized.

In light of these challenges, it is imperative to evaluate current prognostic scores in mechanically ventilated stroke patients to comprehend their limitations and to investigate hybrid or artificial intelligence-based models that incorporate neurological severity, systemic physiology, and ventilatory parameters. This narrative review seeks to consolidate existing knowledge regarding functional prognostic scores in ventilated stroke patients, elucidate the advantages and disadvantages of available instruments, and delineate avenues for future research and clinical implementation.

Stroke in Intubated and Mechanically Ventilated Patients

Indications for Intubation

After a stroke, intubation is usually necessary when the person is unconscious (Glasgow Coma Scale ≤ 8), their airway is blocked, they have persistent hypoxemia, or they need mechanical ventilation to treat respiratory failure [10]. Large hemispheric infarctions, brainstem strokes, and intracerebral hemorrhages with mass effect frequently require airway protection [11]. Furthermore, swift neurological decline or imminent herniation may necessitate urgent intubation for stabilization prior to surgical or interventional interventions [12]. Epidemiological studies indicate that around 10-20% of patients with severe acute stroke necessitate invasive ventilation, underscoring a clinically distinct and high-risk subgroup. In this group of people, the length of time they need mechanical ventilation usually ranges from 3 to 10 days, depending on how severe their stroke is, any complications, and their overall health. According to Sonneville and colleagues' SPICE study protocol, intubation is often required for acute stroke patients due to reduced consciousness, airway compromise, or respiratory failure, reflecting the severity and complexity of this subgroup [7]

Respiratory Compromise and Mechanical Ventilation

Respiratory failure is common in severe strokes, usually because of central hypoventilation, aspiration, or pneumonia that happens at the same time [13]. Mechanical ventilation offers vital support but may impact intracranial pressure and hemodynamics, potentially influencing neurological outcomes [14]. Ventilation strategies must meticulously balance oxygenation and carbon dioxide regulation, as both hyperventilation and hypoventilation can aggravate ischemic injury or cerebral edema [15].

Challenges in Functional Assessment

Intubation and sedation make neurological exams a lot harder. To test their language and motor skills, standard scales like the National Institutes of Health Stroke Scale (NIHSS) require patients to be able to talk and move. Such behavior is often not possible in patients who are sedated or unresponsive [16]. This limitation may lead to bias in functional prediction and highlights the necessity for modified scoring systems or supplementary parameters that account for systemic severity, duration of ventilation, and complications [17].

Defining Functional Prognosis

Functional prognosis post-stroke includes various aspects. Disability indicates the extent of remaining neurological impairment. Dependence means that you need help with everyday tasks. Quality of life encompasses cognitive, emotional, and social dimensions [18,19]. Early prediction of functional outcomes is clinically crucial, informing decisions regarding the timing of tracheostomy, rehabilitation strategies, and the allocation to intensive care versus palliative care approaches.

Reference Scales

The Modified Rankin Scale (mRS) measures global disability on a scale of 0 to 6, where 0 means no symptoms and 6 means death [20]. The Barthel Index rates how independent someone is in their daily activities on a scale from 0 (totally dependent) to 100 (totally independent) [21]. The Glasgow Outcome Scale (GOS) categorizes recovery from death to satisfactory recovery [22]. These scales offer a standardized framework for measuring outcomes, benchmarking interventions, and guiding prognostic assessment ; they remain essential for both research and clinical decision-making in ventilated stroke patients.

Main Prognostic Scores After a Stroke

Numerous prognostic scores have been established to forecast functional outcomes in patients experiencing acute stroke. However, their usefulness is limited for patients who are intubated and on mechanical ventilation. Multicenter observational studies also highlight these limitations in mechanically ventilated stroke patients (7). In this part, we talk about the main stroke and ICU scores, how well they predict outcomes when they are available, which parts don't work when a person is sedated, and how adaptations or hybrid models can make them more useful.

Overall Stroke Scores

NIHSS

The National Institutes of Health Stroke Scale (NIHSS) evaluates stroke severity in 11 areas, such as consciousness, language, motor function, sensory deficits, and visual fields [23]. In general populations, it shows strong predictive power for functional outcomes, with AUC values for the three-month mRS often exceeding 0.80 [21]. However, in mechanically ventilated patients, factors requiring patient cooperation, such as language comprehension and adherence to commands, cannot be accurately assessed. This limitation diminishes predictive accuracy, and early post-extubation reassessment may occasionally yield superior prognostic information [25]. These limitations have been confirmed in multicenter observational studies (7). Adapted strategies, such as estimating deficits or utilizing proxy assessments, have been suggested but lack adequate validation.

iScore

iScore combines age, type of stroke, severity of the stroke at the start, other health problems, and functional status before the stroke to predict death and functional outcomes at 30 days and 1 year [26]. It shows excellent discrimination in general stroke populations (AUC 0.79–0.83). In mechanically ventilated patients, the inability to accurately evaluate neurological deficits during sedation restricts its direct applicability. Observational evidence supports this limitation (7), but its inclusion of systemic comorbidities partially addresses this deficiency, rendering it somewhat informative in critically ill populations.

ASTRAL

ASTRAL predicts functional outcomes over three months based on age, stroke severity (NIHSS), time to presentation, glucose range, and level of consciousness [27]. Discrimination is robust in awake patients (c-statistics 0.78–0.85); however, sedation complicates consciousness evaluation and motor/language scoring, diminishing accuracy in ICU patients. This has been specifically observed in mechanically ventilated cohorts (7). Some research indicates that recalibrating scores post-extubation enhances correlation with long-term functional outcomes.

DRAGON

The DRAGON score combines age, glucose, onset-to-treatment time, NIHSS [28], and other factors. It is primarily validated for strokes treated with thrombolysis, which restricts its generalizability. Similar to NIHSS and ASTRAL, components reliant on patient cooperation during sedation are ineffective, as highlighted in multicenter studies (7), indicating the necessity for post-extubation reassessment or hybrid methodologies.

THRIVE

THRIVE uses age, NIHSS, and comorbidity burden to guess what will happen in three months [29]. Its performance in general stroke populations is strong (AUC ~0.80), but it can't be used on patients who are sedated or intubated because it depends on NIHSS. Hybrid models that use APACHE II or SOFA may make predictions more accurate. Limitations in ventilated patients have also been confirmed in recent multicenter observations [7].

Hemorrhagic Stroke Prognostic Scores

Specific tools exist for hemorrhagic stroke, particularly for intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH).

ICH Score

The ICH Score is one of the most widely used prognostic tools for intracerebral hemorrhage. It integrates five variables: age, Glasgow Coma Scale score, hematoma volume, infratentorial location, and presence of intraventricular hemorrhage. This score has demonstrated strong ability to predict both short- and long-term mortality as well as functional outcome [30]. Because of its simplicity and early applicability, it is commonly used in emergency departments and intensive care units.

However, in intubated and sedated patients, some of its key components–particularly the Glasgow Coma Scale–may be distorted by sedative drugs, leading to an artificial worsening of the score. Motor and verbal responses cannot be reliably assessed in paralyzed or intubated patients, which may result in overly pessimistic prognostic classification [30].

Hunt and Hess Scale

For subarachnoid hemorrhage, the Hunt and Hess scale evaluates initial clinical severity based on neurological status, ranging from mild headache to deep coma. It is widely used for early prognostic stratification and clinical decision-making. Nevertheless, it remains partly subjective and strongly dependent on bedside neurological examination.

In mechanically ventilated and sedated patients, its reliability is markedly reduced, as consciousness level and motor responses are influenced by sedation rather than by neurological damage alone. This limits its prognostic accuracy in the ICU setting [31].

Overall, although hemorrhagic stroke scores are essential for early risk stratification, their performance is reduced in mechanically ventilated patients, and their interpretation must always take into account sedation, intubation, and the broader ICU context.

Scores for Intensive Care Unit (ICU) Severity

APACHE II, SOFA, and SAPS II

These scoring systems assess systemic physiology and organ dysfunction rather than deficits specific to stroke [32-34]. They are valuable for predicting mortality in patients on mechanical ventilation, but their capacity to forecast functional independence is limited. Recent multicenter observational studies [7] have confirmed that while ICU severity scores are reliable predictors of survival, they do not adequately capture neurological recovery or long-term functional outcomes in ventilated stroke patients. These tools are therefore best used in conjunction with neurological assessments or hybrid models when estimating functional prognosis.

Models that are a mix of both

Combining neurological scores with ICU severity scores or procedural parameters has shown promise. For instance, the combination of NIHSS and APACHE II, or models that take into account age, stroke location, sedation-adjusted consciousness, and length of mechanical ventilation, have shown better ability to tell if someone is functionally dependent at 3–6 months [35-38]. Hybrid models demonstrate the importance of post-extubation evaluations, ventilatory complications, and weaning success–elements frequently missing from conventional stroke scores. Recent prospective multicenter data [7] highlight that integrating systemic ICU metrics with neurological assessment improves functional prognostication compared with using either score alone.

After Extubation Measures

Reassessment post-extubation facilitates the evaluation of previously inaccessible domains, including speech, motor function, and advanced cognitive tasks. Research demonstrates that these metrics substantially enhance predictions of functional outcomes, particularly when combined with hybrid or machine-learning models [39-43].

Summary

Traditional stroke scores work well for people who aren't on a ventilator, but they don't work as well for people in the ICU who are sedated or can't cooperate. ICU severity scores give systemic information that is useful, but they don't give information that is specific to the nervous system. Hybrid models, post-extubation reassessment, and novel AI methodologies present the greatest potential for precise, personalized functional prognostication in ventilated stroke patients.

Validity and Comparison of Prognostic Scores in Mechanically Ventilated Stroke Patients

Predicting functional outcomes in stroke patients who are intubated and mechanically ventilated requires careful consideration of the strengths, limitations, and applicability of each scoring system. Standard stroke-specific scores—NIHSS, ASTRAL, DRAGON, THRIVE, and iScore—are well-validated in general stroke populations but encounter significant challenges in critically ill patients. Sedation and intubation impair assessment of language, comprehension, and fine motor skills, often leading to underestimation of neurological deficits and overestimation of functional independence (Table 1).

The NIHSS remains simple, widely used, and validated in awake populations. Components requiring patient cooperation, such as speech and motor responses, cannot be reliably evaluated under sedation. ASTRAL, which incorporates age, stroke severity, time to presentation, glucose, and consciousness, performs well in predicting ischemic stroke outcomes (AUC 0.78–0.85) but loses accuracy in ICU patients when consciousness cannot be reliably assessed. Similarly, DRAGON (AUC 0.74–0.82 in thrombolyzed patients) and THRIVE (AUC ~0.80) provide robust prognostic information in general populations but are heavily dependent on NIHSS items and show limited validation in mechanically ventilated cohorts. The iScore accounts for comorbidities and pre-stroke functional status (AUC 0.79–0.83 in general stroke), offering some utility in critically ill patients, but data remain sparse for ventilated populations. Overall, classical stroke scores perform best in awake, cooperative patients, and their predictive accuracy is reduced in sedated or intubated individuals.

ICU-specific scores, including APACHE II and SOFA, complement neurological scores by evaluating systemic illness severity, organ dysfunction, and multiorgan failure. These scores reliably predict mortality and highlight the impact of systemic disturbances–such as hypotension, hypoxemia, or sepsis–on outcomes. However, they lack specificity for neurological deficits and frequently underestimate the long-term functional dependence of survivors with severe motor or cognitive impairments. Performance metrics are inconsistently reported ; “not reported” is indicated when data are unavailable. Prospective multicenter ICU cohorts [7] confirm that while ICU scores predict mortality reliably, they provide limited insight into functional recovery without neurological integration.

For hemorrhagic strokes, additional disease-specific tools are widely used. The ICH Score predicts 30-day and long-term mortality in intracerebral hemorrhage and incorporates age, Glasgow Coma Scale, hematoma volume, infratentorial location, and presence of intraventricular hemorrhage. While simple and early-applicable, its accuracy is reduced in intubated and sedated patients due to challenges in assessing consciousness and motor/verbal responses [30]. The Hunt and Hess scale, designed for subarachnoid hemorrhage, evaluates initial clinical severity from mild headache to deep coma. Although useful for early prognostic stratification, its subjectivity and reliance on clinical examination reduce reliability in ventilated patients [31].

Hybrid models combining neurological scores with ICU severity indices (e.g., NIHSS + APACHE II) and ventilatory parameters–such as duration of mechanical ventilation, weaning success, hypoxemic episodes, and respiratory complications–appear most promising. Observational studies show that integrating neurological, systemic, and procedural factors improves differentiation of functional dependency and mortality at 3–6 months (AUC 0.81–0.87 when reported). Data from the SPICE study [7] provide prospective multicenter evidence supporting the superior predictive performance of hybrid approaches compared with neurological or ICU scores alone. Nonetheless, no large-scale, widely validated multicenter study has yet confirmed these findings.

Table 1: A Comparison of Prognostic Scores for Stroke Patients Who Need Mechanical Ventilation

Score	Original Population	Predicted Outcome	Strengths	Limitations in Mechanically Ventilated Patients	Reported AUC / c-statistics
NIHSS	General stroke	Functional outcome (mRS)	Simple, validated, widely used	Cannot reliably assess language/motor deficits under sedation	0.80–0.85 (general); not reported in ventilated ICU
ASTRAL	Acute ischemic stroke	3-month functional outcome	Incorporates time to presentation and glucose	Consciousness assessment affected by sedation	0.78–0.85 (awake); not reported in ventilated ICU
DRAGON	Thrombolyzed stroke	Functional independence	Integrates thrombolysis-specific factors	NIHSS component affected by sedation; limited generalizability	0.74–0.82 (awake); not reported in ventilated ICU
THRIVE	Stroke with comorbidities	3-month mRS	Includes age, comorbidity, and severity	Relies heavily on NIHSS; limited ICU validation	~0.80 (awake); not reported in ventilated ICU
iScore	General stroke	30-day & 1-year mortality & functional outcome	Considers comorbidities and pre-stroke status	Sparse data in ventilated cohorts	0.79–0.83 (general); not reported in ventilated ICU
APACHE II	ICU general	Mortality, indirectly functional outcome	Captures systemic illness severity	Non-specific for neurological deficits; poor sensitivity for functional independence	Not reported for functional outcome
SOFA	ICU general	Organ failure, indirectly functional outcome	Reflects multi-organ dysfunction	Does not reflect neurological recovery or functional dependence	Not reported for functional outcome
ICH Score	Intracerebral hemorrhage	30-day & long-term mortality; functional outcome	Widely validated, simple, early applicable	Glasgow Coma Scale affected by sedation; motor/verbal responses difficult to assess	Reported in multiple studies; AUC 0.80–0.90 in general populations
Hunt & Hess	Subarachnoid hemorrhage	Early clinical severity; mortality prediction	Widely used for initial risk stratification	Subjective; consciousness/motor assessment affected by sedation; limited reliability in ventilated ICU patients	Not consistently reported in mechanically ventilated patients

Legend: Strengths show how well the intended population performed; limitations in mechanically ventilated patients show problems that are unique to stroke patients who are intubated, sedated, or critically ill. "Not reported" means that there were no predictive performance metrics available for populations that were mechanically ventilated. MRS: Modified Rankin Scale

Discussion

Forecasting functional outcomes in intubated and mechanically ventilated stroke patients remains a major challenge in neurocritical care. Evidence presented in this review, including the comparison of prognostic scores (Table 1) and observational studies, highlights several key considerations.

Clinical Utility and Decision-Making

Accurate functional prognostication is critical for guiding clinical decisions, such as the timing and necessity of tracheostomy, early rehabilitation planning, and navigating the balance between intensive care and palliative approaches [10,37-40]. Classical stroke scores–including NIHSS, ASTRAL, DRAGON, and THRIVE–tend to overestimate functional independence in sedated or ventilated patients because essential components such as language, motor responses, and comprehension cannot be reliably assessed [24,27,28]. ICU-specific severity scores, such as APACHE II and SOFA, capture systemic illness and multiorgan dysfunction, providing robust mortality prediction, but they lack sensitivity to neurological deficits and long-term functional dependence [30-32]. Prospective multicenter studies, such as the SPICE cohort [7], indicate that integrating neurological, systemic, and ventilatory parameters enhances early functional prognostication compared with classical stroke or ICU scores alone.

Hybrid models that combine neurological assessments with systemic and ventilatory factors–including duration of mechanical ventilation, weaning success, hypoxemic episodes, and respiratory complications—demonstrate the most reliable prediction of functional outcomes [33,34,44-46]. These multicenter data suggest that hybrid approaches provide actionable early predictions of post-stroke dependency, enabling clinicians to better plan rehabilitation strategies, guide family discussions, and optimize ICU resource allocation [7].

Methodological Limitations

Several factors constrain the interpretation and generalizability of prognostic scores in ventilated stroke populations. Selection bias may occur if studies are included based on availability or perceived relevance, potentially overlooking important datasets. ICU populations are heterogeneous, varying in stroke type, severity, comorbidities, sedation regimens, and ventilation strategies. The narrative review format precluded meta-analytic synthesis. Sedation and altered consciousness impair the reliability of neurological assessments, introducing bias into traditional stroke scoring systems [16,42]. Furthermore, reporting of predictive performance metrics–such as AUC or c-statistics–is inconsistent; when absent, we denote "not reported" for clarity [44-48]. Multicenter prospective studies provide more standardized, high-quality data, allowing for a robust evaluation of score performance in mechanically ventilated patients [7].

Future Perspectives

Emerging approaches, including artificial intelligence (AI) and machine learning, offer the potential to enhance prognostic precision by integrating multimodal data, such as neurological scores, neuroimaging, continuous physiological monitoring, laboratory trends, and ventilatory parameters [40,41,44-46,49-53]. Evidence from multicenter cohorts supports the promise of hybrid or AI-driven models in providing individualized, dynamic predictions of functional outcomes [7]. Standardizing adjustments for sedation effects and incorporating post-extubation reassessments will be critical to improve both accuracy and clinical applicability.

Conclusion

Current prognostic tools demonstrate clear limitations in stroke patients who are intubated and mechanically ventilated. Traditional stroke scores often overestimate functional independence due to sedation and impaired neurological evaluation, while ICU-specific scores lack specificity for neurological outcomes. Integrating neurological, systemic, and ventilatory parameters appears to provide the most accurate and clinically relevant functional predictions. Clinicians should interpret scores with caution, perform post-extubation reassessments when feasible, and rely on multidisciplinary input. There is a pressing need for validated, multidimensional prognostic tools that can support individualized treatment decisions, rehabilitation planning, and informed family counseling.

Declcations

Ethical Clearance

Not Applicable

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Competing interests

The authors declare no competing interests.

Author contributions

TM, AMB, KA, WM, JB, RN, VHTH, PK, JT, TMp, FN, GM, JPI, PM, GML, JN, MB, and BB contributed to the conceptualization and design of the review. TM, AMB, KA, WM, JB, and RN conducted the literature search and data extraction. AMB, TM, JB, RN, and PK synthesized the information, performed critical analysis, and drafted the manuscript. All authors critically revised the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

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Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this article and its supplementary files. Additional data are available from the corresponding author upon reasonable request.

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