Neuro-Cell Molecular Research

Research Article

Neuro-Cell Mol Res 2024;1(3):89-94

Diagnostic accuracy of computed tomography in acute ischemic stroke: A retrospective evaluation of sensitivity, specificity, and time-dependent performance

İsmail Taşkent

Department of Radiology, Faculty of Medicine, Kastamonu Univesity, Kastamonu, Turkiye

***Corresponding Author:**
İsmail Taşkent,
Department of Radiology, Faculty of Medicine, Kastamonu Univesity, Kastamonu, Turkiye
Mail: itaskent@kastamonu.edu.tr
Orcid ID: 0000-0001-6278-7863

DOI: 10.5281/zenodo.14557798

Received: **29 November 2024**
Accepted: **29 December 2024**
Published: **31 December 2024**

Abstract

Computed tomography (CT) is a widely accessible and rapid imaging modality for acute ischemic stroke diagnosis, but its sensitivity in early stages remains suboptimal compared to diffusion-weighted MRI (DWI-MRI). This study aimed to evaluate the diagnostic performance of CT in comparison with DWI-MRI in acute ischemic stroke.

A retrospective, single-center study was conducted, including 80 patients with suspected acute ischemic stroke and 30 controls who underwent both CT and DWI-MRI within 24 hours of presentation. Gray-white matter density differences and the hyperdense middle cerebral artery (HD-MCA) sign were analyzed to enhance CT's diagnostic accuracy. Sensitivity, specificity, and the Area Under the Curve (AUC) were calculated for CT across four time intervals (0-6h, 6-12h, 12-24h, 24-48h).

The overall diagnostic accuracy of CT (AUC=0.717) was moderate, with sensitivity and specificity values of 69.6% and 50% in the 0-6-hour interval. CT performance improved in the 12-24-hour interval, with sensitivity and specificity reaching 68.8% and 66.7%, respectively. The HD-MCA sign was observed in 18.8% of patients and showed 100% specificity but low sensitivity (30%). Gray-white matter density measurements significantly improved the diagnostic objectivity of CT, particularly in early stages.

CT remains a crucial tool for the early evaluation of stroke due to its accessibility and rapid imaging capabilities. However, integrating objective measurements such as gray-white matter density ratios and complementary imaging modalities like DWI-MRI can enhance its diagnostic performance. Future studies should focus on prospective, multi-center designs with larger patient cohorts, potentially integrating artificial intelligence, to refine these strategies.

Keywords: Acute ischemic stroke; Computed tomography; Diffusion-weighted MRI; Diagnostic accuracy

Introduction

Acute ischemic stroke is one of the leading causes of death in developed countries and is also a significant contributor to long-term disability and loss of function. Stroke, caused by the blockage of cerebral vessels, requires urgent medical intervention and is a condition that can be effectively treated with prompt diagnosis [1]. Significant advancements have been made over time in the development of standard procedures for treating acute ischemic stroke. Alongside these advancements, the need for reliable imaging methods to enable accurate early diagnosis has become increasingly important [2].

Computed tomography (CT) and diffusion-weighted magnetic resonance imaging (DWI-MRI) are two widely used and essential diagnostic methods in the imaging of acute stroke cases [3,4]. CT is the preferred method for the initial evaluation of stroke patients due to its rapid imaging capability and widespread accessibility. CT is particularly effective in excluding other pathologies, such as haemorrhage, with a high success rate. Its ability to provide quick results and the availability of CT scanners in nearly all hospitals are significant advantages [5]. However, the sensitivity of CT in detecting ischemic areas can be limited; early ischemic findings may not always be clearly visible, leading to delays in diagnosis for some patients [6,7]. Previous studies have highlighted the diagnostic specificity of the hyperdense middle cerebral artery sign but noted its limited sensitivity [8]. Furthermore, time-dependent changes in CT's diagnostic accuracy remain underexplored in large cohorts [9].

While CT is invaluable for ruling out haemorrhage and other pathologies, its limitations in detecting subtle ischemic changes necessitate complementary modalities like DWI-MRI, particularly in the early stages of stroke [10]. On the other hand, DWI-MRI is a method capable of detecting early changes in intracellular and extracellular water movement, allowing the identification of ischemia in brain tissue at an early stage. The high diagnostic accuracy of DWI-MRI in cases of acute ischemic stroke makes it particularly valuable during critical intervention periods [11]. Studies have shown that DWI-MRI is more sensitive than CT in detecting small and early-stage infarcts [12,13]. However, the use of DWI-MRI has certain limitations; it requires a longer imaging time, has limited accessibility, and may be contraindicated in certain patient groups, making it challenging to be the first-choice method in all cases [5].

This study aims to retrospectively evaluate the diagnostic effectiveness of CT by comparing it with DWI-MRI in patients presenting to the emergency department with suspected acute ischemic stroke.

Materials and Methods

Patient Selection

This retrospective, single-centre study includes patients who presented to our emergency department with suspected acute ischemic stroke between 2022 and 2024 and underwent both CT and DWI-MRI imaging. Inclusion criteria were as follows: patients aged 18 years or older with a diagnosis of acute ischemic stroke who had undergone both CT and DWI-MRI imaging within the first 24 hours of presentation and those whose demographic and clinical data were fully accessible. Patients were excluded if CT or DWI-MRI data were unavailable, imaging was performed at a different centre, other brain pathologies such as haemorrhage were identified, or artefacts were detected in CT or MRI images.

Imaging and Measurements

All patients underwent initial evaluation with CT followed by DWI-MRI in accordance with the acute stroke protocol. Brain CT scans were performed using a Toshiba (Alexion) 16-slice Helical CT scanner with axial images acquired at a slice thickness of 5 mm. DWI-MRI scans were conducted using GE Signa Explorer 1.5 of the Tesla system employing diffusion-weighted sequences (b=1000 s/mm²) with axial slices of 3-5 mm thickness.

To enhance the objectivity of acute ischemic stroke diagnosis using computed tomography (CT), gray-white matter density ratios were utilised. Hounsfield Unit (HU) values were compared in specific grey and white matter regions in affected and unaffected hemispheres (**Figure 1**). All images were evaluated using the Advantage Windows workstation (ADW 4.7 Ext. 16 Software, GE Company, U.S.A.). Gray-white matter density ratios were calculated by measuring HU values in the insular cortex and lentiform nucleus of both hemispheres; bilateral differences were compared, and if a significant difference was detected in the affected hemisphere, the existing CT findings were considered positive for ischemia. This approach aims to move beyond subjective evaluations, thereby improving the reliability and diagnostic efficacy of CT in stroke diagnosis [14].

Data Collection and Statistical Analysis

The demographic characteristics of the patients (age, gender) and the time of presentation were obtained retrospectively from patient records. CT and DWI-MRI images were evaluated by a radiology specialist with approximately 7 years of experience, and the presence, location, and extent of ischemic areas detected by both methods were recorded. Ischemic areas identified by DWI-MRI were considered the gold standard. Time intervals (0-6h, 6-12h, 12-24h, and 24-48h) were chosen based on clinical relevance and previous studies emphasizing the dynamic nature of ischemic changes [15].

The collected data were analysed using SPSS version 23.0 (SPSS Inc., Chicago, IL). Continuous variables were presented as mean ± standard deviation, while categorical variables were expressed as percentages (%). The agreement between CT and DWI-MRI results was evaluated using kappa statistics, with a significance threshold set at $p<0.05$. Receiver Operating Characteristic (ROC) curve analysis was performed to assess the diagnostic performance of CT compared to DWI-MRI, and the Area Under the Curve (AUC) was calculated.

Results

The demographic characteristics of the 80 patients included in the study and the 30 individuals in the control group were similar. The mean age of the patient group was calculated as 58,43±11,19 years (range 40-79), and that of the control group as 58,42±12,55 years (range 40-79). Gender

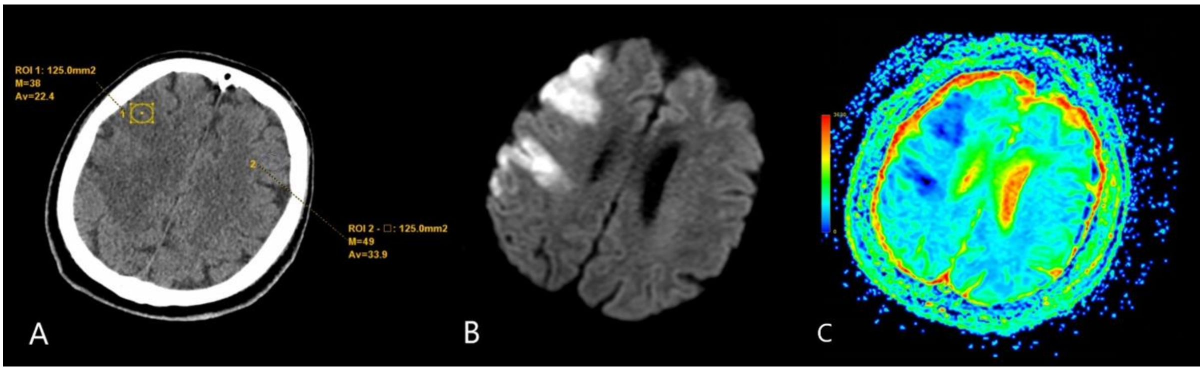

Figure 1. *Multimodal Imaging of Acute Ischemic Stroke in a 63-Year-Old Male Patient: CT, DWI-MRI, and ADC Map Showing Ischemic Changes in the Right Frontoparietal Region.* ***Figure 1A:*** *Brain CT image showing a loss of gray-white matter differentiation and decreased Hounsfield Unit (HU) density values in the affected hemisphere compared to the contralateral side.* ***Figure 1B:*** *DWI-MRI image of the same patient, demonstrating hyperintense areas in the right frontoparietal region indicative of diffusion restriction, consistent with early ischemic changes.* ***Figure 1C:*** *ADC (Apparent Diffusion Coefficient) map of the patient showing reduced ADC values in the right frontoparietal region, corroborating the findings on DWI-MRI and confirming the presence of ischemia.*

Table 1. *Demographic and clinical characteristics of the study and control groups*

Category	Patient Group	Control Group	P value
Number of patients	80	30	
Age	58.43±11.19 (40-79)	58.42±12.55 (40-79)	0.24
Gender (F/M)	39/41	16/14	0.66
Time	18.26±14.39 (2-48)	NA	NA
CT positive	48 (60%)	5 (16.7%)	NA
Hyperdense MCA	15 (18.8%)	NA	NA

NA: Non aplicable, CT: computed tomography, MCA: middle cerebral artery

Table 2. *Positivity rates, sensitivity, and specificity values of CT according to time intervals*

Time	BT positive	BT sensitivity	BT specificity
0-6 h	16/23	69.6%	50%
6-12h	8/19	42.1%	60%
12-24h	11/16	68.8%	66.7%
24-48h	13/22	59.1%	70%

h: hours

distribution in the patient group was 39 females and 41 males, while the control group had 16 females and 14 males (**Table 1**).

The proportion of CT-positive cases was 60% (n=48) in the patient group, compared to 16.7% (n=5) in the control group. The hyperdense MCA (middle cerebral artery) sign was observed exclusively in the patient group, with a prevalence of 18.8% (n=15). The low CT-positive rate in the control group supports the test's ability to differentiate stroke cases (**Table 1**).

In this study, the diagnostic accuracy of CT and the hyperdense MCA (HD_MCA) sign in detecting acute ischemic stroke was evaluated using ROC analysis. The AUC value for CT was found to be 0.717, indicating a moderate level of diagnostic accuracy. In contrast, the AUC value for HD_MCA was calculated as 0.594, demonstrating low performance in distinguishing between positive and negative cases (**Figure 2**).

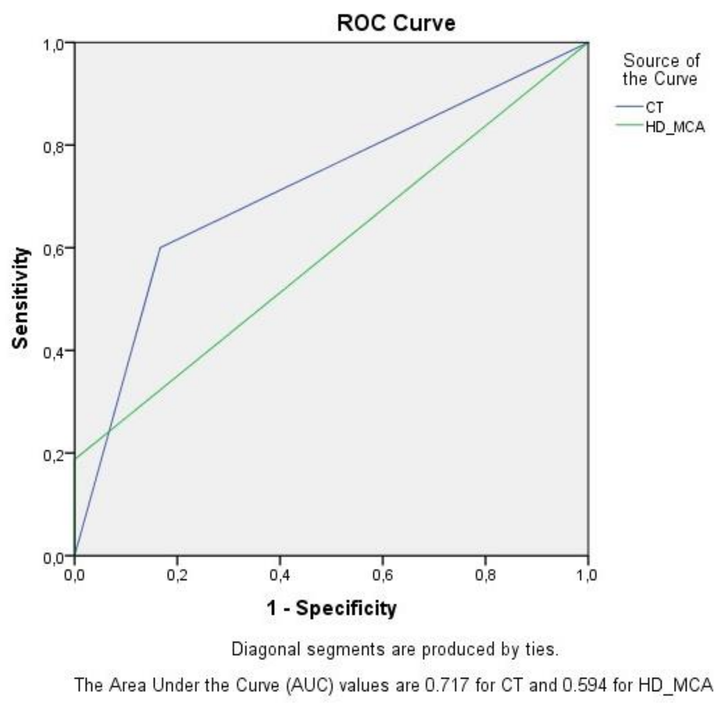

Figure 2. *ROC Curve Analysis Comparing BT and HD_MCA for Diagnostic Performance in Stroke Detection*.

The diagnostic performance of CT was evaluated across different time intervals in the study. In the initial 0-6-hour time frame, the positivity rate for CT was 69.6% (16/23), with a sensitivity of 69.6% and a specificity of 50%. In the 6-12-hour interval, the positivity rate dropped to 42.1% (8/19), with sensitivity and specificity calculated as 42.1% and 60%, respectively. For the 12-24-hour interval, the positivity rate increased to 68.8% (11/16), with a sensitivity of 68.8% and a specificity of 66.7%. Finally, in the 24-48-hour interval, the positivity rate was 59.1% (13/22), with sensitivity and specificity values of 59.1% and 70%, respectively (**Table 2**).

Discussion

In this study, the diagnostic performance of CT and the HD MCA sign in acute ischemic stroke was retrospectively evaluated. CT demonstrated moderate diagnostic accuracy (AUC=0.717), whereas HD MCA exhibited a lower diagnostic performance (AUC=0.594).

Acute ischemic stroke is one of the leading causes of death and a significant contributor to long-term disability and loss of function [16]. Stroke, caused by the blockage of cerebral vessels, requires urgent medical intervention and is a condition that can be effectively treated with prompt diagnosis [17]. Significant advancements have been made over time in the development of standard treatment procedures for acute ischemic stroke, highlighting the increasing need for reliable imaging methods to enable accurate early diagnosis [18]. Early CT findings, such as the HD MCA sign, can be valuable indicators of the presence of vessel occlusion [19]. In the literature, the HD MCA sign is reported to have 100% specificity but only 30% sensitivity; it is typically observed in large cortical and deep MCA infarcts, with a limited association with poor prognosis [20]. This study highlights the potential benefits of early imaging methods in the diagnosis of acute ischemic stroke and demonstrates that the diagnostic efficacy of CT can be enhanced through objective measurements. The imbalance between positive (80) and negative (30) cases, along with the presence of ties in the dataset, may have limited the discriminative power of the results, particularly for HD_MCA. In conclusion, while CT demonstrated acceptable diagnostic accuracy, HD_MCA alone was insufficient for a definitive diagnosis but may serve as a supportive finding.

The diagnosis of acute ischemic stroke using CT and DWI-MRI varies depending on the time window and the imaging modality employed. The literature emphasises the use of objective criteria, such as grey-white matter density ratios, to enhance the sensitivity of CT in the early stages [9]. In our study, the evaluation of CT across different time intervals revealed that sensitivity was highest (69.6%) during the 0-6-hour window, while specificity was lower (50%) compared to other time periods. This indicates that CT is effective in excluding other pathologies, such as haemorrhages, during the early phase but may have limitations in identifying ischemic areas. As time progressed, the diagnostic accuracy of CT improved, with sensitivity and specificity reaching 68.8% and 66.7%, respectively, in the 12-24-hour window. This suggests that CT becomes more effective in distinguishing ischemic regions over time. However, the lower sensitivity observed in the 6-12-hour window (42.1%) highlights the diagnostic limitations of CT during this specific period.

The hyperdense MCA sign on CT is an important indicator for detecting early ischemic changes, with a reported specificity of 100%. However, its sensitivity remains low, at around 30%. This suggests that while the HD MCA sign can serve as a specific marker in the early phase, it may not comprehensively assess all stroke cases [21]. In our study, the HD MCA sign was identified in 15 patients (18.75%) and was absent in the control group, consistent with findings in the literature.

Our study utilised density differences in grey and white matter between the affected region and the contralateral hemisphere to enhance the objective assessment capability of CT in stroke diagnosis. The literature highlights these methods as effective tools for detecting early ischemic changes and valuable complements to subjective evaluations [21,22]. In our study, grey-white matter density measurements improved the diagnostic accuracy and objectivity of CT in identifying ischemic areas. Particularly in the early stages, this approach is considered a method that can enhance the limited diagnostic capacity of CT.

Our findings align with those of previous studies in the literature; however, the study has certain limitations. Firstly, the retrospective design may have restricted the robustness of the analysis. Additionally, the single-centre nature of the study resulted in a limited sample size for both the patient and control groups. The small number of patients in some time intervals may have introduced bias, particularly in calculating sensitivity and specificity. Furthermore, HU measurements were performed by a single radiologist, which introduces the potential for observer bias and underscores the need for validation through multi-observer analysis in future studies. Nevertheless, our results support the reliability and potential utility of CT in diagnosing acute stroke.

Conclusion

CT remains an essential diagnostic tool in the early evaluation of stroke due to its rapid accessibility and widespread availability. However, its limitations in identifying ischemic areas underline the need for further advancements. Future research should explore integrating CT with complementary imaging modalities, such as MRI or objective measures like grey-white matter density measurement, and applying artificial intelligence to enhance diagnostic accuracy. Additionally, prospective studies involving larger and more diverse patient populations are necessary to validate these findings and refine diagnostic strategies.

Ethics Committee Approval

The study was carried out with the permission of the Kastamonu University Clinical Researches Ethics Committee (Decision No: 2024-KAEK-108).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed

Conflicts of Interest

The authors report no conflicts of interest.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version.

References

1. National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med. 1995;333(24):1581-1587. https://doi.org/10.1056/NEJM199512143332401
2. Lövblad KO, Baird AE. Computed tomography in acute ischemic stroke. Neuroradiology. 2010;52(3):175-187. https://doi.org/10.1007/s00234-009-0633-5
3. Benveniste H, Hedlund LW, Johnson GA. Mechanism of detection of acute cerebral ischemia in rats by diffusion-weighted magnetic resonance microscopy. Stroke. 1992;23(5):746-754. https://doi.org/10.1161/01.str.23.5.746
4. Barber PA, Demchuk AM, Zhang J, Buchan AM. Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. ASPECTS Study Group. Alberta Stroke Programme Early CT Score. Lancet. 2000;355(9216):1670-1674. https://doi.org/10.1016/s0140-6736(00)02237-6

5. Provost C, Soudant M, Legrand L, et al. Magnetic Resonance Imaging or Computed Tomography Before Treatment in Acute Ischemic Stroke. Stroke. 2019;50(3):659-664. https://doi.org/10.1161/STROKEAHA.118.023882
6. Mangesius S, Janjic T, Steiger R, et al. Dual-energy computed tomography in acute ischemic stroke: state-of-the-art. Eur Radiol. 2021;31(6):4138-4147. https://doi.org/10.1007/s00330-020-07543-9
7. Marks MP, Holmgren EB, Fox AJ, Patel S, von Kummer R, Froehlich J. Evaluation of early computed tomographic findings in acute ischemic stroke. Stroke. 1999;30(2):389-392. https://doi.org/10.1161/01.str.30.2.389
8. Chrzan R, Gleń A, Urbanik A. How to avoid false positive hyperdense middle cerebral artery sign detection in ischemic stroke. Neurol Neurochir Pol. 2017;51(5):395-402. https://doi.org/10.1016/j.pjnns.2017.07.009
9. Grøan M, Ospel J, Ajmi S, et al. Time-Based Decision Making for Reperfusion in Acute Ischemic Stroke. Front Neurol. 2021;12:728012. https://doi.org/10.3389/fneur.2021.728012
10. Gattringer T, Enzinger C, Ropele S, Fazekas F. Brain imaging (ct/mri). Ischaemic Stroke in the Young. 2018;113
11. Sorensen AG, Buonanno FS, Gonzalez RG, et al. Hyperacute stroke: evaluation with combined multisection diffusion-weighted and hemodynamically weighted echo-planar MR imaging. Radiology. 1996;199(2):391-401. https://doi.org/10.1148/radiology.199.2.8668784
12. Fiebach J, Jansen O, Schellinger P, et al. Comparison of CT with diffusion-weighted MRI in patients with hyperacute stroke. Neuroradiology. 2001;43(8):628-632. https://doi.org/10.1007/s002340100542
13. Kucinski T, Väterlein O, Glauche V, et al. Correlation of apparent diffusion coefficient and computed tomography density in acute ischemic stroke. Stroke. 2002;33(7):1786-1791. https://doi.org/10.1161/01.str.0000019125.80118.99
14. Wang Y, Deng J, Liu S, Tan J, Chen ZJTJoPR. Comparison of two types of thrombolysis combined with percutaneous transluminal angioplasty for acute thrombosis in arteriovenous fistula and graft. 2024;23(9):1517-1523.
15. Ostrek G, Przelaskowski A. Automatic early stroke recognition algorithm in CT images. Springer; 101-109.
16. Brønnum-Hansen H, Davidsen M, Thorvaldsen P; Danish MONICA Study Group. Long-term survival and causes of death after stroke. Stroke. 2001;32(9):2131-2136. https://doi.org/10.1161/hs0901.094253
17. Hasan TF, Rabinstein AA, Middlebrooks EH, et al. Diagnosis and Management of Acute Ischemic Stroke. Mayo Clin Proc. 2018;93(4):523-538. https://doi.org/10.1016/j.mayocp.2018.02.013
18. Alonso de Leciñana M, Egido JA, Casado I, et al. Guidelines for the treatment of acute ischaemic stroke. Neurologia. 2014;29(2):102-122. https://doi.org/10.1016/j.nrl.2011.09.012
19. Shi C, Killingsworth MC, Bhaskar SMM. Prognostic capacity of hyperdense middle cerebral artery sign in anterior circulation acute ischaemic stroke patients receiving reperfusion therapy: a systematic review and meta-analysis. Acta Neurol Belg. 2022;122(2):423-435. https://doi.org/10.1007/s13760-021-01720-3
20. Leys D, Pruvo JP, Godefroy O, Rondepierre P, Leclerc X. Prevalence and significance of hyperdense middle cerebral artery in acute stroke. Stroke. 1992;23(3):317-324. https://doi.org/10.1161/01.str.23.3.317
21. Koo CK, Teasdale E, Muir KW. What constitutes a true hyperdense middle cerebral artery sign?. Cerebrovasc Dis. 2000;10(6):419-423. https://doi.org/10.1159/000016101
22. Wang GN, Chen XF, Lv JR, Sun NN, Xu XQ, Zhang JS. The prognostic value of gray-white matter ratio on brain computed tomography in adult comatose cardiac arrest survivors. J Chin Med Assoc. 2018;81(7):599-604. https://doi.org/10.1016/j.jcma.2018.03.003