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COMPUTER TOMOGRAPHIC PREDICTORS OF THE COURSE AND OUTCOME OF HEMORRHAGIC STROKES

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Abstract. *Neuroimaging plays a vital role in the diagnosis of intracerebral hemorrhage (ICH) and in identifying its underlying cause. This study assessed CT findings associated with poor outcomes in hemorrhagic stroke both during the acute phase and within 90 days of onset. Key risk factors influencing survival include hematoma volume, intraventricular hemorrhage, and the presence of herniation syndrome. Recognizing indirect computer tomography (CT) predictors of hematoma expansion may enhance prognostic accuracy and support timely, targeted treatment interventions for patients with hemorrhagic stroke.*

Keywords: *hemorrhagic stroke, computer tomography, signs of hematoma expansion.*

Introduction. Intracerebral hemorrhages (ICH) constitute approximately 15–25% of all acute strokes worldwide. Recent data show a growing trend in both morbidity and mortality associated with ICH, with an increasing number of younger individuals being affected. Prompt identification of etiological mechanisms and rapid diagnostic evaluation are essential for effective management [1,2]. In this context, neuroimaging methods, alongside clinical and laboratory assessments, have become indispensable components of the diagnostic process [4].

Among neuroimaging techniques, CT remains a critical tool in the evaluation of hemorrhagic stroke. It allows visualization of the hematoma's size, shape, and location. Typical sites of Spontaneous ICH: lobar 25-30%, putaminal 35-40%, thalamic 20-25%, cerebellar 7-15%, pontine 6%, caudate 5%. (Fig. 1). The hemorrhage itself causes direct injury to neurons and glial cells, triggering a pathological cascade that includes reduced cerebral perfusion (oligemia), disruption of neurotransmitter balance, mitochondrial dysfunction, and cellular swelling (edema) [8].

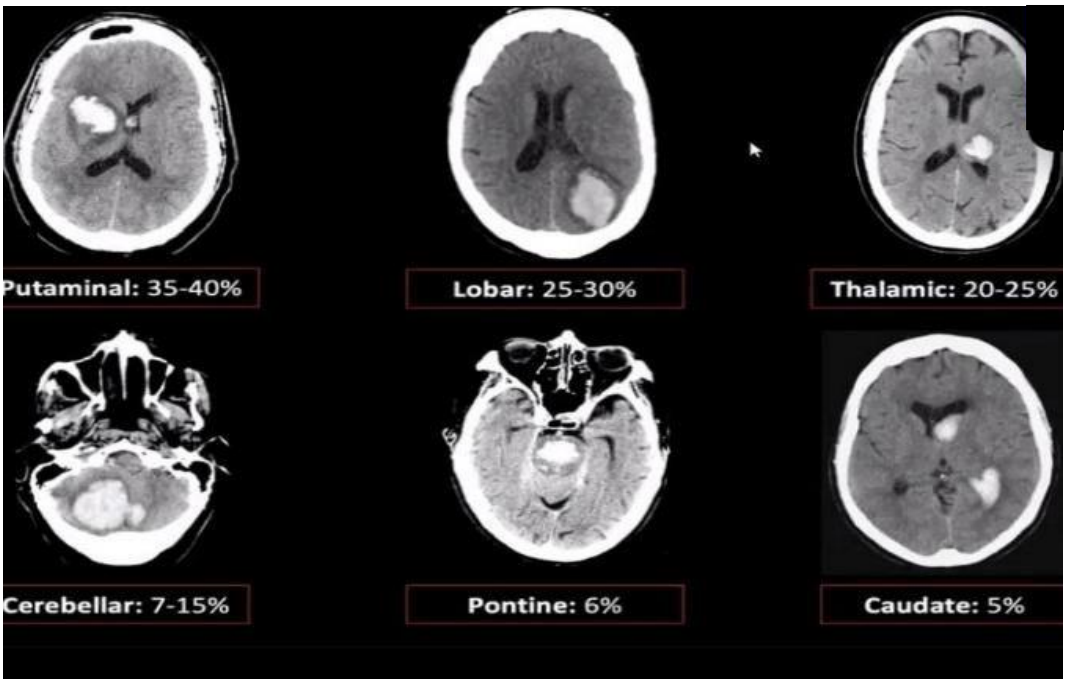

Fig.1. Typical sites of Spontaneous ICH

In cases of hemorrhagic stroke, hematoma expansion refers to a progressive increase in the volume of bleeding within the brain tissue. This progression can lead to significant neurological deterioration and substantially increases the risk of death. Detecting hematoma expansion in a timely manner requires attention to both clinical manifestations and radiological findings [3].

Clinically, hematoma expansion may be indicated by a sudden deterioration in neurological status, which can present as worsening focal neurological deficits or a decline in the level of consciousness. Patients may also experience an intensification of headache [9]. Signs of increased intracranial pressure, such as nausea, vomiting, and impaired consciousness, can also be present. In some cases, the onset of convulsions may signal further expansion of the hemorrhage.

Radiologically, CT scans may reveal several signs indicative of hematoma growth. These include an increase in the size of the hyperdense region compared to earlier imaging, an expansion of the surrounding (perifocal) edema, a shift of midline brain structures, and the appearance of new hemorrhagic areas or progression of existing ones [5,6].

Notably, within the first six hours following stroke onset, approximately 30% of patients experience hematoma expansion. This phenomenon is closely linked to poorer clinical outcomes. CT imaging can also reveal specific features that suggest ongoing bleeding and predict early hematoma growth. These include several characteristic signs.

The black hole sign is observed as areas of mixed density within the hematoma, suggesting bleeding events that have occurred at different times. The mixing sign refers

to regions of clearly demarcated low and high density within the hematoma, reflecting non-uniform bleeding. The island sign describes the presence of three or more small, round or oval hematomas either separated from or partially connected to the main hemorrhagic focus. Lastly, the vortex sign appears as areas of normal or reduced density with irregular, round, or linear shapes within the hematoma, typically indicative of active bleeding within an acute hematoma [7].

These clinical and radiological signs are critical in predicting hematoma expansion and are valuable in guiding therapeutic decisions aimed at improving outcomes in patients with acute ICH.

Aim Of The Study. The aim of this study is to evaluate CT findings associated with unfavorable outcomes in patients with hemorrhagic stroke, both during the acute phase and over a 90-day follow-up period.

Materials And Methods. A retrospective analysis was conducted on patients diagnosed with hemorrhagic stroke in the context of hypertension and atherosclerosis who were admitted to the intensive care and neurological units at the Tashkent Medical Academy Clinic between 2022 and 2024. The study involved 75 patients, comprising 55% men and 45% women, with an average age of 65.7 years. Diagnoses were confirmed using clinical evaluations, laboratory tests, and CT imaging. Brain CT scans were performed at the time of hospital admission using standard imaging equipment. The CT evaluation focused on several parameters, including the location and volume of the hematoma, presence of intraventricular hemorrhage, and CT signs suggestive of potential hematoma expansion over time.

In addition to imaging data, patient demographics such as age and sex were recorded, along with stroke severity as assessed by the National Institutes of Health Stroke Scale (NIHSS) and functional outcomes evaluated using the modified Rankin Scale (mRS). All patients were followed for a period of 90 days. Statistical analysis was carried out using the SPSS software package, version 26.0. A p-value of less than 0.05 was considered statistically significant.

Results and Discussion. All 75 patients underwent standard conservative therapy in accordance with clinical guidelines for hemorrhagic stroke management. According to the types of hemorrhages in the examined patients, the following distribution was observed: parenchymal hemorrhages were the most common, according for 50.6% (n=42) of cases; subarachnoid hemorrhages occurred in 12% (n=10); combined parenchymal-subarachnoid in 8,4% (n=7); brainstem hemorrhages in 3,6% (n=3); intraventricular in 7,2% (n=6); parenchymal-intraventricular

in 10,8% (n=9); subarachnoid-intraventricular in 3.6% (n=3); and cerebellar hemorrhages in 3.6% (n=3). The mean NIHSS score on admission was 16±9.5, and the average mRS score was 4. During the 90-day observation period, mortality was recorded in 12% patients (9 out of 75), with 5 deaths occurring within the first 30 days and 4 occurring between days 31 and 90.

CT predictors of hematoma enlargement were identified in 17 cases. These imaging signs included features such as the mixing sign, black hole sign, whirlpool (or vortex) sign, and island sign—all of which are associated with ongoing bleeding and increased risk of hematoma progression.

Perihematomal edema begins to increase within the first 24 hours following the onset of ICH, reaches its peak around days 5 to 6, and may persist for up to 14 days. The key factors contributing to the deterioration of a patient's condition in ICH include hematoma expansion, intraventricular hemorrhage, perihematomal edema, and the associated inflammatory response.

Hematoma expansion is defined as a progressive increase in the volume of intracerebral bleeding.(Fig.2) This process can significantly worsen the patient's neurological status and is associated with an increased risk of mortality. Early identification of hematoma growth is crucial and relies on both clinical observations and radiological evidence.

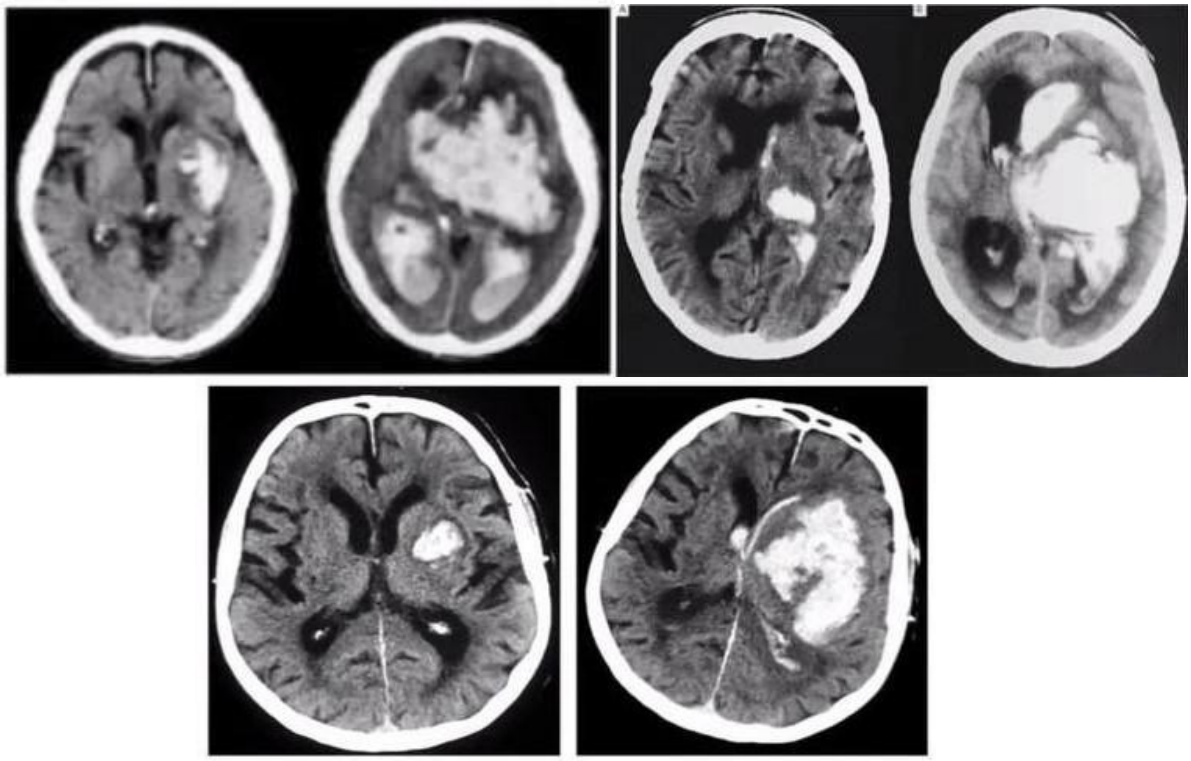

Fig.2. Hematoma Growth

Clinically, hematoma expansion may present as a sudden deterioration in neurological function, including worsening of focal neurological deficits and a reduction in the level of consciousness. Patients may also experience increased headache and symptoms of elevated intracranial pressure, such as nausea, vomiting, and altered consciousness. In some cases, seizures may also occur.

On computed tomography (CT) scans, hematoma expansion is indicated by an increase in the size of the hyperdense region compared to previous imaging, along with an enlargement of the surrounding perifocal edema. Additional radiological signs include a shift in midline brain structures, the appearance of new hemorrhagic foci, or progression of existing hemorrhages. The presence of specific CT markers, collectively referred to as expansion signs, also supports the diagnosis of ongoing or imminent hematoma growth.

In terms of hemispheric involvement, 50.5% of hematomas were localized in the left hemisphere, while 42.7% were found in the right hemisphere. CT predictors of hematoma expansion included the black hole, the satellite sign, the mixing sign (Fig.3).

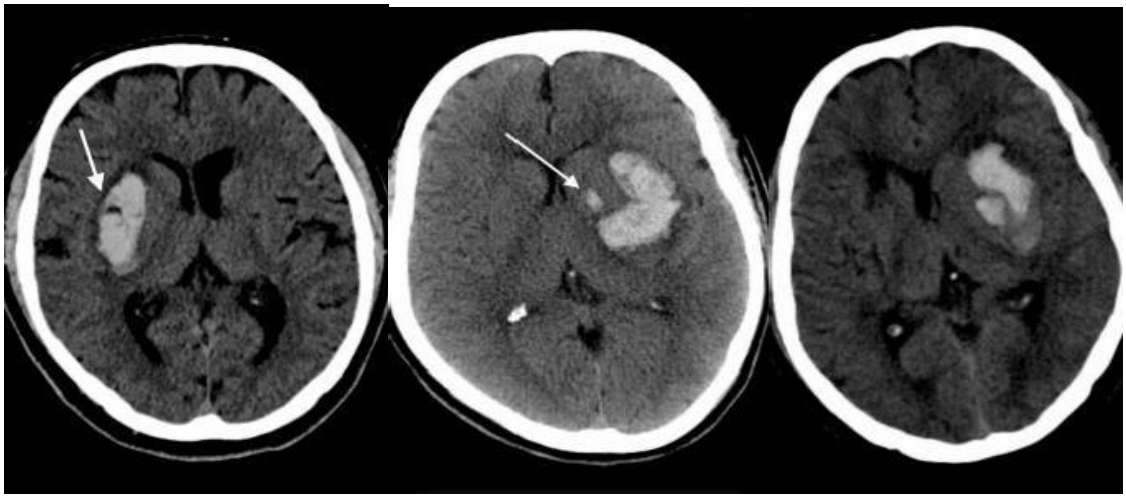

Fig. 3. CT predictors of hematoma expansion: 1-blac hole sign, 2-the satellite sign, 3-the mixing sign.

Among patients with these CT predictors, the frequency of clinical symptoms was significantly higher in the group with unfavorable outcomes compared to those with favorable outcomes. A multivariate logistic regression analysis was conducted, incorporating stroke severity, patient age, hemorrhage location, and CT predictors of hematoma expansion. This model accounted for 36% of the variability in predicting adverse outcomes within a 90-day period.

Based on CT findings, hematoma volumes were classified as follows: 30 mL or less in 9% of cases, 31–50 mL in 45%, 51–70 mL in 27.5%, and greater than 70 mL in 18.5%.

All patients were experiencing their first episode of hemorrhagic stroke. Statistical analysis indicated that age, stroke severity at presentation, and the presence of CT markers predicting hematoma expansion were independent risk factors for mortality within the 90-day period. Larger hematoma volume, deep location, irregular shape, and heterogeneous density were all significantly associated with increased risk of early expansion, particularly within the first 24 hours of symptom onset.

Among patients who exhibited CT predictors of hematoma growth, the rate of poor outcomes was significantly higher compared to those without such predictors. Correlation analysis demonstrated a statistically significant relationship between hematoma volume and both stroke severity (measured by NIHSS) and level of functional impairment (measured by mRS). These findings underscore the value of early CT imaging not only for diagnosis but also for prognostication in acute ICH.

Conclusion. The implementation of standardized CT predictor assessment for hematoma expansion in neurovascular units can enable early identification of hemorrhagic stroke patients with a poor prognosis at the time of hospital admission.

Repeating CT imaging within the first 24 hours after symptom onset can help predict hematoma expansion or the risk of rebleeding. Evaluating CT predictors is valuable for guiding effective treatment strategies and preventing complications. Differential diagnosis plays a key role in detecting specific, often subtle, patterns on neuroimaging.

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