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Original Research Article

Evaluating the Diagnostic and Prognostic Role of CT Perfusion in Acute Ischemic Stroke within 12 Hours of Symptom Onset: A Prospective Study

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Conflict of interest: Nil

Abstract:

Background: Timely and accurate assessment of cerebral perfusion is critical in patients presenting with acute ischemic stroke. CT perfusion (CTP) imaging has emerged as a valuable tool in identifying salvageable brain tissue (penumbra) and differentiating it from irreversibly infarcted tissue (core), especially within the first 12 hours of symptom onset.

Objectives: To evaluate the role of CT perfusion in the diagnosis, management, and prognostic stratification of patients presenting with acute ischemic stroke within 12 hours of symptom onset.

Methods: A prospective observational study was conducted in the Department of Radio-Diagnosis at JLNMCH, and multicentric Hospital, Bhagalpur, Bihar, over a period of 12 months. A total of 60 patients presenting with clinical signs of acute ischemic stroke within 12 hours of onset were included. All patients underwent non-contrast CT, CT angiography, and CT perfusion imaging. CTP parameters such as cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT) were analyzed to differentiate between ischemic core and penumbra. Findings were correlated with neurological status using the NIH Stroke Scale (NIHSS) at admission and follow-up.

Results: CT perfusion imaging identified ischemic penumbra in 70% of patients, guiding the extension of thrombolysis eligibility beyond the conventional time window. A strong correlation was observed between CTP parameters and clinical severity on the NIHSS. Patients with larger penumbra volumes and smaller infarct cores showed better clinical outcomes on follow-up.

Conclusion: CT perfusion imaging plays a vital role in early assessment of acute ischemic stroke, particularly in patients presenting within 12 hours of symptom onset. It provides crucial information for identifying patients who may benefit from reperfusion therapy, even beyond traditional therapeutic windows, thereby improving clinical outcomes.

Keywords: CT Perfusion, Acute Ischemic Stroke, Penumbra, Infarct Core, Cerebral Blood Flow, Thrombolysis, NIHSS, Imaging Biomarkers, Brain Perfusion, Early Diagnosis.

Introduction

Stroke is a leading cause of death and long-term disability worldwide, with ischemic strokes accounting for approximately 85% of all cases. The outcome of an ischemic stroke is critically dependent on the time elapsed since the onset of symptoms and the extent of brain tissue affected. Traditionally, the window for effective thrombolytic treatment has been restricted to within 4.5 hours from symptom onset. However, advances in imaging technology—particularly CT perfusion (CTP) imaging—have transformed the management of acute ischemic stroke by enabling clinicians to assess the physiological status of brain tissue rather than relying solely on a rigid time-based approach [1,2].

CT perfusion imaging is a dynamic imaging technique that evaluates cerebral hemodynamics by measuring key perfusion parameters such as cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT). These parameters help to distinguish between the ischemic core—irreversibly damaged brain tissue—and the penumbra—hypoperfused but potentially salvageable tissue. This differentiation is crucial for identifying patients who are still candidates for reperfusion therapy beyond the standard time limits, especially in cases where the exact onset time is uncertain or falls outside the conventional therapeutic window [3,4].

In rural healthcare settings such as Bihar, where access to tertiary care and specialized stroke units may be delayed due to logistical and infrastructural challenges, timely imaging is vital for decision-making. JLNMCH, Bhagalpur, serves as a key diagnostic hub for the region, and this study aims to highlight the role of CT perfusion in improving stroke management in such resource-limited settings [5].

By providing real-time functional imaging, CTP allows for individualized treatment planning, which includes the possibility of extended-window thrombolysis or thrombectomy in appropriate candidates. Several large trials, such as DAWN and DEFUSE 3, have already demonstrated the benefit of perfusion-based imaging selection in acute stroke patients. However, there is a lack of region-specific data evaluating CTP utility in rural Indian populations where stroke burden is rising, and clinical decision-making tools need adaptation to the local context [6,7].

This prospective study was designed to assess the role of CT perfusion in evaluating patients with acute ischemic stroke presenting within 12 hours of symptom onset. By examining perfusion characteristics, correlating imaging with clinical severity, and evaluating short-term outcomes, this study aims to contribute to a growing body of evidence that supports a more physiology-based approach to stroke management, especially in rural and semi-urban healthcare setups.

Methods

This prospective observational study was conducted in the Department of Radio-Diagnosis, Jawaharlal Nehru Medical College and Hospital (JLNMCH) and multicentric Hospital, Bhagalpur, Bihar, India, over a period of 12 months from January 2023 to December 2023. The study aimed to assess the diagnostic and prognostic utility of CT perfusion in patients presenting with acute ischemic stroke within 12 hours of symptom onset.

A total of 60 patients with clinical suspicion of acute ischemic stroke were enrolled based on the following inclusion criteria: (1) age above 18 years, (2) presentation within 12 hours of onset of focal neurological deficits consistent with stroke, and (3) initial non-contrast CT showing no or minimal early ischemic changes. Patients were excluded if they had: (1) intracranial hemorrhage on initial CT, (2) history of recent trauma or surgery, (3) contraindications to iodinated contrast, or (4) previously diagnosed cerebrovascular disease or stroke.

All eligible patients underwent a systematic imaging protocol including non-contrast CT (NCCT), CT angiography (CTA), and CT perfusion (CTP) using a multi-detector CT scanner. CTP was performed using a standard protocol covering key regions of the brain typically involved in ischemia. Parameters such as cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and time-to-peak (TTP) were analyzed using automated software.

Ischemic core was defined as regions showing significantly reduced CBV and CBF, while penumbra was characterized by preserved CBV but prolonged MTT and TTP. The mismatch between core and penumbra was quantified to assess the extent of salvageable brain tissue. Patients were categorized into different perfusion profiles based on the size and distribution of these zones. Clinical evaluation was done using the NIH Stroke Scale (NIHSS) at the time of admission and repeated at discharge or after 7 days, whichever was earlier. Imaging findings were correlated with clinical outcomes, and patients were followed up for early neurological improvement or deterioration.

The data was analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical data were represented as frequencies and percentages. Statistical correlation between CTP parameters and NIHSS scores was evaluated using Pearson's or Spearman's correlation as applicable. A p-value < 0.05 was considered statistically significant.

This methodology allowed for a comprehensive assessment of the role of CTP in identifying patients suitable for advanced therapies and in predicting clinical prognosis based on early imaging biomarkers.

Results:

A total of 60 patients presenting with acute ischemic stroke within 12 hours of symptom onset were evaluated using CT perfusion imaging. Among them, a significant proportion showed a mismatch pattern suggestive of salvageable penumbra, which directly influenced therapeutic decisions. The results also demonstrated a strong correlation between CT perfusion parameters and clinical severity as measured by the NIHSS. Below are the detailed tabular results:

Table 1: Age and Gender Distribution of Patients

Age Group (Years)	Male (n=36)	Female (n=24)	Total (n=60)
18–30	4	2	6
31–45	6	5	11
46–60	14	9	23
>60	12	8	20

Table 2: Time to Presentation After Stroke Symptoms

Time Interval (Hours)	No. of Patients	Percentage (%)
0–3	18	30.0
>3–6	20	33.3
>6–9	14	23.3
>9–12	8	13.4

Table 3: Presenting Symptoms

Symptom	No. of Patients	Percentage (%)
Hemiparesis	46	76.7
Slurred speech	35	58.3
Facial deviation	28	46.7
Loss of consciousness	12	20.0
Giddiness	10	16.7

Table 4: Infarct Core Volume Based on CTP

Infarct Core Volume (ml)	No. of Patients	Percentage (%)
<10 ml	18	30.0
10–30 ml	25	41.7
>30 ml	17	28.3

Table 5: Penumbra Volume Distribution

Penumbra Volume (ml)	No. of Patients	Percentage (%)
<20 ml	10	16.7
20–50 ml	22	36.7
>50 ml	28	46.6

Table 6: Perfusion Mismatch Profile

Profile Type	No. of Patients	Percentage (%)
Mismatch Profile	42	70.0
Matched Profile	18	30.0

Table 7: Mean Values of CT Perfusion Parameters

Parameter	Mean ± SD
Cerebral Blood Flow (CBF)	24.5 ± 6.2 ml/100g/min
Cerebral Blood Volume (CBV)	3.2 ± 0.8 ml/100g
Mean Transit Time (MTT)	7.6 ± 2.1 sec
Time to Peak (TTP)	9.8 ± 1.9 sec

Table 8: NIHSS vs Infarct Core Volume

Infarct Core Volume (ml)	Mean NIHSS Score
<10 ml	6.4 ± 2.1
10–30 ml	10.7 ± 3.3
>30 ml	15.2 ± 4.5

Table 9: Treatment Allocation Based on CTP

Treatment Modality	No. of Patients	Percentage (%)
IV Thrombolysis	22	36.7
Mechanical Thrombectomy	10	16.7
Conservative Management	28	46.6

Table 10: Clinical Outcome by NIHSS Change

Outcome Category	No. of Patients	Percentage (%)
Significant Improvement (>4 point drop)	28	46.7
Minimal Change (1–3 points)	20	33.3
No Improvement / Worsening	12	20.0

Discussion

Acute ischemic stroke is a medical emergency that necessitates rapid diagnosis and timely intervention to preserve viable brain tissue and improve neurological outcomes. Historically, therapeutic decisions were driven primarily by the time elapsed since symptom onset, limiting intervention to a narrow window of 4.5 hours for intravenous thrombolysis [8]. However, this approach often excludes a substantial subset of patients, especially in rural areas where delayed hospital presentation is common. In this context, CT perfusion (CTP) imaging has emerged as a powerful modality that enables tissue-based, rather than time-based, assessment of stroke, helping clinicians identify patients who can still benefit from reperfusion therapy [9].

The present study, conducted over 12 months at a tertiary healthcare facility in Bhagalpur, Bihar, evaluated the role of CTP in patients presenting within 12 hours of acute stroke symptoms. The findings underscore the significant clinical utility of CTP in detecting penumbra—the potentially salvageable brain tissue—and in guiding therapeutic decisions even beyond the traditional time window.

Our data showed that a majority of patients (70%) presented with a mismatch perfusion profile, indicating the presence of a viable penumbra with a relatively small infarct core. This aligns with global studies such as DEFUSE 3 and DAWN, which demonstrated that patients with such mismatch profiles derive significant benefit from late-window thrombolysis or thrombectomy. The correlation between NIHSS scores and infarct core volume observed in our study further supports the predictive value of CTP in estimating stroke severity and prognosis. Patients with core volumes <10 ml had significantly lower NIHSS scores, whereas those with large infarct cores (>30 ml) showed markedly higher scores and poorer short-term outcomes.

A significant proportion (36.7%) of patients were administered thrombolytic therapy based on favorable CTP findings, despite presenting beyond the standard 4.5-hour window. This highlights how CTP can safely extend the therapeutic window in selected patients. Moreover, 16.7% of patients underwent mechanical thrombectomy guided by vessel occlusion on CTA and viable penumbra identified on CTP. These interventions resulted in substantial neurological improvement at 7-day follow-up, particularly among patients with lower infarct volumes and large penumbral zones [10,11,12].

CTP parameters such as mean CBF, CBV, MTT, and TTP in this study showed similar ranges to those reported in the literature, reinforcing the reproducibility and standardization of these imaging metrics across diverse patient populations. Notably, the average MTT and TTP were elevated in penumbral zones, whereas infarct cores demonstrated markedly reduced CBV and CBF. These distinct patterns allowed for accurate differentiation between irreversibly damaged and salvageable tissue [13,14].

In terms of demographic distribution, the study revealed a male predominance (60%), with the majority of strokes occurring in patients aged 46–60 years, reflecting global stroke epidemiology patterns. Hemiparesis and slurred speech were the most common presenting symptoms, consistent with large-vessel anterior circulation strokes. These clinical features further emphasized the need for detailed vascular and perfusion imaging to guide management [15,16].

One of the critical strengths of this study lies in its real-world applicability in a rural tertiary setting, where delayed presentation is a common challenge. By implementing advanced imaging protocols like CTP, we were able to bridge the gap between symptom onset and therapeutic decision-making, enabling tailored care for each patient based on their tissue viability [17,18].

However, the study does have limitations. The sample size, though adequate for a single-center study, may limit generalizability. Long-term functional outcomes beyond 7 days were not assessed, which could provide deeper insight into the prognostic utility of perfusion imaging. Additionally, factors such as collateral circulation and systemic comorbidities that influence stroke evolution were not extensively analyzed.

Despite these limitations, our findings strongly support the integration of CT perfusion imaging into standard acute stroke protocols, particularly in centers where patients often present beyond traditional treatment windows. CTP serves as a reliable, non-invasive, and informative tool for optimizing patient selection for reperfusion therapies and improving outcomes in acute ischemic stroke.

Conclusion

CT perfusion imaging plays a pivotal role in the evaluation and management of acute ischemic stroke, particularly in patients presenting beyond the conventional time window of 4.5 hours. By enabling a tissue-based approach, CT perfusion helps identify patients with significant ischemic penumbra and relatively small infarct cores who may still benefit from reperfusion therapies. In this study, a substantial number of patients exhibited favorable perfusion profiles, allowing for timely administration of thrombolytic therapy or mechanical thrombectomy, even within a 12-hour window from symptom onset.

The study also demonstrates a strong correlation between perfusion parameters—such as cerebral blood flow, volume, and transit time—and clinical severity as measured by NIHSS scores. CT perfusion not only influenced treatment decisions but also served as a prognostic marker for early neurological recovery.

Incorporating CT perfusion imaging into routine acute stroke evaluation protocols, especially in rural and semi-urban healthcare settings, can significantly enhance the precision and effectiveness of stroke care. Future studies with larger cohorts and extended follow-up periods are warranted to validate these findings and explore the long-term prognostic value of perfusion imaging in acute ischemic stroke.

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