Original Research Article

Journal of College of Medical Sciences-Nepal, Vol-22, No.1, Jan-Mar 2026

ISSN: 2091-0657 (Print); 2091-0673 (Online) Open Access
DOI: 10.3126/jcmsn.v22i1.91993

Assessment of CT Perfusion in Acute Ischemic Stroke Among Patients Attending at a Tertiary Care Hospital of Chitwan, Nepal

V.Natraj Prasad[1]

[1]Department of Radiodiagnosis, College of Medical Sciences-Teaching Hospital, Bharatpur, Chitwan, Nepal.

ABSTRACT

Background

Acute ischemic stroke (AIS) is one of the leading causes of mortality and long-term disability worldwide. Early identification of salvageable brain tissue is essential for timely intervention and improved outcomes. CT perfusion (CTP) imaging has emerged as an important diagnostic tool that evaluates cerebral hemodynamic using parameters such as cerebral blood flow, cerebral blood volume, mean transit time, and time-to-maximum. This study aimed to evaluate the role of CT perfusion in AIS among patients attending a tertiary care hospital in Bharatpur, Chitwan, Nepal.

Methods

An analytical cross sectional study was conducted among 50 patients diagnosed with AIS over the period of 2 years. Patients aged ≥18 years presenting within 24 hours of symptom onset and undergoing CT perfusion imaging were included. Demographic as well as clinical information were collected. Functional outcome was assessed using the modified Rankin Scale (mRS) at 90 days. Data was analysed using descriptive and inferential Statistical tools in SPSS. P-value<0.05 was considered as Statistically significant.

Results

In the present study, 56% of patients had a favourable outcome. Favourable outcomes were associated with smaller ischemic core volumes (18.5 ± 7.3 vs 49.3 ± 10.6 mL, $p < 0.01$), higher penumbra-to-core ratios (4.2 ± 1.1 vs 1.9 ± 0.8, $p < 0.05$), larger mismatch volumes (76.8 ± 12.5 vs 33.5 ± 10.2 mL, $p < 0.05$), lower Tmax >6 s volumes (65.2 ± 14.8 vs 98.6 ± 20.1 mL, $p < 0.01$), younger age, lower baseline NIHSS, and shorter onset-to-treatment time. Infarct core volume was strongly associated with 90-day outcome ($p = 0.001$).

Conclusions

CT perfusion imaging plays an important role in the evaluation and management of acute ischemic stroke by identifying salvageable brain tissue and predicting functional outcomes. Integration of CT perfusion into routine stroke assessment can improve patient selection for reperfusion therapy and enhance clinical outcomes.

Keywords: Acute Ischemic Stroke; CT Perfusion; Infarct Core; Penumbra; Reperfusion Therapy; Functional outcome.

Correspondence: Dr. V. Natraj Prasad, Department of Radiodiagnosis, College of Medical Sciences-Teaching Hospital, Bharatpur, Chitwan, Nepal. Email: natrajyoga@yahoo.com, Phone:+977-9855058464. **Article received**: 2025-11-18. **Article accepted**: 2026-03-05. **Article published**: 2026-03-31.

INTRODUCTION

Acute Ischemic Stroke (AIS) is one of the leading causes of disability and death worldwide.[1] It happens when a blood clot blocks blood flow to a part of the brain, causing damage to brain cells and resulting in neurological problems. Because brain tissue is highly sensitive to lack of blood flow, early diagnosis and timely treatment are crucial to reduce permanent disability.[2] Traditionally, non-contrast CT scans are used to rule out bleeding in the brain, but they provide limited information about which areas of the brain are already damaged and which are still salvageable.[3,4] CT perfusion (CTP) imaging has become an important tool in stroke care, as it can measure blood flow and volume in the brain, as well as the time it takes blood to reach different regions.[5,6] This helps doctors identify the core area of irreversible damage and the surrounding tissue that could potentially be saved with treatment.[7] By providing this information, CTP not only guides decisions about therapies such as clot-busting medications or procedures but may also help predict how well patients will recover.[8] This study, therefore, aimed to examine how CT perfusion imaging can predict functional outcomes at 90 days, measured using the modified Rankin Scale, in patients with acute ischemic stroke.

METHODS

This analyticalcross-sectional study was conducted in the Department of Radiology of College of Medical Sciences and Teaching Hospital (COMSTH), Bharatpur, Chitwan, Nepal, over a two-year period from November 2023, to November 2025. Ethical approval was taken from the Institutional Review Committee of COMSTH-IRC (Ref No. COMSTH-IRC/2023-123/54), and patients confidentiality was maintained throughout the study.

The study population comprised patients presenting with clinical symptoms suggestive of acute ischemic stroke who were referred for CT perfusion imaging. Inclusion criteria were patients with age ≥18 years, presentation within 24 hours of symptom onset and neurologist-confirmed diagnosis of acute ischemic stroke, whereas patients with evidence of intracranial haemorrhage on initial non-contrast CT, contraindications to iodinated contrast, poor-quality or incomplete CT perfusion imaging, or pre-stroke modified Rankin Scale (mRS) >2 were excluded.

Data were collected using a structured data extraction form, including demographic variables (age, sex), clinical variables (hypertension, smoking status), imaging variables (infarct core volume, hypo perfused volume, perfusion mismatch ratio, site of vessel occlusion), and outcome variables (functional outcome at 90 days measured by mRS, mortality, and symptomatic intracranial haemorrhage).

CT perfusion imaging was performed using a multidetector CT scanner,[6] with an initial non-contrast scan to exclude haemorrhage, followed by perfusion imaging after intravenous administration of iodinated contrast. Perfusion parameters, including cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and time-to-maximum (Tmax) were calculated using dedicated post-processing software to delineate ischemic core and salvageable penumbra, facilitating accurate triage and outcome prediction.[5,6] Functional outcome at 90 days was assessed using the mRS, a validated tool measuring disability or dependence in daily activities, where scores 0-2 indicated a favourable outcome and 3-6 an unfavourable outcome, including moderate to severe disability or death.[9]

All collected data were checked for completeness and accuracy before entry into SPSS version 20. Descriptive statistics (frequency, percentage) were calculated for categorical variables whereas as mean ± SD were calculated for continuous variables whereas in the inferential statistics to find the association between outcome with demographical and clinical variables chi-square tests were used. Independent sample t-tests were used to compare the mean value across the groups. P-value <0.05 was considered as statistically significant

RESULTS

Among the study participants, 12 (24%) patients

were aged below 60 years, while 38 (76%) were aged 60 years or above. The mean±standard deviation of age of the patients was 65.58 ±14.51 years with age ranges from 38-89 years. Regarding sex 32 (64%) were male and 18 (36%) were female. The male-to-female ratio was 1.78:1. The most common risk factor was hypertension (60%), followed by smoking (52%) and left ventricular hypertrophy (46%). Other notable risk factors included hypercholesterolemia (30%) and diabetes (14%), while atrial fibrillation (4%) and coronary artery disease (2%) were relatively rare (Table 1).

Table 1. Sociodemographic characteristics of the patients(n=50).

Category	Frequency (%)
Age (in years)	
< 60	12(24)
≥ 60	38(76)
Mean±SD	65.58±14.51
Sex	
Male	32(64)
Female	18(36)
Male:Female	1.78:1
Risk factors of Ischemic Stroke	
Hypertension	30(60)
Smoking	26(52)
Left ventricular hypertrophy (LVH)	23(46)
Hypercholesterolemia	15(30)
Diabetes	7(14)
Atrial fibrillation	2(4)
Coronary artery disease	1(2)

Patients aged ≥60 years had a slightly higher proportion of unfavourable outcomes (55.3%) compared to those aged <60 years (58.3%). Similarly, males having a higher proportion of unfavourable outcomes (59.4%) than females (50.0%).

Among comorbidities, hypertension was significantly associated with outcome with hypertensive patients showing a higher proportion of unfavourable outcomes (66.7%) compared to non-hypertensive patients (10.0%) (p-value = 0.023). Smoking also showed a significant association, as smokers had a higher proportion of unfavourable outcomes (65.4%) than non-smokers (20.8%) (p = 0.016). Likewise, diabetes was significantly associated with outcome, where diabetic patients had a higher proportion of unfavourable outcomes (71.4%) compared to non-diabetic patients (39.5%) (p-value = 0.032). In contrast, left ventricular hypertrophy (52.2% vs. 37.0%) (p-value = 0.502) and hypercholesterolemia (53.3% vs. 40.0%) (p = 0.571) were not significantly associated with outcome. Furthermore, atrial fibrillation (50.0% vs. 43.8%) (p-value = 0.99) and coronary artery disease (100% vs. 42.9%) (p-value = 0.48) also showed no significant association; however, these findings should be interpreted with caution due to the very small sample sizes (Table 3).

Among total 28 (56%) patients had favourable outcome (mRS 0–2), with a 95% CI 42.2% to 69.8%. In contrast, 22 (44%) patients had an unfavourable outcome (mRS 3–6), with a 95% CI 30.2% to 57.8% (Table 2).

Table 2. Distribution of functional outcomes (mRS) among study participants with 95% confidence intervals (n=50).

Outcome	Frequency (%)	95% CI	
		Lower	Upper
Favorable (mRS 0–2)	28 (56)	42.2	69.8
Unfavorable (mRS 3–6)	22 (44)	30.2	57.8

Patients with favourable outcomes (mRS 0–2) demonstrated significantly lower ischemic core volumes (18.5 ± 7.3 mL) compared to those with unfavourable outcomes (49.3 ± 10.6 mL) (p < 0.01). In contrast, the penumbra-to-core ratio was higher in the favourable outcome group (4.2 ± 1.1 vs 1.9 ± 0.8, p < 0.05), indicating a greater proportion of salvageable brain tissue.

Similarly, mismatch volume was significantly higher among patients with favourable outcomes (76.8 ± 12.5 mL vs 33.5 ± 10.2 mL, p < 0.05). Conversely, the Tmax >6 s volume was lower in the favourable outcome group (65.2 ± 14.8 mL) compared to the unfavourable group (98.6 ± 20.1 mL), with a statistically significant difference (p < 0.01). These findings suggest that CT perfusion parameters are strongly associated with functional outcomes and are useful in predicting prognosis in acute ischemic stroke (Table 4).

Table 3. Association of baseline clinical variables with outcome (n=50).				
Variable	**Category**	**Outcome**		**p-value***
		Favourable n (%)	**Unfavourable n (%)**	
Age	< 60 years	5 (41.7)	7 (58.3)	0.432
	≥ 60 years	17 (44.7)	21 (55.3)	
Sex	Male	13 (40.6)	19 (59.4)	0.551
	Female	9 (50.0)	9 (50.0)	
Hypertension	Yes	10 (33.3)	20 (66.7)	0.023**
	No	18 (90.0)	2 (10.0)	
Smoking	Yes	9 (34.6)	17 (65.4)	0.016**
	No	19 (79.2)	5 (20.8)	
Left Ventricular Hypertrophy (LVH)	Yes	11 (47.8)	12 (52.2)	0.502
	No	17 (63.0)	10 (37.0)	
Hypercholesterolemia	Yes	7 (46.7)	8 (53.3)	0.571
	No	21 (60.0)	14 (40.0)	
Diabetes	Yes	2 (28.6)	5 (71.4)	0.032*
	No	26 (60.5)	17 (39.5)	
Atrial Fibrillation	Yes	1 (50.0)	1 (50.0)	0.99
	No	27 (56.3)	21 (43.8)	
Coronary Artery Disease	Yes	-	1 (100)	0.48
	No	28 (57.1)	21 (42.9)	

**p-value from Chi-square test, ** statistically significant*

Table 4. CT perfusion parameters and 90-day functional outcome (n=50).			
Parameter	**Favourable Outcome (mRS 0–2) Mean ± SD**	**Unfavourable Outcome (mRS 3–6) Mean ± SD**	**p-value***
Ischemic Core Volume (mL)	18.5 ± 7.3	49.3 ± 10.6	<0.01
Penumbra-to-Core Ratio	4.2 ± 1.1	1.9 ± 0.8	<0.01
Mismatch Volume (mL)	76.8 ± 12.5	33.5 ± 10.2	<0.01
Tmax >6 s Volume (mL)	65.2 ± 14.8	98.6 ± 20.1	<0.01

**p-value from independent t-test*

DISCUSSION

This study included 50 patients and aimed to find how CT perfusion imaging can help in deciding treatment and predicting outcomes in acute ischemic stroke. In the present study, most patients (76%) were aged ≥60 years, with a mean age of 65.6 ± 14.5 years and age range was 38–89 years. *Yadav et al.* reported a similar mean age of 63.28 ± 15.52 years with the age range 30–94.[10] Other studies also show comparable findings: in Trivandrum, India, the mean age was 67 years[11], and another study at the same centre reported 64.6 years.[12] Studies from northern India reported a mean age of 60.3 years, while younger populations are increasingly affected, with mean ages of 39.8 years in North India and 40.8 years in multicentre Asian studies.[13] These data indicate that while older adults constitute the majority of stroke patients, younger individuals are also becoming vulnerable, likely due to unhealthy lifestyles and modernization.[10]

Regarding the sex distribution, male predominance of were 32 (64%) of acute ischemic stroke and were observed with male: female ratio was 1.78:1. This finding was found to be similar with study conducted in Provincial Hospital of Madhesh Province of Nepal.[12] *Yadav et al*. found that 56% male cases of acute ischemic stroke in Nepal.[10] Similarly, a study conducted at Lucknow, India, reported that 68% of stroke patients were male.[14] Similarly, a study from AIMS, Delhi showed a

male-to-female ratio of 5:1.[15] The sex distribution of stroke patients varies across countries. Hospital-based stroke registries in China, Germany, India, and Iran also reported a higher proportion of males, especially in Asian countries, partly due to fewer female smokers. This male predominance may be linked to greater exposure to smoking and alcohol, while hypertension and diabetes also contribute, influenced by urbanization and changing lifestyles.[10] In the present study, hypertension was the most common risk factor, observed in 60% of patients with acute ischemic stroke. Other prevalent risk factors included smoking (52%) and left ventricular hypertrophy (46%), highlighting the importance of modifiable cardiovascular risks.[10] Less frequent risk factors were hypercholesterolemia (30%) and diabetes (14%), while atrial fibrillation (4%) and coronary artery disease (2%) were rare. These findings are consistent with other studies: diabetes, alcoholism, and smoking were reported in 55%, 35%, and 39.1% of stroke patients, respectively.[16] A community-based study in Colombo, Sri Lanka, among 2313 adults (≥18 years) found hypertension (62.5%), smoking (50%), excess alcohol (45.8%), diabetes (33.3%), TIA (29.2%), and family history (20.8%) as major risk factors.[17] In Qatar, hypertension was seen in 63% of stroke patients,[18] while the NINDS study reported hypertension (66%), smoking (43%), ischemic heart disease (25%), and diabetes mellitus (24%).[19] Similarly, in the ECASS III trial, hypertension (62%), diabetes (14%), smoking (30%), and previous stroke (7.7%) were observed.[20] A study from Chandigarh reported even higher prevalence, with hypertension (87.7%), diabetes (54.8%), dyslipidaemia, and obesity as prominent risk factors.[21] These data collectively emphasize that hypertension, smoking, diabetes, and lifestyle-related factors remain the most significant contributors to ischemic stroke across populations.[10]

Out of the total study population, 28 (56%) patients achieved a favourable outcome (mRS 0–2), with a 95% confidence interval ranging from 42.2% to 69.8%. Conversely, 22 (44%) patients had an unfavourable outcome (mRS 3-6), with a 95% confidence interval of 30.2% to 57.8%. These intervals indicate moderate variability in functional recovery among the study participants and provide a reliable estimate of the proportion of patients achieving independence three months post-stroke.

Analysis of associations between baseline clinical variables and 90-day functional outcomes revealed no statistically significant relationships. Patients younger than 60 years had a slightly higher proportion of favourable outcomes (58.3%) compared to older patients (55.3%), but this was not significant (p-value = 0.432). Similarly, favourable outcomes were observed in 59.4% of males and 50.0% of females (p-value = 0.551). Hypertension and smoking status were also not significantly associated with outcomes (p-value = 0.61 and 0.409, respectively). These findings suggest that sociodemographic characteristics alone may not reliably predict functional recovery in acute ischemic stroke.

CT perfusion imaging demonstrated a strong association with functional outcomes. Patients with favourable outcomes had significantly lower ischemic core volumes (18.5 ± 7.3 mL vs 49.3 ± 10.6 mL, p-value < 0.01), higher penumbra-to-core ratios (4.2 ± 1.1 vs 1.9 ± 0.8, p-value < 0.05), larger mismatch volumes (76.8 ± 12.5 mL vs 33.5 ± 10.2 mL, p-value < 0.05), and lower Tmax >6 s volumes (65.2 ± 14.8 mL vs 98.6 ± 20.1 mL, p-value < 0.01). These results indicate that smaller infarct cores and larger salvageable tissue are predictive of better functional recovery. The findings align with previous studies, emphasizing the prognostic utility of CT perfusion in guiding treatment decisions and predicting patient outcomes in acute ischemic stroke.

CONCLUSIONS

CT perfusion imaging demonstrated a strong association with 90-day functional outcomes in patients with acute ischemic stroke. While demographic and clinical risk factors such as age, sex, hypertension, and smoking status were not significantly associated with recovery, perfusion

parameters including ischemic core volume, penumbra-to-core ratio, mismatch volume, and Tmax >6 volume were closely correlated with favourable outcomes. Patients with smaller infarct cores, larger salvageable tissue, and lower Tmax volumes were more likely to achieve independence at 90 days. These findings highlight the value of CT perfusion as a reliable tool for predicting prognosis, guiding reperfusion therapy decisions, and optimizing patient management. Therefore, routine use of CT perfusion imaging is recommended in the acute stroke setting to improve clinical decision-making and enhance patient outcomes.

Limitations

This study is limited by its single-center design, small sample size, and potential biases, which may affect the generalizability of the findings.

Conflict of Interest: The author declares no conflict of interest.

Funding: No funding was received from any agency to conduct this study.

Availability of data and materials: All data analyzed during this study will be made available upon reasonable request from the corresponding author.

Author contribution: Conceptualization, Literature search, Methodology, Data analysis, Draft manuscript, Final manuscript and accountability: Dr. V. Natraj Prasad.

Acknowledgments

The author would like to acknowledge the residents and faculty of the Department of Radiology at COMSTH for their support during the conduct of this study

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Citation: Prasad VN. Assessment of CT Perfusion in Acute Ischemic Stroke among Patients Attending at a Tertiary Care Hospital of Chitwan, Nepal. JCMS Nepal. 2026; 22(1):1-7.