Journal of Diabetes Research and Endocrinology

Open Access | Opinion Article

Diagnostic and Prognostic Value of Neuroimaging in Acute Stroke

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DESCRIPTION

Neuroimaging has significantly reshaped the medical approach to acute stroke by allowing immediate visualization of brain structures, vascular pathways and cerebral blood flow patterns. When an individual arrives with abrupt weakness, difficulty speaking, facial asymmetry or visual disturbance, imaging plays a decisive role in determining whether the cause is ischemic obstruction or intracranial hemorrhage. This distinction directly influences urgent therapeutic decisions. Computed Tomography(CT) is frequently the first-line imaging method in emergency settings because it is fast, accessible and reliable. A plain CT scan can rapidly detect bleeding, space-occupying lesions, swelling or early signs of infarction. Even though some early ischemic findings may be subtle, the rapid exclusion of hemorrhage is essential before initiating thrombolytic treatment. Beyond the initial scan, advanced CT techniques provide deeper insight into vascular status and tissue viability. CT angiography enables visualization of arterial anatomy, identifying occlusions in major vessels such as the middle cerebral artery. Detecting these blockages promptly allows consideration of endovascular procedures like mechanical thrombectomy. CT perfusion imaging evaluates cerebral blood flow, cerebral blood volume and mean transit time, helping clinicians distinguish between infarct core and surrounding penumbral tissue that may still be salvageable. This physiological assessment supports individualized therapeutic strategies, particularly in patients presenting outside traditional treatment windows.

Magnetic resonance imaging further enhances stroke evaluation through superior tissue characterization. Diffusion-weighted imaging is extremely sensitive to acute ischemia and can reveal abnormalities within minutes after onset. By comparing diffusion restriction with perfusion deficits, clinicians can assess the mismatch between irreversibly injured tissue and potentially recoverable areas. Fluid-attenuated inversion recovery sequences assist in estimating lesion age, especially in cases where the exact onset time is uncertain, such as wake-up strokes. Susceptibility-weighted imaging is valuable for identifying micro bleeds and visualizing thrombus composition, information that can influence decisions regarding anticoagulation and reperfusion therapy. Imaging findings also contribute to prognosis and long-term management. The size and anatomical location of infarction often correlate with anticipated neurological deficits and rehabilitation requirements. Evaluation of extra cranial carotid arteries and intracranial vessels helps identify atherosclerotic narrowing, arterial dissections or embolic sources from the heart. Measuring the degree of carotid stenosis guides decisions about surgical intervention, stent placement or optimized medical therapy. Serial imaging during hospitalization and follow-up allows monitoring for complications such as hemorrhagic transformation, cerebral edema or recurrent ischemic events, enabling timely therapeutic adjustments.

Artificial intelligence has increasingly become integrated into stroke imaging workflows. Automated platforms can calculate the Alberta Stroke Program Early CT Score rapidly and generate perfusion maps with minimal manual input. These tools reduce interobserver variability and provide structured quantitative outputs that assist clinical teams. Automated alerts may notify stroke specialists immediately when imaging suggests large vessel occlusion, shortening the interval between diagnosis and intervention. Although radiologist interpretation remains indispensable, algorithm-based assistance enhances efficiency, particularly in high-volume centers. Efforts to improve access to neuroimaging are equally important. Many rural or economically limited regions lack advanced imaging equipment, contributing to treatment delays. Mobile stroke units equipped with on-board CT

Received: 01-March-2025; Manuscript No: IPNBI-26-23704; **Editor assigned:** 03-March-2025; PreQC No: IPNBI-26-23704 (PQ); **Reviewed:** 17-March-2025; QC No: IPNBI-26-23704; **Revised:** 22-March-2025; Manuscript No: IPNBI-26-23704 (R); **Published:** 31-March-2025; DOI: 10.36648/ipnbi.09.01.45

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Citation: Watanabe K (2025). Diagnostic and Prognostic Value of Neuroimaging in Acute Stroke. J Neurosci Brain Imag. 9:45.

scanners have been introduced in certain areas, enabling prehospital imaging and early triage. Tele-radiology systems permit remote image interpretation by specialists, expanding expertise beyond metropolitan hospitals. Such networks improve equity in acute stroke care and help ensure that timely decisions are not restricted by geographic location. Technological progress continues to refine imaging capabilities. Innovations such as dual-energy CT enhance tissue contrast and may improve detection of subtle hemorrhage or iodine staining after intervention. High-field MRI systems offer improved spatial resolution and better visualization of small infarcts and vascular abnormalities. At the same time, advancements in detector design and image reconstruction are reducing radiation exposure while maintaining diagnostic quality. These developments support safer and more precise evaluation. Artificial intelligence applications are also being designed to assist with triage and outcome prediction. Machine learning algorithms trained on extensive imaging datasets can estimate infarct volume, identify vascular occlusions and highlight minor hemorrhages that might otherwise be overlooked. Some predictive models combine imaging metrics with clinical information such as age, blood pressure, glucose levels and symptom duration to estimate risks of hemorrhagic transformation or poor recovery. These integrated tools assist multidisciplinary teams when considering complex therapeutic decisions. Future directions include portable MRI technologies and compact imaging systems that may extend advanced diagnostics to underserved settings. Continuous collaboration among international stroke centers promotes data sharing and refinement of imaging protocols.