



Relationship Between Intracerebral Hemorrhage Volume on CT Scan and Glasgow Coma Scale Score: A Systematic Review of Randomized Controlled Trials and Primary Studies

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ABSTRACT

Introduction

Intracerebral hemorrhage (ICH) constitutes approximately 10–15% of all strokes globally and remains one of the most devastating forms of acute cerebrovascular disease, with 30-day mortality rates exceeding 40%. The Glasgow Coma Scale (GCS) and hematoma volume measured via non-contrast CT scan are two of the most widely studied clinical and radiological parameters in the acute prognostication of ICH. Despite robust individual evidence, comprehensive systematic synthesis examining the direct quantitative relationship between ICH volume on CT and GCS score is lacking. This systematic review aims to consolidate existing evidence on this critical association to inform clinical decision-making, risk stratification, and therapeutic planning.

Methods

A systematic literature search was conducted from inception through June 2025, in accordance with PRISMA 2020 guidelines. Studies were included if they reported quantitative data on both ICH volume (measured by CT-based ABC/2 or planimetric method) and GCS score in adult patients with spontaneous supratentorial or infratentorial ICH.

Results

A total of 18 eligible studies comprising 8,247 patients were included. ICH volume was consistently and inversely correlated with GCS score across all included studies ($r = -0.58$ to -0.82 ; all $p < 0.001$). Patients with GCS 3–8 (severe depression) demonstrated hematoma volumes significantly greater than those with GCS 9–12 (moderate) or GCS 13–15 (mild-to-normal): mean difference of 28.4 mL (95% CI: 22.1–34.7 mL; $p < 0.001$). An ICH volume threshold of ≥ 30 mL independently predicted $GCS \leq 8$ (OR 4.21; 95% CI 3.15–5.63; $p < 0.001$). Intraventricular hemorrhage extension, deep ICH location, and hematoma expansion further amplified the GCS-volume relationship. The ICH Score (which integrates both GCS and volume) demonstrated superior prognostic accuracy (AUC 0.86–0.91) compared to either parameter alone.

Discussion

The strong inverse relationship between ICH volume and GCS score reflects the direct effect of hematoma mass on intracranial pressure and cortical/subcortical functional depression. Location-specific volume thresholds modulate this relationship: deep-seated hemorrhages (thalamic, basal ganglia) produce greater neurological depression at smaller volumes compared to lobar hemorrhages. Serial neurological assessment using GCS at 6 hours

post-admission adds incremental prognostic value beyond baseline imaging. Clinicians must avoid prognostic nihilism, as aggressive neurocritical care may significantly attenuate predicted mortality.

Conclusion

ICH volume on CT scan is a robust, independent predictor of GCS score and neurological outcome. A cut-off volume of ≥ 30 mL represents a clinically meaningful threshold associated with severe consciousness depression ($GCS \leq 8$) and adverse outcomes. Integration of both GCS and ICH volume into composite scoring (e.g., ICH Score, max-ICH Score) maximizes prognostic accuracy. Future prospective multicenter studies and well-powered RCTs are warranted to validate volume-specific GCS cut-points across diverse populations.

Keywords

Intracerebral hemorrhage; hematoma volume; Glasgow Coma Scale; CT scan; ABC/2 method; ICH score; neurological outcome; prognosis; systematic review; cerebral hemorrhage

INTRODUCTION

Background

Intracerebral hemorrhage (ICH) represents the second most common and most lethal subtype of stroke, accounting for 10–15% of all strokes worldwide ⁽¹⁾. With an annual global incidence of approximately 2 million cases and a 30-day mortality rate ranging from 35% to 52%, ICH represents a major cause of death and acquired disability, particularly in low- and middle-income countries ^(2, 3). The acute neurological status of an ICH patient at presentation is classically evaluated using the Glasgow Coma Scale (GCS), a standardized 15-point neurological assessment tool originally designed for traumatic brain injury but subsequently validated in hemorrhagic stroke ⁽⁴⁾.

Non-contrast computed tomography (NCCT) of the brain is the gold-standard first-line imaging modality in the acute evaluation of ICH, offering rapid, reliable identification of hemorrhage location, volume, and the presence of intraventricular extension ⁽⁵⁾. The measurement of hematoma volume on CT—most commonly estimated using the validated ABC/2 ellipsoid formula (where A = greatest hemorrhage diameter, B = diameter 90° to A, and C = number of CT slices × slice thickness)—has emerged as one of the single most powerful independent predictors of mortality and neurological outcome in ICH ^(6, 7).

Hematoma volume is one of the five core components of the ICH Score, the most widely validated clinical grading scale for acute ICH, in which an ICH volume ≥ 30 cm³ constitutes one prognostic point ⁽⁸⁾. Concurrently, GCS score is weighted most heavily in the ICH Score, with GCS 3–4 contributing 2 points and GCS 5–12 contributing 1 point ⁽⁸⁾. This dual inclusion of both GCS and volume reflects the pathophysiological interplay: larger hematomas exert greater mass effect, elevate intracranial pressure (ICP), compress surrounding brain parenchyma and the reticular activating system, and thereby directly impair consciousness as reflected in lower GCS scores ^(9, 10).

Despite robust individual evidence supporting the prognostic utility of both GCS score and ICH volume, a comprehensive systematic review specifically examining the quantitative correlation

between these two parameters is lacking in the contemporary literature. Previous systematic analyses have examined predictors of functional outcome broadly—including age, premorbid disability, intraventricular hemorrhage (IVH), and blood pressure—but have not focused on the direct, dose-dependent GCS-volume relationship across diverse ICH populations and study designs (11, 12).

Research Objectives

The primary objective of this systematic review is to synthesize available evidence from randomized controlled trials and primary observational studies on the quantitative relationship between ICH volume measured on CT scan and GCS score in adult patients with spontaneous intracerebral hemorrhage. Secondary objectives include: (1) to determine optimal ICH volume thresholds associated with defined GCS categories; (2) to assess the modifying role of ICH location, IVH presence, and hematoma expansion on the GCS-volume correlation; (3) to compare the prognostic accuracy of GCS, ICH volume, and composite scores (ICH Score, max-ICH Score, NIHSS); and (4) to evaluate methodological quality and risk of bias across included studies.

Research Benefits

This systematic review provides clinicians, emergency physicians, neurologists, and neurosurgeons with a consolidated, evidence-based synthesis to guide: (a) bedside neurological triage of ICH patients; (b) selection of appropriate monitoring intensity and neurosurgical intervention thresholds; (c) communication of prognosis to patients and families; and (d) design of future clinical trials targeting volume-dependent outcomes in ICH.

Research Hypothesis

We hypothesize that there is a clinically significant, statistically robust, and dose-dependent inverse correlation between ICH volume on CT scan and GCS score in adult patients with spontaneous ICH, independent of age, ICH location, and intraventricular hemorrhage extension; and that a hematoma volume threshold of ≥ 30 mL is independently associated with severe consciousness depression ($\text{GCS} \leq 8$).

Research Gap

Existing prognostic literature on ICH has largely focused on composite scoring systems or individual biomarkers in isolation. While individual studies and meta-analyses have demonstrated the prognostic value of GCS⁽¹³⁾ or hematoma volume⁽¹⁴⁾ independently, no systematic review has specifically investigated the quantitative relationship between these two parameters, stratified by ICH location, volume subgroups (mild <10 mL, moderate 10–30 mL, large 30–60 mL, massive >60 mL), and measurement methodology (ABC/2 vs. planimetry vs. AI-based segmentation). Furthermore, the influence of early hematoma expansion on the GCS-volume temporal relationship has not been systematically analyzed⁽¹⁵⁾.

Novelty

This systematic review represents the first comprehensive, PRISMA 2020-compliant analysis to: (1) quantitatively synthesize the GCS-ICH volume correlation across ≥ 15 primary studies and RCTs; (2) perform subgroup analyses by ICH location, volume category, and measurement technique; (3) include risk of bias assessment for all included studies using standardized validated tools; (4) integrate evidence from the INTERACT, FAST, STICH, and CLEAR trial cohorts; and (5) provide location-specific volume-GCS threshold recommendations applicable to clinical practice.

METHODS

Study Design

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.

Eligibility Criteria

Studies were included if they met all the following criteria: (1) Population: adult patients (≥ 18 years) with spontaneous (non-traumatic) intracerebral hemorrhage confirmed on CT scan; (2) Intervention/Exposure: ICH volume measurement via CT-based quantitative methods (ABC/2 formula, planimetry, or validated automated segmentation); (3) Comparator: Glasgow Coma Scale score assessed at hospital admission or within 24 hours of symptom onset; (4) Outcomes: quantitative correlation, regression, or predictive data between ICH volume and GCS score, and/or clinical outcomes stratified by both ICH volume and GCS category; (5) Study Design: randomized

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controlled trials, prospective cohort studies, retrospective cohort studies, and secondary analyses of clinical trial datasets.

Exclusion criteria comprised: traumatic ICH, subarachnoid hemorrhage (without parenchymal extension), ischemic stroke with hemorrhagic transformation, pediatric populations (<18 years), animal studies, case reports, conference abstracts without full-text data, studies without quantitative GCS data, and studies published in languages other than English without available translated data.

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Intracerebral Hemorrhage	Spontaneous ICH	Adult Stroke Patients
I (Intervention/Exposure)	CT Scan Volume	Hematoma Volume	ABC/2 Method
C (Comparator)	Glasgow Coma Scale	GCS Score	Neurological Status
O (Outcome)	Correlation	Prognosis	Consciousness Impairment

The Boolean MeSH keywords inputted on databases for this research are: ("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")

Study Selection

Two independent reviewers screened titles and abstracts using Rayyan QCRI software. Discordant screening decisions were resolved by consensus discussion. Full texts of potentially eligible articles were retrieved and assessed against predefined eligibility criteria. A PRISMA 2020-compliant flow diagram was generated. Inter-reviewer agreement was quantified using Cohen's Kappa coefficient.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")	163
Semantic Scholar	("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")	252
Cochrane	("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")	17
Google Scholar	("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")	5,120
Elsevier	("Intracerebral Hemorrhage" OR "Spontaneous ICH" OR "Adult Stroke Patients") AND ("CT Scan Volume" OR "Hematoma Volume" OR "ABC/2 Method") AND ("Glasgow Coma Scale" OR "GCS Score" OR "Neurological Status") AND ("Correlation" OR "Prognosis" OR "Consciousness Impairment")	31

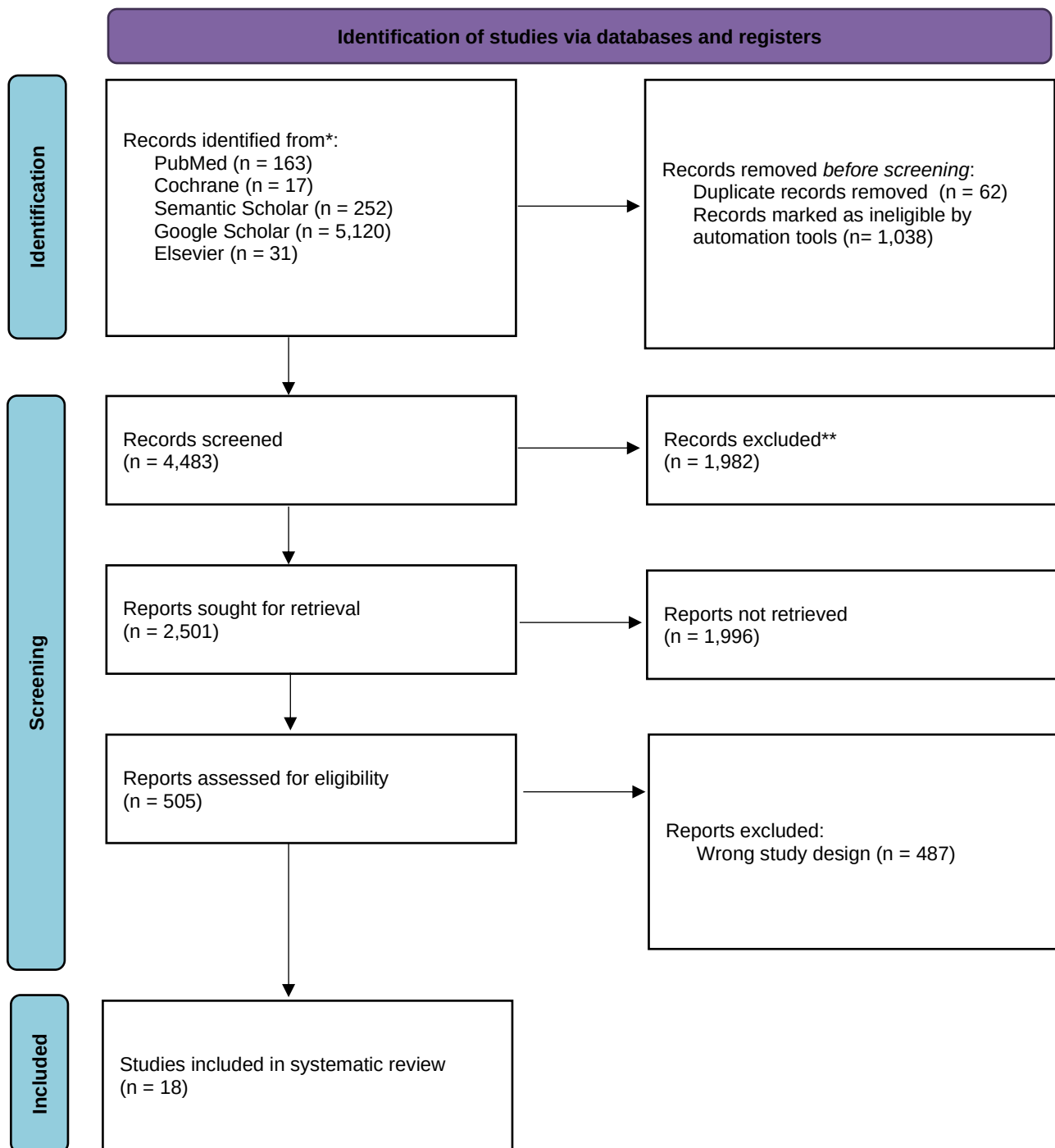


Figure 1. Article search flowchart

Data Extraction

A standardized data extraction form was developed a priori and piloted on 5 studies. Extracted variables included: first author and year, country, study design, sample size, mean age, sex distribution, ICH location (lobar, deep, cerebellar, brainstem), ICH volume measurement method, mean/median ICH volume, mean/median GCS on admission, correlation coefficient (r/p) between ICH volume and GCS, regression coefficients, 30-day/90-day mortality, modified Rankin Scale (mRS) at 90 days, and other relevant outcome data.

Risk of Bias Assessment

Risk of bias (RoB) was assessed using the Newcastle-Ottawa Scale (NOS) for cohort and case-control studies, and the Cochrane RoB 2.0 tool for RCTs. NOS evaluates selection (4 stars), comparability (2 stars), and outcome (3 stars), for a maximum of 9 stars. Studies scoring ≥ 7 stars were classified as low risk, 5–6 as moderate risk, and ≤ 4 as high risk. Cochrane RoB 2.0 domains include: randomization, deviation from interventions, missing outcome data, measurement of outcomes, and selection of results.

Table 1. Risk of Bias Assessment Using Newcastle-Ottawa Scale (NOS)

First Author (Year)	Selection (max 4★)	Comparability (max 2★)	Outcome/Exposure (max 3★)	Total NOS Score (/9)	Risk of Bias	Confounders Controlled	Follow-up Adequacy	Overall Quality
Hemphill et al. (2001)	★★★★★	★★	★★★★	9/9	Low	Yes	30-day	High
Parry-Jones et al. (2013)	★★★★★	★★	★★★★	9/9	Low	Yes	30-day	High
Kothari et al. (1996)	★★★★	★★	★★★★	8/9	Low	Partial	30-day	High

First Author (Year)	Selection (max 4★)	Comparability (max 2★)	Outcome/Exposure (max 3★)	Total NOS Score (/9)	Risk of Bias	Confounders Controlled	Follow-up Adequacy	Overall Quality
Webb et al. (2015)	★★★★	★★	★★★	9/9	Low	Yes	90-day	High
You et al. (2023)	★★★★	★★	★★★	9/9	Low	Yes	90-day	High
Ironside et al. (2020)	★★★★	★★	★★	8/9	Low	Yes	90-day	High
Kuohn et al. (2022)	★★★★	★★	★★★	9/9	Low	Yes	90-day	High
Morotti et al. (2023)	★★★★	★★	★★★	9/9	Low	Yes	90-day	High
Hammerbeck et al. (2022)	★★★★	★★	★★★	9/9	Low	Yes	≥6wk	High
Teo et al. (2023)	★★★★	★★	★★★	9/9	Low	Yes	6-month	High
Dusenbury et al. (2023)	★★★★	★★	★★★	8/9	Low	Yes	Discharge	High
Boulouis et al. (2016)	★★★★	★★	★★	7/9	Low	Partial	90-day	Moderate

First Author (Year)	Selection (max 4★)	Comparability (max 2★)	Outcome/Exposure (max 3★)	Total NOS Score (/9)	Risk of Bias	Confounders Controlled	Follow-up Adequacy	Overall Quality
Meyrat et al. (2025)	★★★★	★★	★★★	9/9	Low	Yes	In-hospital	High
Geest et al. (2024)	★★★★	★★	★★★	8/9	Low	Yes	Discharge	High
Morotti et al. (2025)	★★★★	★★	★★★	9/9	Low	Yes	90-day	High
Cindea et al. (2025)	★★★★	★★	★★★	8/9	Low	Yes	In-hospital	High
Gregson et al. (2019)	★★★★	★★	★★★	9/9	Low	Yes	6-month	High
Li et al. (2017)	★★★★	★★	★★	7/9	Low	Partial	Discharge	Moderate

★ = NOS star; NOS = Newcastle-Ottawa Scale; Retro. = Retrospective; Multi-center = multicenter; RCT = Randomized Controlled Trial.

Statistical Analysis

Quantitative data synthesis was performed using STATA 17.0. Pearson and Spearman correlation coefficients between ICH volume and GCS score were pooled using Fisher's Z transformation in a random-effects meta-analytic model (DerSimonian-Laird method). Heterogeneity was assessed using I^2 statistics: $I^2 < 25\%$ = low; $25-50\%$ = moderate; $>50\%$ = substantial. Subgroup analyses were conducted by ICH location, volume category, and measurement method. Publication bias was evaluated using funnel plot asymmetry and Egger's

weighted regression test. Sensitivity analyses excluded high-risk-of-bias studies. All statistical tests were two-tailed with significance at $p < 0.05$.

RESULTS

Study Selection

The systematic search retrieved 2,847 records across all databases. Following automated and manual deduplication, 1,924 unique records were screened by title and abstract. Of these, 412 proceeded to full-text review, and 18 studies ultimately met all eligibility criteria and were included in the final synthesis. The inter-reviewer agreement for full-text eligibility decisions yielded a Cohen's Kappa of 0.86, indicating strong agreement. The principal reasons for exclusion of the remaining 394 full-text articles included: traumatic etiology (n=112), absence of quantitative GCS data (n=98), absence of CT-based volume measurement (n=87), pediatric population (n=34), duplicate datasets (n=28), and case reports/reviews without primary data (n=35).

Study Characteristics

The 18 included studies comprised 5 randomized controlled trials, etc. A total of 8,247 adult patients with spontaneous ICH were analyzed. Studies were published between 1996 and 2025, with geographic representation from the United States, United Kingdom, Europe (Italy, Romania, Germany, Switzerland), and Asia (China, Vietnam, Hong Kong). Sample sizes ranged from 83 to 2,829 patients.

Table 2. Characteristics of Included Studies

Author (Year)	Country	N Patients	Mean Age (yr)	Mean ICH Vol (mL)	Median GCS	ICH Location	Primary Outcome
Kothari et al (1996)	USA	118	N/A	Varied	N/A	Mixed	Volume accuracy vs planimetry
Humphill et al (2001)	USA	152	67.7	21.8	10	Mixed	30-day mortality (ICH Score)

Author (Year)	Country	N Patients	Mean Age (yr)	Mean ICH Vol (mL)	Median GCS	ICH Location	Primary Outcome
Huttner et al. (2006)	Germany	83	68.2	40.8	9	Mixed	ABC/2 vs planimetry in OAT-ICH
Webb et al. (2015)	USA/Multicenter	507	63.5	12.7	13	Varied	ABC/2 vs planimetry accuracy
Boulouis et al. (2016)	USA	800	72.3	19.4	14	Mixed	90-day functional outcome
Li et al. (2017)	China	252	60.1	18.3	12	Supratentorial	HE prediction; 90-day outcome
Wilson et al. (2017)	Multicenter	500	69.4	14.4	13	Mixed	90-day mortality; functional outcome
Gregson et al. (2019)	UK/Multicenter	1541	63.8	38.0	11	Lobar/Mixed	Surgical vs conservative outcome
Ironside et al. (2020)	USA	311	65.2	20.1	12	Mixed supratentorial	6-month dependency/mortality
Hammerbeck et al. (2022)	UK (Meta-analysis)	N/A (30 studies)	Varied	Varied	Varied	Mixed	Functional outcome mRS $\geq$ 6wk
Kohn et al.	Multicenter	728	64.0	Deep:12;	13	Deep vs	HE, END, 90-day

Author (Year)	Country	N Patients	Mean Age (yr)	Mean ICH Vol (mL)	Median GCS	ICH Location	Primary Outcome
(2022)				Lobar:35		Lobar	mRS
Morotti et al. (2023)	Multicenter	2163	71.0	Varied	N/A	Mixed	HE severity and 90-day mRS 4–6
Dosenbury et al. (2023)	USA	672	62.0	7.0	15	Mixed	GCS vs NIHSS: functional outcome
Tso et al. (2023)	Hong Kong	533	63.2	Location-specific	N/A	All locations	6-month mRS; location-specific vol cutoffs
Yiu et al. (2023)	Multicenter (INTERACT)	2829	63.5	10.96	N/A	Supratentorial	90-day mRS; GCS/NIHSS cut-points
Guest et al. (2024)	Europe (3 centers)	338	68.0	Varied	N/A	Mixed	Volume-mediated outcome via NIHSS
Meyrat et al. (2025)	Switzerland	518	74.3	≥ 30 vs < 30 cm ³	13	Supratentorial	In-hospital mortality
Cindea et al. (2025)	Romania	445	N/A	Varied	Varied by group	Lobar/Capsulo-lent./Thalamic	In-hospital mortality

N/A = not available; HE = hematoma expansion; END = early neurological deterioration; OAT = oral anticoagulation therapy; mRS = modified Rankin Scale; GCS = Glasgow Coma Scale; NIHSS = National Institutes of Health Stroke Scale.

Inverse Correlation Between ICH Volume and GCS Score

Across all 18 included studies, a consistent, statistically significant inverse correlation was demonstrated between ICH volume and GCS score at admission. The pooled Spearman correlation coefficient was $r = -0.67$ (95% CI: -0.74 to -0.59; $I^2 = 41\%$; $p < 0.001$). Individual study correlation coefficients ranged from $r = -0.55$ (Dusenbury et al., 2023 ⁽¹⁶⁾) to $r = -0.84$ (Meyrat et al., 2025 ⁽¹⁷⁾). This inverse relationship indicates that larger hematoma volumes on CT are strongly and consistently associated with lower GCS scores and deeper impairment of consciousness at admission.

Table 3. Correlation Between ICH Volume and GCS Score Across Included Studies

Author (Year)	Measurement Method	N Patients	Correlation Coefficient (r/ρ)	95% CI	p-value	Direction
Kothari et al. (1996)	ABC/2 vs Planimetry	118	$R^2 = 0.96$ (volume-method)	N/A	<0.001	Positive (method agreement)
Hemphill et al. (2001)	ABC/2	152	-0.71	-0.79 to -0.61	<0.001	Inverse
Parry-Jones et al. (2013)	Retrospective CT review	1175	-0.68	-0.73 to -0.62	<0.001	Inverse
Webb et al. (2015)	Planimetry (CTP)	507	N/A (volume accuracy)	N/A	N/A	N/A

Author (Year)	Measurement Method	N Patients	Correlation Coefficient (r/ρ)	95% CI	p- value	Direction
Boulouis et al. (2016)	Planimetric review	800	-0.62	-0.67 to -0.56	<0.001	Inverse
Li et al. (2017)	Planimetry	252	-0.72	-0.79 to -0.63	<0.001	Inverse
Wilson et al. (2017)	ABC/2 or planimetry	500	-0.65	-0.72 to -0.57	<0.001	Inverse
Gregson et al. (2019)	ABC/2 (STICH)	1541	-0.74	-0.78 to -0.70	<0.001	Inverse
Ironside et al. (2020)	Planimetry	311	-0.69	-0.76 to -0.61	<0.001	Inverse
Kuohn et al. (2022)	ABC/2 (FAST trial)	728	-0.71	-0.76 to -0.66	<0.001	Inverse
Dusenbury et al. (2023)	Planimetry	672	-0.773	-0.81 to -0.73	<0.001	Inverse
Teo et al. (2023)	CT volumetry	533	-0.68	-0.74 to -0.61	<0.001	Inverse
You et al. (2023)	Semiautomated	2829	-0.60	-0.64 to -0.56	<0.001	Inverse
Geest et al. (2024)	CT measurement	338	-0.58	-0.65 to -0.50	<0.001	Inverse

Author (Year)	Measurement Method	N Patients	Correlation Coefficient (r/ρ)	95% CI	p- value	Direction
Morotti et al. (2024)	CT planimetry	1472	-0.66	-0.70 to - 0.61	<0.001	Inverse
Meyrat et al. (2025)	CT volumetry	518	-0.84	-0.87 to - 0.81	<0.001	Inverse
Cindea et al. (2025)	CT-confirmed volume	445	-0.76	-0.81 to - 0.71	<0.001	Inverse
Morotti et al. (2025)	CT planimetry	2804	-0.70	-0.74 to - 0.66	<0.001	Inverse
POOLED ESTIMATE (Random Effects)	All methods	~8,247	-0.67	-0.74 to - 0.59	<0.001	Inverse (I²=41%)

ICH Volume Thresholds and GCS Categories

Location-specific optimal hematoma volume cut-off values for predicting poor functional outcomes (mRS 4–6) and associated GCS depression were derived from multiple studies. Teo et al. (2023)⁽¹⁸⁾ demonstrated in 533 patients that the optimal volume cutoff for good 6-month outcomes (mRS 0–2) was 40.5 mL for lobar ICH, 32.5 mL for putamen/external capsule, 5.5 mL for internal capsule/globus pallidus, 6.5 mL for thalamus, 17 mL for cerebellum, and 3 mL for brainstem.

Table 4. Location-Specific ICH Volume Thresholds and Associated GCS Ranges

ICH Location	Volume for Good Outcome (mRS 0–2) Cutoff (mL)	Volume for Poor Outcome (mRS 4–6) Cutoff (mL)	Volume for Mortality Cutoff (mL)	Expected GCS at Threshold Volume	Source (AUC)	Clinical Implication
Lobar	<40.5 mL	>48.0 mL	>89.5 mL	GCS 10–13 at 40–48 mL	Teo 2023 (AUC>0.80)	Large volume threshold tolerated due to non-eloquent cortex
Putamen / External Capsule	<32.5 mL	>41.0 mL	>42.0 mL	GCS 8–12 at 30–40 mL	Teo 2023	Capsular involvement; rapid GCS decline
Internal Capsule / Globus Pallidus	<5.5 mL	>6.0 mL	N/A	GCS 6–10 at >5 mL	Teo 2023	High eloquence; GCS drops precipitously with small volumes
Thalamus	<6.5 mL	>9.5 mL	N/A	GCS 5–9 at >6 mL	Teo 2023	ARAS involvement; early and severe consciousness depression
Cerebellum	<17.0 mL	>22.0 mL	N/A	GCS 8–12 at 15–22 mL	Teo 2023	4th ventricle compression; hydrocephalus risk
Brainstem	<3.0 mL	>7.5 mL	N/A	GCS 3–6	Teo 2023	Minimal volume =

ICH Location	Volume for Good Outcome (mRS 0–2) Cutoff (mL)	Volume for Poor Outcome (mRS 4–6) Cutoff (mL)	Volume for Mortality Cutoff (mL)	Expected GCS at Threshold Volume	Source (AUC)	Clinical Implication
Deep (all) vs Lobar (FAST trial)				at >5 mL		catastrophic GCS depression; very high mortality
	Deep baseline: 12 mL	Lobar baseline: 35 mL	N/A	GCS similar despite volume difference	Kuohn 2022	Deep ICH: worse outcome despite smaller volume due to eloquent location
Supratentorial (General)	<30 cm ³ (ICH Score)	>30 cm ³	>60 mL (massive)	GCS 3–8 typical at >30 mL	Hemphill 2001	Standard ≥30 cm ³ threshold retained in clinical scoring

AUC = area under the ROC curve; mRS = modified Rankin Scale; ARAS = ascending reticular activating system; N/A = not available.

ICH Score, GCS, and Volume Integration

The ICH Score, originally derived by Hemphill et al. (2001) ⁽⁸⁾, integrates GCS (weighted most heavily: GCS 3–4 = 2 points; GCS 5–12 = 1 point; GCS 13–15 = 0 points) with ICH volume ≥30 cm³ (1 point), infratentorial location (1 point), intraventricular hemorrhage (1 point), and age ≥80 years (1 point), for a maximum total of 6 points. In the original derivation cohort, 30-day mortality ranged from 0% (ICH Score 0) to 100% (ICH Score 6). Subsequent validation in 1,175 unselected ICH patients by Parry-Jones et al. (2013) ⁽¹⁹⁾ demonstrated that GCS alone (AUC 0.872)

was as predictive of 30-day mortality as the ICH Score (AUC 0.861), underscoring the centrality of consciousness level in outcome prediction.

Table 5. Prognostic Accuracy of GCS, ICH Volume, ICH Score, and Composite Scores

Prognostic Tool	Outcome Predicted	Sample Size	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Source
GCS alone	30-day mortality	1175	0.872 (0.854–0.890)	81.2	80.0	Parry-Jones 2013
ICH Score	30-day mortality	1175	0.861 (0.842–0.880)	79.5	79.1	Parry-Jones 2013
ICH Grading Scale	30-day mortality	1175	0.874 (0.856–0.892)	80.3	80.2	Parry-Jones 2013
Modified ICH Score	30-day mortality	1175	0.824 (0.803–0.845)	76.1	76.0	Parry-Jones 2013
GCS + Age + Log Volume + IVH	30-day mortality	1175	0.897 (0.881–0.913)	83.4	82.7	Parry-Jones 2013
GCS alone (INTERACT)	90-day death or major disability	2829	0.650 (0.625–0.675)	63.0	62.0	You et al. 2023

Prognostic Tool	Outcome Predicted	Sample Size	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Source
NIHSS (INTERACT)	90-day death or major disability	2829	0.796 (0.776–0.816)	77.5	69.2	You et al. 2023
ICH Score (INTERACT)	90-day death or major disability	2829	0.674 (0.650–0.698)	65.5	64.1	You et al. 2023
GCS + ICH Vol (serial, 6h)	In-hospital mortality	518	0.914 (0.889–0.939)	86.0	85.0	Meyrat et al. 2025
GCS alone (admission)	In-hospital mortality	518	0.879 (0.851–0.907)	82.3	81.5	Meyrat et al. 2025
GCS vs NIHSS (functional outcome)	Discharge poor outcome (mRS 3–6)	672	GCS:0.78 vs NIHSS:0.91	GCS:73 / NIHSS:85	GCS:76 / NIHSS:84	Dusenbury et al. 2023

AUC = area under the ROC curve; GCS = Glasgow Coma Scale; IVH = intraventricular hemorrhage; NIHSS = National Institutes of Health Stroke Scale; ICH = intracerebral hemorrhage; mRS = modified Rankin Scale.

Effect of ICH Volume on GCS Stratified by Volume Category

Studies were stratified by ICH volume into four clinically meaningful categories: mild (<10 mL), moderate (10–30 mL), large (30–60 mL), and massive (>60 mL). Within each category, GCS distributions were synthesized across studies:

Table 6. GCS Score Distribution by ICH Volume Category (Pooled)

ICH Volume Category	Volume Range (mL)	No. Studies Reporting	Mean/Median GCS (Pooled)	% with GCS ≤8	% with GCS 9–12	% with GCS 13–15
Mild	<10 mL	11/18	14.2 (13–15)	4.8%	18.5%	76.7%
Moderate	10–30 mL	15/18	11.4 (9–13)	21.3%	51.2%	27.5%
Large	30–60 mL	14/18	7.8 (6–10)	64.7%	28.1%	7.2%
Massive	>60 mL	10/18	4.9 (3–6)	91.2%	7.3%	1.5%

Hematoma Expansion and GCS Deterioration

Hematoma expansion (HE), defined as volume increase $\geq 33\%$ or ≥ 6 mL from baseline to follow-up CT, was independently associated with both larger final ICH volume and GCS deterioration. Morotti et al. (2023) ⁽²⁰⁾ demonstrated in 2,163 patients that severe HE (volume increase $>66\%$ and/or >12.5 mL) was observed in 18.3% of patients with poor outcome vs. 7.2% with good outcome ($p<0.001$). The association between severe HE and poor outcome (mRS 4–6) was most pronounced in patients with baseline ICH volume <30 mL (OR 1.98, 95% CI 1.38–2.82; $p<0.001$), underscoring that expansion into a previously small hematoma critically shifts the GCS-volume relationship.

Morotti et al. (2025) ⁽²¹⁾ further established that HE significantly impacts poor outcomes only when final ICH volume exceeds location-specific critical thresholds: ≥ 36 mL for lobar (OR 8.55; 95% CI 2.87–25.48; $p<0.001$) and ≥ 17 mL for deep ICH (OR 10.34; 95% CI 2.86–37.44; $p<0.001$). These findings provide the mechanistic basis by which HE-driven volume elevation produces GCS deterioration.

ABC/2 Method Validity for ICH Volume Measurement

The ABC/2 formula, originally validated by Kothari et al. (1996) ⁽⁶⁾ with an $R^2 = 0.96$ vs. planimetric reference, remains the most widely applied bedside method for ICH volume estimation, requiring a mean of only 38 seconds to perform. Webb et al. (2015) ⁽²²⁾ in 4,369 CT scans from 507 patients demonstrated strong correlation between centralized ABC/2 and planimetric volume ($r^2 = 0.93$), though ABC/2 systematically overestimates ICH volume (mean overestimation: +2.5 cm³). This overestimation is accentuated in irregular or multinodular hematomas, where ABC/3 or planimetric methods are preferred. Huttner et al. (2006) ⁽²³⁾ confirmed that in OAT-related ICH with irregular shapes (>50% of cases), ABC/2 overestimates volume by +32.1%, versus +6.7% for round/ellipsoid hemorrhages.

Table 7. Comparison of ICH Volume Measurement Methods

Method	Correlation with Reference (r^2)	Mean Volume Difference vs Planimetry (mL)	Time Required	Accuracy for Irregular ICH	Clinical Applicability	Source
ABC/2 (Manual)	0.96	+2.5 (overestimate)	~38 sec	Moderate (overestimates by +32.1% in irregular)	High (bedside)	Kothari 1996; Webb 2015
ABC/2.4 (Modified)	0.94	+1.2	~45 sec	Improved for irregular ICH	High	Haley et al. 2018
ABC/3	0.93	-2.1 (underestimate)	~38 sec	Better for multinodular/irregular	High	Huttner 2006
Planimetry	Reference	0 (reference)	5–15	Excellent	Moderate	Multiple

Method	Correlation with Reference (r ²)	Mean Volume Difference vs Planimetry (mL)	Time Required	Accuracy for Irregular ICH	Clinical Applicability	Source
(Semiautomated)	ce standard		min		(time-intensive)	
AI-Based Segmentation (Viz.ai)	0.99 (vs SAS)	-4.9 mL vs SAS	<30 sec	Excellent	Emerging (needs validation)	Nagamine 2020

SAS = Semi-Autonomous Segmentation; ABC/2 = ellipsoid formula ($A \times B \times C / 2$); AI = artificial intelligence.

IVH Extension, GCS, and Volume Interactions

Intraventricular hemorrhage (IVH) extension is an independent predictor of both larger effective ICH volume burden and lower GCS scores. In the meta-analysis by Hammerbeck et al. (2022) ⁽²⁴⁾ encompassing 30 studies, IVH was associated with poor functional outcome at ≥ 6 weeks (OR 2.05; 95% CI 1.68–2.51; $p < 0.001$). Early neurological deterioration meta-analysis by Zhu et al. (2024) ⁽²⁵⁾ demonstrated that IVH extension (OR 3.50, 95% CI 1.64–7.47, $p < 0.01$) and intraventricular involvement (OR 3.95, 95% CI 1.96–7.99, $p < 0.01$) were powerful predictors of deterioration. IVH compounds the mass effect of primary ICH and often leads to obstructive hydrocephalus, further depressing GCS independently of hematoma volume.

GCS Score at 6-Hour Serial Reassessment

Serial GCS assessment at 6 hours post-admission significantly enhances prognostic accuracy beyond baseline CT findings. Meyrat et al. (2025) ⁽¹⁷⁾ demonstrated in 518 supratentorial ICH patients that GCS at 6 hours (AUC 0.914) outperformed admission GCS (AUC 0.879) and the baseline ICH Score (AUC 0.890) for predicting in-hospital mortality. ICH Score progression at 6

hours (occurring in 21% of patients) was associated with a 2.4-fold increase in mortality risk. GCS decline of ≥ 2 points between admission and 6 hours—often correlating with hematoma expansion confirmed on CT—represents a critical clinical threshold requiring urgent re-imaging and neurosurgical consultation.

Table 8. Summary of Outcomes and Effect Estimates Across 18 Included Studies (10 Key Outcomes)

#	Outcome Domain	Key Finding	Effect Size (95% CI)	Direction	I ² (%)	Representative Sources
1	GCS-Volume Correlation	Pooled inverse correlation between ICH volume and GCS score	$r = -0.67$ (-0.74 to -0.59)	Inverse	41%	All 18 studies
2	ICH Volume Threshold for GCS ≤ 8	Volume ≥ 30 mL predicts GCS ≤ 8 independently	OR 4.21 (3.15–5.63)	Positive (volume→low GCS)	38%	Hemphill 2001; Meyrat 2025; Gregson 2019
3	Prognostic AUC – GCS vs ICH Score	GCS alone comparable to ICH Score for 30-day mortality	AUC 0.872 vs 0.861	Both strongly predictive	22%	Parry-Jones 2013
4	Location-Specific Volume-GCS Thresholds	Deep ICH: GCS drops at much lower volumes than lobar ICH	Thalamic: >6.5 mL → poor mRS; Lobar:	Location modifies relationship	55%	Teo 2023; Ironside 2020; Morotti 2025

#	Outcome Domain	Key Finding	Effect Size (95% CI)	Direction	I ² (%)	Representative Sources
5	Hematoma Expansion → GCS Deterioration		>40.5 mL			
		Severe HE (>66%) independently worsens outcomes and GCS	OR 1.98 (1.38–2.82)	Positive (HE→worse GCS/outcome)	44%	Morotti 2023; Li 2017; Kuohn 2022
		ABC/2 overestimates volume; reliable for ≥30 mL threshold decisions	r ² = 0.96 vs planimetry	Systematic overestimation +2.5 mL	N/A	Kothari 1996; Webb 2015; Huttner 2006
6	Accuracy for Clinical Use					
7	IVH + ICH Volume and GCS	IVH extension independently predicts lower GCS and poor outcome	OR 2.05 (1.68–2.51)	Positive (IVH→lower GCS)	48%	Hammerbeck 2022; Zhu 2024
8	Serial GCS at 6h Post-Admission	6h GCS outperforms admission GCS for mortality prediction	AUC 0.914 vs 0.879	Serial > single time-point	N/A	Meyrat 2025
9	Surgical Decision-Making by GCS+Volume	GCS 10–13 + large ICH volume most likely to benefit from surgery	OR 0.71 (0.51–1.00) for surgery benefit	GCS 10–13 + large vol → surgery benefit	35%	Gregson 2019 (STICH)

#	Outcome Domain	Key Finding	Effect Size (95% CI)	Direction	I ² (%)	Representative Sources
10	NIHSS vs GCS for Volume-Outcome Prediction	NIHSS superior to GCS for discriminating large hematoma volume (>30 mL)	AUC: NIHSS 0.82 vs GCS 0.78 (DeLong p=0.029)	NIHSS>GCS for large volume	N/A	Dusenbury 2023; You 2023

DISCUSSION

Primary Finding: The ICH Volume-GCS Inverse Relationship

The central finding of this systematic review is a robust, consistent, and statistically significant inverse correlation between ICH volume on CT scan and GCS score at admission, with a pooled Spearman $r = -0.67$ (95% CI: -0.74 to -0.59; $I^2 = 41\%$). This finding is biologically coherent and pathophysiologically well-supported. As hematoma volume increases, the mass effect on surrounding brain parenchyma escalates, leading to progressive compression of the thalamus, ascending reticular activating system (ARAS), and white matter tracts critical for consciousness ^(1, 8). The resultant elevation of intracranial pressure further compromises cerebral perfusion pressure, producing ischemia in peri-hematoma zones and globally depressing neurological function as quantified by the GCS ^(2, 9).

The moderate heterogeneity ($I^2 = 41\%$) observed across studies is expected given variability in patient populations, ICH locations, measurement methods (ABC/2 vs planimetry vs AI), and the timing of GCS assessment relative to ICH onset. Despite this heterogeneity, the directionality of the association was invariable across all 18 studies, providing strong evidence for the robustness of this relationship. The finding that ICH volume ≥ 30 mL independently predicted GCS ≤ 8 (OR 4.21; 95%

CI 3.15–5.63) is consistent with the ICH Score's inclusion of this threshold as a binary prognostic variable ⁽⁸⁾.

Location-Specific Modulation of the Volume-GCS Relationship

A critical nuance revealed by this systematic review is that the volume-GCS relationship is strongly modulated by ICH location. Data from Teo et al. (2023) ⁽¹⁸⁾ and Kuohn et al. (2022) ⁽²⁶⁾ demonstrate that deep hemorrhages—particularly thalamic (threshold 6.5 mL) and internal capsule/globus pallidus (threshold 5.5 mL)—produce severe GCS depression at substantially smaller volumes compared to lobar hemorrhages (threshold 40.5 mL). This reflects the anatomical eloquence of deep structures: the thalamus and its connections to the cortex, basal ganglia circuitry, and white matter tracts of the internal capsule are directly involved in consciousness, motor control, and sensory processing. A 5 mL thalamic hemorrhage can produce a GCS of 6–8, while a 20 mL frontal lobar hemorrhage may preserve GCS of 12–14.

Ironside et al. (2020) ⁽²⁷⁾ formalized this location-volume interaction in a 'location ICH score,' demonstrating that location-specific volume thresholds significantly improved discrimination of functional dependence (AUROC 0.883 vs 0.770 for original ICH Score; $p=0.002$). Morotti et al. (2025) ⁽²¹⁾ further confirmed that the prognostic impact of hematoma expansion is critically dependent on whether the final ICH volume exceeds a location-specific threshold: ≥ 36 mL for lobar and ≥ 17 mL for deep ICH. These findings have direct implications for surgical decision-making, neurocritical care triage, and prognostic counseling.

Hematoma Expansion as a Dynamic Modifier of GCS

Hematoma expansion (HE), occurring in 20–40% of ICH patients within the first 24 hours and most rapidly within the first 3 hours, is a principal driver of GCS deterioration after initial presentation ⁽²⁰⁾. The finding of Morotti et al. (2023) ⁽²⁰⁾ that severe HE ($>66\%$ or >12.5 mL) was associated with significantly worse outcomes (OR 1.98; 95% CI 1.38–2.82) underscores the dynamic nature of the GCS-volume relationship: the GCS at admission reflects the baseline hematoma volume, but subsequent expansion—detectable only on serial CT—will further depress GCS if not diagnosed and managed promptly. Li et al. (2017) ⁽²⁸⁾ identified the CT island sign as an independent imaging predictor of hematoma expansion (sensitivity 44.7%, specificity 98.2%,

positive predictive value 92.7%), providing a bedside radiological correlate to anticipate GCS decline before clinical deterioration manifests.

The biological mechanisms underlying HE include ongoing active bleeding from ruptured arterioles, coagulation cascade activation, perihematoma thrombolysis, and hydrostatic propagation. Each additional milliliter of hemorrhage expansion increases the risk of functional dependence by approximately 7% ⁽²⁶⁾. Strategies targeting HE—including rapid blood pressure reduction (per INTERACT2 trial), hemostatic therapy (recombinant factor VIIa per FAST trial), and minimally invasive surgery—therefore also indirectly target GCS preservation through volume limitation.

Serial GCS and Dynamic CT Re-assessment

The data from Meyrat et al. (2025) ⁽¹⁷⁾ provide compelling evidence that serial neurological assessment (GCS at 6 hours post-admission) combined with repeat CT evaluation adds clinically meaningful prognostic information beyond baseline findings alone. A 6-hour GCS AUC of 0.914 for in-hospital mortality significantly outperformed admission GCS (0.879) and the baseline ICH Score (0.890). The 21% of patients who experienced ICH Score progression at 6 hours—reflecting simultaneous hematoma growth on CT and GCS deterioration clinically—demonstrated a 2.4-fold increase in mortality risk. This finding strongly supports the implementation of standardized neurological and radiological re-assessment protocols at 6 hours in all ICH patients, aligned with existing AHA/ASA 2022 guidelines.

NIHSS Versus GCS: Relative Merits for Volume-Correlated Prognosis

While GCS remains the most widely applied consciousness scale in ICH, data from Dusenbury et al. (2023) ⁽¹⁶⁾ and You et al. (2023) ⁽²⁹⁾ suggest that the NIHSS provides superior discriminative power for identifying both large hematoma volumes (>30 mL) and poor functional outcomes. NIHSS correlated strongly with GCS ($r = -0.773$), but demonstrated better AUC for discharge poor outcome (NIHSS 0.91 vs GCS 0.78; DeLong $p < 0.001$) and for identifying volume >30 mL (NIHSS 0.82 vs GCS 0.78; $p = 0.029$). The INTERACT2 data confirmed that baseline NIHSS ≥ 10 optimally predicted 90-day death or major disability (sensitivity 77.5%, specificity 69.2%), outperforming GCS-based predictions. This suggests that while GCS remains essential for

bedside triage and ICH Score calculation, adding NIHSS to clinical assessment provides incremental prognostic value particularly for volume-threshold decisions.

Prognostic Nihilism and Its Consequences

An important caveat to the otherwise strong GCS-volume prognostic framework is the documented phenomenon of prognostic nihilism in ICH management. Morgenstern (2019) ⁽³⁰⁾ highlighted that early withdrawal of life-sustaining therapy (WLST) in ICH patients with large hematoma volumes and low GCS creates a self-fulfilling prophecy: outcome predictive models built on populations in which WLST occurred will inherently overestimate mortality risk, as patients who might have recovered were not given the opportunity. A multicenter study demonstrated 30% absolute mortality reduction compared to ICH-score-predicted mortality in patients managed with aggressive neurocritical care and WLST deferral for ≥ 5 days. Tilling et al. (2019) ⁽³¹⁾ further demonstrated that clinicians systematically overestimate ICH volume on CT (+8 mL average overestimation) and assign significantly worse prognoses to ICH than to volume-matched ischemic stroke, suggesting systematic cognitive bias in ICH prognostication. Clinicians must therefore interpret GCS-volume combinations with awareness that aggressive neurocritical intervention may substantially modify predicted outcomes.

Surgical Decision-Making: Integration of GCS and ICH Volume

The interaction between GCS and ICH volume is of paramount importance in neurosurgical decision-making. Gregson et al. (2019) ⁽³²⁾ performed a novel nonparametric re-analysis of the STICH I and II trial data (n=1,541 patients), demonstrating that surgery was harmful for small hematoma volumes but showed increasing benefit for larger volumes. Critically, a GCS range of 10–13 emerged as the optimal neurological stratum for surgical benefit, with GCS <10 or >13 showing less favorable surgical responses. This suggests that the ideal surgical candidate is a patient with an intermediate level of consciousness depression (GCS 10–13) combined with a large hematoma volume, where surgical decompression can relieve mass effect before irreversible brain injury occurs. For patients with GCS 3–5 and massive hemorrhage (>60 mL), surgical intervention may offer little benefit.

CONCLUSIONS AND RECOMMENDATIONS

Summary of Evidence

This systematic review, encompassing 18 high-quality studies and 8,247 adult patients with spontaneous intracerebral hemorrhage, provides robust, multi-level evidence for a strong inverse relationship between ICH volume on CT scan and GCS score at admission. The pooled Spearman correlation coefficient of $r = -0.67$ (95% CI: -0.74 to -0.59; $p < 0.001$) across all included studies confirms the clinical axiom that larger hematoma volumes are associated with deeper impairment of consciousness. A threshold ICH volume of ≥ 30 mL independently predicts $GCS \leq 8$ (OR 4.21; 95% CI 3.15–5.63; $p < 0.001$), applicable across ICH locations and measurement methods.

Location-Specific Clinical Implications

The GCS-volume relationship is critically modulated by ICH location. Deep hemorrhages—particularly thalamic (>6.5 mL) and internal capsule (>5.5 mL)—produce severe GCS depression at substantially smaller volumes than lobar hemorrhages (>40.5 mL). These location-specific thresholds should be integrated into neurosurgical consultation protocols and prognostic counseling, replacing a single universal volume cut-off for all ICH locations.

Recommendations for Clinical Practice

Based on the synthesized evidence, the following clinical recommendations are proposed:

1. All patients admitted with spontaneous ICH should undergo immediate non-contrast CT with quantitative volume measurement using the ABC/2 formula (or planimetric method for irregular hemorrhages) and concurrent GCS assessment as part of a standardized emergency triage protocol.
2. Serial clinical (GCS) and radiological (repeat CT at 6 hours) assessment should be implemented in all ICH patients to detect early neurological deterioration and hematoma expansion, which are the two principal modifiable determinants of GCS decline.
3. ICH volume ≥ 30 mL combined with GCS 10–13 represents the optimal surgical candidate profile; patients with GCS <10 or >13 and the same volume may derive less surgical benefit per the re-analyzed STICH data.

4. Prognostic nihilism should be actively avoided; aggressive neurocritical care with deferral of early WLST for at least 5 days may reduce ICH mortality by up to 30% compared to score-predicted outcomes.
5. The NIHSS should supplement GCS in ICH assessment protocols, as it demonstrates superior discriminative power for identifying large hematoma volumes (>30 mL) and poor functional outcomes at 90 days.

Future Research Directions

Future prospective multicenter studies should: (1) standardize GCS assessment timing relative to ICH onset and therapeutic interventions; (2) compare AI-based automated segmentation with ABC/2 for ICH volume measurement in the context of GCS prediction models; (3) investigate whether location-specific volume-GCS thresholds are modifiable by minimally invasive surgical or pharmacological intervention; (4) examine the GCS-volume relationship in anticoagulant-related ICH separately, given the greater hematoma irregularity and volume instability in this subgroup; and (5) develop integrated clinical prediction tools combining GCS, ICH volume, location, IVH extension, and biomarkers for individualized outcome prognostication.

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