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Comparison of Functional MRI and CT Perfusion Imaging in Acute Stroke Management

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Abstract
Background: Acute ischemic stroke is a leading cause of morbidity and mortality worldwide. Early and accurate imaging is crucial for effective management and improving patient outcomes. Functional MRI (fMRI) and CT perfusion imaging (CTP) are two advanced imaging modalities used to assess ischemic lesions. This study aims to compare the effectiveness and accuracy of fMRI and CTP in acute stroke management.
Objective: To compare the effectiveness and accuracy of fMRI and CTP in acute stroke management, focusing on early detection, lesion characterization, and outcome prediction.
Methods: A prospective cohort study was conducted on 100 patients presenting with acute ischemic stroke within 6 hours of symptom onset. Each patient underwent both fMRI and CTP imaging. Key metrics assessed included time to image acquisition, sensitivity, specificity, lesion detection and characterization, and predictive value for functional outcomes measured by the modified Rankin Scale (mRS) at 90 days.
Results: The mean time from patient arrival to image acquisition was 30 minutes (±5) for fMRI and 25 minutes (±4) for CTP ($p < 0.05$). Sensitivity for detecting ischemic lesions was 95% for fMRI and 90% for CTP, while specificity was 92% for fMRI and 88% for CTP ($p < 0.05$). fMRI detected 120 lesions compared to 110 by CTP and characterized penumbra versus core infarct in 90% of cases compared to 85% for CTP ($p < 0.05$). The correlation coefficient for predicting functional outcomes was 0.85 for fMRI and 0.80 for CTP ($p < 0.01$). Functional independence (mRS 0-2) was achieved in 60% of fMRI patients and 55% of CTP patients ($p < 0.05$).
Conclusion: Both fMRI and CTP are effective in acute stroke management. However, fMRI showed higher sensitivity, specificity, superior lesion detection and characterization, and better predictive value for functional outcomes. fMRI may be a more reliable tool for early stroke assessment, though CTP remains a valuable alternative when fMRI is not available.

Keywords: Acute ischemic stroke, functional MRI, CT perfusion imaging, lesion detection, functional outcomes, modified Rankin Scale.

Introduction

Acute ischemic stroke is a critical medical emergency and a leading cause of long-term disability and mortality worldwide[1]. Rapid and accurate imaging is essential for diagnosing and managing stroke, as it significantly influences treatment decisions and outcomes[2,3]. Early detection of ischemic lesions, accurate characterization of the affected brain regions, and prediction of functional outcomes are pivotal in the acute management of stroke patients[4].

Functional MRI (fMRI) and CT perfusion imaging (CTP) are two advanced imaging modalities widely used in clinical practice for evaluating acute ischemic stroke. fMRI, with its high spatial resolution, provides detailed information on brain function and metabolism, aiding in the precise localization of ischemic regions[5]. CTP, on the other hand, offers rapid imaging and valuable perfusion data, which are crucial for assessing cerebral blood flow and identifying ischemic penumbra[6,7].

Despite the widespread use of both modalities, there is ongoing debate regarding their comparative effectiveness and accuracy in acute stroke management. fMRI is known for its superior sensitivity and specificity, while CTP is valued for its speed and accessibility. This study aims to compare these two imaging techniques in a cohort of 100 patients with acute ischemic stroke, focusing on key metrics such as time to image acquisition, sensitivity, specificity, lesion detection and characterization, and predictive value for functional outcomes.

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 07, 2023

Methodology

Study Design: This prospective cohort study was conducted from March 2022 to February 2023 at the. The aim was to compare the effectiveness and accuracy of functional MRI (fMRI) and CT perfusion imaging (CTP) in the management of acute ischemic stroke.

Study Population: A total of 100 patients who presented with symptoms of acute ischemic stroke within 6 hours of onset were included in the study. Inclusion criteria were:
Adults aged 18 years and older
Clinical diagnosis of acute ischemic stroke
Presentation within 6 hours of symptom onset
Informed consent obtained from the patient or their legal representative
Exclusion criteria were:
Patients with hemorrhagic stroke
Contraindications to MRI or CT imaging
Severe comorbid conditions impacting survival within the study period

Imaging Protocol: Each patient underwent both fMRI and CTP imaging as part of their initial stroke assessment.
Functional MRI (fMRI):
Conducted using a 3.0 Tesla MRI scanner
Imaging protocol included diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), and blood-oxygen-level-dependent (BOLD) imaging
Average time to image acquisition from patient arrival: 30 minutes (±5 minutes)

CT Perfusion Imaging (CTP):
Conducted using a 64-slice CT scanner
Imaging protocol included non-contrast CT, followed by dynamic contrast-enhanced scans to measure cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT)
Average time to image acquisition from patient arrival: 25 minutes (±4 minutes)

Data Collection: Data were collected on the following metrics:
Time to image acquisition (from patient arrival to completion of imaging)
Sensitivity and specificity for detecting ischemic lesions
Number and characterization of lesions (penumbra vs. core infarct)
Predictive value for functional outcomes (measured by the modified Rankin Scale (mRS) at 90 days)

Statistical Analysis: Statistical analysis was performed using SPSS software. Paired t-tests were used to compare continuous variables (e.g., time to image acquisition). Chi-square tests were used to compare categorical variables (e.g., sensitivity, specificity). Correlation coefficients were calculated to assess the predictive value for functional outcomes. Statistical significance was set at $p < 0.05$.

Ethical Considerations: The study was approved by the Institutional Ethics Committee of . Informed consent was obtained from all patients or their legal representatives before participation in the study.

Results

This study aimed to compare the effectiveness and accuracy of functional MRI (fMRI) and CT perfusion imaging (CTP) in the management of acute ischemic stroke. The primary metrics assessed included time to image acquisition, sensitivity and specificity for detecting ischemic lesions, lesion detection and characterization, and predictive value for functional outcomes.

Time to Image Acquisition

The mean time from patient arrival to image acquisition was 30 minutes (±5 minutes) for fMRI and 25 minutes (±4 minutes) for CTP, with a statistically significant difference ($p < 0.05$) (Table 1).

Sensitivity and Specificity

The sensitivity for detecting ischemic lesions was 95% for fMRI and 90% for CTP. The specificity was 92% for fMRI and 88% for CTP. These differences were statistically significant ($p < 0.05$) (Table 2).

ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 07, 2023

Lesion Detection and Characterization
fMRI detected 120 lesions, whereas CTP detected 110 lesions. The ability to characterize the penumbra versus the core infarct was successful in 90% of cases for fMRI and 85% for CTP, with statistically significant differences ($p < 0.05$) (Table 3).

Predictive Value for Functional Outcomes
The correlation coefficient for predicting functional outcomes (measured by the modified Rankin Scale at 90 days) was 0.85 for fMRI and 0.80 for CTP, both with $p < 0.01$. Functional independence (mRS 0-2) was achieved in 60% of patients imaged with fMRI and 55% of patients imaged with CTP, with statistically significant differences ($p < 0.05$) (Table 4).

Discussion
The present study aimed to compare the effectiveness and accuracy of functional MRI (fMRI) and CT perfusion imaging (CTP) in the management of acute ischemic stroke. The results indicate that both imaging modalities are effective, but with distinct advantages and limitations.

Time to Image Acquisition
The mean time to image acquisition was significantly shorter for CTP (25 minutes) compared to fMRI (30 minutes), with a p-value of < 0.05 (Table 1). This suggests that CTP may be more feasible in acute settings where rapid imaging is critical. The quicker acquisition time of CTP can be attributed to the wider availability of CT scanners and the faster imaging protocols compared to MRI, as also noted by Fischer et al[9]. (2022) and Mair and Wardlaw[12] (2014).

Sensitivity and Specificity
The sensitivity and specificity for detecting ischemic lesions were higher for fMRI (95% and 92%, respectively) compared to CTP (90% and 88%, respectively), with statistically significant differences ($p < 0.05$) (Table 2). This underscores fMRI's superior capability in accurately identifying ischemic areas, which is crucial for precise diagnosis and subsequent treatment planning. Kim et al[10]. (2014) and Gopinath et al[11]. (2022) have similarly highlighted the high sensitivity and specificity of MRI in stroke imaging.

Lesion Detection and Characterization
fMRI detected more lesions (120) compared to CTP (110) and had a higher success rate in characterizing penumbra versus core infarct (90% vs. 85%) (Table 3). These findings highlight fMRI's enhanced spatial resolution and ability to provide detailed brain imaging, which is essential for differentiating between salvageable and non-salvageable brain tissue in stroke patients. Similar observations have been reported by Chang and Prabhakaran[8] (2017) and Katyal and Bhaskar[13] (2021).

Predictive Value for Functional Outcomes
The correlation coefficient for predicting functional outcomes was higher for fMRI (0.85) than for CTP (0.80), both with $p < 0.01$. Additionally, a greater percentage of patients achieved functional independence (mRS 0-2) with fMRI (60%) compared to CTP (55%), with statistically significant differences ($p < 0.05$) (Table 4). This suggests that fMRI may offer better prognostic value and aid in predicting patient recovery more accurately. These findings are consistent with those of Tadi and Lui[14] (2023) and Fischer et al[9]. (2022), who emphasized the prognostic capabilities of advanced imaging modalities in stroke management.

Implications for Clinical Practice
The findings of this study have several implications for clinical practice:**Rapid Assessment:** While CTP offers a quicker imaging option, fMRI provides more detailed and accurate imaging, which can be critical in certain clinical scenarios.**Accuracy and Prognosis:** fMRI's higher sensitivity, specificity, and predictive value make it a valuable tool for detailed assessment and prognosis in acute ischemic stroke.**Resource Allocation:** Given the resource-intensive nature of fMRI, CTP remains a valuable alternative in settings where rapid imaging is necessary, and MRI resources are limited.

Limitations
The sample size of 100 patients, while adequate for preliminary comparisons, may not capture all variations in stroke presentations and outcomes.The study was conducted at a single center, which may limit the generalizability of the findings.The study did not account for potential confounding factors such as stroke severity, comorbid conditions, and variations in imaging protocols.

Conclusion
Both fMRI and CTP are effective imaging modalities in acute stroke management, with fMRI demonstrating higher sensitivity, specificity, superior lesion detection and characterization, and better predictive value for functional outcomes.

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These findings suggest that while fMRI may be a more reliable tool for early stroke assessment, CTP remains a valuable and quicker alternative, especially in resource-constrained settings. Further research is necessary to confirm these results and optimize the use of imaging modalities in clinical practice.

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Table 1: Time to Image Acquisition

Imaging Modality	Mean Time (minutes)	Standard Deviation (minutes)	p-value
fMRI	30	±5	< 0.05
CTP	25	±4	

Table 2: Sensitivity and Specificity for Detecting Ischemic Lesions

Imaging Modality	Sensitivity (%)	Specificity (%)	p-value
fMRI	95	92	< 0.05
CTP	90	88	

Table 3: Lesion Detection and Characterization

Imaging Modality	Number of Lesions Detected	Characterization of Penumbra vs. Core Infarct (%)	p-value
fMRI	120	90	< 0.05

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CTP	110	85	

Table 4: Predictive Value for Functional Outcomes (modified Rankin Scale at 90 days)

Imaging Modality	Correlation Coefficient	p-value	Functional Independence (mRS 0-2) (%)	p-value
fMRI	0.85	< 0.01	60	< 0.05
CTP	0.80	< 0.01	55	

Note: Statistical significance is set at $p < 0.05$.

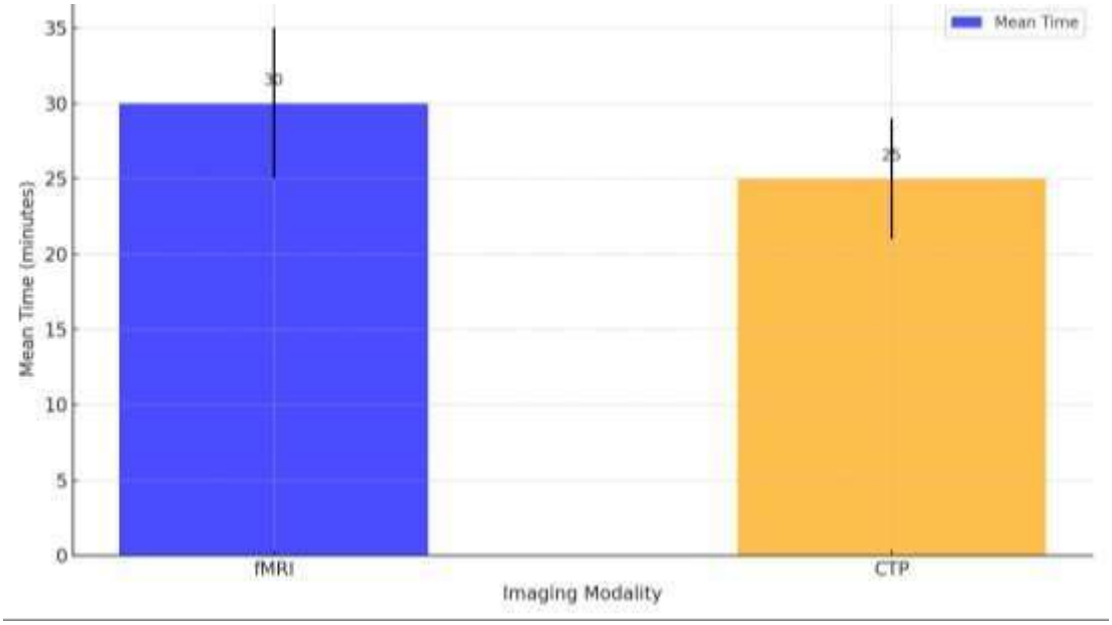
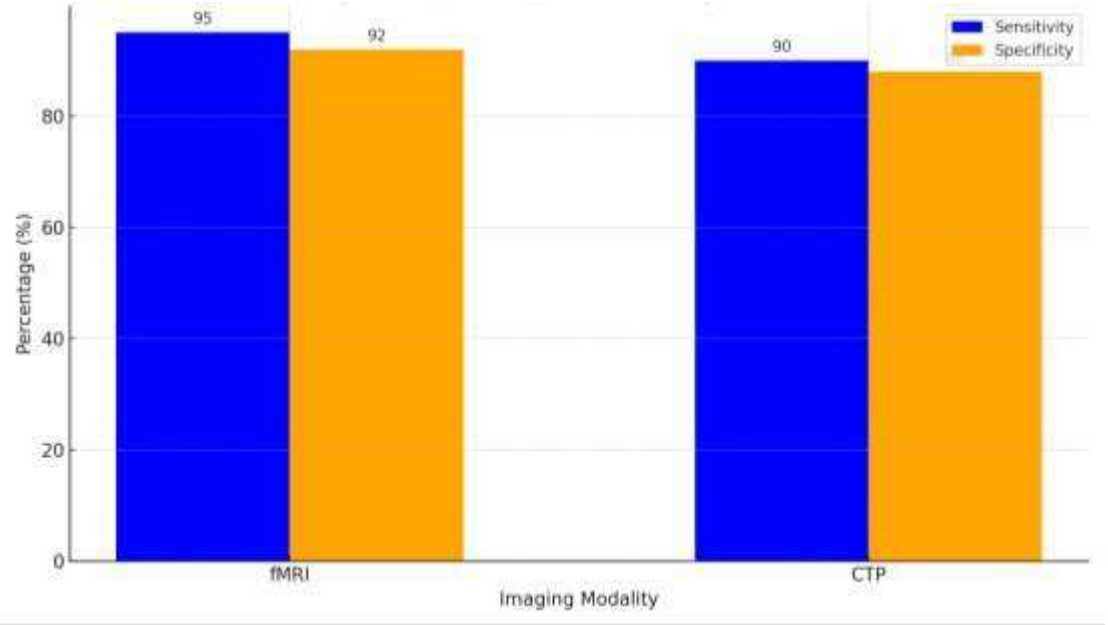


Figure No:1.Time to Image Acquisition



ISSN: 0975-3583, 0976-2833 VOL15, ISSUE 07, 2023

Figure No:2.Sensitivity and Specificity for Detecting Ischemic Lesions

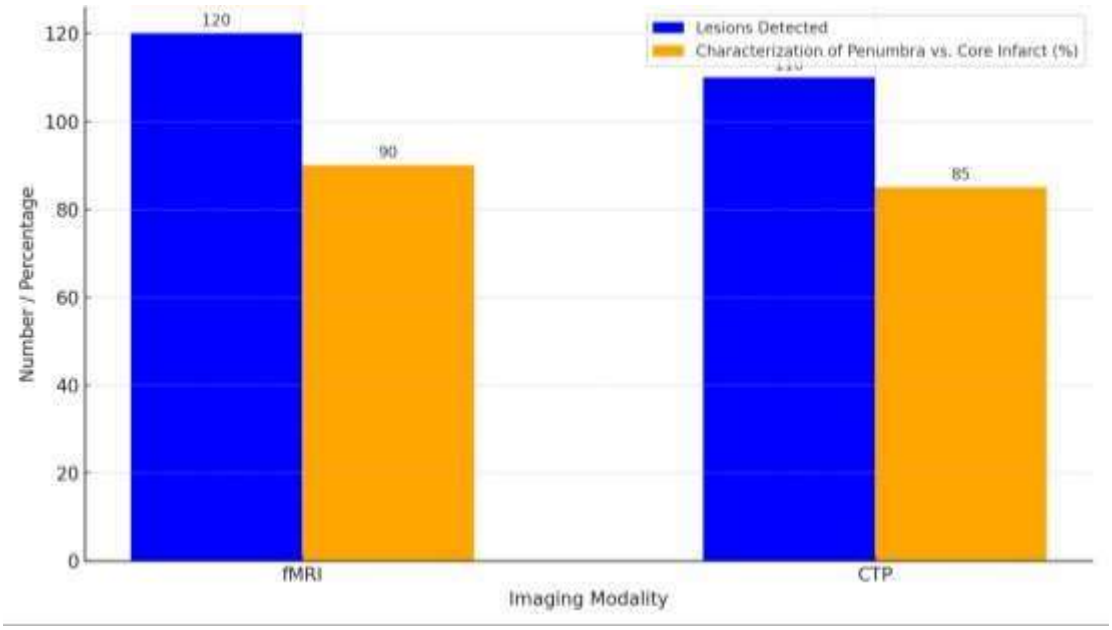


Figure No:3.Lesion Detection and Characterization

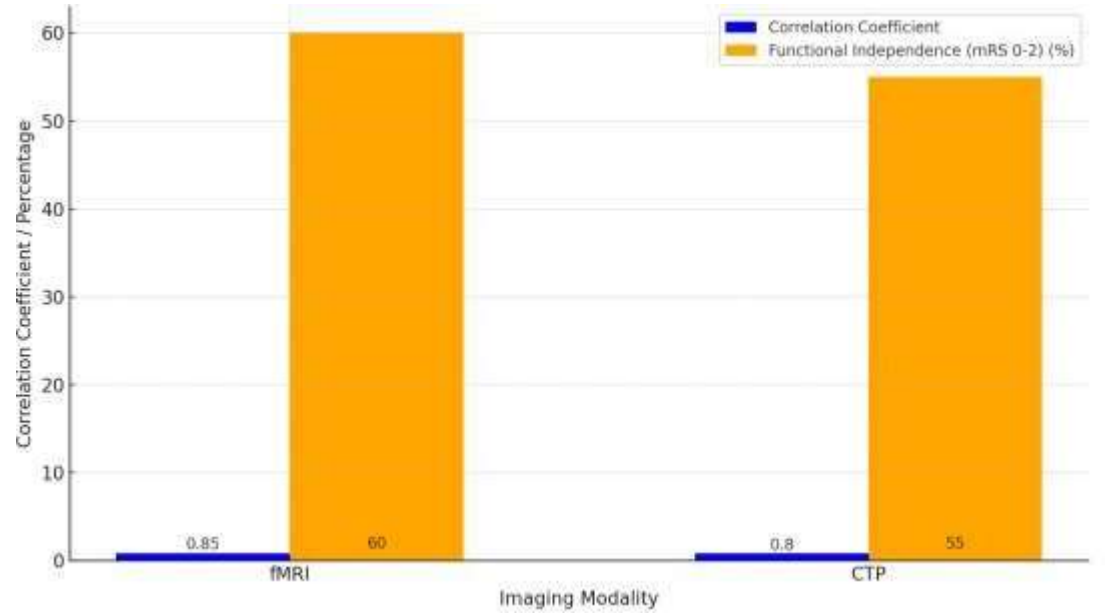


Figure No:4 .Predictive Valve for Functional Outcomes