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Original Research Article

PREDICTORS OF POOR OUTCOME IN INTRA-CEREBRAL HEMORRHAGE BASED ON CT AND MRI SCORING SYSTEMS

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ABSTRACT

Background: Intra-cerebral hemorrhage (ICH) remains one of the most devastating forms of stroke, associated with high rates of mortality and long-term disability despite advances in acute care and neuroimaging. Accurate prediction of outcomes in ICH is crucial for guiding clinical decision-making, prognostication, and tailoring individualized management strategies. Computed tomography (CT) and magnetic resonance imaging (MRI) have emerged as cornerstone modalities for the assessment of ICH severity, location, and complications. Various imaging-based scoring systems, including the ICH score, Functional Outcome in Patients with Primary Intracerebral Hemorrhage (FUNC score), Graeb score, and MRI-based hematoma expansion or diffusion-weighted imaging markers, have been developed to stratify patients according to the risk of poor functional outcomes and mortality. This article reviews the predictors of poor outcome in ICH, emphasizing the role of CT and MRI scoring systems, their comparative strengths, and their clinical applicability. Special attention is given to hematoma volume, intraventricular extension, hematoma location, perihematomal edema, and radiological markers of hematoma expansion as major determinants of prognosis. By synthesizing current evidence, the study highlights how imaging-based scoring systems can be integrated into routine practice to enhance early prognostication and optimize management strategies for ICH patients. **Objectives:** The primary objective of this article is to comprehensively examine the predictors of poor outcome in intra-cerebral hemorrhage (ICH), with a particular focus on imaging-based scoring systems derived from computed tomography (CT) and magnetic resonance imaging (MRI).

Materials and Methods: A narrative review was conducted using PubMed, MEDLINE, Embase, and Cochrane Library databases up to June 2025. Search terms included “intracerebral hemorrhage,” “ICH score,” “CT scoring,” “MRI predictors,” and related keywords. Eligible studies included randomized trials, cohort studies, registries, systematic reviews, and meta-analyses evaluating CT/MRI-based predictors of outcome in adult patients with spontaneous ICH. Excluded were studies on traumatic hemorrhage, subarachnoid hemorrhage, ischemic transformation, case reports, small series (<10 patients), non-English literature without translation, and animal studies. Data extraction focused on prognostic accuracy, validation, and clinical applicability of scoring systems.

Results: CT-derived systems, particularly the ICH score, remain the most widely validated and clinically used predictors of mortality and functional independence. The Graeb score and FUNC score provide additional prognostic granularity, especially in intraventricular hemorrhage and functional recovery, respectively. MRI-derived predictors—such as perihematomal edema volume, spot sign on susceptibility-weighted imaging, and microbleed burden—offer

mechanistic insights into secondary brain injury, hematoma expansion, and long-term outcomes. Comparative analysis showed CT is superior for rapid triage and emergency prognostication, while MRI offers richer pathophysiological detail, aiding subacute prognostication and research applications. Limitations include heterogeneity across scoring systems, lack of MRI standardization, and limited integration of multimodal predictors in routine practice.

Conclusion: Imaging-based prognostic scoring systems play a central role in predicting poor outcomes in ICH. CT-based models dominate acute care, while MRI enhances understanding of secondary injury and long-term prognosis. Integration of both modalities, along with advanced predictive tools, holds promise for improving patient-centered care and research in ICH management.

Keywords: Intra-cerebral hemorrhage; CT scoring systems; MRI scoring systems; ICH score; Graeb score; hematoma volume; perihematomal edema; outcome predictors; stroke prognosis

INTRODUCTION

Intra-cerebral hemorrhage (ICH) accounts for approximately 10–15% of all strokes worldwide but remains the most devastating subtype in terms of morbidity and mortality. Unlike ischemic stroke, where therapeutic options such as thrombolysis and thrombectomy have transformed outcomes, the management of ICH is largely supportive, with limited disease-modifying interventions currently available.[1] The global burden is significant, with mortality rates approaching 40% within the first month of onset and only a minority of survivors regaining functional independence. The socioeconomic impact is equally profound, as survivors often require prolonged rehabilitation and long-term care, thereby imposing a considerable strain on healthcare systems.[2] Accurate early prognostication in ICH is a cornerstone of clinical management. Identifying patients who are at high risk for poor outcomes can help guide the intensity of acute care, inform discussions with patients' families, and facilitate appropriate allocation of healthcare resources.[3] Moreover, prognostic accuracy is critical in clinical trials evaluating novel therapies, where stratification based on baseline risk ensures comparability across treatment groups. Traditional clinical predictors such as age, level of consciousness on presentation, comorbidities, and initial neurological deficits provide important prognostic information but often lack sufficient precision when used in isolation.[4]

Pathophysiological basis of prognostic imaging markers: The clinical severity and outcome of ICH are closely tied to its underlying pathophysiology. Hematoma expansion, which occurs in up to one-third of patients within the first 24 hours, is a major driver of early neurological deterioration and mortality. Larger hematoma volumes exert mass effect, increase intracranial pressure, and disrupt neural networks, correlating directly with poor outcomes. Intraventricular extension of blood leads to obstructive hydrocephalus and impaired cerebrospinal fluid circulation, further worsening prognosis.[5] Perihematomal edema, reflecting a combination of toxic blood product breakdown, inflammation, and disruption of the blood–brain barrier, contributes to delayed neurological decline and is a marker of ongoing secondary brain injury. Microvascular fragility and small-vessel disease, which can be visualized on susceptibility-weighted MRI, not only predispose to the index hemorrhage but also signal a higher likelihood of recurrence and poor long-term recovery.[6]

Neuroimaging thus serves as more than a diagnostic tool; it provides a real-time window into these pathophysiological processes. Computed tomography (CT) remains the first-line modality due to its rapid availability, high sensitivity for acute hemorrhage, and ability to delineate hematoma size and location. Magnetic resonance imaging (MRI), while less frequently used in the hyperacute setting, offers superior characterization of underlying vascular malformations, microbleeds, and perihematomal edema. Importantly, both CT and MRI have provided the foundation for the development of several scoring systems designed to predict outcomes more accurately than clinical features alone.[7]

Imaging-Based Prognostic Scoring Systems: Over the past two decades, multiple imaging-based scoring systems have been validated to stratify ICH patients according to mortality and functional outcome risk. The ICH score, derived primarily from CT imaging, integrates hematoma volume, location, intraventricular extension, age, and Glasgow Coma Scale (GCS) score to provide a simple yet powerful predictor of outcome. The Graeb score quantifies the degree of intraventricular hemorrhage and has been shown to correlate strongly with prognosis. MRI-based predictors, including diffusion-weighted imaging (DWI) changes, susceptibility-weighted imaging (SWI) markers of hematoma expansion, and quantification of perihematomal edema, have further expanded the radiological toolkit for prognostication. Despite these advances, variability exists in the predictive accuracy of different scoring systems, and questions remain regarding their optimal use in clinical practice. The heterogeneity of ICH—arising from variations in hematoma location, volume, underlying etiology, and secondary complications—

underscores the need for comprehensive prognostic frameworks.

Rationale for this study: This article explores the predictors of poor outcome in ICH with a particular emphasis on CT and MRI-based scoring systems. By linking pathophysiological mechanisms with imaging markers, and reviewing validated prognostic models, it seeks to highlight their clinical applicability and relevance in guiding management, improving prognostic accuracy, and informing research directions in acute ICH care.

MATERIALS AND METHODS

Study design: This work was designed as a narrative review aimed at synthesizing current evidence regarding predictors of poor outcome in intracerebral hemorrhage (ICH), with an emphasis on CT- and MRI-based scoring systems. The review methodology was structured to ensure comprehensive coverage of both classical and contemporary literature, while prioritizing studies with strong clinical relevance and validated prognostic frameworks.

Literature search strategy: An extensive literature search was performed using electronic databases including PubMed, MEDLINE, Embase, and Cochrane Library up to June 2025. The following key terms and Boolean operators were employed in varying combinations: "intracerebral hemorrhage," "ICH," "computed tomography," "CT scoring," "magnetic resonance imaging," "MRI predictors," "ICH score," "Graeb score," "FUNC score," "hematoma expansion," "perihematomal edema," and "outcome predictors." Additional manual searches were conducted in reference lists of relevant articles to identify studies not captured by the initial database queries.

Studies were considered eligible if they met the following criteria:

Inclusion Criteria

• **Population:** Adult patients with spontaneous intracerebral hemorrhage.

• **Focus:** Investigations evaluating imaging-based predictors of outcome using CT or MRI scoring systems.

• **Outcome Measures:** Mortality, functional outcome (commonly measured by the modified Rankin Scale or Glasgow Outcome Scale), or hematoma-related clinical deterioration.

• **Study Types:** Randomized controlled trials, prospective or retrospective cohort studies, systematic reviews, meta-analyses, and large observational registries.

Exclusion Criteria

1. Studies focusing solely on traumatic intracranial haemorrhage, subarachnoid haemorrhage, or haemorrhagic transformation of ischemic stroke.
2. Case reports, case series with fewer than 10 patients, non-English language publications without available translations, and animal studies.

Data extraction and synthesis: Data from eligible studies were extracted independently by the reviewers, focusing on study design, patient population, imaging modality, scoring system applied, and reported prognostic accuracy. Particular attention was given to the methodological quality and validation status of each scoring system. The evidence was synthesized qualitatively, with findings grouped according to imaging modality (CT or MRI) and the specific prognostic scoring system under evaluation.

Quality assessment: While this review did not apply formal meta-analytic techniques, methodological rigor and risk of bias of included studies were assessed through appraisal of study design, sample size, reproducibility of imaging measurements, and outcome reporting. Preference was given to studies with prospective design, multicentre participation, and validated outcome measures.

Specific aims include:

1. To review the pathophysiological basis of imaging predictors such as hematoma volume, perihematomal edema, and intraventricular extension, and their role in clinical deterioration.
2. To evaluate established CT-based scoring systems (e.g., ICH score, Graeb score, FUNC score, and other volumetric indices) in terms of their prognostic accuracy for functional outcome and mortality.
3. To examine MRI-based markers and scoring systems, including diffusion- and susceptibility-weighted imaging features, perihematomal edema quantification, and hematoma expansion predictors.
4. To compare the strengths and limitations of CT and MRI scoring systems in the acute and subacute phases of ICH.
5. To identify gaps in current prognostic models and highlight opportunities for future integration of multimodal imaging into clinical practice.

RESULTS

This review identified several validated imaging-based predictors and scoring systems that have been consistently associated with poor outcomes in intracerebral hemorrhage (ICH). CT-based models remain the most widely applied in acute clinical settings, while MRI-based predictors provide additional insights into secondary injury and long-term outcomes. The findings are summarized in the following tables.

Table 1: CT-derived prognostic scoring systems in ICH (CT-based scoring systems)

Scoring System	Key Imaging Parameters	Outcome Predicted	Clinical Utility	Limitations
ICH Score	Hematoma volume, GCS, age, intraventricular extension, infratentorial location	30-day mortality, functional independence	Simple, validated across cohorts, widely used	May oversimplify, limited MRI integration
FUNC Score	Hematoma volume, age, GCS, pre-ICH cognition, location	Functional independence at 90 days	Emphasizes functional recovery, not just survival	Requires more variables, less widely adopted
Graeb Score	Degree of intraventricular hemorrhage (location + volume)	Mortality, poor functional outcome	Strong prognostic tool for IVH-related deterioration	Limited to IVH; not generalizable to lobar ICH
Modified Graeb Score	Quantifies IVH volume more precisely	Same as Graeb with higher precision	Better reproducibility than original	Still IVH-specific
Hemphill's Modified ICH Score	Expanded version of ICH score with refinements	Mortality, long-term outcome	Improves prediction granularity	Limited widespread adoption

Table 2: MRI-derived prognostic predictors in ICH (MRI-Based Predictors and Scores)

Predictor/Score	Imaging Marker	Outcome Predicted	Clinical Utility	Limitations
Perihematomal Edema Volume	T2/FLAIR hyperintensity quantification	Functional decline, delayed deterioration	Reflects secondary injury and inflammation	Time-dependent, operator variability
Hematoma Expansion Signs (Spot Sign on SWI/DWI)	Active bleeding/contrast extravasation	Hematoma growth, early mortality	Identifies patients for hemostatic therapy trials	Limited availability in acute setting
Diffusion Restriction Adjacent to Hematoma	Cytotoxic edema	Neurological worsening, poor long-term outcome	Sensitive to tissue injury beyond hematoma	May not be specific; influenced by timing
Microbleeds Burden (SWI/T2*)	Small vessel disease markers	Risk of recurrence, poor recovery	Links ICH to underlying vasculopathy	Often chronic marker, less acute relevance
MRI-based Composite Scores	Integrating edema, hematoma expansion, and tissue injury	Functional outcome and survival	More comprehensive, research-level development	Not widely standardized yet

Table 3: Comparative strengths and limitations of CT vs MRI in ICH prognostication (CT vs MRI Comparative Utility)

Imaging Modality	Strengths	Limitations	Best Context of Use
CT	Widely available, rapid acquisition, sensitive for acute hemorrhage, basis of validated scores (ICH, Graeb, FUNC)	Limited soft tissue contrast, poor characterization of edema or underlying pathology	Emergency settings, early triage, large cohorts, initial prognostication
MRI	Superior tissue characterization, detects perihematomal edema, microbleeds, and active bleeding signs, research-level composite scores	Limited availability in acute care, longer acquisition time, contraindications (pacemakers, unstable patients)	Subacute phase, detailed prognostication, research settings, evaluation of secondary injury

Table 1 highlights the central role of CT-based scores, particularly the ICH score, Graeb score, and FUNC score, in providing rapid and widely validated prognostic estimates in acute ICH. Table 2 emphasizes MRI-based predictors, which offer additional insights into secondary injury (perihematomal edema, cytotoxic changes) and risk of expansion or recurrence (spot sign, microbleeds), thereby complementing CT findings. Table 3 directly contrasts CT and MRI, underscoring the speed and accessibility of CT versus the pathophysiological depth of MRI. Together, these findings demonstrate that while CT remains indispensable in acute care, MRI plays an increasingly important role in refining long-term prognostication and understanding disease mechanisms.

DISCUSSION

This review highlights the pivotal role of neuroimaging in predicting outcomes in intracerebral hemorrhage (ICH), with both CT and MRI-based scoring systems providing complementary prognostic information. Accurate prognostication in ICH is essential for guiding clinical management, informing family discussions, allocating healthcare resources efficiently, and designing stratified interventions in research settings.[8]

Interpretation of key findings: CT-based scoring systems, particularly the ICH score and Graeb score, remain the mainstay of early prognostication. Their widespread use stems from rapid acquisition, high sensitivity for acute hemorrhage, and validated predictive accuracy for both mortality and functional outcome.[9] Hematoma volume, intraventricular extension, hematoma location, and initial neurological status remain consistent strong predictors of poor outcomes. The FUNC score extends this predictive capability by incorporating pre-ICH cognitive status and emphasizing functional recovery, which is particularly valuable for long-term

care planning.[10] MRI-based predictors provide deeper insights into pathophysiological processes underlying secondary brain injury. Perihematomal edema, cytotoxic diffusion restriction, and susceptibility-weighted imaging markers of microbleeds or active bleeding reflect ongoing tissue damage, small vessel disease, and the risk of hematoma expansion.[11] These markers complement CT by offering a mechanistic understanding of neurological deterioration that goes beyond gross hematoma characteristics. MRI-based composite scoring systems, while still primarily in the research domain, have shown promising results in predicting both early deterioration and long-term functional outcomes.[12]

Clinical implications: The integration of imaging-based scoring systems into routine clinical practice can enhance prognostic accuracy and support individualized care. For example, a high ICH score on admission CT can prompt early aggressive interventions and intensive monitoring, while MRI findings such as significant perihematomal edema or multiple microbleeds may influence decisions on anticoagulation, blood pressure management, or rehabilitation strategies.[13] Moreover, the complementary use of CT and MRI allows clinicians to balance rapid triage with detailed pathophysiological assessment, improving both acute management and long-term outcome prediction.

Comparative strengths and limitations of CT vs MRI: CT remains indispensable for emergency assessment due to its speed, accessibility, and reliability in detecting acute hemorrhage. Its scoring systems are simple, validated, and highly reproducible across diverse clinical settings [14]. However, CT is limited in characterizing secondary injury, subtle microvascular pathology, and perihematomal tissue changes, which can influence functional outcomes. MRI overcomes these limitations by offering high-resolution soft tissue contrast, the ability to detect microbleeds, active bleeding signs, and edema quantification, but it is less accessible in acute care and may be contraindicated in unstable patients. Therefore, a combined CT-MRI approach CT for rapid initial triage and MRI for detailed risk stratification—represents the optimal strategy where feasible.[15]

Limitations of existing scoring systems: Despite their utility, existing scoring systems have inherent limitations. CT-based scores may oversimplify complex pathophysiological processes, while MRI-based scores are not yet standardized for routine clinical use. Variability in timing of imaging, operator dependency, and heterogeneity of ICH etiologies also impact prognostic accuracy. Additionally, most studies focus on short-term outcomes, and there is a relative paucity of data on integrating multimodal imaging scores for long-term functional recovery and quality of life.

Future directions: Future research should aim to:

1. Develop integrated multimodal scoring systems combining CT and MRI markers for more precise prognostication.
2. Standardize MRI-based predictors, including automated quantification of perihematomal edema, microbleeds, and diffusion abnormalities.
3. Explore artificial intelligence and machine learning models that can dynamically combine imaging, clinical, and laboratory data to predict outcomes with higher accuracy.
4. Conduct prospective multicenter studies evaluating how imaging-based prognostication can guide targeted therapeutic interventions, such as hemostatic therapy, minimally invasive hematoma evacuation, or individualized rehabilitation strategies.

Imaging-based scoring systems, derived from CT and MRI, are indispensable tools for predicting poor outcomes in ICH. CT remains the cornerstone for rapid triage and early prognostication, while MRI provides detailed insights into secondary injury and long-term functional risk. A nuanced understanding of the strengths and limitations of each modality allows clinicians to tailor management strategies, optimize outcomes, and advance research in ICH care. Ongoing developments in multimodal imaging and machine learning integration hold promise for even more precise, patient-centered prognostication in the future.

CONCLUSION

Imaging-based scoring systems derived from CT and MRI play a central role in predicting poor outcomes in intra-cerebral hemorrhage (ICH). CT-based scores provide rapid, reliable, and widely validated prognostic information in the acute setting, while MRI offers detailed insights into secondary injury, hematoma expansion, and microvascular pathology. Integration of both modalities allows for a more nuanced, patient-centered approach to prognostication and management. Despite their utility, existing scoring systems have limitations, and ongoing research into multimodal imaging and advanced predictive models holds promise for improving accuracy and guiding individualized therapy. Incorporating these insights into clinical practice can enhance decision-making, optimize outcomes, and inform future strategies in ICH care.

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