

ROLE OF REPEAT COMPUTED TOMOGRAPHY SCAN ON INTRACEREBRAL HEMORRHAGE IN HYPERTENSIVE PATIENTS OF 30–50 YEARS OF AGE

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Abstract

Background: Spontaneous intracerebral hemorrhage (ICH) is a serious neurological emergency and a condition which causes morbidity and mortality. Hypertension is one of the most important modifiable risk factors and hematoma expansion without apparent neurological deterioration may be more frequent in the early stages and affect prognosis.

Aim: To determine the rate of hematoma expansion in spontaneous ICH patients with hypertension (aged 30–50) on repeat non-contrast computed tomography (NCCT) and its correlation with admission blood pressure, baseline NCCT predictors and subsequent management.

Methodology: This was a prospective observational cohort study that included 81 hypertensive patients aged 30–50 years presenting within 6 hours of symptom onset to tertiary-care hospitals in Lahore. Baseline NCCT confirmed ICH, and repeat NCCT was performed at 24 ± 6 hours. Hematoma volume was estimated using the ABC/2 method. Data were analyzed using SPSS, with $p < 0.05$ considered significant.

Results: The mean age was 40.5 ± 6.3 years and 54.3% were male. 40 patients (49.4%) had hematoma expansion. Expansion was not significantly associated with either the admission systolic or diastolic blood pressure ($p = 0.065$ and $p = 0.456$). Baseline NCCT predictors had a sensitivity of 70.0% and a specificity of 73.2%, with a statistically significant association with hematoma expansion ($p < 0.001$). Of expansion cases, 42.5% were asymptomatic. Patients with expansion had more management changes than those without expansion (72.5% vs. 24.4%; $p < 0.001$). The moderate or high clinical utility for repeat NCCT was seen in 59.3% of patients.

Conclusion: An increased risk of hematoma expansion was noted and was often asymptomatic. Baseline NCCT markers had moderate predictive value while admission blood pressure did not. Repeat NCCT at ~ 24 hours was informative about progression and led to management decisions in some patients with hypertensive ICH.

INTRODUCTION

Intracerebral hemorrhage (ICH) is a severe form of stroke associated with substantial mortality and long-term disability. Bleeding into the brain parenchyma produces immediate mechanical injury, while inflammation, oxidative stress, blood–brain barrier disruption, perihematomal

edema, and raised intracranial pressure contribute to secondary neurological damage [1–6]. Hematoma expansion during the early phase of ICH is particularly important because enlargement of the hemorrhage can increase mass effect and worsen neurological outcome [7].

Hypertension is the major modifiable risk factor for spontaneous ICH and contributes to chronic small-vessel injury, including lipohyalinosis and fibrinoid necrosis. Hypertensive hemorrhage commonly involves deep cerebral structures such as the basal ganglia and thalamus, and elevated blood pressure at presentation has been investigated as a potential contributor to hematoma enlargement and poor outcome [8–12].

Non-contrast computed tomography (NCCT) is the primary imaging modality for acute ICH because it is rapid, widely available, and provides information regarding hematoma location, size, intraventricular extension, and mass effect. Hematoma volume can be estimated using the ABC/2 method. Baseline NCCT markers such as the swirl sign, black hole sign, blend sign, and island sign have also been studied as indicators of ongoing bleeding and subsequent hematoma expansion [14,17,18].

Repeat NCCT can directly demonstrate interval hematoma growth, including expansion that occurs without obvious neurological deterioration. However, routine repeat imaging in clinically stable patients remains debated because of radiation exposure, resource utilization, and cost. This issue is particularly important in resource-limited health systems, where imaging protocols should balance early detection of clinically important progression against unnecessary repeat examinations [19–23].

The present study evaluated hematoma expansion detected on repeat NCCT in hypertensive patients aged 30–50 years and assessed its relationship with admission blood pressure, baseline NCCT predictors, clinical deterioration, and subsequent medical or surgical management.

METHODOLOGY

Research Design:

This was a prospective observational study of patients with spontaneous intracerebral hemorrhage (ICH). Eligible patients were consecutively enrolled at admission after application of the inclusion and exclusion criteria.

Clinical and radiological data, including clinical details, blood pressure, neurological status, and

initial NCCT findings, were recorded at presentation. Patients were followed prospectively, and a repeat NCCT scan was obtained at 24 ± 6 hours to assess hematoma expansion. No study intervention was assigned; patients were managed according to the clinical protocols of the participating institutions. The observational design allowed assessment of the natural course of hematoma expansion and the clinical utility of repeat NCCT.

Clinical Settings:

The study was conducted in the Departments of Radiology and Neurology at Jinnah Hospital, Doctor Hospital, and Hameed Latif Hospital, Lahore. These tertiary-care hospitals had CT imaging and stroke-care facilities. The multicenter setting provided patients from more than one institution. The same imaging and management protocols were reported to be used at all sites to promote consistency in data collection.

Sample Size:

The required sample size was estimated using Cochran's formula:

$$n = Z^2 \times p \times (1 - p) / e^2 \text{ Where:}$$

n = number of samples needed

Z = Z-score associated with the desired level of confidence (usually 1.96 for 95% confidence interval)

p = expected proportion of hematoma expansion

$(1 - p)$ is the proportion without hematoma expansion.

A margin of error (absolute precision) of 10% (0.10) was used because the anticipated number of eligible patients was limited.

$$n = (1.96)^2 \times 0.30 \times 0.70 / (0.10)^2 \quad n = 3.8416 \times 0.21 / 0.01$$

$$n = 0.8067 / 0.01$$

$$n = 80.67 \approx 81 \text{ patients}$$

Sampling Technique:

Consecutive sampling, a non-probability sampling technique, was used. Patients with spontaneous intracerebral hemorrhage who met the inclusion and exclusion criteria were

enrolled consecutively until the required sample size was reached.

Duration of Study:

The study was conducted over a period of 4 months.

Selection Criteria:

The sample was determined according to the inclusion and exclusion criteria.

Inclusion Criteria:

- Age 30–50 years
- Patients with spontaneous intracerebral hemorrhage confirmed on baseline NCCT.
- Hypertensive patients (known and/or newly diagnosed at admission)
- Presentation within 6 hours of onset of symptoms.
- Patients who provided informed consent

Exclusion Criteria:

- Traumatic brain injury
- Tumor, AVM, aneurysm (secondary hemorrhage)
- Anticoagulant therapy
- Surgical intervention before repeat CT

Ethical Considerations:

The study was carried out in accordance with the ethical guidelines approved by the Ethical Committee of Superior University, Lahore, to protect the rights and well-being of the participants. All participants provided informed consent before enrollment.

All data and information collected were treated confidentially and were used only for research purposes. Participant confidentiality was maintained throughout the study.

All adult participants who took part in the study provided written informed consent after receiving an explanation of the study purpose, procedures, potential risks, and potential benefits. Participation was voluntary, and participants could withdraw at any time without affecting their clinical care.

Data Collection Procedure:

Patients with spontaneous intracerebral hemorrhage (ICH) with presentation within 6 hours of onset of symptoms were eligible to participate provided they met the inclusion criteria. A non-contrast computed tomography (NCCT) scan of the brain was obtained to confirm the diagnosis and to document initial characteristics of the hematomas after initial clinical stabilization.

All included patients had a repeat NCCT scan performed at 24 ± 6 hours after the baseline scan, irrespective of the clinical status. This was done to evaluate radiological progression and identify expansion of hematoma, even if not clinically apparent.

Both baseline and repeat computed tomography (CT) were used to measure hematoma volume by the ABC/2 method to ensure a standardized and reproducible estimation of intracerebral hemorrhage size. All CT images were analyzed/interpreted by a consultant radiologist for accuracy and consistency in reporting.

Clinical parameters were recorded at admission and at repeat imaging. These included the Glasgow Coma Scale (GCS) score and vital signs, specifically blood pressure. The average of two admission SBP readings obtained 5–10 minutes apart was used as the admission SBP measure.

Repeat imaging was performed and any evidence of expansion of the hematoma was documented. A structured proforma was also completed to record any change in clinical management following this. This comprised the escalation of antihypertensive treatment, the start of osmotherapy, transfer to the intensive care unit (ICU) or high dependency unit (HDU), neurosurgical consultation or surgical intervention.

All data were collected systematically to ensure completeness, uniformity, and accuracy for subsequent statistical analysis.

Data Analysis:

Collected data were entered, cleaned, and analyzed using the Statistical Package for the Social Sciences (SPSS). Quantitative variables such as age, blood pressure, and hematoma volume were expressed as mean $\pm$ standard deviation when approximately normally

distributed and as median (interquartile range [IQR]) when not normally distributed.

Frequencies and percentages were used to present qualitative variables, including gender, hypertension status, hematoma expansion, silent hematoma expansion, and management changes.

The independent-samples t-test was used to compare continuous variables such as admission SBP and DBP between the hematoma-expansion and no-expansion groups when its assumptions were met. The chi-square test was used to assess associations between categorical variables, including hypertension status, baseline NCCT predictors, clinical deterioration, and management change. A p-value < 0.05 was considered statistically

significant.

RESULTS

All 81 consecutive patients with spontaneous ICH who attended the Radiology and Neurology departments of the participating multicenter hospitals were analyzed. The sample size was calculated using Cochran's formula ($n = 81$). Quantitative variables were reported as mean $\pm$ SD or median (IQR), as appropriate, and qualitative variables as frequencies and percentages. The chi-square test was used to assess associations between categorical variables, and the independent-samples t-test was used to compare continuous variables between groups when appropriate. A p-value < 0.05 was considered statistically significant.

TABLE 1: Demographic and Baseline Clinical Characteristics

Variable	Category	Value (n=81)
Age (years)	Mean $\pm$ SD (range 30–50)	40.5 $\pm$ 6.3
Gender, n (%)	Male	44 (54.3)
	Female	37 (45.7)
Symptom-to-arrival time (hrs)	Median (IQR)	2.5 (1.4–3.8)
GCS at admission	Mean $\pm$ SD	10.6 $\pm$ 2.7
Hypertension status, n (%)	Regular medication	28 (34.6)
	Irregular / no medication	29 (35.8)
	Newly diagnosed	24 (29.6)

The average age of the participants was 40.5 $\pm$ 6.3 years, reflecting that the study sample was within the predefined age range of 30–50 years. Of the 81 patients, 44 (54.3%) were male and 37 (45.7%) were female. The median time from symptom onset to hospital presentation was 2.5 hours (IQR: 1.4–3.8), consistent with the inclusion criterion of presentation within 6

hours. The mean admission GCS score was 10.6 $\pm$ 2.7. Regarding hypertension history, 28 (34.6%) patients were taking antihypertensive medication regularly, 29 (35.8%) reported irregular or no medication use, and 24 (29.6%) were newly diagnosed with hypertension at presentation.

TABLE 2: GCS at Admission

GCS Category	Frequency	Percent (%)	Cumulative %
Severe (GCS 3–8)	17	21.0	21.0
Moderate (GCS 9–12)	37	45.7	66.7
Mild (GCS 13–15)	27	33.3	100.0
Total	81	100.0	

The Glasgow Coma Scale (GCS) severity categories of the 81 patients at admission are shown in Table 2. The majority, 37 (45.7%), had

a moderate GCS score (9–12), followed by 27 (33.3%) with mild GCS scores (13–15) and 17 (21.0%) with severe impairment (GCS 3–8).

TABLE 3: Frequency Distribution of Gender

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	44	54.3	54.3	54.3
Female	37	45.7	45.7	100.0

Participants' gender distribution is presented in the table. Among the 81 participants, 44 (54.3%) were male, while 37 (45.7%) were

female. Therefore, there were slightly more males than females in the study.

TABLE 4: Time from Symptom Onset to Hospital Arrival

Time to arrival	n (%)
Mean $\pm$ SD (hours)	2.68 $\pm$ 1.53
Median (IQR) (hours)	2.5 (1.4–3.8)
Range (min–max) (hours)	0.2–5.7
1 hour	14(17.3)
1–2 hours	19(23.5)
2–4 hours	31(38.3)
4–6 hours	17(21.0)

All 81 patients were seen within the 6-hour inclusion window. The mean time from symptom onset to hospital arrival was 2.68 $\pm$ 1.53 hours, the median was 2.5 hours (IQR: 1.4–3.8), and the range was 0.2–5.7 hours.

Fourteen patients (17.3%) arrived within 1 hour, 19 (23.5%) within 1–2 hours, 31 (38.3%) within 2–4 hours, and 17 (21.0%) within 4–6 hours. Thus, 64 patients (79.0%) arrived within 4 hours.

TABLE 5: Admission Blood Pressure Readings

Parameter	Mean $\pm$ SD
Systolic BP – 1st reading (mmHg)	170.8 $\pm$ 16.8
Diastolic BP – 1st reading (mmHg)	102.0 $\pm$ 10.5
Systolic BP – 2nd reading (mmHg)	170.7 $\pm$ 18.1
Diastolic BP – 2nd reading (mmHg)	102.2 $\pm$ 10.9
Mean admission SBP (mmHg)	170.8 $\pm$ 17.3
Mean admission DBP (mmHg)	102.1 $\pm$ 10.6

The mean and standard deviation (SD) of blood pressure (BP) at admission are shown in the table. The mean systolic blood pressure (SBP) in the first measurement was 170.8 $\pm$ 16.8 mmHg and the mean diastolic blood pressure (DBP) was 102.0 $\pm$ 10.5 mmHg. In the second reading, the mean SBP was 170.7 $\pm$ 18.1 mmHg and the

mean DBP was 102.2 $\pm$ 10.9 mmHg. The overall mean admission SBP was 170.8 $\pm$ 17.3 mmHg, while mean admission DBP was 102.1 $\pm$ 10.6 mmHg. Overall, results showed that participants' BP was high at admission, and there was little variation in measurements between the first BP and the second.

TABLE 6: Frequency Distribution of Hypertension History

	Frequency	Percent	Valid Percent	Cumulative Percent
Regular medication	28	34.6	34.6	34.6
Irregular / no medication	29	35.8	35.8	70.4

Newly diagnosed	24	29.6	29.6	100.0
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The medication status of the participants is displayed in the table. Of the 81 participants, 28 (34.6%) were using their medication regularly, and 29 (35.8%) were irregular or not using any medications. Another 24 (29.6%) were newly

diagnosed, and thus did not have a history of medication use. Overall, irregular or no medication use was the most common group, followed by regular medication use, and newly diagnosed cases.

TABLE 7: Frequency Distribution of Hypertensive Status at Admission

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes (SBP ≥ 140 or DBP ≥ 90 mmHg)	72	88.9	88.9	88.9
No	9	11.1	11.1	100.0

Averaged two times (mean) systolic blood pressure (SBP) was 170.8 ± 17.3 mmHg and the mean diastolic blood pressure (DBP) was 102.1 ± 10.6 mmHg for patients at admission. The vast majority of patients (72, 88.9%) had an acutely

elevated blood pressure on top of an established or newly discovered hypertension (Table 4) when using the operational threshold established in the study, which is SBP ≥ 140 mmHg or DBP ≥ 90 mmHg.

TABLE 8: Baseline Clinical and NCCT Imaging Characteristics

Variable	Category	Value
Time to initial CT (hrs)	Mean $\pm$ SD	3.3 ± 1.4
Initial hematoma volume (mL)	Mean $\pm$ SD	23.1 ± 9.5
Hematoma location, n (%)	Basal ganglia	23(28.4)
	Thalamus	20(24.7)
	Lobar	23(28.4)
	Posterior fossa (pons/cerebellum)	15(18.5)
NCCT expansion predictors present, n (%)	Yes	39(48.1)
Intraventricular extension, n (%)	Yes	36(44.4)

The mean time from symptom onset to the initial non-contrast CT (NCCT) was 3.3 ± 1.4 hours. The mean hematoma volume measured by the ABC/2 method at the initial time was 23.1 ± 9.5 mL. The most common sites for hemorrhage were the lobar and basal ganglia locations (23, 28.4% each), followed by thalamus (20, 24.7%) and posterior fossa (15,

18.5%). Thirty-nine (48.1%) patients had at least one of the recognized NCCT markers of expansion (blend sign, black-hole sign, island sign, swirl sign, or irregular hematoma margin) on the baseline scan, and 36 (44.4%) of the patients had intraventricular extension of the hemorrhage.

TABLE 9: Frequency Distribution of Hematoma Location

Hematoma Location	Frequency	Percent	Cumulative Percent
Basal ganglia	23	28.4	28.4
Lobar	23	28.4	56.8
Thalamus	20	24.7	81.5
Posterior fossa	15	18.5	100.0

(pons/cerebellum)			
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The distribution of the lesions by site is shown in the table. These were most frequently the basal ganglia (23, 28.4%) and the lobar areas (23, 28.4%). Thalamic involvement was found in 20 cases (24.7%) and 15 cases (18.5%) were

in the posterior fossa, the pons and the cerebellum. In general, the results showed that the basal ganglia and lobar areas were the most commonly involved anatomical areas while the involvement of the posterior fossa was the least.

TABLE 10: Repeat CT Findings and Frequency of Hematoma Expansion

Variable	Value
Time to repeat CT (hrs), mean $\pm$ SD	24.4 $\pm$ 4.1
Repeat hematoma volume (mL), mean $\pm$ SD	30.5 $\pm$ 14.9
Absolute volume increase (mL), median (IQR)	5.2 (−0.3 to 15.1)
Percentage increase (%), median (IQR)	24.3 (−1.6 to 67.8)
Hematoma expansion present, n (%)	40 (49.4)
No hematoma expansion, n (%)	41 (50.6)

Repeat NCCT was carried out at the mean of 24.4 $\pm$ 4.1 hours after the baseline scan (24 $\pm$ 6 hours according to the study protocol). There was a mean hematoma volume of 30.5 $\pm$ 14.9 mL on repeat imaging versus a baseline volume of 23.1 $\pm$ 9.5 mL. The median absolute volume increase was 5.2 mL (IQR: −0.3 to 15.1), and the median percentage increase was 24.3% (IQR: −1.6% to 67.8%). Hematoma expansion defined by the pre-specified criteria (absolute

increase of >6 mL or relative increase of >33%) was noted on second computed tomography in 40 of 81 patients (49.4%). This is the primary finding that directly met the first aim of the study and confirmed that in almost half of the patients, there was clinically important radiological progression, where the initial scan would have missed the true progressive nature of the hemorrhage.

TABLE 11: Cross-tabulation between Baseline NCCT Predictors and Hematoma Expansion

Baseline NCCT predictors	Expansion on repeat CT	No expansion on repeat CT	Total
Present	28	11	39
Absent	12	30	42
Total	40	41	81

The relationship between baseline NCCT predictors and hematoma expansion on repeated CT are as follows. Of the 39 participants with baseline NCCT predictors, 28 participants experienced expansion and 11 participants did not experience expansion. Among the 42 without baseline NCCT predictors, 12 had expansion and 30 did not

have expansion. Overall, expansion of the haematomas occurred in 40 of 81 participants (49.4%), and in 41 of 81 (50.6%) did not expand. Hematoma expansion was significantly more frequent among patients with baseline NCCT predictors than among those without predictors ($p < 0.001$).

TABLE 12: Predictive Markers for Hematoma Expansion

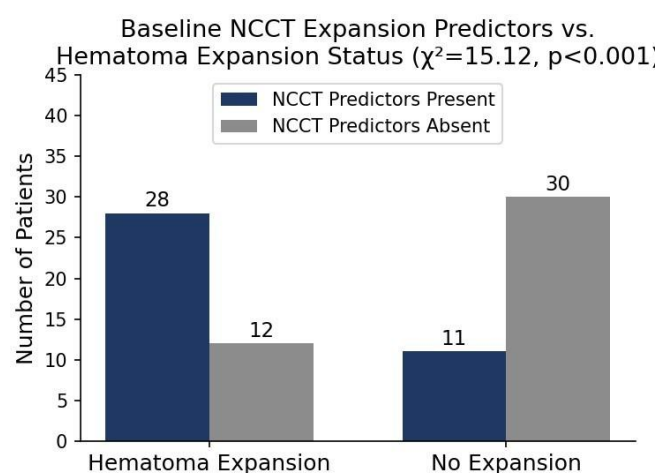
Diagnostic parameter	Value
Sensitivity	70.0%
Specificity	73.2%
Positive predictive value	71.8%

Negative predictive value	71.4%
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The table shows the ability of the baseline NCCT predictors to detect hematoma expansion on repeat CT. The sensitivity was 70.0%, meaning that the predictors correctly identified 70% of patients with hematoma expansion. Specificity was 73.2%, meaning that 73.2% of those who did not have expansion were correctly identified as negative. The positive predictive value (PPV) was 71.8%,

indicating that around 72% of the patients who had positive NCCT predictors subsequently developed hematoma expansion. The negative predictive value (NPV) was 71.4%, meaning that roughly 71% of those who did not have any predictors were not likely to experience expansion. The results are overall moderate predictive performance of baseline NCCT predictors for subsequent hematoma expansion.

FIGURE 1: Baseline NCCT Predictors of Expansion Stratified by Repeat-CT Outcome



The occurrence of known NCCT predictors was significantly associated with subsequent hematoma expansion on repeat CT. In the patients with baseline NCCT predictors, 28 (71.8%) patients underwent expansion, whereas only 12 (28.6%) without baseline NCCT predictors expanded. Absolute volume increase was also much higher among patients with

baseline predictors (median increase 13.5 mL) compared to patients without baseline predictors (median increase 1.7 mL). The baseline markers had a 70.0% sensitivity, 73.2% specificity, 71.8% positive predictive value and 71.4% negative predictive value in identifying those who would later have expansion on the follow-up scan.

TABLE 13: Frequency Distribution of Intraventricular Extension

	Frequency	Percent	Cumulative Percent
Present	36	44.4	44.4
Absent	45	55.6	100.0

The table shows the number of participants who have or do not have the assessed finding. Among the 81 participants, the finding was present in 36 (44.4%) and absent in 45 (55.6%).

In this respect, the majority of the participants (55.6%) did not show the finding, and 44.4% showed it.

TABLE 14: Admission Blood Pressure by Hematoma Expansion Status

Blood pressure parameter	Expansion present (n=40)	No expansion (n=41)	p-value
Mean SBP (mmHg), mean $\pm$ SD	167.6 $\pm$ 15.6	173.9 $\pm$ 18.5	0.065
Mean DBP (mmHg), mean $\pm$ SD	101.3 $\pm$ 10.4	102.8 $\pm$ 10.8	0.456

The table 14 presents the comparison of admission blood pressure between patients with and without hematoma expansion. The mean SBP was 167.6 $\pm$ 15.6 mmHg for those with expansion and 173.9 $\pm$ 18.5 mmHg for those without expansion. The difference in the mean

SBP between the two groups was not statistically significant ($p = 0.065$). Also, no statistically significant difference was found between the mean DBP values in the expansion group (101.3 $\pm$ 10.4 mmHg) and the no-expansion group (102.8 $\pm$ 10.8 mmHg), $p = 0.456$.

TABLE 15: Admission Hypertensive Status by Hematoma Expansion Status

Hypertensive at admission	Expansion present	No expansion	Total
Yes	36	36	72
No	4	5	9
Total	40	41	81

There was no statistically significant difference in mean admission systolic BP between patients who developed hematoma expansion (167.6 $\pm$ 15.6 mmHg) and those who did not (173.9 $\pm$ 18.5 mmHg). Diastolic BP likewise did not

differ significantly between groups (101.3 $\pm$ 10.4 vs. 102.8 $\pm$ 10.8 mmHg, $p = 0.456$). Similarly, there was no significant association between admission hypertensive status and hematoma expansion.

TABLE 16: Hypertension History by Hematoma Expansion Status

Hypertension status	Expansion, n (%)	No expansion, n (%)	Total
Regular medication	17(60.7)	11(39.3)	28
Irregular / no medication	16(55.2)	13(44.8)	29
Newly diagnosed	7(29.2)	17(70.8)	24

No statistically significant association was demonstrated between hypertension history and hematoma expansion across the three categories. Expansion occurred in 17 of 28 (60.7%) patients taking antihypertensive medication regularly, 16 of 29 (55.2%) with

irregular or no medication use, and 7 of 24 (29.2%) newly diagnosed patients. The overall difference did not reach statistical significance based on the available 3×2 table ($\chi^2 p = 0.056$). This pattern may warrant further investigation in larger studies.

TABLE 17: Clinical Deterioration and GCS Change by Hematoma Expansion Status

Clinical status	Expansion present (n=40)	No expansion (n=41)	p-value
Clinical deterioration, n (%)	23(57.5)	4(9.8)	<0.001
Clinically stable, n (%)	17(42.5)	37(90.2)	—
GCS change, mean $\pm$ SD	-2.2 $\pm$ 2.3	-0.1 $\pm$ 1.2	<0.001

The table shows the clinical status and Glasgow Coma Scale (GCS) change in those with and without expansion of hematoma. Twenty-three (57.5%) participants with expansion experienced clinical deterioration while only 4

(9.8%) of participants without expansion experienced clinical deterioration. On the other hand, the majority of participants with no expansion were clinically stable (90.2%) versus 42.5% of the participants in the

expansion group. The difference was statistically significant ($p < 0.001$).

Similarly, the mean change in GCS was -2.2 ± 2.3 in the expansion group and -0.1 ± 1.2 in the no-expansion group, with a statistically

significant difference ($p < 0.001$). Overall, hematoma expansion was significantly associated with clinical deterioration and a greater decline in GCS score.

TABLE 18: Frequency of Silent Hematoma Expansion

Silent hematoma expansion (radiological expansion without clinical deterioration)	n
Present (among the 40 patients with expansion)	17 (42.5% of expansion group)
Absent – expansion with clinical deterioration	23 (57.5% of expansion group)

Overall, clinical deterioration occurred in 27 (33.3%) patients, including 23 (57.5%) patients with hematoma expansion and 4 (9.8%) patients without hematoma expansion. Seventeen of the 40 patients (42.5%) with radiologically confirmed hematoma expansion

did not experience clinical deterioration and were therefore classified as having silent hematoma expansion. These findings indicate that clinical assessment alone may not identify all cases of radiological expansion.

TABLE 19: Blood Pressure Status at 24 Hours

Variable	Value
BP at 24h – SBP (mmHg), mean $\pm$ SD	145.4 ± 17.7
BP at 24h – DBP (mmHg), mean $\pm$ SD	84.8 ± 10.9
Target BP achieved (SBP < 140 mmHg), n (%)	33 (40.7)

The mean SBP and DBP at 24 hours were 145.4 ± 17.7 mmHg and 84.8 ± 10.9 mmHg, respectively. Overall, 33 (40.7%) patients reached the predefined target of SBP < 140

mmHg. The available data did not demonstrate a statistically significant difference in 24-hour BP measures between the expansion and no-expansion groups.

TABLE 20: Management Change by Hematoma Expansion Status

Management change	Expansion (n=40)	No expansion (n=41)	Total	P value
Yes	29 (72.5)	10 (24.4)	39	< 0.001
No	11 (27.5)	31 (75.6)	42	

Patients with hematoma expansion had more management changes (29, 72.5%) than patients without expansion (10, 24.4%). No management change was reported in 11 (27.5%)

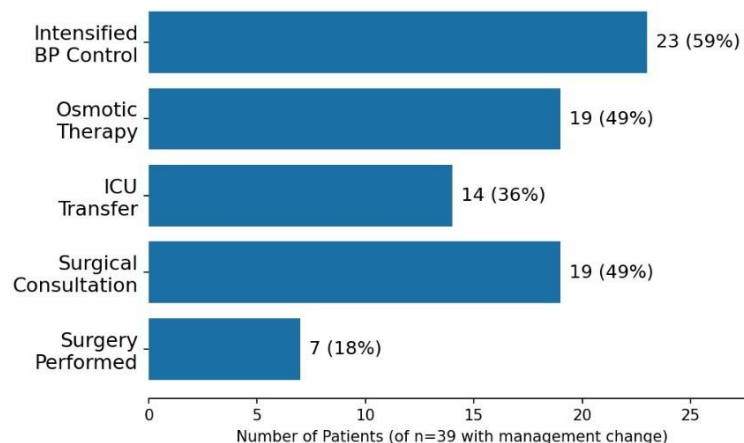
patients in the expansion group and 31 (75.6%) in the no-expansion group. Overall, 39 (48.1%) participants had a documented management change.

TABLE 21: Nature of Management Changes Instituted

Type of management change	n
Intensified BP control	23
Osmotic therapy	19

Neurosurgical consultation	19
ICU transfer	14
Surgical evacuation performed	7

FIGURE 2: Nature of Management Change Following Repeat CT



In total, a change in clinical management was done in 39 (48.1%) of the 81 patients after the repeat CT.

The bar chart shows the types of management changes recorded among the 39 patients with a documented change. Intensified blood-pressure control was the most common intervention (23 patients), followed by osmotic therapy and

neurosurgical consultation (19 patients each). ICU transfer was recorded in 14 patients, and surgical evacuation was performed in 7 patients. Because patients could receive more than one management intervention, the intervention counts are not mutually exclusive. Overall, medical management changes were more frequently recorded than surgical evacuation.

TABLE 22: Frequency Distribution of Modified Rankin Scale (mRS) at Discharge

	Frequency	Percent	Valid Percent	Cumulative Percent (%)
mRS 0-1	18	22.2	22.2	22.2
mRS 2-3	25	30.9	30.9	53.1
mRS 4-5	27	33.3	33.3	86.4
mRS 6 (Deceased)	11	13.6	13.6	100.0

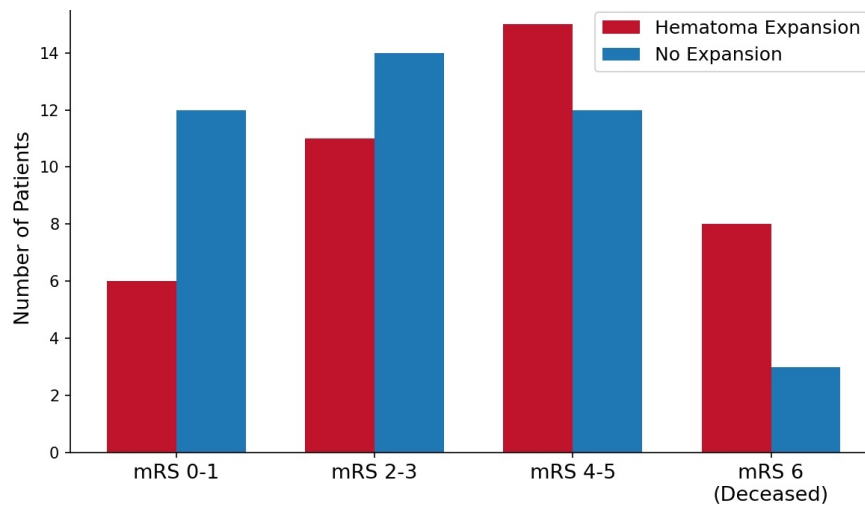
The distribution of participants according to modified Rankin Scale (mRS) outcome is presented in the table. The most common outcome was mRS 4-5 (33.3%), followed by mRS 2-3 (30.9%) and mRS 0-1 (22.2%). Death

(mRS 6) occurred in 11 (13.6%) participants. Overall, poor functional outcome (mRS 4-6) was more frequent than good functional outcome (mRS 0-3).

TABLE 23: ICU/HDU Admission, Length of Stay, and Discharge Disability by Expansion Status

Variable	Expansion present (n=40)	No expansion (n=41)	p-value
ICU/HDU admission, n (%)	23 (57.5)	15 (36.6)	0.109
Length of stay (days), mean $\pm$ SD	11.2 $\pm$ 5.7	11.8 $\pm$ 4.9	0.575
mRS 4-6 at discharge, n (%)	23 (57.5)	15 (36.6)	0.109*

FIGURE 3: Distribution of Modified Rankin Scale (mRS) at Discharge by Hematoma Expansion Status



In total, 38 of the 81 admissions (46.9%) involved ICU/HDU admission. The proportion admitted to ICU/HDU was 57.5% in the expansion group and 36.6% in the no-

expansion group, but the difference was not statistically significant ($p = 0.109$). The mean length of hospital stay was 11.5 ± 5.3 days overall and did not differ significantly between groups.

TABLE 24: GCS at Repeat CT

GCS Category	Frequency	Percent (%)	Cumulative %
Severe (GCS 3–8)	33	40.7	40.7
Moderate (GCS 9–12)	30	37.0	77.8
Mild (GCS 13–15)	18	22.2	100.0
Total	81	100.0	

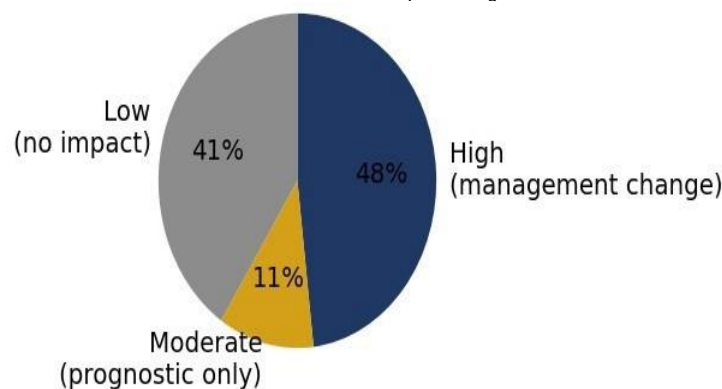
The GCS scores at repeat CT are shown in Table 24. Thirty-three patients (40.7%) had severe GCS scores (3–8), 30 (37.0%) had

moderate scores (9–12), and 18 (22.2%) had mild scores (13–15).

TABLE 25: Clinical Utility of Repeat CT scan

Clinical utility of repeat CT	n (%)
High (led to management change)	39 (48.1%)
Moderate (prognostic information only)	9 (11.1%)
Low (no impact on management)	33 (40.7%)

FIGURE 4: Clinical Utility of Repeat CT scan



The overall clinical utility of repeat CT, based on its documented impact on patient management, was high in 39 (48.1%) patients, moderate in 9 (11.1%) patients, and low in 33 (40.7%) patients. Thus, repeat CT provided either actionable or prognostically useful information in 48 of 81 patients (59.3%).

DISCUSSION

The present study evaluated repeat NCCT in 81 hypertensive patients aged 30–50 years with spontaneous intracerebral hemorrhage. Hematoma expansion was detected in 40 patients (49.4%), indicating that radiological progression was common during the early phase of ICH. This finding is consistent with evidence that hematoma growth frequently occurs within the first 24 hours and may be identified through follow-up imaging [19,20].

Admission systolic and diastolic blood pressure were not significantly associated with hematoma expansion ($p = 0.065$ and $p = 0.456$). This suggests that a single admission blood-pressure measurement may not adequately reflect subsequent blood-pressure variability or treatment response. Blood pressure should therefore be interpreted together with neurological status and imaging findings [21,24].

Baseline NCCT predictors were significantly associated with hematoma expansion ($p < 0.001$), with 70.0% sensitivity and 73.2% specificity. These findings support the use of baseline NCCT markers for early risk stratification, while their moderate predictive performance indicates that they should complement rather than replace follow-up

imaging [17,18].

Importantly, 42.5% of expansion cases were asymptomatic. Management changes were also more frequent in patients with expansion than in those without expansion (72.5% vs. 24.4%; $p < 0.001$), and repeat NCCT showed moderate or high clinical utility in 59.3% of patients. Thus, repeat imaging at approximately 24 hours may provide clinically relevant information by detecting silent hematoma expansion and supporting subsequent management decisions [20,22,23].

CONCLUSION

Hematoma expansion occurred in 49.4% of hypertensive patients aged 30–50 years with spontaneous ICH, and 42.5% of expansion cases were clinically silent. Admission blood pressure was not significantly associated with expansion, whereas baseline NCCT predictors showed moderate predictive performance and a significant association with hematoma growth. Management changes were considerably more frequent among patients with expansion. Repeat NCCT at approximately 24 hours therefore provided useful information for detecting radiological progression and supporting clinical management, particularly when expansion was not apparent on clinical assessment.

LIMITATIONS

- Sample size 81 participants met the calculated minimum sample but may have been insufficient to detect statistically significant in some secondary outcomes such as ICU admission and discharge mRS.

- Limited number of centers and single city setting: the study was conducted at tertiary-care centers in Lahore, which may limit generalizability to other regions and healthcare settings.
- The ABC/2 method is less accurate than computer-assisted volumetric analysis, particularly for irregularly shaped hematomas [11,29].
- Hematoma expansion occurring very early (<6 hours) or late (>30 hours) expansion may not have been captured by the fixed repeat-CT interval of 24 ± 6 -hours
- Only discharge mRS was available; standard 30- or 90-day functional outcomes were not recorded, and the observational design precludes causal interpretation.
- Patients who underwent surgical intervention before the scheduled repeat CT were excluded, which may have introduced selection bias by excluding patients with more severe disease

RECOMMENDATIONS

- Repeat NCCT at 24 ± 6 hours may be considered in selected clinically stable ICH patients when silent hematoma expansion is a concern. However, larger prospective multicenter studies are needed before routine repeat imaging can be recommended for all patients.
- Blood pressure should be monitored and managed throughout the acute period according to established clinical protocols; admission BP alone should not be used to determine whether hematoma expansion is present.
- Maintain clinical suspicion for silent expansion even when the neurological examination remains stable.
- Although patients with established hypertension showed higher expansion rates than newly diagnosed patients in this cohort; the difference of not statistically significant and requires confirmation in larger studies.
- Conduct larger multicenter studies using standardized and, where feasible, computer-assisted volumetric measurements and 90-day functional outcomes.
- Improve community hypertension

screening and treatment adherence.

- Evaluate the cost-effectiveness of routine versus selective repeat CT protocols in resource-limited settings.

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