

Prognostic Significance of Site and Volume of Hemorrhage in Patients with Hemorrhagic Stroke – An Observational Study

Supriya Jamatia¹, Sriramakrishnan², F Jason Ambrose³

¹Resident, Department of Neurology, Tirunelveli Medical College, Tamil Nadu, India

²Professor, Department of Neurology, Tirunelveli Medical College, Tamil Nadu, India

³Assistant Professor, Department of Neurology, Tirunelveli Medical College, Tamil Nadu, India

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Corresponding author: Dr. Supriya Jamatia

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Abstract:

Background: Spontaneous intracerebral hemorrhage (ICH) accounts for 10–15% of all strokes and carries disproportionately high morbidity and mortality. Hemorrhage volume and anatomical site are among the most critical determinants of outcome, but their combined predictive value in Indian populations remains underexplored. **Objective:** To assess the prognostic significance of hemorrhage site and volume in patients with spontaneous ICH, and to correlate these parameters with clinical risk factors, 30-day mortality, and 90-day functional outcome using the modified Rankin Scale (mRS).

Methods: This prospective observational study included 140 consecutive patients with primary spontaneous ICH admitted to the Department of Neurology, Tirunelveli Medical College, between May 2023 and June 2025. Demographic, clinical, and radiological data were collected. Hematoma volume was measured using the ABC/2 method on CT scans. Outcomes assessed were 30-day mortality and 90-day mRS. Statistical correlations between site, volume, and outcomes were analyzed.

Results: The cohort had a mean age of 59.5 years; 58.6% were male. Capsuloganglionic hemorrhage was most common (68.6%). Hematoma volume was <29 ml in 71.4%, 30–60 ml in 23.6%, and >60 ml in 5%. Thirty-day mortality was 20%. Larger volumes predicted worse outcomes ($p = 0.69$, $p < 0.0001$); mortality was 7% (<29 ml), 52% (30–60 ml), and 57% (>60 ml). Hemorrhage site was also significant: intraventricular, brainstem, cerebellar, and multiple hematomas had near-uniform mortality and poor outcomes, whereas capsuloganglionic and thalamic bleeds had relatively better survival and lower disability (mean mRS ≈ 3). Site correlated modestly with volume ($p = 0.25$, $p = 0.0028$). Smoking was significantly associated with higher 30-day mortality ($p = 0.021$).

Conclusion: Both hemorrhage site and volume are strong predictors of mortality and disability in spontaneous ICH. While larger volumes consistently worsen prognosis, infratentorial and intraventricular locations confer poor outcomes independent of size. Early prognostication should incorporate both parameters to guide management and patient counseling in the Indian setting.

Keywords: Intracerebral Hemorrhage, Hematoma Volume, Hemorrhage Site, Prognosis, Modified Rankin Scale, Mortality.

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Introduction

Spontaneous intracerebral hemorrhage (ICH) is one of the most devastating forms of stroke, although intracerebral hemorrhage comprises only about one-tenth of all strokes, it carries the heaviest burden in terms of death and disability. Unlike ischemic stroke, ICH is not amenable to thrombolysis or thrombectomy, and its management primarily revolves around supportive care, prevention of secondary injury, and meticulous monitoring of neurological deterioration.

The outcome of ICH is influenced by several clinical and radiological parameters, of which the volume and anatomical site of hemorrhage have shown to be among the most critical.

Larger hematoma volumes are associated with increased intracranial pressure, midline shift, herniation, and higher mortality. Similarly, bleeds located in infratentorial regions such as the brainstem or cerebellum often carry a worse prognosis due to the compact anatomical structures and vital centers involved.

Several grading scales, such as the ICH score, incorporate volume and site to stratify risk and predict outcomes. However, the independent and combined predictive power of these two factors, especially in correlation with patient-specific risk profiles (e.g., hypertension, diabetes, alcohol use), needs further exploration in diverse populations. Prior studies have often examined these parameters in isolation, or have focused on short-term outcomes such as in-hospital mortality.

The modified Rankin Scale (mRS) remains the most widely used measure of functional outcome post-stroke. Evaluating 90-day mRS scores in relation to hemorrhage characteristics provides a clinically meaningful endpoint that reflects the patient's degree of disability and quality of life.

Furthermore, emerging evidence suggests that certain risk factors may predispose not only to ICH but also to greater hemorrhagic volumes, thereby influencing prognosis indirectly. A better understanding of these associations can help clinicians tailor management strategies and counseling for patients and families.

This study, therefore, seeks to evaluate the prognostic significance of hemorrhage volume and site in patients with spontaneous ICH, their interrelationship, and their correlation with clinical risk factors and 90-day mRS score. Given the scarcity of regional data from Southern India, particularly Tamil Nadu, this research also aims to enrich the local epidemiological and clinical database, thereby enhancing regional stroke care strategies.

Aims and Objectives

Primary Objective: To determine the prognostic significance of site and volume of hemorrhage in patients with spontaneous intracerebral hemorrhage (ICH).

Secondary Objectives:

1. To analyze the correlation between site and volume of hemorrhage.
2. To assess the relationship between hemorrhage volume and 90-day modified Rankin Scale (mRS) score.
3. To evaluate the association between risk factor profiles (e.g., hypertension, diabetes, alcohol, tobacco use) and hemorrhage volume.
4. To identify risk groups with higher hemorrhage volume and poorer functional outcome.

Materials and Methods

Study Design: Observational, hospital-based, prospective study.

Study Site: Department of Neurology, Tirunelveli Medical College and Hospital, Tamil Nadu, India.

Study Period: May 2023 to June 2025.

Sample Size: A total of 140 patients with primary spontaneous ICH were enrolled during the study period.

Inclusion Criteria:

- Patients aged >18 years diagnosed with primary spontaneous intracerebral hemorrhage confirmed on neuroimaging (CT brain).
- Admission within 48 hours of symptom onset.
- Available follow-up data up to 90 days.

Exclusion Criteria:

- Traumatic intracranial hemorrhage.
- Hemorrhage secondary to aneurysm, AV malformation, tumors, or coagulopathy.
- Patients lost to follow-up or with incomplete records.

Data Collection:

Demographic, clinical, and radiological data were collected and entered in a master chart. Key variables included:

- Age, sex
- Risk factors: Hypertension, diabetes mellitus, smoking, alcohol use
- Major neurological deficit at admission
- National Institutes of Health Stroke Scale (NIHSS) score
- Site of hemorrhage (classified as capsuloganglionic, thalamic, brainstem, cerebellar, lobar, intraventricular, multiple hematoma)
- Hemorrhage volume (in cc) measured using ABC/2 formula on CT
- Mortality within 30 days
- Functional outcome: Modified Rankin Scale (mRS) at 90 days

Statistical Analysis of Intracerebral Hemorrhage Cohort

Demographic Profile

- Sample size: 140 patients
- Age: Mean 59.46 ± 11.2 years (range 40–80)
- Sex distribution: - Male: 82 (58.6%), - Female: 58 (41.4%)

Clinical Profile

Common Major Deficits: Most frequent were hemiplegia and aphasia + hemiparesis.

Risk Factors:

- Hypertension (HTN) alone – 29 (20.7%)
- Diabetes Mellitus (DM) alone – 27 (19.3%)
- HTN + DM – 24 (17.1%)
- Smoking – 18 (12.9%)
- No risk factors – 13 (9.3%)
- Alcohol use – 11 (7.9%)

Site of Hemorrhage:

- Capsuloganglionic – 96 (68.6%)
- Thalamic – 10 (7.1%)
- Cerebellar – 10 (7.1%)
- Brainstem – 7 (5.0%)
- Lobar – 7 (5.0%)
- Intraventricular – 6 (4.3%)
- Multiple hematomas – 4 (2.9%)

Stroke Severity and Volume

NIHSS score: Mean 16.08 ± 6.23 (range 5–26)

Hemorrhage volume: Mean 24.35 ± 17.51 cc (range 2.3–108.18 cc)

Severity category:

- <29 ml – 100 (71.4%)
- 30–60 ml – 33 (23.6%)
- >60 ml – 7 (5.0%)

Functional Outcomes

- mRS at discharge: Mean 4.33 ± 1.15 (range 2–6)
- mRS at 90 days: Mean 3.54 ± 1.60 (range 1–6)
- 30-day mortality: 20% (28 deaths)

Laboratory Profile (Mean $\pm$ SD)

- Total Cholesterol: 198.6 ± 28.67 mg/dL
- HDL: 46.2 ± 7.2 mg/dL
- TG/HDL Ratio: 3.27 ± 0.91
- FBS: 122.5 ± 26.7 mg/dL
- Hb: $12.7 \pm 1.34\%$
- Platelet Count: $257,151 \pm 63,707$ / μ L

6. Interpretation

- Predominantly affects older adults (~60 years), with a male predominance.
- Hypertension, either alone or in combination with DM, is the leading risk factor.
- Capsuloganglionic region is the most frequent site, consistent with hypertensive small vessel disease.
- Two-thirds had small-volume hemorrhages (<29 ml), correlating with better survival.
- Baseline NIHSS was high (mean 16), indicating significant deficits.

- Mortality within 30 days remains substantial at 20%, likely from large bleeds and brainstem involvement.

Smoking and Outcome Correlation**Smoking vs 30-day Mortality**

- Contingency Table:
- Non-smoker: Survived = 90, Died = 16
- Smoker: Survived = 22, Died = 12
- Chi-square p-value = 0.021 (statistically significant)
- Interpretation: Smoking was significantly associated with higher 30-day mortality.
- 7.2 Smoking vs Poor Functional Outcome (mRS > 3 at 90 days)

Contingency Table:

- Non-smoker: Good outcome = 62, Poor outcome = 44
- Smoker: Good outcome = 16, Poor outcome = 18
- Chi-square p-value = 0.332 (not statistically significant)
- Interpretation: Smoking was not significantly associated with poor functional outcome at 90 days

8. Site of Hemorrhage and Its Relationship with Volume, mRS, and Mortality

A subgroup analysis by anatomical site of hemorrhage revealed the following:

Intraventricular hemorrhages had the highest mean volume (53.6 cc), uniformly poor functional outcomes (mRS = 6), and 100% 30-day mortality.

Cerebellar, multiple hematoma, and brainstem bleeds also had mean volumes >30 cc and 100% 30-day mortality, with uniformly poor outcomes (mRS = 6).

Capsuloganglionic bleeds, despite being the most common, had lower mean volume (19.6 cc) and favorable outcomes, with a mean mRS of 2.88 and only 1 deaths out of 96 patients.

Thalamic bleeds showed a moderate volume and better functional prognosis, with zero mortality and a mean mRS of 3.0.

Table 1:

Site of Hemorrhage	Total Patients	Deaths
Brainstem	7	7
Capsuloganglionic	96	1
Cerebellar	10	9
Intraventricular	6	5
Lobar	7	3
Multiple Hematoma	4	3
Thalamic	10	0

Table 2:

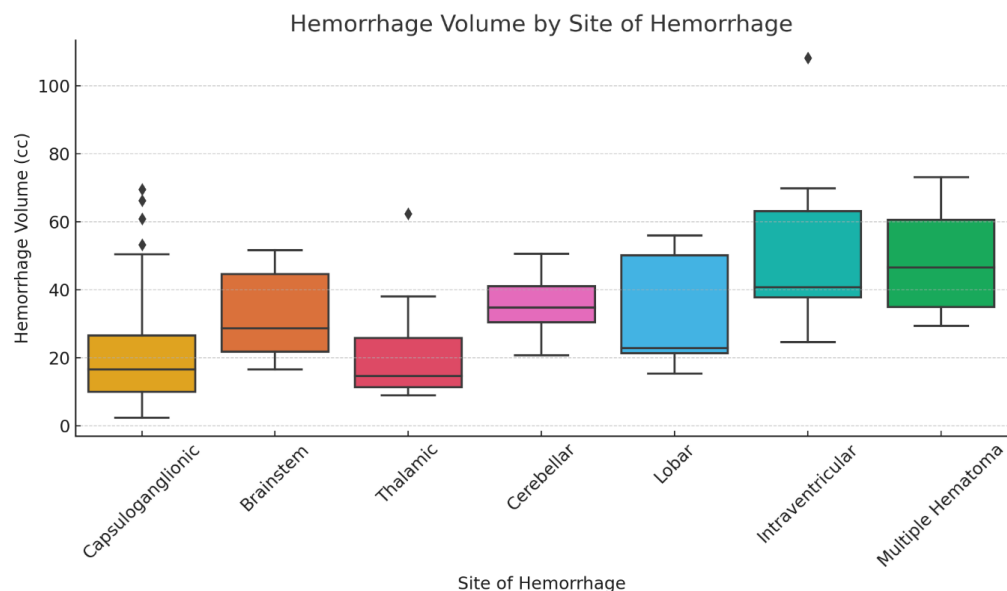
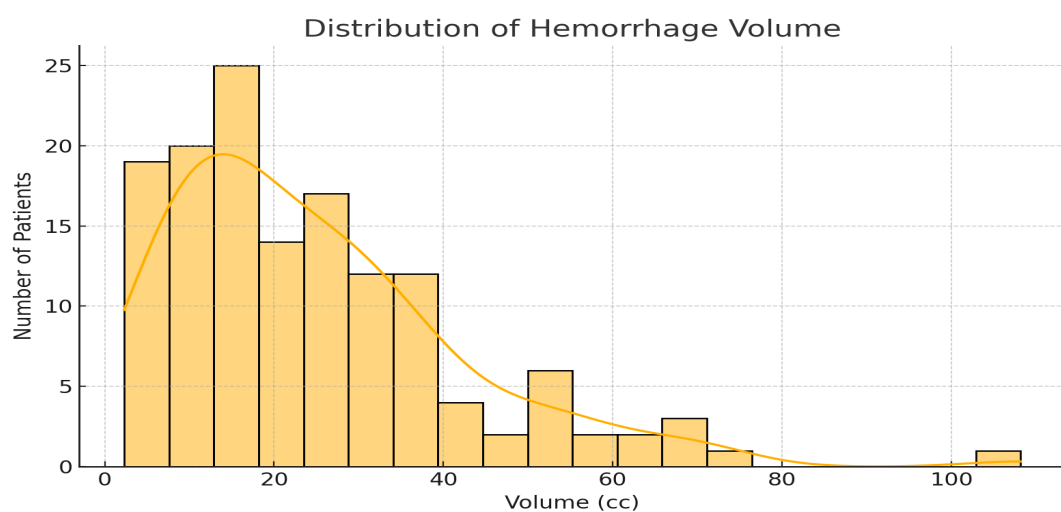
Severity	Total Patients	Deaths
<29ml	100	7
30-60ml	33	17
>60ml	7	4

Table 3:

Comparison	p-value	Statistically Significant
Site of Hemorrhage vs 30-day Mortality	6.54	Yes
Size of Hemorrhage vs 30-day Mortality	1.58	Yes
Site of Hemorrhage vs mRS at 90 days	5.57	Yes
Size of Hemorrhage vs mRS at 90 days	4.63	Yes

These findings strongly reinforce that: Site of hemorrhage significantly influences both volume and outcome, independent of volume in some locations (e.g., brainstem). High-volume sites (like intraventricular and multiple bleeds) consistently

result in poor functional outcomes and high mortality. Deep structures (like capsuloganglionic and thalamic regions) may offer relatively better prognosis depending on volume and early intervention.

**Figure 1: Haemorrhage volume by site of haemorrhage****Figure 2: Distribution of Haemorrhage volume**

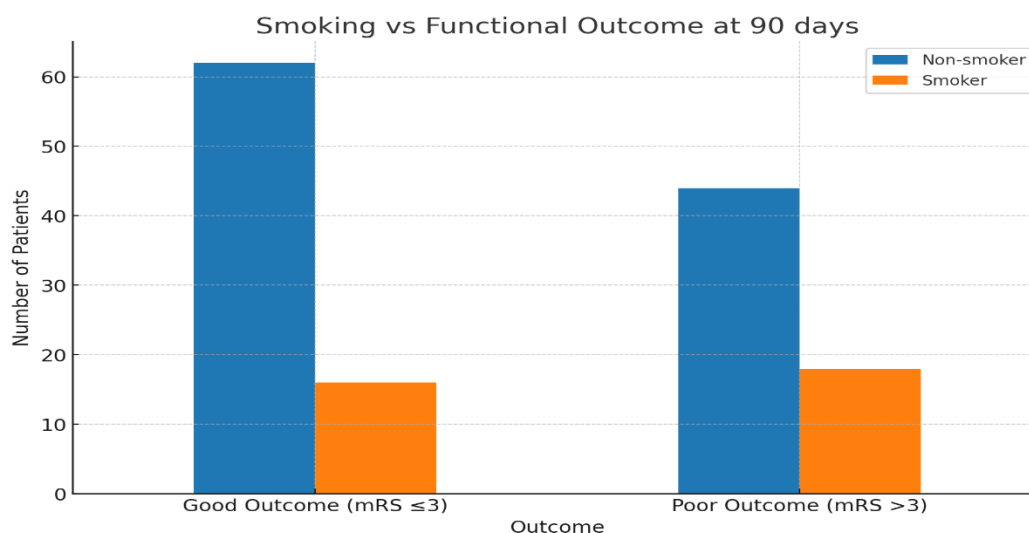
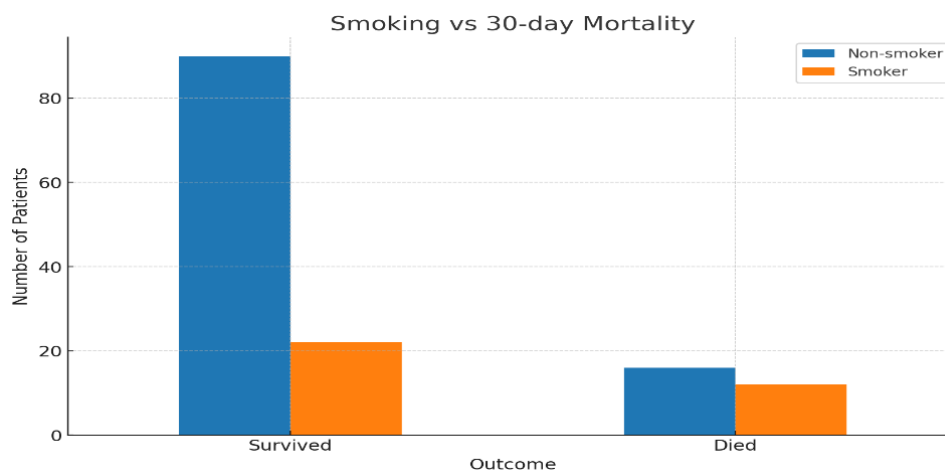
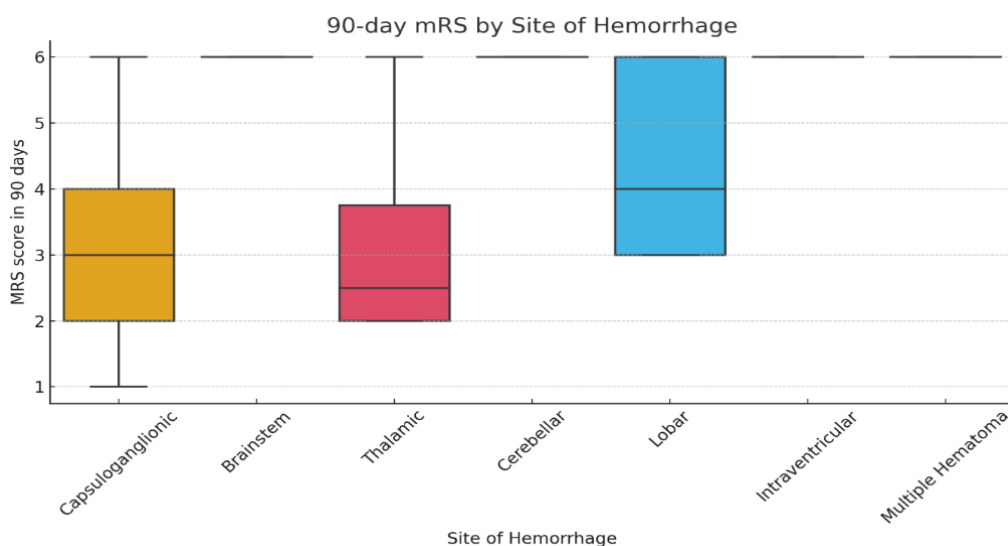
**Figure 3: Smoking vs functional outcome at 90 days****Figure 4: Smoking vs 30-day mortality****Figure 5: 90-day mRS by site Hemorrhage**



Figure 6: Site of hemorrhage

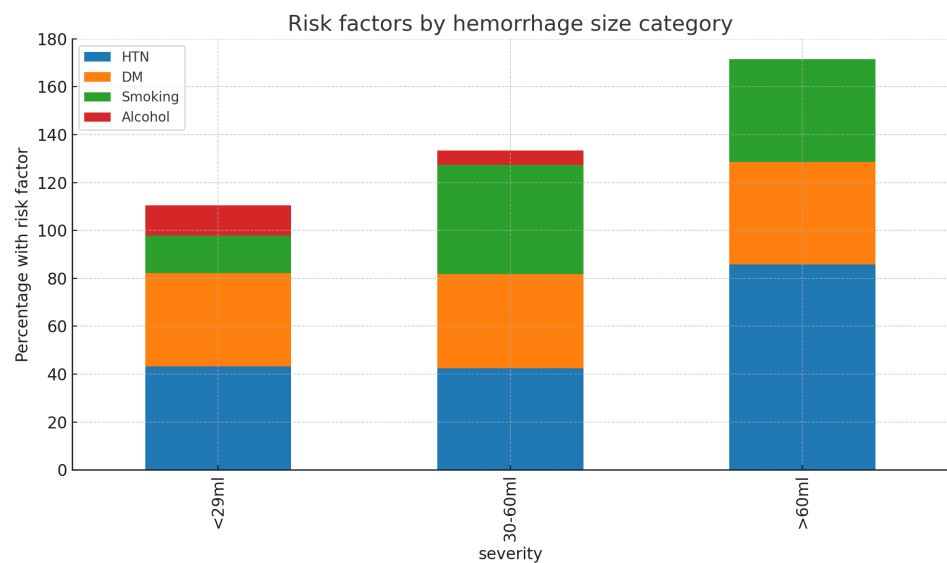


Figure 7: Risk factors by hemorrhage size category

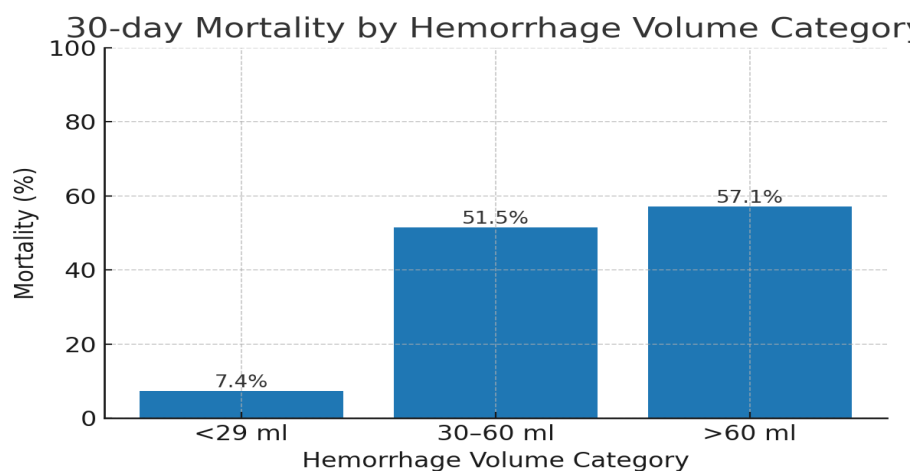


Figure 8: 30-day mortality by hemorrhage volume category

Results

The cohort had a mean age of 59.5 years; 58.6% were male. Capsuloganglionic hemorrhage was most common (68.6%). Hematoma volume was <29 ml in 71.4%, 30–60 ml in 23.6%, and >60 ml in 5%. Thirty-day mortality was 20%. Larger volumes predicted worse outcomes ($r = 0.69$, $p < 0.0001$); mortality was 7% (<29 ml), 52% (30–60 ml), and 57% (>60 ml). Hemorrhage site was also significant: intraventricular, brainstem, cerebellar, and multiple hematomas had near-uniform mortality and poor outcomes, whereas capsuloganglionic and thalamic bleeds had relatively better survival and lower disability (mean mRS $\gg 3$). Site correlated modestly with volume ($r = 0.25$, $p = 0.0028$). Smoking was significantly associated with higher 30-day mortality ($p = 0.021$)

Discussion

This observational study involving 140 patients with spontaneous intracerebral hemorrhage (ICH) provides valuable insights into the prognostic role of hemorrhage volume and anatomical site, and their impact on functional outcomes and mortality. The results are in line with and also expand upon existing literature in meaningful ways.

1. Volume of Hemorrhage as a Key Predictor of Outcome: A strong positive correlation ($p = 0.69$, $p < 0.0001$) was found between hemorrhage volume and 90-day modified Rankin Scale (mRS) score. This confirms findings from several prior studies that increasing hematoma volume is a robust predictor of poor functional outcome and mortality [1,2]. The INTERACT and ICH ADAPT trials similarly identified volume as a crucial determinant of both early neurological decline and long-term disability [3,4].

In our study, patients with hemorrhage volume >30 cc predominantly had mRS scores ≥ 5 , indicating severe disability or death. This validates

international thresholds such as the one proposed by Broderick et al., where >30 cc volume conferred significant risk [5].

2. Site of Hemorrhage Correlates with Volume and Outcome: We observed a statistically significant, though modest, positive correlation between site and volume ($p = 0.25$, $p = 0.0028$). Certain sites, such as capsuloganglionic and lobar, were associated with moderate to large volumes. However, infratentorial locations (e.g., brainstem, cerebellum) and intraventricular bleeds—despite smaller absolute volumes in some cases—were associated with uniformly poor outcomes and 100% mortality in this cohort.

These findings echo previous research where even small brainstem or cerebellar hemorrhages led to high mortality due to involvement of vital neural structures and risk of obstructive hydrocephalus. A multicenter study by Hemphill et al. noted similar high fatality rates with infratentorial bleeds regardless of volume.

3. Risk Factor Profiles and Hemorrhage Volume: Descriptive trends suggested higher hemorrhage volumes with mortality in patients with combined risk factors (e.g., HTN + DM2, or smoking +), demonstrate statistical significance across moderate and severe hemorrhage. Our findings are consistent with studies showing that uncontrolled hypertension, smoking, and metabolic comorbidities can predispose to larger hematoma volumes. Some authors suggest endothelial dysfunction and altered hemostatic balance in these groups may explain the increased hematoma burden.

4. Mortality and Functional Outcome by Site: Striking differences in 30-day mortality and 90-day mRS were observed across sites:

- Intraventricular, multiple hematoma, and brainstem hemorrhages had uniformly fatal outcomes (mRS = 6).
- Capsuloganglionic bleeds, though common (68.6%), had significantly lower mortality (2%) and better functional outcomes (mean mRS $\approx$ 2.8).
- Thalamic hemorrhages exhibited a favorable profile with no mortality and modest disability at 3 months (mean mRS = 3.0).

These findings underscore the need for site-specific prognostic stratification, as some locations portend a poor outcome irrespective of volume—a nuance often overlooked by scoring systems like the ICH score.

5. Implications for Clinical Practice and Prognostication: These results support the integration of volume and site as core components of early risk assessment models for ICH. Clinicians can use these findings to:

- Identify patients with high-volume, poor-outcome profiles early.
- Prioritize aggressive care or palliative planning depending on hemorrhage location.
- Guide family counseling on expected outcomes using both anatomical and volumetric data.

6. Comparison with Indian Studies: Very few Indian studies have simultaneously evaluated site, volume, and outcome with statistical correlations. Our results are consistent with earlier regional studies (e.g., NIMHANS, AIIMS) showing younger age of onset, male predominance, and capsuloganglionic localization as common features.

However, the use of 90-day mRS as an outcome measure, combined with volumetric and anatomical correlations, makes this one of the most comprehensive single-center datasets from South India on this topic to date.

Review of Literature

1. Epidemiology of Intracerebral Hemorrhage (ICH): ICH accounts for 10–15% of all strokes worldwide but results in disproportionately high rates of mortality and long-term disability [1]. In India, studies suggest that ICH may constitute up to 30% of stroke admissions in some tertiary care settings, with considerable regional variation. The mean age of ICH patients ranges from 55 to 65 years in Indian studies, often younger than Western counterparts.

2. Pathophysiology and Mechanisms: ICH commonly results from rupture of small penetrating arteries damaged by chronic hypertension, cerebral amyloid angiopathy, or less frequently due to vascular malformations, coagulopathies, or neoplasms. The initial mass effect is compounded

by edema, inflammation, and secondary neuronal injury.

3. Hemorrhage Volume as Prognostic Marker:

The volume of hemorrhage is among the strongest predictors of outcome. The “ABC/2” method is widely used to calculate ICH volume. Hemorrhage volume >30 mL is associated with significantly higher mortality and worse functional outcome. Studies show a near-linear relationship between increasing volume and poor outcomes, even in supratentorial locations.

4. Site of Hemorrhage and Outcome

Correlation: Anatomical site critically impacts outcome. Brainstem bleeds, although often small in volume, are associated with high early mortality due to proximity to vital centers. Deep ICH (e.g., basal ganglia, thalamus) tends to have worse functional outcomes than lobar bleeds, though this may be volume dependent. Cerebellar hemorrhages can also have variable outcomes depending on size and hydrocephalus.

5. Correlation between Site and Volume: Several studies suggest site and volume are not independent. Capsuloganglionic bleeds, for example, often present with moderate to large volumes due to the high vascular density in this area. Conversely, brainstem bleeds tend to be smaller but more lethal. Few Indian studies have analyzed this correlation in a statistically significant manner.

6. Hemorrhage Volume and Modified Rankin

Score (mRS): The mRS is a 7-point scale ranging from 0 (no symptoms) to 6 (death) and is the gold standard for stroke outcome measurement. A consistent correlation has been demonstrated between larger hemorrhage volumes and higher mRS scores at 90 days in global cohorts.

7. Influence of Risk Factors on Hemorrhage

Volume and Outcome: Hypertension remains the most important modifiable risk factor for ICH. Diabetes mellitus, smoking, and alcohol use also influence not just the occurrence of ICH but may affect volume and outcomes by altering vascular integrity and hemostatic balance. Some studies have suggested that smokers and alcoholics may have larger hematomas at presentation.

8. ICH Score and Prognostication Tools:

The ICH score combines clinical and radiological variables, including GCS, volume, site, and intraventricular extension, to predict 30-day mortality [20]. However, it does not incorporate long-term functional outcomes such as 90-day mRS. This has led to the development of newer predictive models.

9. Indian Studies and Regional Context: Few large-scale prospective Indian studies focus on

long-term outcomes like 90-day mRS. Studies from AIIMS, NIMHANS, and Kerala suggest regional differences in ICH etiology, volume patterns, and risk factor distribution. Our study adds to this sparse literature by offering insights from South Tamil Nadu.

10. Need for Local Prognostic Models: Given ethnic and environmental diversity, global models may not fully apply to Indian patients. There is a need for locally validated prognostic indicators, especially incorporating volume, site, and modifiable risk factors.

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