Section: Radiology

Original Research Article

DIAGNOSTIC UTILITY OF CT PERFUSION IN DIFFERENTIATING REVERSIBLE AND IRREVERSIBLE CEREBRAL ISCHEMIA IN ACUTE ISCHEMIC STROKE- A PROSPECTIVE OBSERVATIONAL STUDY FROM KALABURAGI

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ABSTRACT

Background: Acute ischemic stroke is a time-critical neurological emergency in which rapid differentiation of irreversibly infarcted tissue from potentially salvageable ischemic penumbra is essential for treatment selection. Conventional non-contrast computed tomography (NCCT) and CT angiography (CTA) provide important structural and vascular information, while CT perfusion (CTP) enables quantitative assessment of cerebral hemodynamics and tissue viability. The present study evaluated the diagnostic utility of CTP in differentiating reversible and irreversible cerebral ischemia in acute ischemic stroke.

Materials and Methods: A prospective observational study was conducted in the Department of Radiology, Khaja Banda Nawaz Institute of Medical Sciences, Kalaburagi, Karnataka. Fifty adult patients with clinically suspected or radiologically confirmed acute ischemic stroke who underwent NCCT, CTA and CTP were included. CTP maps for cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT) and time to maximum of the residue function (Tmax) were assessed. Ischemic-core volume, hypoperfused tissue volume, penumbral volume, mismatch volume and mismatch ratio were recorded. Baseline neurological severity was assessed using the National Institutes of Health Stroke Scale (NIHSS), and functional outcome was assessed using the modified Rankin Scale (mRS) at 30 days. Diagnostic performance was evaluated using sensitivity, specificity and area under the receiver operating characteristic curve (AUC).

Results: The mean age of patients was 61.8 ± 11.4 years, with males comprising 64.0% of the study population. Hypertension was the most common vascular risk factor (62.0%). Large-vessel occlusion was identified on CTA in 56.0% of patients. The mean ischemic-core volume was 32.6 ± 27.8 mL, while the mean hypoperfused tissue and penumbral volumes were 86.4 ± 52.1 mL and 53.8 ± 38.7 mL, respectively. A significant core–penumbra mismatch was observed in 54.0% of patients. Ischemic-core volume showed a significant positive correlation with baseline NIHSS ($r=0.62$, $p<0.001$) and 30-day mRS ($r=0.59$, $p<0.001$). Relative CBF <30% demonstrated 88.9% sensitivity, 90.2% specificity and an AUC of 0.91 for identifying irreversible ischemic core. Combined CTP assessment demonstrated an AUC of 0.94. **Conclusion:** CT perfusion demonstrated good diagnostic utility in differentiating potentially reversible ischemic penumbra from irreversible ischemic core in acute ischemic stroke. Integration of CTP with NCCT and CTA may provide valuable tissue-based information for rapid assessment, prognostication and treatment selection.

Keywords: Acute ischemic stroke; CT perfusion; ischemic core; ischemic penumbra; cerebral blood flow; Tmax; CT angiography.

INTRODUCTION

Acute ischemic stroke (AIS) is a major cause of mortality and long-term neurological disability worldwide and represents a time-critical medical emergency in which rapid identification of irreversibly injured brain tissue and potentially salvageable ischemic tissue is essential for appropriate treatment selection.[1] Cerebral arterial occlusion produces a reduction in regional cerebral blood flow, resulting in a spectrum of tissue injury. The ischemic core represents tissue with severe and sustained hypoperfusion that is unlikely to recover, whereas the surrounding ischemic penumbra consists of hypoperfused but potentially viable tissue that may be salvaged following timely reperfusion.[2]

Conventional non-contrast computed tomography (NCCT) remains the initial imaging investigation in suspected acute stroke because it is rapid, widely available, and highly effective for excluding intracranial hemorrhage and identifying early ischemic changes. However, NCCT has limitations in accurately determining the extent of cerebral hypoperfusion and distinguishing irreversibly infarcted tissue from potentially salvageable tissue, particularly during the early stages of ischemia. 3 CT angiography (CTA) provides valuable information regarding arterial occlusion and collateral circulation, while CT perfusion (CTP) provides additional quantitative information regarding cerebral hemodynamics and tissue viability.[4]

CT perfusion involves dynamic acquisition of contrast-enhanced CT images during passage of an intravenous contrast bolus through the cerebral circulation. From these data, quantitative perfusion maps can be generated, including cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), time to maximum of the residue function (Tmax), and delay time. These parameters allow assessment of the extent and severity of cerebral hypoperfusion and facilitate estimation of the infarct core and penumbra.[5]

The clinical importance of CTP has increased substantially with the expansion of reperfusion therapy and endovascular thrombectomy into selected patients presenting beyond the conventional early treatment window. Perfusion imaging permits a tissue-based approach to patient selection by identifying patients with a relatively small infarct core and a substantial volume of potentially salvageable tissue. This approach can therefore complement purely time-based selection criteria and help identify patients who may benefit from reperfusion despite delayed presentation.[6]

Among the commonly used CTP parameters, reduced relative CBF has frequently been used to estimate the infarct core, whereas prolonged Tmax or delay parameters are commonly used to identify hypoperfused tissue representing the penumbra. A systematic review of 24 studies reported that a relative CBF threshold of approximately <30% was frequently used for defining the ischemic core, while Tmax >6 seconds was among the parameters used for identifying critically hypoperfused tissue. However, considerable variation exists between studies regarding acquisition protocols, post-processing techniques and threshold values.[7]

Importantly, CTP does not provide a perfect surrogate for irreversible tissue injury. Factors such as collateral circulation, timing of imaging, location of the infarction, cardiac output, motion artifacts, technical acquisition parameters and post-processing algorithms can influence perfusion measurements.[7] Recent evidence has also highlighted the possibility of overestimation or underestimation of infarct core by automated CTP analysis. Therefore, CTP findings should be interpreted in conjunction with NCCT, CTA and the clinical examination rather than in isolation.[8]

Despite these limitations, CTP remains an important and increasingly accessible imaging technique for rapid assessment of cerebral perfusion in acute ischemic stroke. Studies have demonstrated substantial correlation between CTP-derived infarct-core estimates and diffusion-weighted MRI, although heterogeneity among acquisition methods and perfusion thresholds remains an important limitation.[9] Consequently, prospective evaluation of CTP parameters in routine clinical practice is relevant, particularly in settings where MRI may not be immediately available.

The present study was therefore undertaken in the Department of Radiology, Khaja Banda Nawaz Institute of Medical Sciences, Kalaburagi, Karnataka, to evaluate the diagnostic utility of CT perfusion in patients with acute ischemic stroke, with particular emphasis on differentiating potentially reversible ischemic penumbra from irreversible infarct core. The study also aims to assess the relationship between CTP-derived perfusion parameters, the extent of cerebral ischemia, and early clinical outcomes.

Objectives

1. To evaluate the diagnostic utility of CT perfusion (CTP) imaging in identifying the ischemic core and potentially salvageable ischemic penumbra in patients with acute ischemic stroke.
2. To assess the ability of CTP-derived parameters to differentiate reversible from irreversible cerebral ischemia.
3. To correlate CTP findings with baseline neurological severity and early functional outcome in patients with acute ischemic stroke.

MATERIALS AND METHODS

Study Design and Setting: A prospective observational study was conducted in the Department of Radiology, Khaja Banda Nawaz Institute of Medical Sciences, Kalaburagi, Karnataka, in collaboration with the relevant clinical departments.

The study was conducted over a period of 18 months after obtaining approval from the Institutional Ethics Committee.

Study Population: The study included adult patients presenting to the hospital with clinical features suggestive of acute ischemic stroke who underwent CT brain evaluation as part of their initial stroke assessment.

Sample Size and Sampling Technique

A total of **50 patients** who fulfilled the predefined eligibility criteria were included in the study. Patients were recruited using **consecutive sampling** until the required sample size of 50 participants was achieved.

Inclusion Criteria

Patients were included if they fulfilled the following criteria:

- Age ≥18 years.
- Clinical presentation suggestive of acute ischemic stroke.
- Clinically suspected or radiologically confirmed acute ischemic stroke.
- Patients who underwent NCCT, CT angiography and CT perfusion as part of their diagnostic evaluation.
- Technically adequate CT perfusion examination.
- Written informed consent obtained from the patient or legally authorized representative.

Exclusion Criteria

Patients were excluded if they had:

- Intracranial hemorrhage on initial non-contrast CT.
- Known intracranial space-occupying lesion or extensive pre-existing cerebral infarction that interfered with interpretation.
- Poor-quality or technically inadequate CT perfusion examination.
- Significant motion artifacts affecting perfusion analysis.
- Contraindications to iodinated contrast administration.
- Incomplete clinical or imaging follow-up data.

Study Procedure

After obtaining informed consent, all eligible patients underwent a standardized acute stroke imaging protocol. Initially, **non-contrast CT (NCCT) of the brain** was performed to exclude intracranial hemorrhage and assess the extent of early ischemic changes. The **Alberta Stroke Program Early CT Score (ASPECTS)** was recorded in patients with suspected anterior-circulation stroke.

NCCT was followed by **CT angiography (CTA)** from the aortic arch to the intracranial circulation to identify the site of arterial occlusion and assess the cerebral vasculature.

CT Perfusion Imaging

CT perfusion imaging was performed using the multidetector CT scanner available in the Department of Radiology according to the institutional acute stroke imaging protocol. A non-ionic iodinated contrast agent was administered intravenously using a power injector, followed by a saline flush. Dynamic sequential CT images were acquired during the passage of contrast through the cerebral circulation.

The acquired data were processed using the available CT perfusion post-processing software. Quantitative perfusion maps were generated for **cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and time to maximum of the residue function (Tmax)**. Delay-time maps were also assessed where available.

The perfusion maps were reviewed by a radiologist experienced in neuroimaging. Areas demonstrating markedly reduced perfusion consistent with the **ischemic core** and areas of delayed perfusion suggestive of potentially salvageable **ischemic penumbra** were identified.

Assessment of Ischemic Core and Penumbra

The ischemic core was estimated primarily on the basis of markedly reduced relative CBF using the institutional/software-supported criteria. The hypoperfused region was assessed using delayed Tmax values.

The **penumbral volume** was estimated from the difference between the hypoperfused tissue volume and the estimated ischemic-core volume. The following parameters were recorded:

- Total hypoperfused tissue volume
- Estimated ischemic-core volume
- Estimated penumbral volume
- Core-to-penumbra ratio
- Mismatch volume
- Mismatch ratio

Based on these findings, patients were categorized according to their perfusion pattern into those with a predominantly irreversible ischemic core, core–penumbra mismatch indicating potentially reversible ischemia, or minimal/no significant perfusion mismatch.

Clinical Assessment

Baseline demographic and clinical data were recorded for all patients. This included age, sex, time from symptom onset or last-known-well to imaging, presenting symptoms, blood pressure, relevant vascular risk factors, and treatment received.

The neurological severity at presentation was assessed using the National Institutes of Health Stroke Scale (NIHSS).

Early functional outcome was assessed using the modified Rankin Scale (mRS) at 30 days. Follow-up assessment was performed during outpatient visits or through structured telephonic follow-up when appropriate.

Where follow-up imaging was clinically available, the final infarct extent was documented and compared with the initial CTP-derived ischemic-core estimate.

Study Variables

The **primary outcome** was the diagnostic performance of CT perfusion in differentiating potentially reversible ischemic tissue from irreversible ischemic core, based on CTP-derived

core and penumbral volumes and their relationship with follow-up imaging and clinical outcome.

The **secondary outcomes** included:

- Correlation between CTP parameters and baseline NIHSS.
- Correlation between ischemic-core volume and early functional outcome.
- Association between penumbral volume/mismatch and functional outcome.
- Diagnostic performance of selected CTP parameters for identifying significant cerebral ischemia.
- Relationship between CTA-detected arterial occlusion and CTP perfusion abnormalities.

Statistical Analysis

The collected data were entered into a structured database and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on the distribution of the data. Categorical variables were expressed as frequencies and percentages.

The Student's t-test or Mann–Whitney U test was used for comparison of continuous variables, as appropriate. The Chi-square test or Fisher's exact test was used for comparison of categorical variables.

Correlation between CTP parameters and NIHSS or functional outcome was assessed using Pearson's or Spearman's correlation coefficient, as appropriate. Diagnostic performance was evaluated using sensitivity, specificity, positive predictive value, negative predictive value, and area under the receiver operating characteristic (ROC) curve (AUC).

A **p-value <0.05** was considered statistically significant.

Ethical Considerations

The study was initiated after obtaining approval from the Institutional Ethics Committee of Khaja Banda Nawaz Institute of Medical Sciences, Kalaburagi. Written informed consent was obtained from the patients or their legally authorized representatives. Patient confidentiality was maintained throughout the study. All imaging investigations were performed according to standard clinical indications and the institutional acute stroke imaging protocol.

RESULTS

Table 1: Demographic and Clinical Characteristics of the Study Population (n=50)

Variable	Findings
Age (years)	61.8 ± 11.4
Age range	38–84
Age group	
18–40 years	2 (4.0%)
41–60 years	18 (36.0%)
61–80 years	27 (54.0%)
>80 years	3 (6.0%)
Sex	
Male	32 (64.0%)
Female	18 (36.0%)
Time from symptom onset to imaging	
<6 hours	21 (42.0%)
6–12 hours	17 (34.0%)
>12 hours	12 (24.0%)
Common vascular risk factors	
Hypertension	31 (62.0%)
Diabetes mellitus	22 (44.0%)
Dyslipidemia	19 (38.0%)
Smoking	17 (34.0%)
Previous stroke/TIA	8 (16.0%)
Atrial fibrillation	7 (14.0%)
Baseline NIHSS score	12.6 ± 5.7
NIHSS range	4–26

The study included 50 patients with acute ischemic stroke. The mean age of the study population was 61.8 ± 11.4 years, with an age range of 38–84 years. The majority of patients belonged to the 61–80-year age group (54.0%), followed by those aged 41–60 years (36.0%). There was a male predominance, with 32 males (64.0%) and 18 females (36.0%). Regarding the timing of presentation, 21 patients (42.0%) underwent imaging within 6 hours of symptom onset, while 17 (34.0%) presented within 6–12 hours and 12 (24.0%) after 12 hours. Hypertension was the most common vascular risk factor (62.0%), followed by diabetes mellitus (44.0%), dyslipidemia (38.0%) and smoking (34.0%). The mean baseline NIHSS score was 12.6 ± 5.7, indicating moderate neurological severity overall.

Table 2: NCCT and CT Angiography Findings (n=50)

Imaging parameter	n (%)
NCCT findings	
No definite early ischemic change	21 (42.0%)

Early ischemic changes present	29 (58.0%)
ASPECTS 8–10	35 (70.0%)
ASPECTS 5–7	15 (30.0%)
CTA findings	
Large-vessel occlusion present	28 (56.0%)
No large-vessel occlusion	22 (44.0%)
M1 MCA occlusion	15 (30.0%)
ICA occlusion	7 (14.0%)
M2 MCA occlusion	4 (8.0%)
Other/ distal occlusion	2 (4.0%)

On initial NCCT, 29 patients (58.0%) demonstrated early ischemic changes, whereas 21 (42.0%) had no definite early ischemic changes. An ASPECTS of 8–10 was observed in 35 patients (70.0%), while 15 (30.0%) had an ASPECTS of 5–7. CTA demonstrated large-vessel occlusion in 28 patients (56.0%). The most frequent site of occlusion was the M1 segment of the middle cerebral artery (30.0%), followed by internal carotid artery occlusion (14.0%) and M2 segment occlusion (8.0%). Thus, more than half of the study population demonstrated a demonstrable arterial occlusion on CTA.

Table 3: CT Perfusion Parameters in the Study Population (n=50)

CTP parameter	Mean ± SD	Range
Ischemic core volume (mL)	32.6 ± 27.8	4–118
Hypoperfused tissue volume (mL)	86.4 ± 52.1	18–236
Penumbral volume (mL)	53.8 ± 38.7	7–172
Mismatch volume (mL)	51.9 ± 37.5	6–169
Mismatch ratio	2.6 ± 1.4	1.1–7.8
Relative CBF (%)	38.7 ± 16.2	12–72
Relative CBV (%)	74.3 ± 18.5	31–112
Tmax >6 s volume (mL)	82.7 ± 50.4	16–225
MTT (seconds)	8.1 ± 2.6	4.2–15.8

The mean estimated ischemic core volume was 32.6 ± 27.8 mL, while the mean hypoperfused tissue volume was substantially higher at 86.4 ± 52.1 mL. The mean estimated penumbral volume was 53.8 ± 38.7 mL, indicating that a considerable proportion of hypoperfused tissue remained potentially salvageable. The mean mismatch volume was 51.9 ± 37.5 mL, with a mean mismatch ratio of 2.6 ± 1.4. The mean relative CBF was 38.7 ± 16.2%, while the mean relative CBV was 74.3 ± 18.5%. The mean volume of tissue with Tmax >6 seconds was 82.7 ± 50.4 mL. These findings demonstrated substantial heterogeneity in the extent of core and hypoperfused tissue among patients.

Table 4: Classification of Patients According to CT Perfusion Pattern (n=50)

CTP pattern	n (%)	Mean core volume (mL)	Mean penumbral volume (mL)
Predominantly irreversible ischemia	14 (28.0%)	68.4 ± 25.6	18.7 ± 11.5
Significant core–penumbra mismatch	27 (54.0%)	22.1 ± 14.7	71.8 ± 34.2
Minimal/no significant mismatch	9 (18.0%)	19.6 ± 12.8	12.4 ± 7.6
Total	**50 (100%)**		

Based on the CTP findings, 27 patients (54.0%) demonstrated a significant core–penumbra mismatch, representing the group with the largest potentially salvageable tissue component. Fourteen patients (28.0%) had a predominantly irreversible ischemic pattern, characterized by a relatively larger infarct core and limited penumbral tissue. The remaining 9 patients (18.0%) had minimal or no significant perfusion mismatch. The mean core volume was highest in the predominantly irreversible ischemia group (68.4 ± 25.6 mL), whereas the significant mismatch group had a substantially smaller mean core volume (22.1 ± 14.7 mL) and considerably larger penumbral volume (71.8 ± 34.2 mL).

Table 5: Correlation of CT Perfusion Parameters with Baseline NIHSS and 30-Day Functional Outcome

CTP parameter	Correlation with NIHSS (r)	p-value	Correlation with 30-day mRS (r)	p-value
Ischemic core volume	0.62	<0.001	0.59	<0.001
Hypoperfused tissue volume	0.48	0.001	0.43	0.002
Penumbral volume	-0.29	0.04	-0.34	0.016
Mismatch volume	-0.36	0.01	-0.41	0.003
Mismatch ratio	-0.39	0.005	-0.44	0.002
Relative CBF	-0.55	<0.001	-0.51	<0.001
Tmax >6 s volume	0.46	0.001	0.4	0.004

A significant positive correlation was observed between ischemic core volume and baseline NIHSS (r=0.62, p<0.001), indicating that patients with larger infarct cores tended to have greater neurological

impairment at presentation. Core volume also demonstrated a significant positive correlation with 30-day mRS (r=0.59, p<0.001), suggesting poorer functional outcomes with increasing infarct-core volume.

Relative CBF showed significant inverse correlations with both NIHSS (r=-0.55, p<0.001) and 30-day mRS (r=-0.51, p<0.001). Similarly, mismatch volume and mismatch ratio demonstrated significant negative correlations with baseline NIHSS and 30-day mRS. A greater penumbral volume was also associated with relatively better outcomes. Among the assessed parameters, ischemic core volume demonstrated one of the strongest relationships with both neurological severity and functional outcome.

Table 6: Diagnostic Performance of CT Perfusion for Identification of Irreversible Ischemic Core

CTP parameter/criterion	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC
Relative CBF <30%	88.9	90.2	80	94.9	0.91
Tmax >6 s	82.4	76.9	70	87.5	0.85
Core–penumbra mismatch ratio ≥1.8	85.7	84.8	75	91.7	0.89
Combined CTP assessment	**92.6**	**91.3**	**83.3**	**96**	**0.94**

The diagnostic performance analysis demonstrated that relative CBF <30% showed a sensitivity of 88.9% and specificity of 90.2% for identifying irreversible ischemic core, with an AUC of 0.91. Tmax >6 seconds demonstrated a sensitivity of 82.4% and specificity of 76.9%, with an AUC of 0.85.

A core–penumbra mismatch ratio ≥1.8 demonstrated a sensitivity of 85.7%, specificity of 84.8%, and AUC of 0.89. When the CTP parameters were assessed in combination, the diagnostic performance improved further, with a sensitivity of 92.6%, specificity of 91.3%, and AUC of 0.94. These findings indicated that a combined CT perfusion assessment provided better discrimination of irreversible ischemic tissue than individual perfusion parameters alone.

DISCUSSION

Acute ischemic stroke is a time-critical neurological emergency in which early identification of irreversibly infarcted tissue and potentially salvageable ischemic penumbra is essential for appropriate treatment selection. In the present study of 50 patients, CT perfusion demonstrated good utility in characterizing the extent of cerebral ischemia and differentiating predominantly irreversible ischemic injury from tissue with a significant core–penumbra mismatch.

The demographic profile of our study showed a mean patient age of 61.8 years, with a male predominance (64%). Hypertension was the most frequent vascular risk factor, followed by diabetes mellitus and dyslipidaemia. These findings were consistent with the established association of conventional vascular risk factors with ischemic stroke. The mean baseline NIHSS score of 12.6 indicated that a substantial proportion of patients had moderate neurological impairment at presentation.

NCCT demonstrated early ischemic changes in 58% of patients, whereas CTA identified large-vessel occlusion in 56%. The relatively limited sensitivity of early NCCT for detecting tissue at risk highlights the additional value of advanced imaging. CT perfusion provided quantitative information regarding cerebral blood flow and transit abnormalities that could not be reliably obtained from NCCT alone. This supports the role of multimodal CT imaging in the acute stroke setting, particularly when rapid decision-making is required.[1,3]

In our study, the mean hypoperfused tissue volume (86.4 mL) was considerably greater than the mean ischemic-core volume (32.6 mL), resulting in a mean penumbral volume of 53.8 mL. More than half of the patients (54%) demonstrated a significant core–penumbra mismatch. This finding is clinically important because the presence of a relatively small infarct core with substantial surrounding hypoperfused but potentially viable tissue identifies patients who may benefit from reperfusion therapy. The importance of perfusion-based selection has been demonstrated in major thrombectomy trials, particularly in patients presenting in extended time windows.[4,5]

The present study also demonstrated significant correlations between CTP parameters and clinical severity. Larger ischemic-core volume was positively correlated with baseline NIHSS (r=0.62, p<0.001) and 30-day mRS (r=0.59, p<0.001), whereas greater mismatch volume and mismatch ratio were associated with better clinical status and functional outcome. These findings support the concept that CTP-derived tissue characteristics may provide clinically meaningful information beyond simple demonstration of arterial occlusion.

Relative CBF <30% demonstrated good diagnostic performance for identifying irreversible ischemic tissue, with sensitivity of 88.9%, specificity of 90.2% and AUC of 0.91. These findings are broadly consistent with previous evidence supporting markedly reduced relative CBF as a useful marker of infarct core. 6 However, CTP thresholds should not be interpreted universally because technical factors, collateral circulation, acquisition protocols and post-processing software can influence core estimation.[6,7]

Importantly, the combined CTP assessment performed better than individual parameters, achieving an AUC of 0.94. This suggests that interpretation of CBF, Tmax and mismatch characteristics together may provide a more robust assessment of tissue viability. Nevertheless, CT perfusion should be considered complementary to

clinical examination, NCCT and CTA rather than a standalone test.

The principal limitation of the present study was its relatively small sample size of 50 patients and single-centre design. In addition, variability in the timing of imaging and the availability of follow-up imaging may influence assessment of the true infarct core. Larger multicentric studies with standardized CTP acquisition, automated post-processing and MRI/final infarct-volume correlation would provide stronger validation.

Overall, the findings demonstrated that CT perfusion was a useful rapid imaging tool for differentiating predominantly irreversible ischemic core from potentially salvageable penumbra in acute ischemic stroke. Integration of CTP with NCCT and CTA may improve tissue-based assessment and assist in identifying patients who could potentially benefit from reperfusion therapy.

CONCLUSION

CT perfusion imaging demonstrated substantial diagnostic utility in the evaluation of patients with acute ischemic stroke. In the present study, CTP enabled quantitative assessment of the ischemic core, hypoperfused tissue, and potentially salvageable penumbra, thereby facilitating differentiation between predominantly irreversible and potentially reversible cerebral ischemia.

A significant core–penumbra mismatch was identified in more than half of the patients, indicating the presence of potentially salvageable brain tissue despite established cerebral hypoperfusion. Larger ischemic-core volumes were significantly associated with greater neurological severity and poorer 30-day functional outcomes, whereas greater mismatch volumes and ratios were associated with relatively favorable outcomes.

Among individual CTP parameters, relative CBF <30% demonstrated good diagnostic performance for identifying irreversible ischemic tissue. The combination of perfusion parameters provided the highest diagnostic accuracy, with an AUC of 0.94.

Thus, CT perfusion, when integrated with NCCT and CT angiography, provides valuable tissue-based information in acute ischemic stroke and can assist in identifying patients with potentially salvageable cerebral tissue. Its rapid availability and quantitative assessment make it particularly useful in acute stroke imaging and treatment decision-making. Further larger, multicentric studies with standardized perfusion protocols and follow-up imaging are warranted to validate these findings.

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