ORIGINAL ARTICLE

Coagulation parameters (PT, APTT, INR) as determinants of peri-lesional attenuation and clinical severity in intracerebral hemorrhage: A retrospective analytical study

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ABSTRACT

Background and aim: Intracerebral hemorrhage (ICH) is associated with high mortality and severe neurological disability, largely driven by secondary brain injury such as perihematomal edema (PHE) and hematoma expansion. Abnormalities in coagulation parameters, including prothrombin time (PT), activated partial thromboplastin time (APTT), and international normalized ratio (INR), may be associated with bleeding characteristics and radiological features. Quantitative assessment of peri-lesional attenuation using Hounsfield Unit (HU) values on non-contrast computed tomography (NCCT) provides a practical approach to evaluate tissue changes. This study aimed to investigate the relationship between coagulation parameters, peri-lesional attenuation, and neurological severity measured by the National Institutes of Health Stroke Scale (NIHSS) in patients with ICH.
Methods: This study used an analytic observational design with a retrospective approach in patients with primary ICH treated at Dr. Wahidin Sudirohusodo Hospital, Makassar. Data were obtained from medical records, including PT, APTT, and INR values, NCCT findings for HU measurement using a region-of-interest (ROI)

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method, and NIHSS scores at admission. Statistical analysis was performed to assess relationships between variables, with a significance level of $p < 0.05$.

Results: A total of 150 patients were included, with a predominance of male patients and a mean age of 55.1 ± 15.2 years. A weak but statistically significant association was observed between INR and peri-lesional attenuation. However, coagulation parameters were not significantly associated with neurological severity as measured by NIHSS. Multivariate analysis showed that age and hematoma volume were the main independent predictors of neurological severity.

Conclusions: Coagulation parameters show a limited association with peri-lesional attenuation and are not significantly associated with clinical severity in patients with ICH. Clinical and radiological factors, particularly age and hematoma volume, remain the primary determinants of early neurological impairment. Integration of laboratory and imaging findings may support clinical evaluation, although their predictive value for early severity appears limited. (www.actabiomedica.it)

Key words: intracerebral hemorrhage; coagulation parameters; Hounsfield unit; peri-lesional attenuation; NIHSS; CT scan

Introduction

Intracerebral hemorrhage (ICH) remains a major challenge in neurology and public health due to its acute presentation, severe clinical impact, and limited therapeutic options (1,2). Unlike the more common ischemic stroke (IS), ICH is associated with substantially higher mortality and morbidity rates and imposes a significant economic and social burden on patients, families, and healthcare systems (1-3). Epidemiological data indicate that the global incidence of ICH is approximately 24 per 100,000 population per year, with a 30-day mortality rate exceeding 40% (3,4). In Asia, including Indonesia, the incidence is even higher, likely reflecting the high prevalence of uncontrolled hypertension and disparities in access to healthcare services (4,5). These findings highlight the urgent need for improved strategies in early detection, risk stratification, and management of ICH (1,2). Following the initial hemorrhagic event, the pathological process extends beyond primary bleeding and involves a cascade of secondary brain injury mechanisms (6,7). One of the most prominent processes is the development of perihematomal edema (PHE), which represents the accumulation of fluid surrounding the hematoma due to blood–brain barrier disruption, inflammatory responses, and osmotic changes (6,8). PHE evolves dynamically over time, beginning with early osmotic shifts and progressing to later inflammatory-mediated injury driven by blood degradation products. Previous studies have demonstrated that the extent and progression of PHE are associated with neurological deterioration, increased need for intensive care, and higher mortality (8-10). Therefore, accurate assessment of peri-lesional tissue changes is essential for clinical evaluation and prognostication (6,10). Advances in neuroimaging, particularly non-contrast computed tomography (NCCT), have significantly improved the evaluation of ICH (11,12). One quantitative imaging parameter that has gained increasing attention is the Hounsfield Unit (HU), which reflects tissue attenuation on CT imaging (11). Acute hematomas typically exhibit high attenuation due to the presence of concentrated hemoglobin, whereas surrounding peri-lesional regions demonstrate relatively lower attenuation related to increased water content and tissue alterations (12,13). Quantitative assessment of peri-lesional attenuation using HU values provides a practical and accessible approach to characterize tissue changes in the acute phase of ICH (13-15). However,

it is important to note that such measurements may reflect a composite signal influenced by edema, adjacent brain tissue, and partial volume effects rather than pure edema alone (14,15). In addition to radiological factors, coagulation parameters play a central role in the pathophysiology and progression of ICH (16,17). Prothrombin time (PT), activated partial thromboplastin time (APTT), and international normalized ratio (INR) are widely used to assess hemostatic function (17). Abnormalities in these parameters are commonly observed in patients receiving anticoagulant therapy or with underlying coagulopathies and may increase the risk of hematoma expansion and adverse clinical outcomes (18-20). Dysregulation of coagulation can contribute to ongoing bleeding, increased intracranial pressure, and further secondary brain injury, including peri-lesional tissue changes (16,19). Therefore, integrating laboratory and imaging parameters may provide a more comprehensive understanding of disease progression (16,20). Despite growing interest in imaging biomarkers, the relationship between peri-lesional attenuation, coagulation status, and clinical outcomes in ICH remains incompletely understood, particularly in resource-limited settings (10,14,21). This study aims to investigate the association between coagulation parameters (PT, APTT, INR), peri-lesional attenuation measured by HU on NCCT, and neurological severity assessed using the National Institutes of Health Stroke Scale (NIHSS). By integrating radiological and laboratory data, this study seeks to contribute to improved risk stratification and clinical decision-making in patients with ICH (1,2,21).

Materials and Methods

Study design and setting

This study was an analytic observational study with a retrospective cohort design conducted at Dr. Wahidin Sudirohusodo General Hospital, Makassar, Indonesia, a tertiary referral center for neurological disorders. The study included patients diagnosed with primary ICH who were admitted between January 2023 and December 2025. Clinical, laboratory, and radiological data were obtained from electronic medical records and verified using the hospital Picture Archiving and Communication System (PACS). The main objective was to evaluate the relationship between coagulation parameters PT, APTT, and INR, peri-lesional attenuation measured by HU on NCCT, and neurological severity assessed using the NIHSS. Ethical approval for this study was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Hasanuddin University. Because the study was retrospective and used anonymized data, patient confidentiality was strictly maintained throughout the research process. All laboratory data were verified through cross-checking with original medical records prior to analysis to ensure accuracy and minimize data entry errors.

Sample criteria

We included adult patients (≥18 years) who were diagnosed with primary ICH confirmed by NCCT head. To be eligible, patients had to have complete laboratory results at admission, including PT, APTT, and INR. In addition, peri-lesional attenuation needed to be clearly visible on CT and suitable for HU measurement using the region of interest (ROI) method. A documented NIHSS score at the time of admission was also required to assess neurological severity. Patients were excluded if the hemorrhage was caused by trauma, tumor, aneurysm, arteriovenous malformation, or other structural vascular abnormalities. We also excluded patients with a history of prior brain surgery at the same anatomical location, as well as those with incomplete clinical, laboratory, or imaging data. After applying these criteria, a total of 150 patients were included in the final analysis.

Research procedure

Eligible patients were identified through hospital records using diagnostic coding and radiological confirmation of ICH. Demographic characteristics, including age and sex, were recorded. Clinical severity was assessed using the NIHSS score obtained at admission, reflecting the degree of acute neurological deficit, and hematoma volume was estimated using the ABC/2 method on baseline CT imaging (21–24).

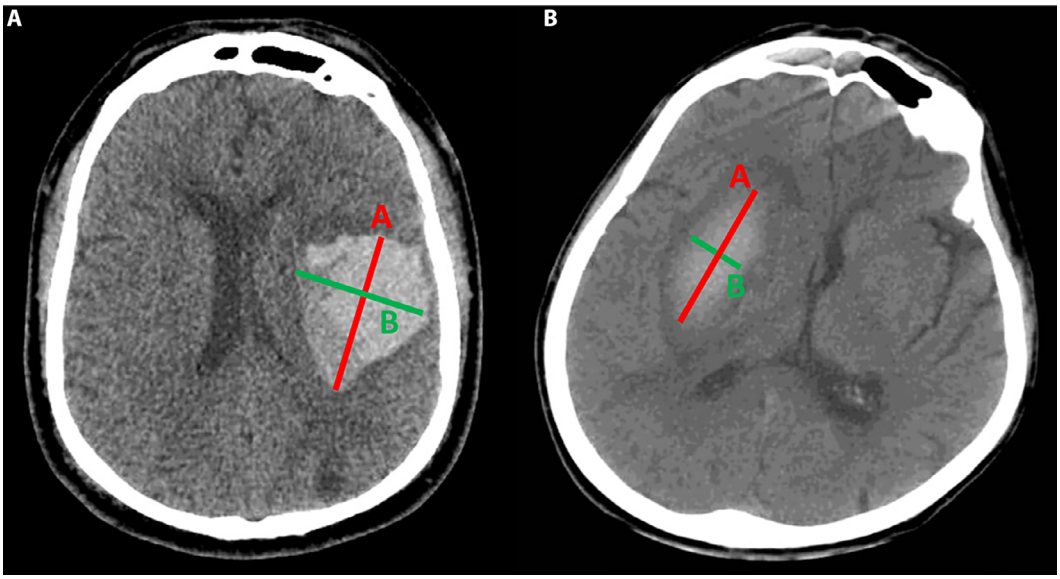

Figure 1. Illustration of the ABC/2 method for calculating hematoma volume on axial non-contrast computed tomography (CT) images. The longest diameter of the hematoma (A) is marked in red on the axial slice where the hematoma appears largest. The diameter perpendicular to A (B) is marked in green on the same slice. The depth (C) is calculated by multiplying the number of CT slices showing the hematoma by the slice thickness. Hematoma volume is then estimated using the formula (A × B × C) / 2. This method provides a simple and practical approximation of total hematoma volume. (A). Intracerebral hemorrhage in the left temporoparietal lobe with an estimated volume of approximately 53.8 cc; (B). Intracerebral hemorrhage involving the right caudate nucleus and lentiform nucleus with an estimated volume of approximately 33.6 cc.

Laboratory data, including PT, APTT, and INR values, were collected from the first blood examination performed at hospital admission using standardized automated coagulation analyzers (17). Information regarding prior anticoagulant therapy was not consistently available in the medical records and therefore could not be included in the analysis. Radiological data were reviewed independently through PACS. Hematoma volume was calculated using the ABC/2 method, and peri-lesional attenuation density was measured in HU as shown in the Figure 1. CT scans were obtained at the time of hospital admission. However, due to the retrospective design, the exact time interval between symptom onset and CT acquisition was not consistently available and therefore could not be included in the analysis. The timing of CT acquisition relative to symptom onset was not standardized, which may have contributed to variability in attenuation measurements (8,25). All collected data were coded and entered into a secure database to ensure patient confidentiality prior to statistical analysis.

Imaging methodology

Peri-lesional attenuation was measured using a region-of-interest (ROI) approach on non-contrast CT images. Circular or oval ROIs were placed within the hypodense area surrounding the hematoma, while carefully avoiding visible vessels, calcifications, and major artifacts as shown in the Figure 2. Given the inherent limitation of manual ROI placement, particular attention was paid to avoid inclusion of the hematoma core and cortical gray matter as much as possible. However, we acknowledge that this method may still be weakly associated with by partial volume effects, especially in regions with heterogeneous tissue composition. Therefore, the measured attenuation values were interpreted as peri-lesional attenuation rather

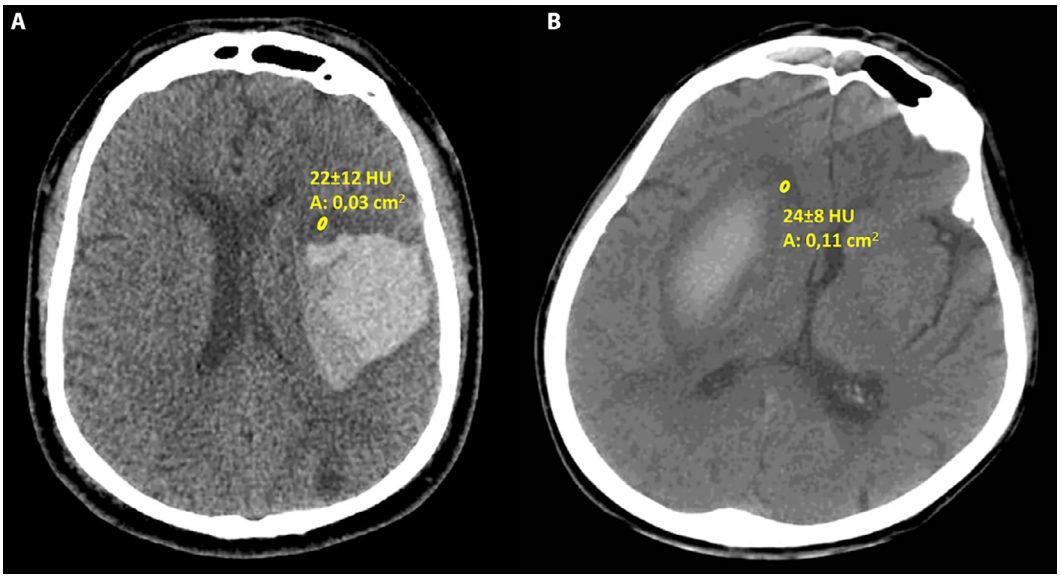

Figure 2. Illustration of a non-contrast computed tomography (CT) scan demonstrating the measurement of peri-lesional attenuation. A circular or oval region of interest (ROI) is placed within the hypodense area surrounding the hematoma, carefully avoiding large vessels, calcifications, and imaging artifacts. The degree of tissue attenuation within this region is quantified using Hounsfield Unit (HU) measurement. The mean HU value obtained from the selected ROI is recorded as the representative peri-lesional attenuation.

than pure perihematomal oedema, as they may represent a composite of edema, adjacent brain parenchyma, and marginal hematoma components rather than pure edema alone (10,13-15).

Data and statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation (SD) or median (minimum–maximum) according to their distribution, while categorical variables were expressed as frequencies and percentages. Data normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. As most variables were not normally distributed, non-parametric statistical methods were applied. Spearman rank correlation analysis was used to evaluate the relationship between coagulation parameters (PT, APTT, INR), peri-lesional attenuation-HU values, and NIHSS scores. To identify independent predictors of neurological severity, multivariate linear regression analysis was performed, including age, hematoma volume, HU values, and coagulation parameters as covariates. A two-tailed p-value <0.05 was considered statistically significant, and 95% confidence intervals were reported where appropriate. Figure 3 showed the study flow diagram of this study.

Results

Baseline characteristics of the study population

This study was conducted at Dr. Wahidin Sudirohusodo Hospital, Makassar from January 2023 to December 2025. Table 1 showed the baseline demographic, clinical, and radiological characteristics of patients with primary ICH. Of the total 150 research subjects, the majority were male, namely 88 people (58.7%), while female subjects numbered 62 people (41.3%). The average age of the subjects was 55.09 ± 15.17 years. Based on age group, the largest number of subjects were in the

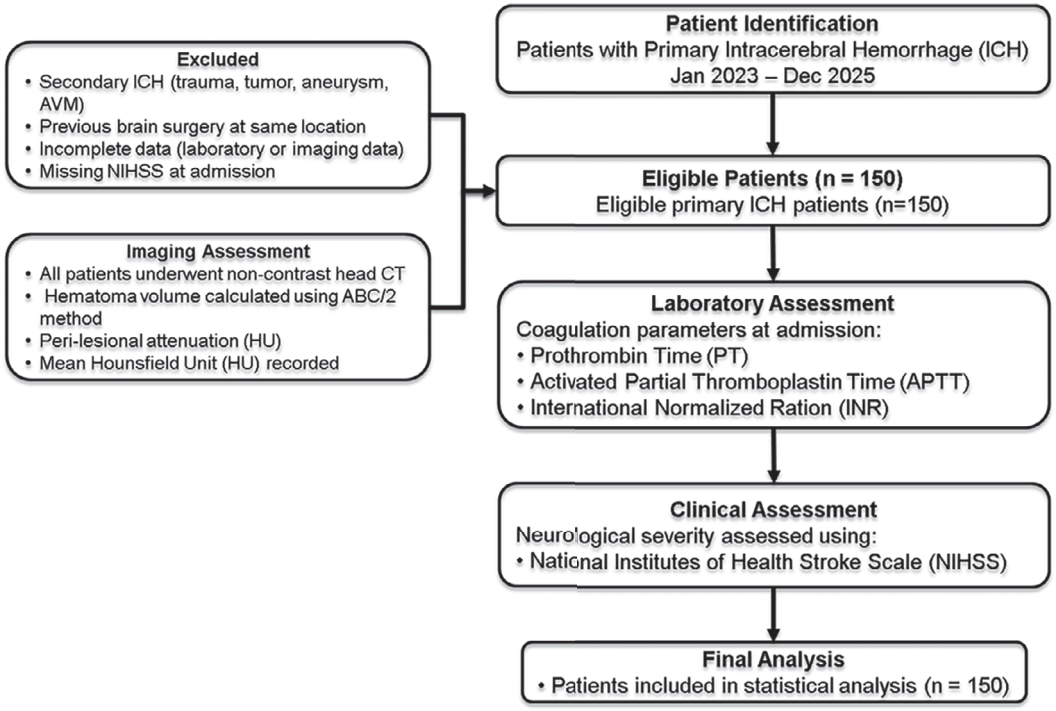

Figure 3. Study flow diagram: Coagulation parameters and peri-lesional attenuation in intracerebral hemorrhage.

Table 1. Baseline demographic, clinical, and radiological characteristics of patients with primary intracerebral hemorrhage (n = 150).

Characteristic	Value
Sex, n (%)	
Male	88 (58.7%)
Female	62 (41.3%)
Age (years), mean ± SD	55.09 ± 15.17
18–24 years, n (%)	6 (4.0%)
25–44 years, n (%)	30 (20.0%)
45–59 years, n (%)	55 (36.7%)
≥ 60 years, n (%)	59 (39.3%)
Coagulation Parameters, mean ± SD (min–max)	
Prothrombin Time (PT), seconds	11.81 ± 8.23 (9.50–111.30)
Activated Partial Thromboplastin Time (APTT), seconds	24.29 ± 6.80 (16.0–95.0)
International Normalized Ratio (INR)	1.26 ± 0.98 (1.0–12.7)
Clinical Severity	
NIHSS score, mean ± SD (min–max)	11.75 ± 7.50 (0–35)
Radiological Parameters	
Hematoma volume (mL), mean ± SD (min–max)	17.98 ± 15.81 (0.2–80.1)
Peri-lesional attenuation (HU), mean ± SD (min–max)	38.43 ± 5.08 (27–58)

≥ 60 years group, namely 59 people (39.3%), followed by the 45–59 years age group with 55 people (36.7%), 30 subjects (20.0%) in the 25–44 age group, and the fewest in the 18–24 age group, with 6 subjects (4.0%). The clinical parameters of the research subjects showed a wide range of values, with a mean PT of 11.81 ± 8.23 (9.50–111.30), APTT 24.29 ± 6.80 (16.0–95.0), and INR 1.26 ± 0.98 (1.0–12.7), which illustrate differences in coagulation status between subjects. The mean NIHSS score of 11.75 ± 7.50 (0–35) indicated varying degrees of clinical severity, with a tendency towards moderate to severe. In radiological parameters, the mean lesion/hemorrhage volume of 17.98 ± 15.81 (0.2–80.1) indicated a wide variation in lesion size, while the mean peri-lesional attenuation HU value of 38.43 ± 5.08 (27–58) reflected differences in tissue density on radiological examination. Notably, the observed attenuation values were higher than those typically reported for pure perihematomal edema. This suggests that the measurements may reflect mixed tissue composition, potentially was weakly associated with by partial volume effects, rather than representing isolated edema (10,13-15).

Coagulation parameter values (PT, APTT, INR) in patients with Intracerebral Haemorrhage (ICH)

As shown in Table 2, Spearman correlation analysis was performed to evaluate the relationship between coagulation parameters, peri-lesional attenuation Hounsfield Unit (HU), and NIHSS score in patients with primary intracerebral hemorrhage. There was a weak positive correlation between PT and APTT (r = 0.183; p = 0.025) and INR (r = 0.201; p = 0.014). No significant correlation was observed between APTT and INR (p = 0.570). These findings indicate a partial correlation between coagulation parameters in ICH patients, although the strength of the correlation is weak.

Peri-lesional attenuation Hounsfield Unit (HU) values on head CT scans in patients with Intracerebral Haemorrhage (ICH)

Peri-lesional attenuation (HU) had a weak but significant positive correlation with INR (r = 0.224; p = 0.006), but was not associated with PT, APTT, or NIHSS score. This indicates that hemorrhage density is more closely related to INR values than to other parameters.

Clinical outcome values based on NIHSS scores in patients with Intracerebral Hemorrhage (ICH)

NIHSS scores did not show a significant relationship with PT, APTT, INR, or HU (p > 0.05), suggesting that the clinical severity in ICH patients is likely was weakly associated with by factors other than coagulation parameters and hemorrhage density.

Table 2. Spearman correlation between coagulation parameters, peri-lesional attenuation- Hounsfield Unit (HU), and NIHSS score in primary Intracerebral Hemorrhage (ICH) (n = 150).

Variables	r (95% CI)	p	Strength
PT–APTT	0.183 (0.023 to 0.334)	0.025*	Weak
PT–INR	0.201 (0.042–0.350)	0.014*	Weak
APTT–INR	–0.047 (–0.206 to 0.114)	0.570	NS
INR–Peri-lesional attenuation	0.224 (0.066–0.371)	0.006**	Weak
PT–Peri-lesional attenuation	0.013 (–0.148–0.173)	0.872	NS
APTT–Peri-lesional attenuation	–0.064 (–0.222 to 0.098)	0.433	NS
PT–NIHSS	–0.075 (–0.232–0.086)	0.364	NS
APTT–NIHSS	0.052 (–0.109 to 0.212)	0.524	NS
INR–NIHSS	0.064 (–0.097–0.222)	0.440	NS
Peri-lesional attenuation–NIHSS	0.005 (–0.155–0.165)	0.951	NS

Spearman rank correlation test. *P < 0.05; **P < 0.01. 95% CI calculated using Fisher's z-transformation.
Abbreviation: NS = not significant. Strength classification: 0.20–0.39 = weak.

Relationship between coagulation parameters (PT, APTT, INR) and peri-lesional attenuation Hounsfield Unit (HU) density

The INR parameter showed a significant relationship with HU density in patients with ICH with a value of r = 0.224 and p = 0.006, indicating a positive relationship with a weak correlation strength. Meanwhile, PT (p = 0.872) and APTT (p = 0.472) did not show a significant relationship with HU values, so it can be concluded that intracranial hemorrhage density is more related to INR values than other coagulation parameters.

Relationship between coagulation parameters (PT, APTT, INR) and clinical outcomes based on the National Institutes of Health Stroke Scale (NIHSS) score

There was no statistically significant relationship between the coagulation parameters PT, APTT, or INR and the NIHSS score in patients with ICH. The correlation values between PT and NIHSS showed r = −0.075 with p = 0.364, APTT and NIHSS showed r = 0.058 with p = 0.479, and INR and NIHSS showed r = 0.064 with p = 0.440. All p-values were greater than 0.05, indicating that changes in coagulation parameter values were not significantly related to the clinical severity of patients based on NIHSS scores.

Correlation of PT, APTT, and INR with peri-lesional attenuation Hounsfield Unit Density (HU) and NIHSS score in patients with primary Intracerebral Hemorrhage (ICH)

Based on the results of multiple linear regression analysis, Table 3 shows the results of the multivariate linear regression analysis of factors associated with neurological severity (NIHSS score) in patients with primary intracerebral hemorrhage. It was found that age and hemorrhage volume had a statistically significant relationship with clinical outcomes based on NIHSS scores in patients with ICH, with values of p = 0.006 and p = 0.010, respectively. This indicates that the older the patient and the greater the hemorrhage volume, the higher the NIHSS score tends to be, reflecting a more severe clinical condition. Meanwhile, the coagulation parameters PT, APTT, and INR did not show a significant relationship with the NIHSS score (p > 0.05). In addition, HU density was also not significantly associated with clinical outcomes based on NIHSS scores (p = 0.972). These findings suggest that, after controlling for other variables in the regression model, coagulation parameters and HU values were only weakly associated with clinical outcomes in patients with ICH, whereas age and hematoma volume remained significant predictors, consistent with established evidence in ICH outcome studies (1,12,21,22).

Table 3. Multivariate linear regression analysis of factors associated with neurological severity (NIHSS Score) in patients with primary intracerebral hemorrhage.

Variable	β Coefficient	p-value
Age	0.112	0.006**
Prothrombin Time (PT)	−0.080	0.795
Activated Partial Thromboplastin Time (APTT)	0.133	0.453
International Normalized Ratio (INR)	−0.331	0.886
Hemorrhage Volume	0.098	0.010*
Peri-lesional Attenuation	0.004	0.972

*Statistically significant at *P < 0.05; **P < 0.01.

Discussion

Characteristics of the research sample

This retrospective study included 150 patients with ICH, demonstrating heterogeneous demographic, clinical, and radiological characteristics. Male patients were more prevalent than females (58.7% vs. 41.3%), consistent with previous epidemiological findings showing a higher stroke risk in men, particularly in middle age, likely related to greater exposure to vascular risk factors such as hypertension, smoking, and metabolic disorders, while estrogen may offer partial protection in women before menopause (3-5). The mean age was 55.09 ± 15.17 years, with the largest proportion in the ≥60-year group. Increasing age

is well known to be associated with vascular ageing, progressive atherosclerosis, and accumulation of cardiovascular risk factors, all of which contribute to the higher incidence of stroke in older populations (3-5). Clinical findings showed considerable variability, particularly in coagulation parameters such as PT, APTT, and INR, reflecting differences in hemostatic status among patients. These abnormalities may be related to anticoagulant therapy, comorbid conditions, and systemic inflammatory responses, which can influence bleeding progression and clinical outcomes (16-20). The mean NIHSS score of 11.75 ± 7.50 indicates that most patients presented with moderate to severe neurological deficits, consistent with prior studies demonstrating that initial stroke severity is closely associated with outcomes and mortality (1,2,21). Radiologically, hematoma volume varied widely (17.98 ± 15.81 mL), and larger volumes are known to be associated with more extensive brain injury and worse neurological impairment (1,12,22,24,26). The mean HU value of 38.43 ± 5.08 reflects variability in tissue characteristics on CT imaging. These findings collectively highlight the complex and heterogeneous nature of intracerebral hemorrhage (10,11,13-15).

Coagulation parameter measurements (PT, APTT, INR)

This study revealed a small yet statistically significant association between PT and APTT, as well as between PT and INR. These associations are anticipated, as PT and INR indicate the extrinsic pathway, whereas APTT signifies the intrinsic pathway of the coagulation cascade (16,17). The detected weak association indicates that, while these measures are related, they may be affected by distinct physiological and pathological causes. The absence of connection between APTT and INR suggests that disruptions in intrinsic and extrinsic pathways may arise independently in people with ICH. Coagulation irregularities in this illness are complex and may be influenced by factors like bleeding intensity, systemic inflammation, consumption of clotting factors, and anticoagulant administration (16-20). The lack of comprehensive information regarding previous anticoagulant therapy constitutes a significant limitation. The significant fluctuation in PT and INR readings suggests that patients taking oral anticoagulants may be present, potentially distorting the observed relationships (18,20).

Peri-lesional attenuation on computed tomography imaging

Peri-lesional attenuation quantified by HU exhibited a weak although significant correlation with INR. This indicates that global coagulation status may correlate with specific radiological features of ICH, however the strength of this correlation is constrained. From a pathophysiological standpoint, an increased INR indicates compromised clot formation and may correlate with extended bleeding, potentially affecting hematoma composition and its visualization on CT imaging (13,16-20). Nonetheless, a significant methodological problem is the comparatively elevated attenuation values found in this work. Prior work suggests that authentic perihematomal edema usually has lower attenuation values, often ranging from 5 to 33 HU. The elevated values found in our cohort presumably indicate partial volume effects associated with manual ROI measurements, where neighboring gray matter or hematoma boundaries may be incorporated. Consequently, the HU values shown in this study ought to be regarded as peri-lesional attenuation rather than mere edema. A significant problem is the absence of regular timing between symptom onset and CT acquisition. PHE is a progressive phenomenon that changes over time, and discrepancies in imaging timing may have influenced the diversity in attenuation levels (6-10,25). This temporal fluctuation may partially elucidate the observed modest relationships. No significant correlation was observed between peri-lesional attenuation and PT, APTT, or NIHSS scores. This indicates that CT attenuation alone does not directly correlate with clinical severity. Neurological damage in ICH is predominantly determined by structural factors, including hematoma volume, location, and mass effect (1,11,12,21,22).

Clinical outcomes and NIHSS

The present study did not demonstrate a significant association between coagulation parameters and

NIHSS scores. This finding indicates that coagulation abnormalities at admission may not directly translate into the degree of neurological impairment. The NIHSS score primarily reflects functional deficits related to the anatomical impact of hemorrhage rather than systemic coagulation status (21,22). Multivariate analysis further confirmed that age and hematoma volume were the main independent predictors of neurological severity. Older patients and those with larger hematomas tended to have higher NIHSS scores, reflecting more severe clinical conditions. These findings are consistent with previous studies identifying hematoma volume as a key determinant of outcome in intracerebral hemorrhage (1,12,22,24,26). Overall, these results suggest that while coagulation parameters and peri-lesional attenuation provide useful biological and radiological insights, they have limited value as independent predictors of early neurological severity (3-5,21). A comprehensive assessment that integrates clinical, radiological, and laboratory findings remains essential in the management of ICH.

Clinical relevance and practical implications

The findings of this study suggest that coagulation parameters have limited value in predicting early neurological severity in ICH. Although INR showed a weak association with peri-lesional attenuation, this did not translate into clinical severity as measured by NIHSS. In clinical practice, greater emphasis should be placed on patient age and hematoma volume when assessing disease severity. Coagulation parameters remain important primarily for evaluating bleeding risk and guiding therapeutic decisions.

Limitations

This study has multiple limitations. In the first instance, owing to the retrospective nature of the study, it is subject to any inaccuracies in data intake or transcription. Although we carefully assessed and verified all data against primary medical records, residual errors cannot be entirely excluded. Nonetheless, this highlights the need for thorough data validation when using routinely obtained clinical data. The second crucial restriction is that the examination of the peri-lesional attenuation based on manual region-of-interest (ROI) techniques is still relatively limited. Without semi-automated segmentation or established attenuation thresholds, the measurements may suffer from partial volume effects and can include adjacent normal brain tissue borders or hematoma borders. The apparent associations might be due to the fact that reported Hounsfield Unit (HU) values do not only reflect pure perihematomal edema but rather composite peri-lesional signal. Third, the timing of CT capture was not always consistent with the onset of symptoms. Timing differences may was weakly associated with the attenuation levels observed, since perihematomal edema is an evolving process. The temporal confounding that may have been introduced due to the lack of timely CT data in this study might have influenced the accuracy of the detected associations. Fourth, this trial did not collect detailed information on the use of anticoagulant drug therapy in the past. The fact that there is a great deal of variability in the PT and INR suggests that patients cannot be completely ruled out for being on oral anticoagulants. This heterogeneity could also have confounded the observed associations.

Lastly, due to the fact that this study was performed at a single tertiary referral center, findings may not be generalizable to other cohorts.

To overcome the limitations

Future studies should consider the adoption of prospective design with standardized data collection protocols to reduce risks of errors in data entry or transcription and improve overall reliability. For imaging methodology, semi-automated or fully automated segmentation techniques using preestablished attenuation thresholds (e.g., 5–33 HU) should be applied to better differentiate true perihematomal edema from adjacent brain parenchyma and hematoma components, thus minimizing partial volume effects. Moreover, because it gives a better and reproducible depiction of edema morphology as compared to traditional 2D ROI-based

methods, volumetric (3D) analysis is favored. Moreover, future multicenter studies with integral and uniform CT acquisition protocols must include specific report of the lag time between initiation symptoms and imaging. Including time-to-CT as a covariate in the statistical models would better adjust for dynamic evolution of perihematomal edema and temporal confounding. Endorsement of comprehensive data on previous anticoagulation therapy is also imperative so as to account for any potential confounding. Advanced imaging techniques like radiomics or texture analysis may also offer a more comprehensive understanding of the heterogenic tissue environment, further strengthening CT-based biomarker prediction in intracerebral hemorrhage.

Conclusions

In conclusion, this study revealed that among the assessed coagulation markers, only the International Normalized Ratio exhibited a weak yet statistically significant correlation with peri-lesional attenuation quantified by Hounsfield Units on non-contrast CT. Coagulation measures, such as PT, APTT, and INR, had no significant correlation with neurological severity as evaluated by the NIHSS score. Multivariate analysis revealed that age and hematoma volume were the primary independent predictors of neurological severity in patients with intracerebral hemorrhage. The findings indicate that clinical and radiographic criteria are more significant in assessing early neurological damage than laboratory coagulation markers. While coagulation profiles are crucial for assessing bleeding risk and informing treatment choices, their utility as predictors of early clinical severity seems to be limited. An exhaustive evaluation that combines clinical assessment and radiological results is crucial in the therapy of intracerebral hemorrhage.

Abbreviations:

ICH Intracerebral haemorrhage
IS Ischemic stroke
BBB Blood-brain barrier
PHE Perihematomal edema
NCCT non-contrast computed tomography
HU Hounsfield unit
PT Prothrombin time
APTT Activated partial thromboplastin time
INR International normalized ratio
PACS Picture archiving and communication system
NIHSS National Institutes of Health Stroke Scale
ROI Region-of-interest
DICOM Digital Imaging and Communications in Medicine
SPSS Statistical Package for the Social Sciences

Ethic Approval: All research designs were reviewed and approved by the Health Research Ethics Committee of Dr. Wahidin Sudirohusodo Hospital, Makassar– Faculty of Medicine, Hasanuddin University (381/UN4.6.4.5.31/PP36/2026).

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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