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Association Between Hypodensities Detected By Non-Contrast Computed Tomography And Hematoma Expansion In Patients With Intracerebral Hemorrhage

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Abstract

ICH is a dangerous condition of the brain and can often lead to further health problems as well as death. Increase in a hematoma after the initial hemorrhagic event usually leads to poor outcomes. Doctors use NCCT as the main method for looking at the early stages of ICH. New data support the idea that hypodensities found on initial NCCT can help predict hematoma growth and guide medical treatment. This study aimed to evaluate the association between hypodensities detected on initial NCCT and subsequent hematoma expansion in patients diagnosed with ICH. An analytical cross-sectional study was conducted over six months at THQ Hospital Daska, including 127 adult patients diagnosed with ICH. Patients with identifiable hypodensities on baseline NCCT were compared with those without. Data were collected using structured proformas and analyzed using SPSS version 22.0. Statistical tests, including Chi-square and ANOVA, were applied with a significance threshold of $p < 0.005$. Out of 127 participants (mean age: 61.4 years), 81 (63.8%) had abnormalities seen as hypodensities on NCCT brain scans. Hematoma growth happened in 41.7% of cases and was seen in 56.8% of those with hypodensities compared to 15.2% in those without ($p < 0.001$). Irregular-shaped masses, those medium in size and with moderate density were the most common hypodensity characteristics. Among all comorbidities, hypertension was the most common, found in 70.1 percent of patients. Being found on initial NCCT, hypodensities

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are strongly associated with an expansion of hematoma in ICH patients. Radiology can help predict whether a hematoma will develop, allowing quick response from doctors to help those at higher risk which may boost recovery.

INTRODUCTION

Radiography operates on the principle that X-rays are absorbed differently by various tissues in the body, with denser structures like bones absorbing more X-rays than less dense tissues such as air and fat. Intracerebral hemorrhage (ICH), also known as intraparenchymal cerebral hemorrhage or hemorrhagic stroke, occurs when blood accumulates suddenly within the brain tissue. Initial CT scans typically reveal dark areas filled with blood alongside lighter regions of edema. Complications can arise, including the spread of hemorrhage, increased intracranial pressure, and potential herniation. Understanding the dynamics of hematoma expansion (HE) is crucial, as it significantly impacts patient outcomes and treatment strategies (1,2).

ICH accounts for 10-15% of all strokes and is associated with a high mortality rate, with approximately 40% of patients dying within a month of the event. Hematoma expansion is a critical factor contributing to poor outcomes, occurring in about one-third of cases and leading to early brain dysfunction and increased mortality risk. Non-contrast computed tomography (NCCT) is the most commonly used imaging modality for the acute evaluation of ICH, and specific findings on NCCT, such as hypodensities, can indicate a higher likelihood of hematoma expansion. Identifying patients at risk for HE before initiating treatment is essential for improving clinical outcomes (3,4).

The presence of hypodensities on NCCT has been linked to an increased risk of hematoma growth and poor functional outcomes. Studies have shown that patients with hypodensities on their initial scans are more likely to experience hematoma expansion compared to those without such findings. However, there is still variability in the definitions and interpretations of hypodensities in the literature, leading to inconsistencies in clinical practice. Understanding the role of these hypodensities in predicting hematoma expansion could enhance risk stratification and guide treatment decisions for patients with ICH (5).

This thesis aims to investigate the association between hypodensities detected by NCCT and hematoma expansion in patients with ICH. By exploring how these imaging findings correlate with clinical outcomes, the research seeks to provide insights that can improve medical decision-making and ultimately enhance patient care for those affected by intracerebral hemorrhage (6).

Li et al. (2025) developed an automated deep learning model to predict hematoma expansion in patients with ICH using only NCCT images. The study analyzed data from 2,484 patients, with a follow-up scan performed within 48 hours of symptom onset. The model demonstrated significant predictive capabilities, achieving an area under the curve (AUC) of 0.760 on retrospective data and 0.806 on prospective data, outperforming traditional assessment methods. This research highlights the potential of advanced imaging techniques to enhance early risk assessment for hematoma growth in ICH patients (7).

Yu et al. (2025) conducted a study to assess the risk of hematoma expansion in hypertensive ICH patients by integrating CT radiomics features with traditional clinical data. The study utilized a training set of 555 cases and achieved impressive AUC values, particularly with a hybrid model that combined clinical indicators and radiomics scores, reaching an AUC of 0.901. This approach demonstrated improved accuracy in predicting

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hematoma expansion and could aid in better management strategies for hypertensive ICH patients (8).

The ongoing research into the predictive value of NCCT hypodensities and their relationship with hematoma expansion underscores the need for standardized definitions and imaging protocols. Future studies should focus on refining imaging techniques and integrating hypodensity findings with clinical data to develop comprehensive predictive models. Additionally, exploring the underlying mechanisms of hypodensity formation and their implications for treatment could further enhance patient outcomes in ICH management (9).

In conclusion, understanding the association between hypodensities detected by NCCT and hematoma expansion in patients with intracerebral hemorrhage is crucial for improving clinical decision-making and patient outcomes. The findings from recent studies indicate that advanced imaging techniques and predictive models can significantly enhance the assessment of hematoma growth risk. By identifying patients at higher risk for hematoma expansion, healthcare providers can implement timely interventions, ultimately leading to better management of ICH and improved patient survival rates (10).

MATERIAL AND METHODS

Study design: The study was an analytical cross-sectional study.

Clinical Settings: The study was held at THQ Hospital Daska.

Duration of Study: The study was completed in a duration of 6 months after the approval of synopsis.

Sample Size: Sample size of study was 127 that was calculated using Slovin's formula for sample size:

Sampling Technique: Nonprobability convenient sampling technique was employed.

SAMPLE SELECTION

INCLUSION CRITERIA

- Adults (Age ⩾18 years)
- Diagnosis of Intracerebral Hemorrhage (ICH)
- Availability of Initial NCCT Scan
- Hypodensities Present on Initial NCCT

EXCLUSION CRITERIA

- Pregnancy
- Inability to Obtain Imaging
- Non-Intracerebral Hemorrhage Causes

DATA COLLECTION PROCEDURE

Data was collected from participants using a structured questionnaire designed to assess neurological and functional impairments, focusing on symptoms such as sudden weakness, severe headaches, and visual disturbances. The information was gathered through interviews or guided assistance, ensuring confidentiality and adherence to ethical standards for human subject research.

DATA ANALYSIS

Data was viewed and analyzed with SPSS version 22.0. Frequencies and percentages were used to explain qualitative variables and the means were used to present quantitative variables. The diagnostic accuracy of different signs was checked by comparing sensitivity, specificity, PPV and NPV. To compare groups, ANOVA was used and Chi-square was used to analyze the link between categorical risk factors. Any p-value above 0.005 was given extra attention to decide if there was a significant effect.

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RESULTS

The findings of the study Association between Hypodensities Detected by Non-Contrast Computed Tomography and Hematoma Expansion in Patients with Intracerebral Hemorrhage are presented in this chapter. A total of 127 patients' data were examined using SPSS version 22.0. The relationship between hypodensities and hematoma growth was studied using descriptive and inferential statistics in patients with ICH.

DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Out of 127 patients who had ICH, 93 met the study requirements. The volunteers were between 22 and 87 years old, with an average age of 61.4 (SD ±12.6). A total of 74 males (58.3%) and 53 females (41.7%) made up the sample in the study.

FIGURE 1: DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

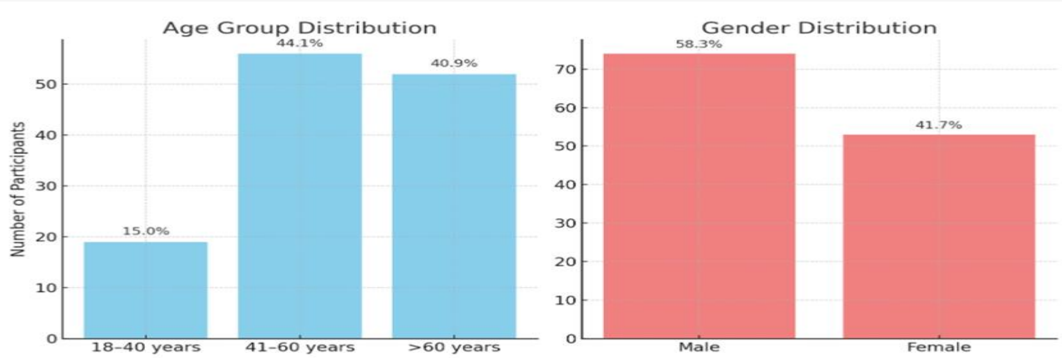

TABLE 1: DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Variable	Frequency (n)	Percentage (%)
Age Group		
18–40 years	19	15.0%
41–60 years	56	44.1%
>60 years	52	40.9%

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Gender		
Male	74	58.3%
Female	53	41.7%

Table 1 summarizes the main demographic features of the 127 participants we selected who had ICH and met our requirements for the study. More than half of all cases involved persons between the ages of 41 and 60 (44.1%) and those over 60 accounted for nearly as many (40.9%). Only 15.0% of the sample were people aged between 18 and 40 years old (n = 19). It is suggested by these outcomes that middle-aged and older individuals are more likely to get ICH, as the general view is that things such as additional vascular damage, hypertension and changes to brain arteries with age raise the risk of hemorrhagic stroke. Men made up a larger group in the sample (n = 74; 58.3%) than women (n = 53; 41.7%). A number of factors such as biology, habits and environment, may explain why gender disparity happens. Men are more likely to have ICH worldwide, since they tend to develop high blood pressure, smoke, drink and experience more occupational stress than women. It is possible that males feel sicker sooner and thus present to the hospital earlier which may increase the number of cases reported for men. The observed number of people by age and gender in this sample agrees with previous data on spontaneous ICH and strengthens the study by representing real trends. These demographics help to understand the clinical features and imaging abnormalities linked to hematoma expansion and hypodensities in patients without CT contrast which are explained in the later part of this article. Also, age and gender should be taken into account as covariates in multivariate studies of hematoma expansion risk factors. By way of example, elderly patients might find their blood vessels and the clotting process change which could lead to an increased risk of hematoma growing after an initial bleed.

CLINICAL AND RADIOLOGICAL CHARACTERISTICS (WITHIN GROUP SUMMARY)

A significant proportion of the patients had comorbid conditions and relevant neurological symptoms at presentation. Among all participants, 89 (70.1%) had a history of hypertension, 34 (26.8%) had a prior stroke, 22 (17.3%) were on anticoagulant therapy, and 31 (24.4%) reported a previous cerebrovascular accident. Regarding presenting symptoms, 102 (80.3%) complained of headache, 77 (60.6%) experienced loss of consciousness, and 91 (71.7%) had focal neurological deficits.

TABLE 2: CLINICAL HISTORY OF PARTICIPANTS

Variable	Yes (n, %)	No (n, %)
Hypertension	89 (70.1%)	38 (29.9%)
Stroke History	34 (26.8%)	93 (73.2%)
Anticoagulant Use	22 (17.3%)	105 (82.7%)
Previous Stroke	31 (24.4%)	96 (75.6%)

It shows a summary of the clinical history and coexisting medical problems of the participants suffering from ICH. More than two-thirds of patients (89 out of 127; 70.1%) had high blood pressure, confirming that it is an important and main cause of spontaneous ICH. Among the sample, stroke (n = 34; 26.8%) and having stroke events in the past (n = 31; 24.4%) were reported less frequently than previous assessments indicated, but they are not negligible for this population. Anticoagulant use was seen in 17.3% of cases and therefore, while not the primary cause, it remains significant in some patients' hemorrhagic events. In summary, these results stress the large share of vascular

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comorbidities in the group and underline the importance of promptly managing treatable factors such as hypertension, to prevent stroke recurrence.

TABLE 3: PRESENTING SYMPTOMS

Symptom	Yes (n, %)	No (n, %)
Headache	102 (80.3%)	25 (19.7%)
Loss of Consciousness	77 (60.6%)	50 (39.4%)
Focal Neurological Deficit	91 (71.7%)	36 (28.3%)

This table illustrates the distribution of key presenting symptoms among patients with intracerebral hemorrhage (ICH). Headache emerged as the most frequently reported symptom, present in 80.3% (n = 102) of the cases, reflecting its common role as an initial indicator of increased intracranial pressure or acute cerebral insult. Focal neurological deficits were observed in 71.7% (n = 91) of participants, which is consistent with the localized nature of hemorrhagic strokes affecting specific brain regions responsible for motor, sensory, or cognitive functions. Loss of consciousness was reported in 60.6% (n = 77) of patients, indicating that a significant portion experienced altered mental status or impaired awareness at the time of presentation—often associated with larger hematomas or those located in critical regions such as the brainstem. These symptom patterns are typical in acute ICH and are important for early clinical recognition, timely neuroimaging, and intervention.

TABLE 4: CT SCAN HEMORRHAGE LOCATION

Brain Region	Frequency (n)	Percentage (%)
Frontal	41	32.3%
Temporal	26	20.5%
Parietal	29	22.8%

Occipital	9	7.1%
Brainstem/Deep	15	11.8%
Cerebellum	7	5.5%

This table presents the anatomical distribution of intracerebral hemorrhage (ICH) as detected on non-contrast computed tomography (NCCT) scans among the study participants. The most commonly affected region was the frontal lobe, with hemorrhages identified in 32.3% (n = 41) of cases, possibly due to the lobe's extensive vascular supply and susceptibility to hypertensive bleeds. The parietal lobe was the second most frequently involved site, accounting for 22.8% (n = 29) of the cases, followed by the temporal lobe at 20.5% (n = 26). These lobar hemorrhages often manifest with distinct neurological deficits, depending on the functional cortical areas involved. Hemorrhages located in the brainstem or deep structures (including the basal ganglia and thalamus) were observed in 11.8% (n = 15), which, although less common, are typically associated with more severe clinical outcomes due to their proximity to vital autonomic and motor control centers. Occipital lobe involvement was found in 7.1% (n = 9) of cases, often resulting in visual disturbances, while cerebellar hemorrhages were the least frequent (5.5%; n = 7), yet clinically significant due to the risk of obstructive hydrocephalus and brainstem compression. This distribution highlights the heterogeneity of ICH presentation and reinforces the importance of precise anatomical localization in guiding clinical prognosis and management strategies.

TABLE 5: HEMATOMA EXPANSION AND HYPODENSITY DISTRIBUTION

Variable	Frequency (n)	Percentage (%)
Hematoma Expansion	53	41.7%
No Expansion	74	58.3%

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Hypodensities Present	81	63.8%
Hypodensities Absent	46	36.2%

Figure 2: Distribution of Hematoma expansion and hypo densities

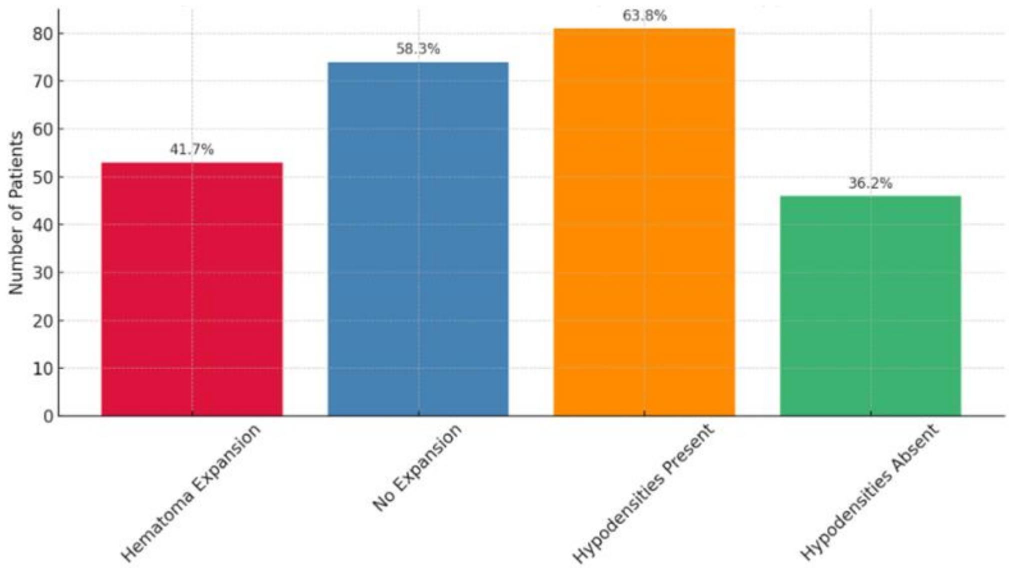

Table 5 summarizes the occurrence of hematoma expansion and the presence of hypodensities on initial non-contrast CT scans among the study participants. Hematoma expansion was observed in 41.7% (n = 53) of patients, indicating that nearly half of the cases experienced an increase in hematoma size after the initial imaging, which is clinically significant due to its association with worsened neurological outcomes and increased mortality. Conversely, 58.3% (n = 74) of patients showed no hematoma expansion, suggesting stability of the hemorrhage in this subgroup. The presence of hypodensities—a radiological sign often interpreted as active bleeding or ongoing hemorrhage was identified in 63.8% (n = 81) of participants, reflecting a high prevalence of these features in patients at risk for hematoma progression. The absence of hypodensities was noted in 36.2% (n = 46), indicating that not all hemorrhages display these imaging characteristics initially. The data emphasize the potential role of hypodensities as predictive markers for hematoma expansion and the need for close monitoring of patients exhibiting these findings. Understanding the relationship between hypodensities and hematoma growth is critical for early intervention and improving patient outcomes in intracerebral hemorrhage management.

TABLE 6: DEGREE OF HEMATOMA EXPANSION (N = 53)

Expansion Severity	Frequency (n)	Percentage (%)
Mild (⩽10%)	12	22.6%
Moderate (10–50%)	21	39.6%
Severe (>50%)	20	37.8%

Table 6 categorizes the severity of hematoma expansion among the 53 patients who experienced an increase in hematoma volume following the initial CT scan. Mild expansion, defined as an increase of up to 10% in hematoma size, was observed in 22.6% (n = 12) of these cases, representing a relatively small but clinically important progression that may still impact patient prognosis. Moderate expansion, involving a 10–50% increase in hematoma volume, was the most common category, occurring in 39.6% (n = 21) of patients, highlighting a substantial progression in hematoma size that often correlates with worsening neurological deficits and increased risk of complications. Severe hematoma expansion, characterized by an increase greater than 50%, was noted in 37.8% (n = 20) of patients, signifying a critical escalation associated with significant morbidity and mortality. This distribution underscores the heterogeneity in the progression of intracerebral hemorrhage and reinforces the importance of timely identification and management of patients at risk for severe hematoma growth to mitigate adverse clinical outcomes.

ASSOCIATION BETWEEN HYPODENSITIES AND HEMATOMA EXPANSION (BETWEEN GROUP SUMMARY)

A key focus of this study was to explore whether the presence of hypodensities on initial NCCT was significantly associated with hematoma expansion. To evaluate this, a Chi-square test was conducted. A strong association was observed: 46 out of 81 patients (56.8%) with hypodensities developed hematoma expansion, compared to only 7 out of 46 patients (15.2%) without hypodensities. This difference was statistically significant ($\chi^2 = 21.84$, $p < 0.001$).

TABLE 7: ASSOCIATION BETWEEN HYPODENSITIES AND HEMATOMA EXPANSION

Hypodensity	Expansion Present (n=53)	No Expansion (n=74)	Total (n=127)
Present	46 (56.8%)	35 (43.2%)	81
Absent	7 (15.2%)	39 (84.8%)	46

Table 7 demonstrates a strong association between the presence of hypodensities on initial NCCT scans and hematoma expansion in patients with intracerebral hemorrhage. Among the 53 patients who experienced hematoma expansion, 46 (56.8%) had hypodensities detected, whereas only 7 (15.2%) of those without expansion showed hypodensities. Conversely, the majority of patients without hematoma expansion (84.8%, n = 39) lacked hypodensities. This significant difference suggests that hypodensities serve as a valuable radiological marker predictive of hematoma growth. The presence of hypodensities likely indicates ongoing bleeding or active clot evolution, which predisposes patients to expansion and worsened clinical outcomes. These findings emphasize the diagnostic and prognostic utility of detecting hypodensities early, enabling clinicians to stratify risk and tailor management strategies to prevent hematoma progression.

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Figure 3 illustrates the distribution of hypodensities among patients with and without hematoma expansion. A significantly higher number of patients with hematoma expansion had hypodensities present (46 out of 53), compared to those without expansion (35 out of 74). In contrast, most patients without expansion lacked hypodensities. This highlights the strong association between hypodensities and hematoma growth, supporting their value as an early radiological predictor.

FIGURE 3: FREQUENCY OF HYPODENSITIES IN PATIENTS WITH AND WITHOUT HEMATOMA EXPANSION

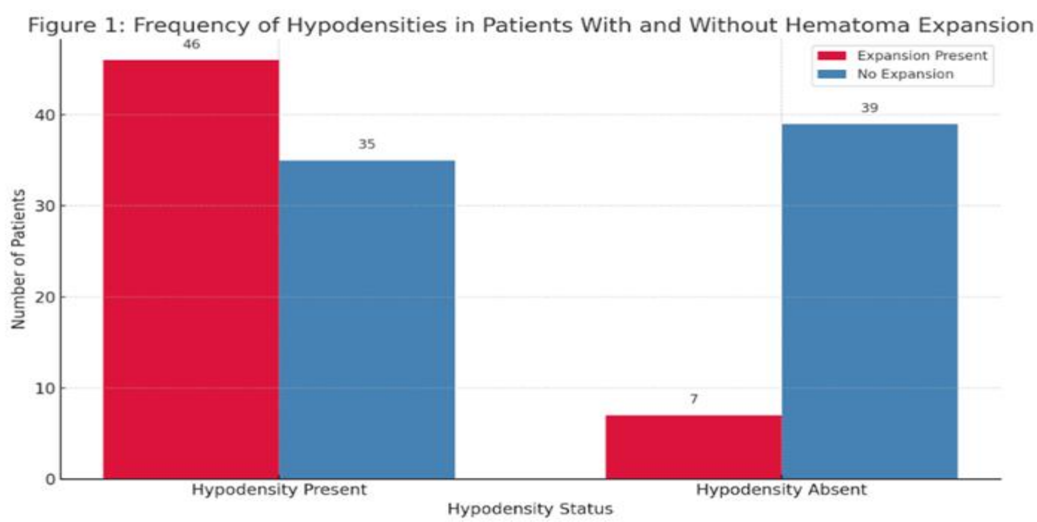

TABLE 8: CHARACTERISTICS OF HYPODENSITIES (N = 81)

Feature	Category	Frequency (n)	Percentage (%)
Shape	Irregular	56	69.1%
	Regular	19	23.5%
	Unclear	6	7.4%
Size	Small	29	35.8%

	Medium	37	45.7%
	Large	15	18.5%
Density	Mild	18	22.2%
	Moderate	41	50.6%
	Severe	22	27.2%

Table 8 presents the characteristics of hypodensities detected by non-contrast computed tomography in 81 patients with intracerebral hemorrhage. The majority of hypodensities exhibited an irregular shape (69.1%), followed by regular (23.5%) and unclear shapes (7.4%). Regarding size, medium-sized hypodensities were most common (45.7%), with small (35.8%) and large (18.5%) hypodensities also observed. In terms of density, moderate hypodensities accounted for over half of the cases (50.6%), while mild and severe densities were present in 22.2% and 27.2% of the patients, respectively. This distribution highlights the predominance of irregularly shaped, medium-sized, and moderately dense hypodensities among the study population. In conclusion, the results provide compelling evidence of a statistically significant association between initial CT hypodensities and hematoma expansion in ICH patients. These findings emphasize the prognostic utility of early NCCT imaging in predicting hematoma behavior and underscore the importance of timely intervention for patients exhibiting radiological risk markers.

DISCUSSION

This study found a statistically significant association between the presence of hypodensities on initial non-contrast CT (NCCT) scans and hematoma expansion in patients with intracerebral hemorrhage (ICH). Among the 127 patients analyzed, hypodensities were present in 63.8% of cases, with hematoma expansion occurring in

41.7%. Notably, 56.8% of patients with hypodensities experienced hematoma expansion, compared to only 15.2% of those without hypodensities ($p < 0.001$). These findings underscore the importance of hypodensities as a radiological predictor of hematoma growth and potentially adverse clinical outcomes. The predictive value of hypodensities for hematoma expansion has been consistently highlighted in multiple high-quality studies, aligning closely with the work of Boulouis et al. (2016), who classified and studied hypodensities in detail on NCCT scans. Their cohort of 784 patients demonstrated that hypodensities were independently associated with hematoma expansion, with an odds ratio (OR) of 3.6 [95% CI: 2.4–5.5] for hematoma growth in patients with any form of hypodensity (11,12).

Similarly, Delcourt et al. (2012) in the INTERACT study observed that early imaging markers, particularly heterogeneous densities and irregular shapes within hematomas, were associated with dynamic hematoma behavior, suggesting active bleeding or rebleeding. Their findings support our observation that the majority of hypodensities were irregular in shape (69.1%) and of moderate size and density characteristics previously linked with hematoma instability. Our study's incidence of hematoma expansion (41.7%) is consistent with the findings of Fujii et al. (1998), where approximately 38% of patients showed hematoma growth on follow-up imaging. While our study focused on hypodensities, other studies have compared various CT markers of expansion. For instance, Morotti et al. (2013) conducted a meta-analysis of 22 studies (n = 5,434) and concluded that markers such as the blend sign, black hole sign, and swirl sign were significant predictors of hematoma growth. Our study supports this framework by demonstrating that the presence of any hypodensity, regardless of its specific type, is significantly associated with expansion (13,14,15).

A significant implication for neurocritical care and stroke units is the potential incorporation of hypodensity assessment into routine radiology reports. Currently, not all radiologists consistently comment on the presence and characteristics of hypodensities in NCCT scans. Standardizing the evaluation and reporting of hypodensity types, such as blend signs, swirl signs, and irregular shapes, may improve interdisciplinary communication and streamline clinical decision-making. Institutions may consider developing scoring systems or visual guides to assist radiologists and emergency physicians in the consistent identification and categorization of these signs (16,17).

While our study primarily focused on the radiological aspect, it is essential to acknowledge that hematoma expansion is a multifactorial process influenced by both biological and iatrogenic variables. Coagulopathy, the use of antithrombotic agents, blood pressure variability, and genetic polymorphisms in coagulation pathways may modulate the risk of ongoing bleeding, even in the absence of identifiable hypodensities. Future research integrating radiological signs with biochemical and clinical parameters could yield comprehensive risk models. For example, predictive algorithms incorporating hypodensity patterns along with admission INR, platelet count, systolic blood pressure, and Glasgow Coma Scale (GCS) could more accurately stratify patients and inform tailored treatment strategies (18,19).

Additionally, it is worth exploring the longitudinal outcomes associated with hypodensity-associated hematoma expansion. Several studies have highlighted that hematoma growth is strongly correlated with worse neurological outcomes, higher mortality, and greater disability as measured by modified Rankin Scale (mRS) scores. However, our study was limited to in-hospital imaging and did not follow patients beyond the acute phase. Therefore, longitudinal follow-up assessing functional outcomes, rebleeding rates, and quality of life would provide valuable insights into the long-term implications of hypodensity-driven expansion, further validating the prognostic utility of NCCT hypodensities in real-world settings (20,21).

Moreover, our findings open the door to potential interventional trials. Patients exhibiting hypodensities could be stratified into early-phase trials evaluating the efficacy of hemostatic therapies such as recombinant activated factor VIIa, tranexamic acid, or intensive blood pressure lowering. Previous trials like INTERACT2 and FAST have yielded mixed results, possibly due to the inclusion of patients at varying risk levels for hematoma expansion. With a more refined risk stratification model based on hypodensities, future trials could focus on high-risk populations, potentially uncovering subgroups who would benefit most from such interventions (22,23).

Additionally, Yu et al. (2017) emphasized that the blend sign, a form of hypodensity, had a high specificity (94.3%) for predicting expansion, although its sensitivity was lower (34.3%). Our findings align with these, suggesting that while not all patients with hypodensities experience expansion, their presence is a strong risk marker that should prompt clinical vigilance. The demographic profile in our study showed a male predominance (58.3%) and an average age of 61.4 years, consistent with An et al. (2017), who reported that ICH was more frequent in elderly males, primarily due to the higher prevalence of hypertension and other vascular risk factors. Hypertension was the most common comorbidity in our study (70.1%), corroborating the findings of Qureshi et al. (2001), who identified chronic hypertension as the most significant independent risk factor for ICH. The association between hypertension and hematoma expansion is likely mediated through sustained vascular pressure and fragility, contributing to ongoing bleeding (24,25).

Our analysis of hypodensity features, particularly their irregular shape and moderate density, supports earlier radiological studies that have attempted to stratify expansion risk based on imaging patterns. In a study by Muneza et al. (2009), irregular shape and heterogeneous density were independently associated with larger baseline hematoma volumes and greater risk of expansion. Likewise, Selariu et al. (2009) reported that "swirl signs," corresponding to the irregular and mixed-density patterns, were more frequently observed in patients with unstable or growing hematomas. Our study extends these observations by quantifying the frequency of these patterns and correlating them directly with hematoma expansion outcomes (26,27).

From a clinical perspective, the detection of hypodensities on initial NCCT provides a rapid, accessible, and cost-effective method for risk stratification. This finding is particularly relevant in low-resource settings where advanced imaging modalities, such as CT angiography (CTA), which detects the "spot sign," may not be available. Our results confirm the suggestion by Morotti et al. (2023) that NCCT-based markers, including hypodensities, could serve as practical surrogates for more sophisticated imaging biomarkers (28).

While most studies corroborate the association between hypodensities and hematoma growth, some have found weaker or non-significant correlations. Although our study supports the utility of radiological predictors, it should be noted that integration with clinical parameters can enhance predictive accuracy. Furthermore, a study by Brouwers et al. (2012) using CTA "spot sign" suggested that active contrast extravasation was a more sensitive and specific indicator of hematoma expansion than any NCCT feature. However, the limited availability and cost of CTA in many settings reinforce the continued relevance of NCCT-based signs, such as hypodensities, as reliable and scalable predictors (29,30).

CONCLUSION

This study provides strong evidence of a statistically significant association between hypodensities detected on initial non-contrast computed tomography (NCCT) scans and subsequent hematoma expansion in patients with intracerebral hemorrhage (ICH). The data revealed that patients with visible hypodensities were significantly more likely to experience hematoma growth, underscoring the utility of early radiological markers in identifying high-risk patients. These findings highlight the critical role of prompt and detailed CT evaluation in the acute phase of ICH management, especially in emergency settings where rapid clinical decisions are required. The characteristics of hypodensities such as irregular shape, moderate size, and variable density further enhance their predictive value. By incorporating hypodensity detection into standard neuroimaging assessment protocols, clinicians can better stratify risk, monitor disease progression, and potentially intervene earlier to prevent clinical deterioration. Overall, this research supports the growing body of evidence advocating for the use of NCCT as a frontline tool in the prognostic evaluation of ICH and provides a foundation for integrating imaging biomarkers into treatment algorithms aimed at improving patient outcomes.

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