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CT Perfusion in Early Stroke Detection: Assessing the Accuracy and Diagnostic Value Over NCCT (A Study Of 50 Patients)

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Abstract: ***Introduction**: A stroke is defined by abrupt onset of a neurologic deficit that is attributable to disruption of blood flow to a focal region of the brain due to a focal vascular cause. Stroke can be classified in to two categories: 1) Ischemic stroke 80 - 85% and 2) Hemorrhagic stroke 15 - 20%. Brain stroke is one of the most important causes of death and disability. It is third most common cause of death worldwide. Age adjusted prevalence rate of stroke in India is 250 - 350/100, 000. Estimated stroke related death is 1.2 % of the total deaths. CT scanning has become a versatile tool in assessing stroke. Limitation of a NCCT scan is that up to 40% of stroke patients have normal scan in first few hours. It cannot detect early signs of ischemia. Recent advance in the field has come up with MDCT in evaluation of ischemic cerebral penumbra. Purpose of present study was to determine role of CT PERFUSION in early detection of stroke. CT PERFUSION parameter images enable us to make distinction between irreversibly damaged infarct core & the potentially reversibly damaged penumbra. Stroke imaging involves evaluation of 4 "P"s: 1) Evaluation of Parenchyma.2) Evaluation of cerebral blood vessels (Pipes).3) Evaluation of Perfusion and 4) Penumbra. This study principally aims to highlight the role of CT PERFUSION to diagnose & confirm the occurrence of stroke as early as possible, to assess potentially salvageable brain tissue and irreversibly infracted tissue, to increase the sensitivity and specificity of stroke diagnosis over that of NCCT and to provide diagnostic value in differentiation between reversibly and irreversibly damaged brain tissue. **Materials and Method**: CT PERFUSION Scan of 50 patients who presented with hemiplegia within12 hours of clinical signs and symptoms were analyzed and findings of CT PERFUSION Scan were correlated with relevant clinical history/investigations pertaining to patient's complaint and was evaluated for diagnosis from the case records/registers. The present study was conducted in the Department of Radio diagnosis and Imaging, at our hospital from December 2022 to December 2023. **Results**: Among 50 patients, 30 males (60%) and 20 females (40%) were studied. Patients were followed up by NCCT scan.10 patients (20%) showed infarct on NCCT, no evidence of penumbra on perfusion scan, no change in follow up scan as compared to initial scan.20 patients (40%) showed normal initial NCCT scan, no evidence of penumbra on perfusion scan & normal follow up scan; suggested Transient Ischemic Attack (TIA), with no damage to cerebral parenchyma.20 patients (40%) showed early signs of ischemia but no hypodense area (infarct) on initial NCCT, there was evidence of penumbra with infarct core on perfusion scan, which on follow up scan developed in to infarct. CT PERFUSION detected presence & absence of penumbra in all 30 patients. CT PERFUSION had differentiated between penumbra & infarct core in all 30 patients; hence accuracy was 100%. **Conclusion**: CT PERFUSION remains accurate & helpful in early diagnosis & confirmation of stroke over NCCT & differentiation between potentially salvageable brain tissue and irreversibly infracted tissue. This is very helpful to decide thrombolytic therapy in management of acute stroke patients which would be beneficial to restrict infarct size.*

Keywords: Stroke, CT PERFUSION, NCCT, Infarct.

1. Introduction

A stroke is defined by abrupt onset of a neurologic deficit that is attributable to disruption of blood flow to a focal region of the brain due to a focal vascular cause. Stroke can be classified in to two categories: 1) Ischemic stroke 80 - 85% and 2) Hemorrhagic stroke 15 - 20%. Brain stroke is one of the most important causes of death and disability. It is third most common cause of death worldwide. Age adjusted prevalence rate of stroke in India is 250 - 350/100, 000. Estimated stroke related death is 1.2 % of the total deaths. CT scanning has become a versatile tool in assessing stroke. Limitation of a NCCT scan is that up to 40% of stroke patients have normal scan in first few hours. It cannot detect early signs of ischemia. Recent advance in the field has come up with MDCT in evaluation of ischemic cerebral penumbra. Purpose of present study was to determine role of CT PERFUSION in early detection of stroke. CT PERFUSION parameter images enable us to make distinction between irreversibly damaged infarct core & the potentially reversibly damaged penumbra. Stroke imaging involves evaluation of 4 "P"s: 1) Evaluation of Parenchyma.2) Evaluation of cerebral blood vessels (Pipes).3) Evaluation of Perfusion and 4) Penumbra. This study principally aims to highlight the role of CT PERFUSION to diagnose & confirm the occurrence of stroke as early as possible, to assess potentially salvageable brain tissue and irreversibly infracted tissue, to increase the

sensitivity and specificity of stroke diagnosis over that of NCCT and to provide diagnostic value in differentiation between reversibly and irreversibly damaged brain tissue.

2. Aims and Objectives

This study principally aims to highlight the role of CT PERFUSION for diagnosis and confirmation of the occurrence of stroke as early as possible and to assess potentially salvageable brain tissue and irreversibly infracted tissue. Furthermore, this study aims to compare sensitivity and specificity of CT PERFUSION to that of Non - Contrast enhanced Computed Tomography in early diagnosis of stroke. Additionally, it aims to assess the role of CT PERFUSION to provide diagnostic value in differentiation between reversibly & irreversibly damaged brain tissue which would form the basis of treatment protocol for the betterment of the patient.

3. Materials and Methods

This observational (cross - sectional) study was conducted on 50 patients for one year from December 2022 to December 2023 in Department of Radiology in PDU Government Medical college and Civil hospital, Rajkot, Gujarat: after taking proper consent from them. The indication and details of the radiological procedure are explained to the patient. A written consent is obtained either from the patient or his/her relatives. Each patient had undergone CT PERFUSION as indicated. Confirmation of the diagnosis was done by following up patient with NCCT and correlated with surgical & clinical outcomes whenever available. Sample size: 50, Study design: observational study, Type of study: prospective, Duration of study: 1 year (December 2022 to December 2023), Place of study: PDU Medical College and Civil Hospital, Rajkot, Instruments used: GE Bright speed 16 slice.

Method of Collection of Data
The main source of data for the study were patients referred to the Radiodiagnosis department who presented with clinical symptoms and signs pertaining to stroke within < 12 hours.

Inclusion Criteria
Patients who show early signs of stroke on NCCT. Patients showing acute neurological deficit < 12 hours. All patients who could be rescanned with CT for follow up. No similar history in past.

Exclusion Criteria
Patients with Stroke of more than 12 hours. Patients who could not be followed up to the final diagnosis are excluded. Patients who demonstrated hemorrhage & mass lesion on NCCT are excluded.

Equipment and Technique Used
CT PERFUSION imaging was performed on Dual source 16 slice computed tomography scanner. The patient was placed on gantry table in the head first position. An 18 - gauge cannula was placed into an ante - cubital vein before the patient entered the scanner. Once in the scanner, the patient's head was immobilized, and the contrast material infusion pump was connected to the cannula. Contrast enhanced scanning was done by power infusion of40 ml of nonionic contrast material at 4ml/sec

CT Perfusion
Computed tomography (CT) perfusion is a new imaging modality that permits the microcirculation of the brain to be evaluated. Unlike conventional CT imaging, which assesses brain structure and morphology, CT perfusion gathers physiologic information about the status of the cerebral perfusion. CT perfusion imaging has the potential to markedly affect the initial evaluation of patients with acute cerebral infarction by helping to identify the ischemic penumbra. Whereas diffusion magnetic resonance imaging can identify dead brain tissue, CT perfusion imaging can help identify dying brain tissue—tissue that may recover with prompt and appropriate therapy. Other work has demonstrated potential uses of CT perfusion imaging in evaluating and following cranial and extracranial steno - occlusive disease, in assessing vasospasm after subarachnoid hemorrhage, in distinguishing neoplasms from infections, and in confirming brain death. Perfusion computed tomography (CT) is a relatively new technique that allows rapid qualitative and quantitative evaluation of cerebral perfusion by generating maps of cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT). The technique is based on the central volume principle (CBF = CBV/MTT) and requires the use of commercially available software employing complex deconvolution algorithms to produce the perfusion maps. From the data, we determine Time to Peak (TTP), Cerebral Blood Flow (CBF) & Cerebral Blood Volume (CBV) values normalized to those of contralateral non ischemic brain to assess stroke. Some controversies exist regarding this technique, including which artery to use as input vessel, the accuracy of quantitative results, and the reproducibility of results. Despite these controversies, perfusion CT has been found to be useful for noninvasive diagnosis of cerebral ischemia and infarction and for evaluation of vasospasm after subarachnoid hemorrhage. Perfusion CT has also been used for assessment of cerebrovascular reserve by using acetazolamide challenge in patients with intracranial vascular stenoses who are potential candidates for bypass surgery or neuroendovascular treatment, for the evaluation of patients undergoing temporary balloon occlusion to assess collateral flow and cerebrovascular reserve, and for the assessment of microvascular permeability in patients with intracranial neoplasms.

4. Limitations

It is important to note that the present study has limitations. Firstly, it was conducted at a single center, which means that the results only provide an estimate of the epidemiology of stroke in a single region of the country. CT perfusion has limitations like contrast allergies and certain patient conditions may preclude its use. Additionally, very recent strokes or those in specific locations might be challenging to differentiate with this technique.

5. Literature Review

Sir Hounsfield invented the CT scan in 1972. Multidetector

CT was established in 1990. Murphy et al. used an animal model to show that cerebral blood flow (CBF) & CBV values obtained from CT perfusion scan could be used to distinguish between oligemic and infarct regions. The concept of ischemic penumbra was introduced by Astrup et al. as a region of hypoperfused, electrically silent and functionally impaired but viable tissue. Since its introduction, penumbra has become the focus of intense imaging research to differentiate it from infarction. Meuli (2004) stated that perfusion CT was now ready to be used in clinical trials as decision making tool for individualizing thrombolytic therapy to stroke patients. Wang et al (2010) noted that CT Perfusion was helpful m differentiating penumbra and core infarct region. A study of 42 patients concluded that mismatch between arterial and venous phase values could be applied to ischemic regions to distinguish reversible injury.

Accurate identification of this “tissue at risk” could be used to identify patients who would benefit most from treatment. Reichenbach et al. evaluated acute stroke by Time - to - Peak Mapping during Initial and Early Follow - up Perfusion CT Studies. Diagnostic time - to - peak maps were generated in 19 of 20 initial and in nine of 10 follow - up perfusion CT studies. The initial time - to - peak map showed perfusion deficits in 14 of 20 patients. Hemispheric territorial infarcts were diagnosed with a sensitivity of 93%. Dittrich et al. studied accuracy of perfusion - CT in predicting malignant middle cerebral artery brain infarction.20patients out of 106 (19 %) developed an infarction. In these patients, a larger area of tissue ischemia was found in all perfusion maps as compared to the remaining patients. Best prediction was found for CBF maps with area of tissue ischemia of> 27.9 % of the hemisphere. Tek am et al. studied CT perfusion imaging in the early diagnosis of acute stroke and CT perfusion findings in comparison to the non - contrast CT findings in two cases of acute cerebral infarction. Non - contrast CT findings were non-specific in the first case and there was minimal hypoattenuation in the superior aspect of the lentiform nucleus in the second case. CT perfusion imaging demonstrated significant perfusion defects in the middle cerebral artery territory in both cases. Khandelwal et al. studied CT perfusion in acute stroke and concluded thar stroke is a heterogeneous syndrome caused by multiple mechanisms, all of which result in disruption of normal cerebral blood flow and thereby cause cerebral dysfunction. Its early diagnosis is important as its treatment is dependent on the time elapsed since ictus. Delay in diagnosis and treatment translates into increase neuronal loss and thereby increased morbidity. CT scan, and in particular perfusion CT, has helped greatly in the early diagnosis of stroke. This article is an endeavor to explain the patho - physiology of cerebral ischemia and the role of CT perfusion in detecting it. Roberts et al. introduced Multi - section Dynamic CT Perfusion for Acute Cerebral Ischemia: The “Toggling - table” Technique–A new CT perfusion technique providing extended anatomic coverage was evaluated in 12 patients with suspected acute middle cerebral artery ischemia. With a multidetector CT scanner, scans were obtained in an alternating fashion at two distinct “toggling" table positions (two 1 - cmsectionseach) during a40 - mL contrast agent bolus (approximately 5 seconds per image), and perfusion parameter maps were created. The CT perfusion results were compared with follow - up images.

Koenig at al. analyzed diagnostic Approach for Early Detection of ischemic. Perfusion CT was performed within 6 hours of symptom onset in 32 patients with possible stroke. CBV, CBF, and TTP were calculated on the basis of the CT results. Perfusion CT results were compared with follow - up CT. Areas of reduced CBF were detected with the aid of perfusion CT in25 of 28 patients with a "proved infarct (sensitivity, 89%). Ischemia was located outside the scanning level in the other three patients and was therefore missed. Perfusion CT revealed various changes in CBF, CBV, and TTP enhancement in ischemic territories. EASTWOOD et al. Correlation of Early Dynamic CT Perfusion Imaging with Whole - Brain MR Diffusion and Perfusion Imaging in Acute Hemispheric Stroke. AJNR Am J Neuroradiol 24: 1869 - 1875, October 2003. Fourteen patients with acute hemispheric stroke symptoms less than 12 hours in duration were studied with single - slice CT perfusion imaging. Hemodynamic parameters included CBF, CBV, and MTT. Extents of abnormality on images were compared by using Kendall correlation. It remains uncertain whether CT perfusion CBV abnormalities correspond well to whole - brain abnormalities.

6. Results

Table 1: Age And Gender Distribution for Stroke

Age Group	No. of Pts	%of Pts	Male No.	Male %	Female No.	Female %
0 - 10	-	-	-	-	-	-
ll - 20	-	-	-	-	-	-
21 - 30	3	6%	2	4%	1	2%
31 - 40	9	18%	6	12%	3	6%
41 - 50	12	24%	9	18%	3	6%
51 - 60	20	40%	12	24%	8	16%
61 - 70	6	12%	1	2%	5	10%
71 - 80	-	-	-	-	-	-
81 - 90	-	-	-	-	-	-
Total	50	100%	30	60%	20	40%

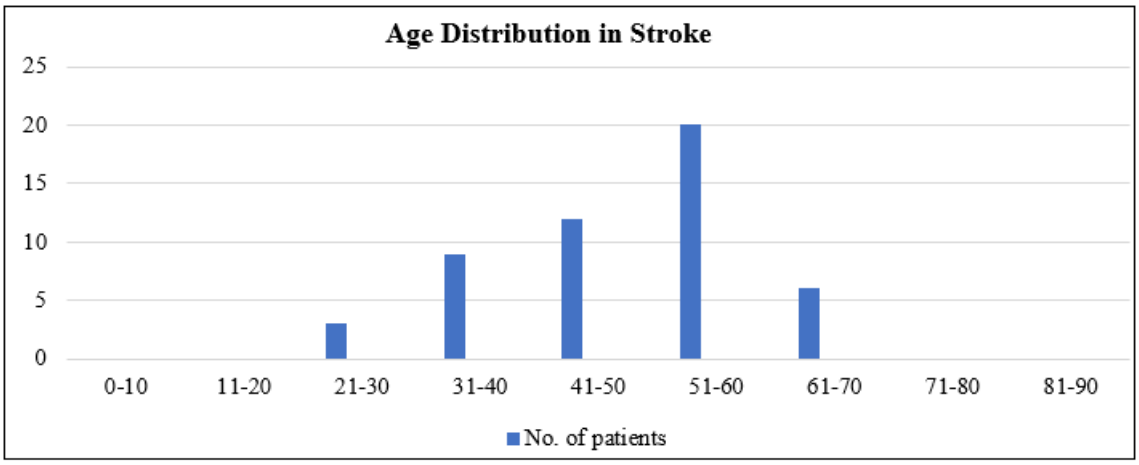

Figure 1: Age Distribution in Stroke

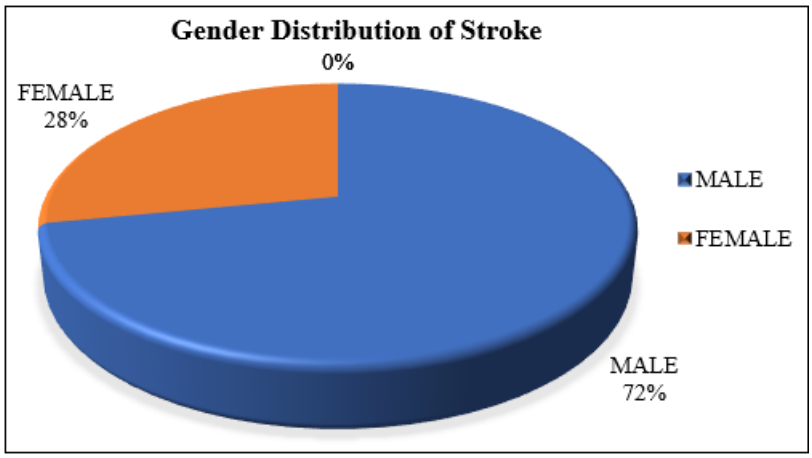

Figure 2: Gender Distribution in Stroke

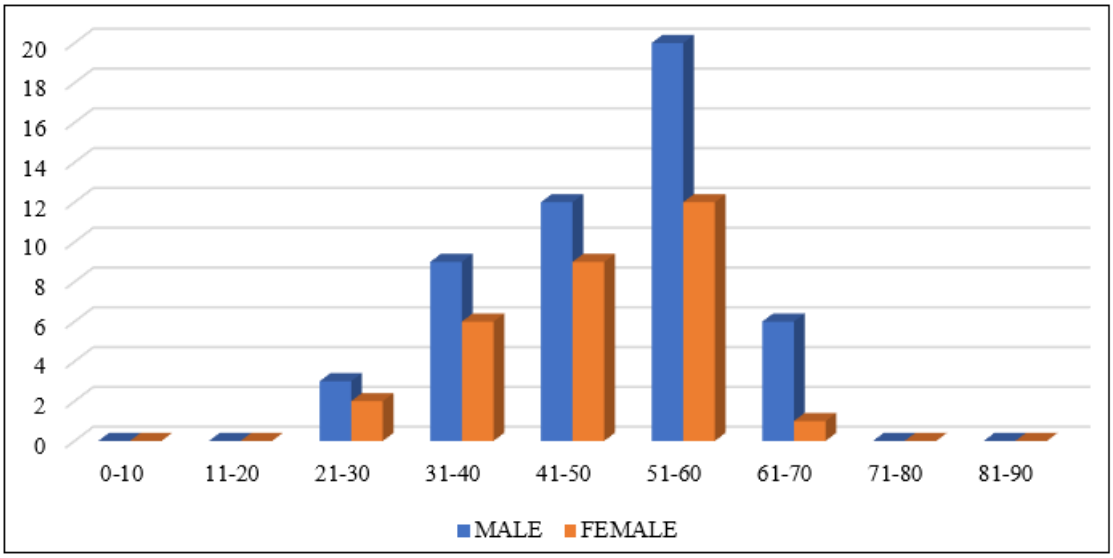

Figure 3: Age and Gender Distribution in Stroke

The age of the patients involved in study ranges from 28 yrs to 70yrs old people.

Stroke was more common in 40 - 60yrsofagegroup (44%).

Stroke was more common in male (60%) as compared to females (40%).

Table 2: Clinical Signs and Symptoms of Stroke

SYMPTOMS	No. of patients
Left hemiplegia	26
Right hemiplegia	19
Coma	5
Total	50

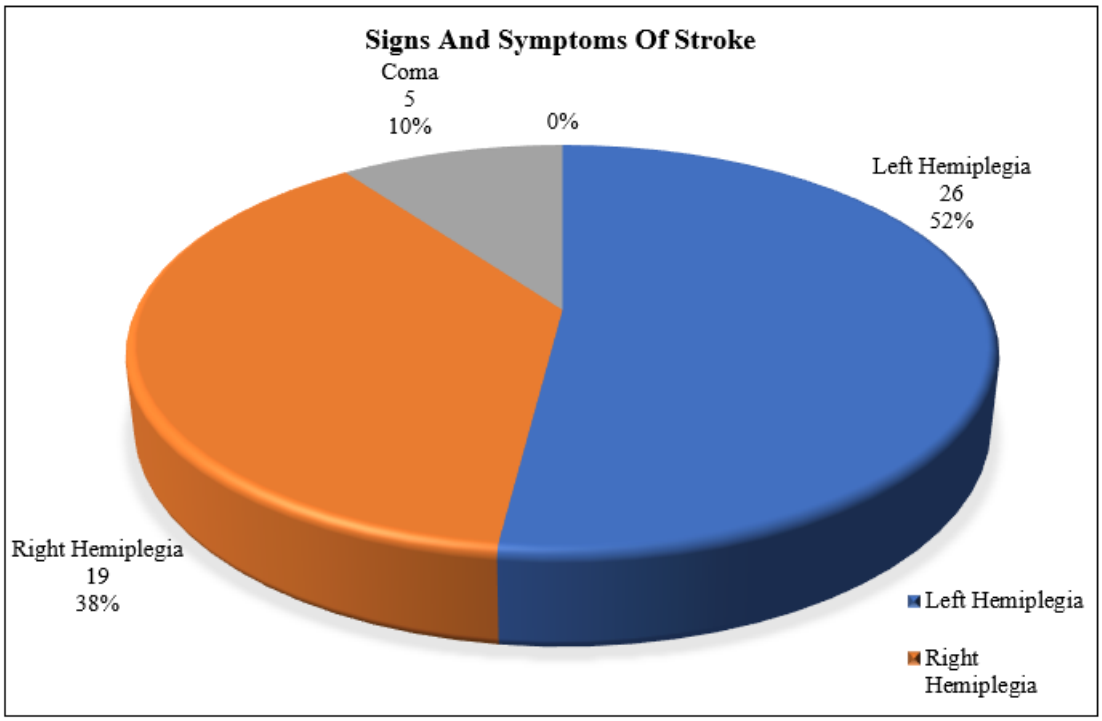

Figure 4: Signs and Symptoms of Stroke

The most common presentation of patients was left hemiplegia in 26 patients (54%), followed by right hemiplegia in 19 patients (36%), followed by coma in 5patients (10%).

Table 3: Duration of Stroke

Presentation	No. of Patients
0 - 6 Hours	22
7 - 12 Hours	28
Total	50

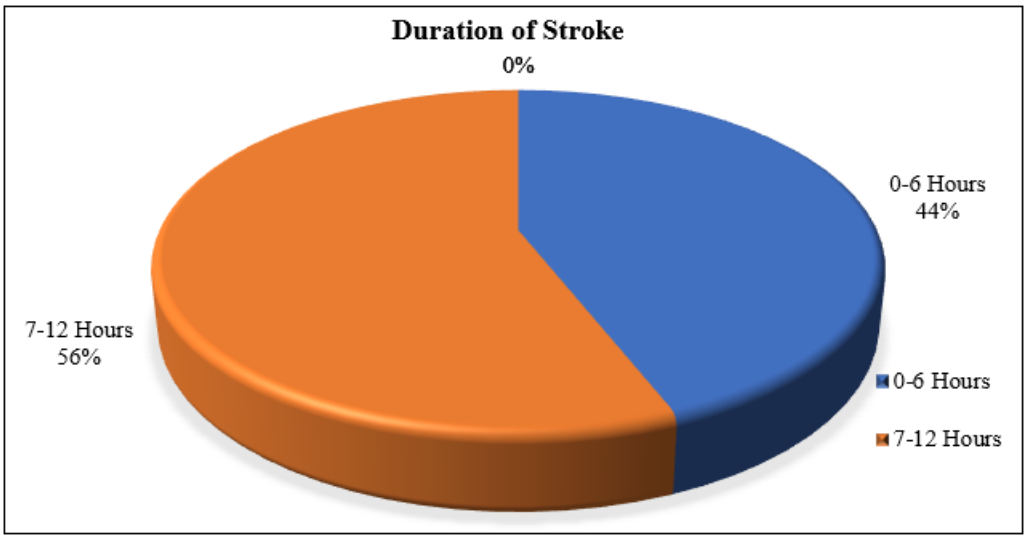

Figure 5: Duration of Stroke

Among 50 patients, 22 patients (44%) presented within 6 hours of clinical signs & symptoms and 28 patients (56%) presented between 7 - 12 hrs.

Table 4: NCCT diagnosis of stroke

Early Signs	No. of Patients		
	Present	Absent	Total
Hypodense Area	10	40	50
Dense MCA Sign	20	30	50
Insular Ribbon Sign	30	20	50
Loss of Grey - White Interface	30	20	50
Obscuration of Lentiform Nucleus	30	20	50

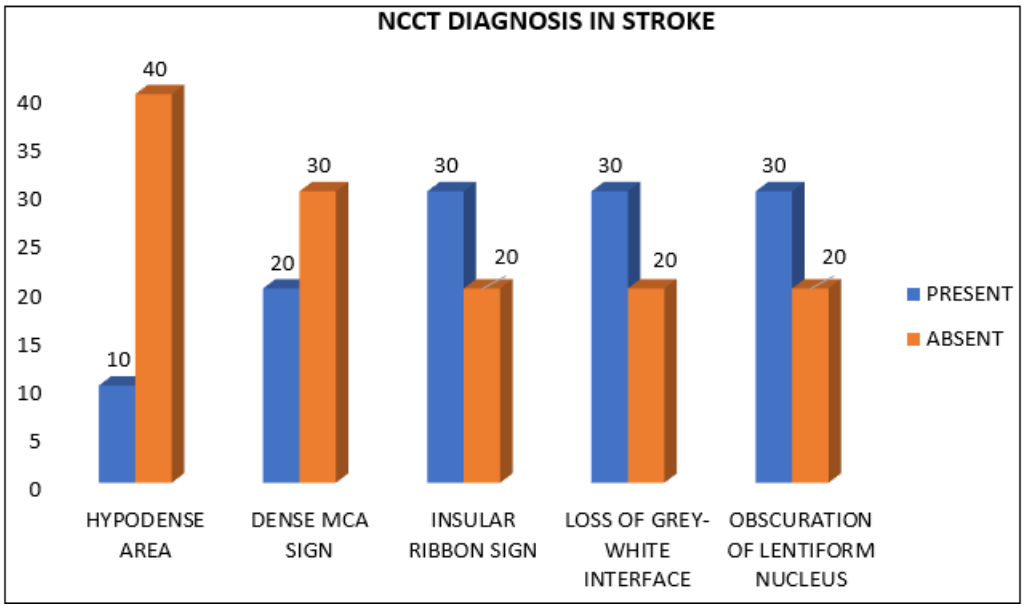

Figure 6: NCCT DIAGNOSIS OF STROKE

40 patients (60%) showed no hypodense area on NCCT,
10 patients 40%) showed hypodense area corresponding to affected side.

20patients (40%) showed DENSE MCA SIGN on NCCT.
30patients (60%) showed INSULAR RIBBON SIGN on NCCT.

30patients (60%) showed LOSSOFGREY - WHITE MATTER DIFFERNTIATION on NCCT.

30patients (60%) showed OBSCURATIONOF LENTIFORM NUCLEUS.

Table 5: Perfusion CT Parameters

Parameters	No. of Patients
↑TTP, ↓CBF, ↑CBV	20
↑TTP, ↓CBF, ↓ CBV	10
TTP, CBF, CBV - N	20
TOTAL	50

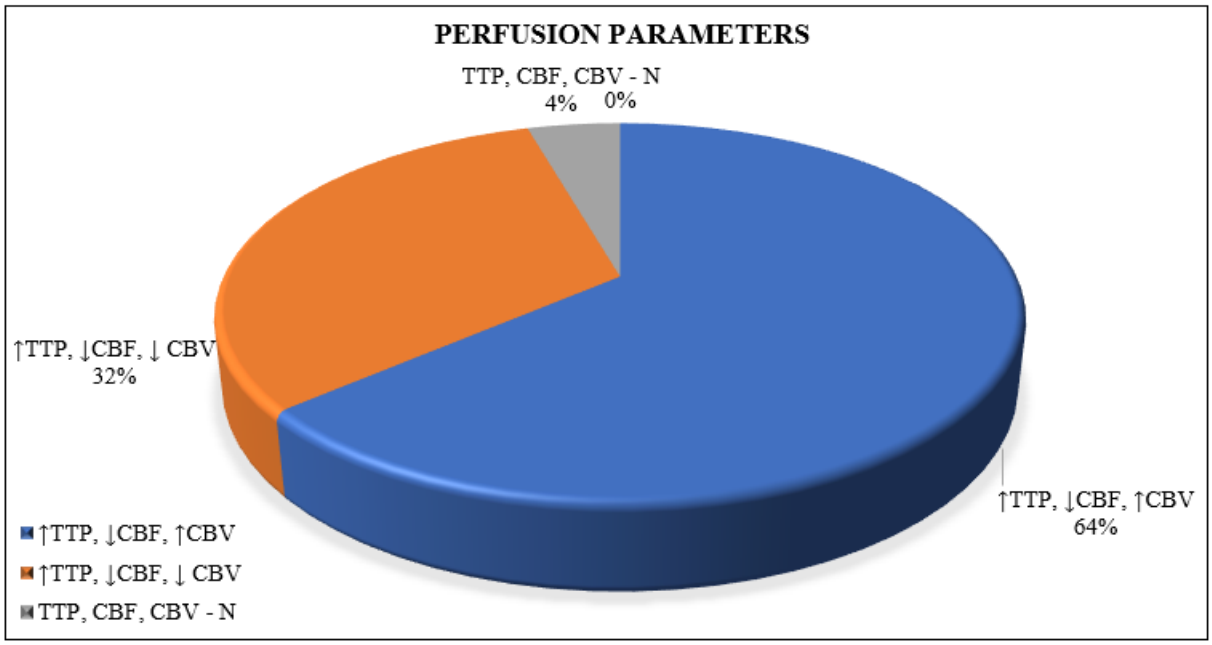

Figure 7: Perfusion Parameters in Stroke

10 patients (20%) showed increased TTP, decreased CBF & decreased CBV on abnormal side as compared to normal side suggestive of infarct without penumbra.

20 patients (40%) showed increased TTP, decreased CBF & increased CBV on abnormal side as compared to normal side suggestive of infarct with penumbra.

20 patients (40%) showed normal TTP, CBF & CBV on both sides suggestive of no ischemic changes in the cerebral parenchyma.

Maximum & minimum value of TTP (millisecond), CBF (ml/100gm/min) & CBV (%) of our study are as described in below mentioned table:

	Infarct		Penumbra		Normal	
PARAMETER	Max.	Min.	Max.	Min.	Max.	Min.
TTP (millisecond)	262.9	132.1	240.6	129.5	295.7	83.3
CBF (ml/100gm/min)	36. I	6.3	53.7	17.8	96.6	43
CBV (%)	27.6	6.1	54.3	24.8	59.7	26.3

Table 6: CT Perfusion Diagnosis

Diagnosis	No. of Patients
Infarct With Penumbra	20
Infarct Without Penumbra	10
Normal	20
Total	50

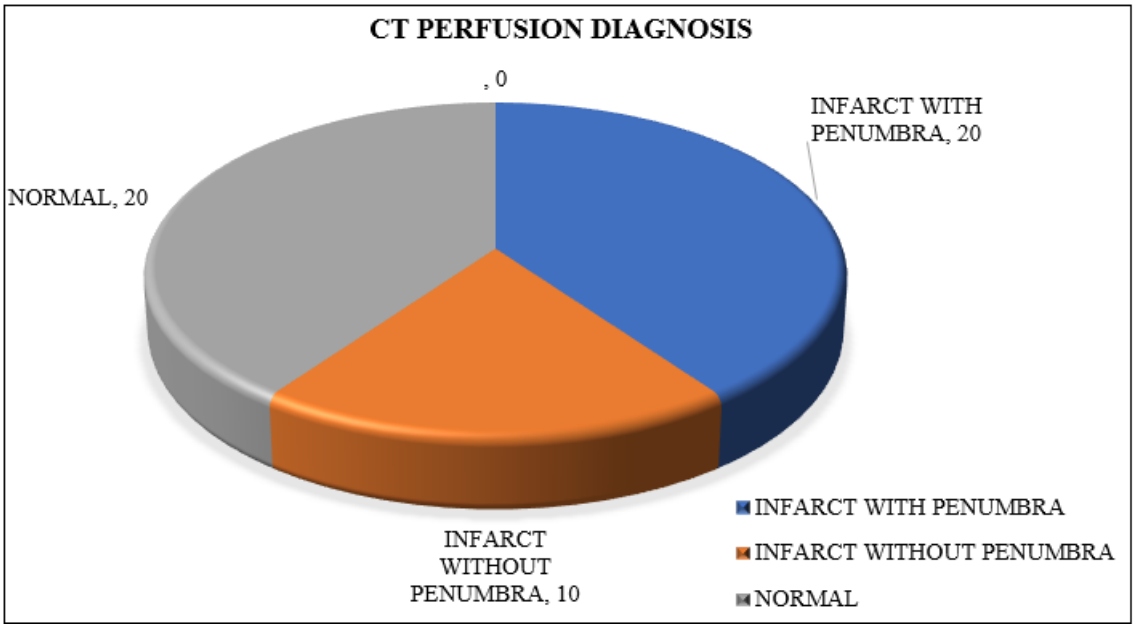

Figure 8: CT Perfusion Diagnosis of Stroke

20 patients (40%) showed infarct with penumbra, 10 patients (20%) showed infarct without penumbra & 20 patients (40%) showed normal study on NCCT & CT PERSION studies.

Table 7: Follow Up NCCT

Diagnosis	No. of Patients
Infarct	30
Normal	20
Total	50

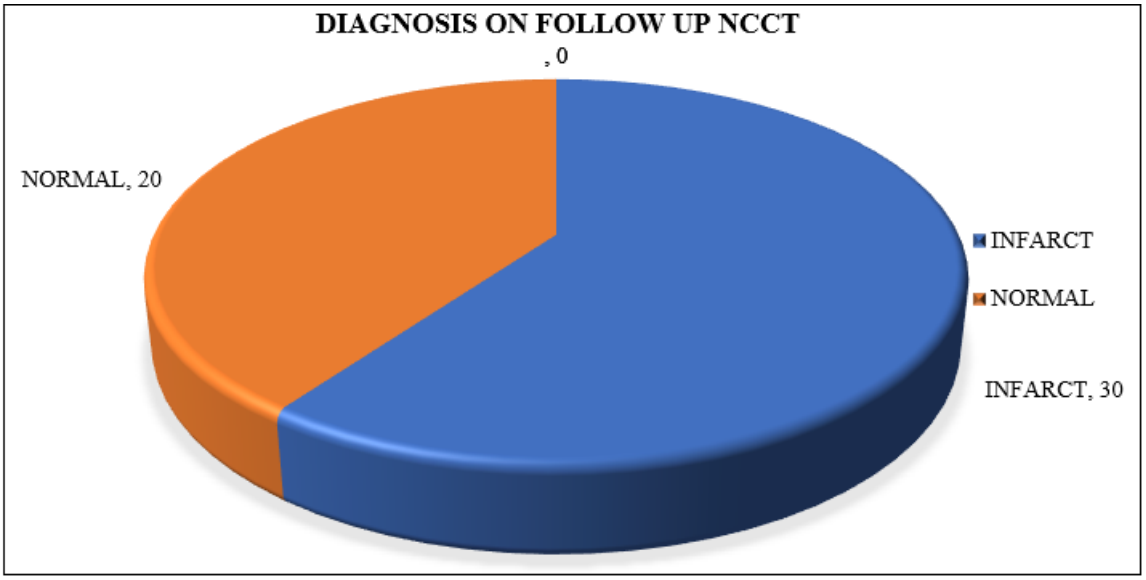

Figure 9: Diagnosis on Follow Up NCCT

Follow up NCCT scan was done within 1 - 4 days after initial scan.
30 patients (60%) showed infarction on the correspondingsites.
(20 patients which showed penumbra on perfusion scan, developed into infarct on follow up NCCT).
20 patients (40%) showed normal study.

7. Conclusion and Summary

A prospective study of CT PERFUSION was performed on 50 patients with hemiplegia presented within 12 hours of clinical signs & symptoms from December 2022 to December 2023. Among 50 patients, 30 males (60%) and 20 females (40%) were studied in our study. Patients were

followed up by NCCT scan.10 patients (20%) showed infarct on NCCT, no evidence of penumbra on perfusion scan, no change in follow up scan as compared to initial scan.20 patients (40%) showed normal initial NCCT scan, no evidence of penumbra on perfusion scan & normal follow up scan; suggested Transient Ischemic Attack (TIA), with no damage to cerebral parenchyma.20 patients (40%) showed early signs of ischemia but no hypodense area (infarct) on initial NCCT, there was evidence of penumbra with infarct core on perfusion scan, which on follow up scan developed in to infarct. CT PERFUSION detected presence & absence of penumbra in all 30 patients. CT PERFUSION had differentiated between penumbra & infarct core in all 30 patients; hence accuracy was 100%. Hence from our study we could conclude thatCT PERFUSION remains accurate & helpful in early diagnosis & confirmation of stroke over NCCT & differentiation between potentially salvageable brain tissue and irreversibly infracted tissue. Detection of infarct core & potentially salvageable penumbra is very helpful to decide thrombolytic therapy in management of acute stroke patients, which would beneficial to restrict infarct size. CT PERFUSION proves to be "The Imaging Modality" which is very good tool in characterizing early signs of ischemia, which could not be detected by NCCT. The method is easy to implement and represents a useful adjunct to the NCCT, moreover it yields valuable information regarding the presence and extent of reversibly & irreversibly damaged ischemic tissue with appropriate hardware & software. It is fast and easy to use. The technique has the potential to play a significant role in patient stratification for thrombolysis. With wide availability of MDCT, CT PERFUSION is the emerging concept of radio - diagnosis.

CT PERFUSION not only allows early detection of cerebral ischemia but also yields valuable information about the extent of perfusion disturbances.

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