https://doi.org/10.29309/TPMJ/2024.31.03.7957

The Professional Medical Journal
www.theprofesional.com
2024, Volume, 31 Issue, 03

ORIGINAL ARTICLE

Diagnostic accuracy of computed tomography brain perfusion in the prediction of acute ischemic stroke taking the findings of MRI as gold standard.

Bushra Ujala[1], Nosheen Ahmad[2], Arwa Naeem[3]

Article Citation: Ujala B, Ahmad N, Naeem A. Diagnostic accuracy of computed tomography brain perfusion in the prediction of acute ischemic stroke taking the findings of MRI as gold standard. Professional Med J 2024; 31(03):393-399. https://doi.org/10.29309/TPMJ/2024.31.03.7957

ABSTRACT… Objectives: To determine the diagnostic accuracy of computed tomography brain perfusion to predict acute ischemic stroke taking the findings of MRI as gold standard. **Study Design:** Cross-sectional Validation study. **Setting:** Department of Radiology Allied Hospital Faisalabad. **Period:** 20th May 2022 to 19th November 2022. **Methods:** A total of 215 individuals, aged between 30 and 70, of both sexes, and exhibiting ischemic stroke symptoms lasting no more than 12 hours, were included. Patients with abnormal renal function tests having renal disease were excluded. The conventional non-contrast CT used in the CT stroke protocol had basal sections that were either 3 mm or 4 mm in thickness and supra tentorial sections that were either 3 mm or 4 mm in thickness. The acquisition parameters were 80kVp and 120mAs. Dynamic CT perfusion was carried out with 4 cm plane coverage. At the seventh day, all patients underwent a follow-up MRI using a 1.5 Tesla Philips MRI scanner. A radiologist examined CTP to look for signs of early ischemic changes. For CT perfusion (CTP), measurements were taken for time to peak (TTP), cerebral blood flow (CBF), and cerebral blood volume (CBV). **Results:** Overall sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of computed tomography brain perfusion in the prediction of acute ischemic stroke taking the findings of MRI as gold standard was 85.37%, 76.09%, 82.68%, 79.55% and 81.40% respectively. **Conclusion:** This study led to the conclusion that diagnostic accuracy of computed tomography brain perfusion to predict acute ischemic stroke is quite high.

Key words: Computed Tomography Perfusion, Ischemic Stroke, Sensitivity.

INTRODUCTION

Stroke, commonly known as cerebrovascular accident (CVA), is a significant global health issue. It stands as a major contributor of morbidity and mortality on a global scale.

A stroke is characterized by the sudden interruption of blood flow to the central region of the brain, causing the demise of brain cells and subsequent impairment of a specific body part due to nerve loss. Stroke can happen when brain cells die as a result of blocked brain vessels, in which case it is referred to as an ischemic stroke. Hemorrhagic stroke is a type of stroke that can happen when a blood artery in the brain ruptures. In general, 85% of strokes are ischemic and 15% are hemorrhagic in nature.

Currently, ischemic stroke stands as a significant contributor to both mortality and substantial functional impairment globally, exacting a considerable human toll and exerting a substantial impact on healthcare systems.[1] Within Asian nations, Pakistan bears a considerable weight of this debilitating ailment, leading to a substantial allocation of resources, financial resources, community workforce, healthcare services, and overall economic impact.[2] In Pakistan, there has been limited research on the occurrence of strokes, but a conservative estimate suggests around 350,000 incidents annually, with a prevalence rate of 22%.[3]

For a patient to receive the best care, an ischemic stroke diagnosis must be made accurately and

1. MBBS, FCPS, FRCR-II, Assistant Prof & HOD Radiology, FMU/Allied Hospital-II FSD.
2. MBBS, FCPS, Associate Professor Radiology, FMU/Allied Hospital-I FSD.
3. MBBS, PGR Radiology, Allied Hospital-II FSD.

Correspondence Address:
Dr. Bushra Ujala
Department of Radiology
FMU/Allied Hospital-II FSD.
bushra_ujala@yahoo.com

Article received on: 27/10/2023
Accepted for publication: 03/01/2024

quickly. Neuroimaging is crucial for assessing acute stroke syndrome, with non-contrast CT (NCCT) scans serving as the primary method. NCCT scans are preferred for evaluating acute ischemic stroke due to their speed, affordability, effectiveness, wide availability, and reliable inter-observer variability. Identifying initial indicators of infarction in non-contrast CT (NCCT) scans can pose difficulties, primarily due to the impact of infarct size and the gravity of ischemia.[4] The past "time-based" approach to intervention has been giving way to "physiology-based" approach since around 2007. It demonstrates deeper comprehension of the hemodynamic alterations brought on by artery occlusion, particularly the discovery of two separate zones in the ischemic hemisphere. The invention of perfusion imaging and other advances in neuroimaging were particularly important in making this possible.

In the past few years, there has been an augmentation in the information supplied by radiologists, attributed to the adoption of supplementary CT techniques like perfusion CT (CTP) and CT angiography (CTA).[5] Despite the widespread use of DWI, The function of CTP in the context of acute stroke situation is still expanding. The relative cost effectiveness, accessibility, and convenience of patient monitoring are only a few of CT's many benefits. In addition to properly distinguishing between permanently infarcted tissue and potentially recoverable ischemic tissue, current research demonstrates that CTP can also be employed to predict the efficacy of thrombolysis. Various data has revealed a strong correlation between CTP results and DWI and MR perfusion.

Perfusion CT (CTP) improves both the sensitivity & specificity to diagnose ischemic stroke that are acute in nature. It assists in ruling out conditions that mimic stroke and provides valuable information for prognosis and treatment decisions.[6] The systematic review of pertinent literature has demonstrated the efficacy of CT perfusion (CTP) examinations in identifying acute strokes. According to an extensive review conducted by Sabarudin et al. (2015) covering studies published from 1993 to 2013, CT perfusion (CTP) exhibits a high level of specificity (>80%) in identifying ischemia and infarcted brain tissue.[7] Shen et al. (2017) systematically assessed and contrasted the diagnostic precision of CTP, NCCT, and CTA in detecting acute ischemic stroke utilizing data from a collective study population of 2168 individuals. They showed that the combined sensitivity of perfusion CT for detecting acute ischemic stroke as 82% and the specificity was 96% taking MRI as gold standard.[8]

Adebayot and Culpan (2020) performed a recent meta-analysis, using MRI as the reference standard, in evaluation of the diagnostic effectiveness of CTP brain in predicting hemorrhagic transformation and patient outcomes in a group of patients experiencing acute ischemic stroke. They predicted that the combined sensitivity & specificity were 85.9%, 73.9%, and accuracy was 79.1%.[9]

CTP is being used more frequently for stroke diagnosis. But to the best of our knowledge, there very limited data is available in the evaluation of the diagnostic value of CTP for ischemic stroke that are acute in nature occurring in Pakistan. Rationale behind this research is to employ Brain CT perfusion for early diagnosis and swift referral in cases of acute ischemic stroke in our context, aiming to reduce morbidity.

OBJECTIVES

To determine the diagnostic accuracy of computed tomography brain perfusion in the prediction of acute ischemic stroke taking the findings of MRI as gold standard.

OPERATIONAL DEFINITIONS

Stroke

According to the criteria set by the World Health Organization (WHO), stroke is characterized as the rapid onset of clinical symptoms indicating focal (or global) disruption of cerebral function, persisting for more than 24 hours, and with no apparent cause other than of vascular origin.
Diagnostic Accuracy: was measured in terms of;
Sensitivity: Ability of CTP to detect those who have acute ischemic stroke.

Specificity: Ability of CTP to exclude those who don't have acute ischemic stroke.
True Positive: Patients having acute ischemic stroke on CTP as well as on MRI.
True negative: Patients having no acute ischemic stroke on CTP as well as on MRI.
False Positive: Patients having acute ischemic stroke on CTP but not on MRI.
False Negative: Patients having no acute ischemic stroke on CTP but have on MRI.
Positive predictive value: The probability that a patient with a positive CT perfusion (CTP) result is experiencing an acute ischemic stroke.
Negative predictive value: The probability that a patient with a negative CT perfusion (CTP) result is not experiencing an acute ischemic stroke.
CTP FINDINGS Severely reduced CBF and CBV indicate core infarction while those with prolonged MTT and its variations, including time to peak and time to maximum indicate penumbra.
MRI DWI FINDINGS High signal on DWI indicates infarction.

METHODS

This Cross-sectional study was conducted at Department of Radiology, DHQ/ Allied Hospital Faisalabad from 20th May 2022 to 19th November 2022.

Sample Size

By using sample size WHO calculator for sensitivity and specificity Sensitivity = 86%9 Specificity = 73.9%9 Prevalence of stroke= 22%3 Absolute Precision =10 % Confidence level = 95% Sample size = 215. The sampling technique was Non-probability, Consecutive sampling.

Inclusion Criteria

All patients with ages between 30-70 and were of either gender and exhibited ischemic stroke symptoms lasting no more than 12 hours

Exclusion Criteria

Kidney disease patients with abnormal renal function tests.
Cases of infarct or hemorrhage diagnosed on NCCT.
Lost on follow up with diffusion MRI.

Data Collection Procedure

The study was carried out after approval from Institutional ethical review committee (CPSP/REU/RAD-2019-035-2898). Written informed consent was taken from those who agree to participate in study. All patients between the ages of 30-70, of both sexes, exhibiting ischemic stroke symptoms lasting no longer than 24 hours were enlisted for non-enhanced CT and CTP by a CT scanner with 128 slices that encompassed both non-contrast CT (NCCT) and CT perfusion (CTP). The usual non-contrast CT stroke protocol included basal sections with slice thickness of either 3 or 4 millimeters and supra tentorial sections with slice thickness of either 5 or 8 millimeters. Dynamic CT perfusion was carried out using a 4 cm plane coverage. A 45-second cine sequence was used to capture the CTP picture, starting 5 seconds after injecting 40 to 50 milliliters of non-ionic iodinated contrast via a peripheral intravenous catheter. Using baseline CT perfusion data, parametric maps of cerebral blood volume (CBV) and mean transit time (MTT) were generated using commercially available software (CT perfusion; GE optima 660). At the seventh day, all patients underwent a follow-up MRI using a 1.5 Tesla Philips MRI scanner. A radiologist examined CTP to look for signs of early signs of ischemia. Time to peak (TTP), cerebral blood flow (CBF), and cerebral blood volume (CBV) were all measured for CTP.

Data Analysis Procedure

Collected data was entered into the SPSS software (25.0). Age, CBV, MTT, penumbra size, and infarct core size were quantitative variables for which mean and SD were calculated. Qualitative variables such as gender, ischemic stroke (Yes/No), Positive and negative CTP results were provided as frequency and percentage. For NCCT and CTP, accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and gold standard DWI MRI were computed (using a 2 x 2 table).

		Ischemic Stroke on MRI	
		Present	Absent
Ischemic Stroke on CTP	Present	True positive (a)	False positive (b)
	Absent	False negative (c)	True Negative (d)

Sensitivity: a / a+c x 100
Specificity: d / b+d x 100
Positive predictive value: a / a+b x 100
Negative predictive value: d / c+d x 100
Diagnostic accuracy: a+d / a+b+c+d x 100

RESULTS

In this research, the age range encompassed individuals between 30 and 70 years, with a mean age of 47.17 ± 11.13 years. The majority of participants, accounting for 127 individuals (59.07%), fell within the 30 to 50 years age bracket, as indicated in Table-I. Among the 215 patients, 143 (66.51%) were female, while 72 (33.49%) were male, resulting in a female-to-male ratio of 1.9:1, as depicted in Figure-1. The mean infarct size was 1.85 ± 0.89 cm2. The mean penumbra size was 2.24 ± 1.12 cm2. The mean cerebral blood volume was 7.2 ± 1.8. The mean MTT was 3.6 ± 2.5.

Among patients with a positive CTP, 105 (True Positive) had acute ischemic stroke and 22 (False Positive) had no acute ischemic stroke on MRI. In 88 patients with a negative CT perfusion (CTP) result, 18 individuals (classified as False Negatives) were identified with acute ischemic stroke on MRI, while 70 individuals (classified as True Negatives) exhibited no signs of acute ischemic stroke on MRI (p=0.0001)- Table-II. In summary, the overall sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of brain CTP to predict acute ischemic stroke taking the findings of MRI as gold standard was 85.37%, 76.09%, 82.68%, 79.55% and 81.40% respectively.

Age (Years)	No. of Patients	%age
30-50	127	59.07
51-70	88	40.93
Total	215	100.0

Table-I. Distribution of patients categorized by age. (n=215).

Mean ± SD = 47.17 ± 11.13 years

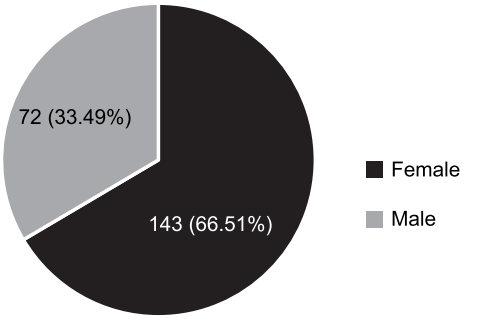

Figure-1. Distribution of patients based on gender (n=215).

	MRI Showing Positive Results	MRI Showing Negative Results	P-Value
CTP showing positive results	105 (TP)*	22 (FP)***	0.0001
CTP showing negative results	18 (FN)**	70 (TN)****	

Table-II. Diagnostic accuracy of brain CTP to predict acute ischemic stroke taking the findings of MRI as gold standard.

*TP=True positive **FP=False positive ***FN=False negative ****TN=True negative

Sensitivity: 85.37%
Specificity: 76.09%
Positive Predictive Value (PPV): 82.68%
Negative Predictive Value (NPV): 79.55%
Diagnostic Accuracy: 81.40%

DISCUSSION

Non-contrast computed tomography and CT angiography are frequently utilized to evaluate patients with suspected acute strokes. Some centers employ computed tomography perfusion (CTP) to assess individuals with penumbra or salvageable tissue[10], and traditionally received limited brain coverage. Nevertheless, due to its expansive coverage and enhanced diagnostic precision in detecting ischemic lesions, whole-brain computed tomography perfusion allows for the assessment of any region of ischemia in the brain[11,12], with similar treatment timeframes to those of conventional CT scanning procedures.13 In order to evaluate acute cerebral events with mild clinical manifestations, inclusion of WB-

CTP in the existing clinical pathway could be a valuable diagnostic augmentation.

I conducted this research to assess the diagnostic precision of CTP brain in predicting ischemic stroke which are acute in nature, using MRI results as the gold standard. In general, the research evaluation of sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of computed tomography brain perfusion in predicting ischemic stroke that are acute in nature taking findings of MRI as gold standard was 85.37%, 76.09%, 82.68%, 79.55% and 81.40% respectively. A systematic review by Sabarudin et al (2015) for articles published between 1993 and 2013 showed that CTP demonstrates elevated specificity (>80%) in identifying ischemic and infarcted brain tissue.[7] Shen et al (2017) systematically evaluate and compare the diagnostic precision of CTP, non-contrast CT (NCCT), and CT angiography (CTA) in the identification of acute ischemic stroke in a study involving a combined patient population of 2168 individuals. They showed that total sensitivity of CTP in detecting acute ischemic stroke was 82% and the specificity was 96% taking MRI as gold standred.[8]

A recent meta-analysis by Adebayot and Culpan (2020) to assess the diagnostic precision of computed tomography brain perfusion in predicting hemorrhagic transformation and patient outcomes in acute ischemic stroke, the study revealed that the combined sensitivity and specificity were 85.9%, 73.9% and accuracy of 79.1% taking MRI as gold standred.[9]

CT perfusion serves as a powerful diagnostic approach, facilitating precise assessment of volumetric core/penumbra mismatch ratios. This allows for the prediction of the volume of potentially salvageable at-risk tissue that could be preserved through recanalization therapy.[14,15] It aids in the selection of stroke patients who should undergo reperfusion therapy and also holds significant prognostic value.[16] When choosing patients for endovascular procedures in combination with tissue plasminogen activator (tPA) therapy, CT may be useful in identifying those patients as well as those in whom tPA use is contraindicated.[17,18]

Because it is a frequently used, affordable, and time-saving approach, CT perfusion is a desirable choice to be used in healthcare settings for the prompt diagnosis as well as early intervention for hyperacute stroke patients in critical need. Quality of life of patients is considerably enhanced by prompt reperfusion of occluded arteries.[19] As a result, CT perfusion reduces both overall mortality and morbidity as well as substantially lowers a nation's economic and social burden.[20]

A 2015 meta-analysis found that the CT perfusion technique's pooled overall sensitivity was 55.7% and its specificity was 92%.[21] According to a 2017 study, CT perfusion scanning shows a sensitivity of 82% and a specificity of 96%. This research emphasized the superior qualities of CT perfusion studies compared to NECT brain scans. It elucidated that although non-contrast CT (NCCT) brain scans can typically detect ischemic infarcts, their efficacy is limited in identifying ischemic infarctions that are early acute (within the initial 24 hours from the onset of symptoms), and This is impacted by the magnitude and extent of the infarction. The benefit of CTP lies in its capability to identify signs of ischemic stroke before they manifest on a non-contrast CT scan.[22]

Tan's study revealed that in identifying the occlusion site, CTA source images exhibited superior performance compared to CTP (with sensitivity of 94.6% & specificity of 100.0% for CTA source images, versus sensitivity of 88.2% & specificity of 95.3% for CTP). On the other hand, for identifying the anatomic distribution of established infarct, CTP outperformed CTA source images (with sensitivity of 80.4% & specificity of 96.8% for CTP, compared to sensitivity of 72.0% & specificity of 98.4% for CTA source images

CONCLUSION

This study concluded that diagnostic accuracy of computed tomography brain perfusion in predicting acute ischemic stroke is quite high. So, we recommend that computed tomography brain perfusion should be used routinely for assessment of acute ischemic stroke. This will

lead to appropriate and prompt management, thereby decreasing morbidity and mortality in these specific patients.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SOURCE OF FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Marchese G, Prochazka B, Widimsky P. **The importance of time: Time delays in acute stroke.** Cor et Vasa. 2016; 58(2):e225-32.

2. Nomani AZ, Nabi S, Badshah M, Ahmed S. **Review of acute ischemic stroke in Pakistan: Progress in management and future perspectives.** Stroke and Vascular Neurology. 2017; 2(1):30-9.

3. Rasheed N, Hamid S, Rani F. **Diagnostic accuracy of NCCT scan with DWI MRI taking it as a Gold Standard in detection of acute ischemic stroke.** Pak J Med & Heal Sci. 2014; 8(3):635-7.

4. Lee CL, Kandasamy R, Raffiq MA. **Computed tomography perfusion in detecting malignant middle cerebral artery infarct.** Surgical Neurology International. 2019; 159(10)1- 17.

5. Alves JE, Carneiro A and Xavier J. **Reliability of CT perfusion in the evaluation of the ischemic penumbra.** Neuroradiol J. 2014; 27: 91-95.

6. Heit JJ, Wintermark M. **Perfusion computed tomography for the evaluation of acute ischemic stroke: Strengths and pitfalls.** Stroke. 2016; 47(4):1153-8.

7. Sabarudin A, Subramaniam C, Sun Z. **Cerebral CT angiography and CT perfusion in acute stroke detection: A systematic review of diagnostic value.** Quant Imaging Med Surg. 2014; 4(4):282.

8. Shen J, Li X, Li Y, Wu B. **Comparative accuracy of CT perfusion in diagnosing acute ischemic stroke: A systematic review of 27 trials.** PloS one. 2017; 12(5):e0176622.

9. Adebayo OD, Culpan G. **Diagnostic accuracy of computed tomography perfusion in the prediction of haemorrhagic transformation and patient outcome in acute ischaemic stroke: A systematic review and meta-analysis.** Eur Stroke J. 2020; 5(1):4-16.

10. Srinivasan A, Goyal M, Al Azri F, et al. **State-of-the-art imaging of acute stroke.** Radiographics. 2006; 26(Suppl 1): S75-S95.

11. Emmer B. **Whole brain CT perfusion in acute anterior circulation ischemia: Coverage size matters.** Neuroradiology. 2014; 56(12): 1121-1126.

12. van den Wijngaard IR. **Value of whole brain computed tomography perfusion for predicting outcome after TIA or minor ischemic stroke.** J Stroke Cerebrovasc Dis. 2015; 24: 2081-2087.

13. Chakraborty S. **Beating the clock: Time delays to thrombolytic therapy with advanced imaging and impact of optimized workflow.** J Stroke Cerebrovasc Dis. 2015; 24(6): 1270-1275.

14. Flottmann F, Broocks G, Faizy TD. **CT-perfusion stroke imaging: A threshold free probabilistic approach to predict infarct volume compared to traditional ischemic thresholds.** Sci Rep. 2017; 7:6679. 10.1038/s41598-017-06882-w

15. Schramm P, Schellinger PD, Klotz E. **Comparison of perfusion computed tomography and computed tomography angiography source images with perfusion-weighted imaging and diffusion-weighted imaging in patients with acute stroke of less than 6 hours' duration.** Stroke. 2004; 35:1652-8. 10.1161/01.STR.0000131271.54098.22

16. Xu S, Wang L, Zhao L. **Clinical application value of brain CT perfusion imaging in the treatment of acute ischemic stroke thrombolytic therapy.** Exp Ther Med. 2019; 17:3971-6. 10.3892/etm.2019.7431

17. Munich SA, Shakir HJ, Snyder KV. **Role of CT perfusion in acute stroke management.** Cor et Vasa. 2016; 58:215-24. 10.1016/j.crvasa.2016.01.008

18. Hana T, Iwama J, Yokosako S. **Sensitivity of CT perfusion for the diagnosis of cerebral infarction.** J Med Invest. 2014; 61:41-5. 10.2152/jmi.61.41

19. Biesbroek JM, Niesten JM, Dankbaar JW, Biessels GJ, Velthuis BK, Reitsma JB, van der Schaaf IC: **Diagnostic accuracy of CT perfusion imaging for detecting acute ischemic stroke: A systematic review and meta-analysis.** Cerebrovasc Dis. 2013, 35:493-501. 10.1159/000350200

20. Menon BK, Campbell BC, Levi C, Goyal M: **Role of imaging in current acute ischemic stroke workflow for endovascular therapy.** Stroke. 2015; 46:1453-61. 10.1161/STROKEAHA.115.009160

21. Xin Y, Han FG. **Diagnostic accuracy of computed tomography perfusion in patients with acute stroke: A meta-analysis.** J Neurol Sci. 2016; 360:125-30. 10.1016/j.jns.2015.11.046

22. Shen J, Li X, Li Y, Wu B. **Comparative accuracy of CT perfusion in diagnosing acute ischemic stroke: A systematic review of 27 trials.** PLoS One. 2017; 12:e0176622.

23. Tan JC, Dillon WP, Liu S, Adler F, Smith WS, Wintermark M. **Systematic comparison of perfusion-CT and CT-angiography in acute stroke patients.** Ann Neurol. 2007; 61: 533-543.

AUTHORSHIP AND CONTRIBUTION DECLARATION

No.	Author(s) Full Name	Contribution to the paper	Author(s) Signature
1	Bushra Ujala	Primary Author	
2	Nosheen Ahmad	Co-Author	
3	Arwa Naeem	Co-Author	