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The Analysis Study of Diagnostic Imaging Performance and Accuracy for Diagnosis of Infarction Stroke : A Comprehensive Systematic Review

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ABSTRACT

Background: Imaging techniques like MRI and CT are advantageous in managing ischemic stroke, a significant occurrence due to a sudden decrease in blood flow to the brain. These techniques aid in identifying patients who would benefit from endovascular treatment (EVT), particularly for acute ischemic stroke (AIS) patients. Understanding the correlation between imaging effectiveness and precision could help formulate strategies for detecting this condition in specific patients. **Methods:** Following the PRISMA 2020 guidelines, this systematic study aimed to analyze entire English literature texts that were published between 2014 and 2024. Only editorials and review articles with a Digital Object Identifier (DOI) were accepted if they were published in the same publication as the submission. A variety of sources, including ScienceDirect, PubMed, and SagePub, were utilized to gather the literature. **Result:** The study analyzed more than 42,000 papers obtained from reputable venues such as Science Direct, SagePub, and PubMed. After deciding to subject eight publications to additional investigation, a thorough examination of the entire body of literature was carried out. **Conclusion:** Advanced imaging techniques, including CT and MRI, are crucial for stroke patients to receive accurate diagnoses and treatment. Artificial intelligence can speed up the process and reduce mistakes, especially for acute ischemic strokes. Non-contrast CT and CT angiography are essential for assessing strokes, while the ASPECTS method measures early brain changes. Perfusion imaging aids in identifying infarcts and assessing patients with AIS.

Keyword: Imaging, MRI, CT, ischemic stroke, AIS

INTRODUCTION

Strokes are a major worldwide cause of physical or mental disability and death. They occur when there is damage to a specific area of the central nervous system due to a vascular problem, resulting in neurological problems.[1] Strokes can be broadly categorized into two types: hemorrhagic strokes and ischemic strokes (ISs). Ischemic strokes occur when a thrombus obstructs or occludes an artery, leading to the interruption or reduction of blood flow to the brain tissue. Ischemic strokes, which occur when there is a sudden decrease in blood flow to the brain, make up a significant 80% of all strokes. The predisposing factors of these stroke subtypes have similarities while also having distinct characteristics. Hypertension is a contributing factor that increases the likelihood of experiencing hemorrhagic strokes. Additionally, it indirectly leads to an increase in ischemic strokes caused by atherosclerosis. Additionally, hyperlipidemia, atrial fibrillation, diabetes, and smoking are variables that increase the risk of strokes caused by atherosclerosis in the blood vessels of the brain and body, as well as strokes caused by blood clots originating from the heart.[2]

Various imaging techniques significantly enhance the clinical management of strokes. To exclude neoplasms and intracranial hemorrhages (ICHs), determine the infarct core, understand the extent of recoverable ischemic penumbras, and obtain real-time data on the vascular lumens, various subtypes of magnetic resonance imaging (MRI) and computed tomography (CT) are used. The choice of imaging modalities is contingent upon the proficiency and accessibility of personnel, as well as the hospital's infrastructure. MRI offers precise and highly sensitive data on smaller infarctions. Additionally, diffusion-weighted imaging (DWI) provides accurate information on the size of the central area affected by the infarction. MRI is also superior in distinguishing stroke-like conditions, including convulsive attacks, migraines, venous infarctions, and neoplasms. However, CT is more commonly utilized, as it can quickly rule out acute cerebral hemorrhages and is faster in terms of speed.[3] CT perfusion (CTP) imaging aids in identifying acute ischemic stroke (AIS) patients who would benefit from endovascular treatment (EVT) by accurately measuring the volume of the core infarct. This eliminates the need for extensive analysis to determine the onset time of strokes that occur in patients without prior symptoms upon waking up.[4] The significance of AIS can be crucial in both clinical and medico-legal contexts, and MRI can offer more precise information. Acute ischemic strokes (AIS) are strokes that last between 24 hours and 7 days. The early hyperacute phase of AIS occurs within the first 6 hours, while the late hyperacute phase occurs between 6 and 24 hours. Subacute ischemic strokes (ISs) typically occur within the time period of 1 to 3 weeks, whereas chronic ISs persist for more than 3 weeks.[5]

Endovascular thrombectomy (EVT) is advantageous for some patients experiencing acute ischemic stroke with large vessel obstruction (LVO) in the later stage, as evidenced by the DEFUSE 3 and DAWN randomized trials.[6,7] The selection of patients in these trials was extremely limited and relied on sophisticated imaging techniques such as CT perfusion and MRI. Although there are several shortcomings in the methodology, the selection criteria used in these trials have been included in important stroke guidelines. These guidelines suggest the use of sophisticated imaging in selecting patients for EVT.[8,9] Thrombectomy device trials currently require the use of advanced neuroimaging for patients who arrive between 6-24

hours after the onset of symptoms. This requirement aligns with the clinical recommendations set by the FDA. The most recent standards have been less stringent, indicating the presence of medical ambiguity.[10] Gaining insight into the correlation between the effectiveness and precision of diagnostic imaging modalities for ischemic stroke might be advantageous in formulating strategies and alleviating the challenges associated with detecting this condition in specific patients.

METHODS

Protocol

The author of the study diligently followed the PRISMA 2020 guidelines, which are a set of rules for conducting systematic reviews and meta-analyses, to guarantee complete adherence to all necessary criteria. To provide accurate and convincing research findings, a well devised technique was utilized.

Criteria for Eligibility

This study provides a thorough examination of the studies conducted in the past ten years on the performance and accuracy of diagnostic imaging for the diagnosis of ischemia stroke or infarction stroke. The objective of this program is to clarify and enhance patient care techniques by doing comprehensive data analysis. The primary objective of this thesis is to emphasize significant themes that are present in a variety of literary works.

To ensure the accuracy of the data used in this research, strict criteria for inclusion and exclusion were implemented. Any English-language material officially released between 2014 and 2024 is eligible for consideration. The exclusion criteria include published reviews, editorials, submissions without a DOI, and duplicate entries within the same journal.

Search Strategy

The study's keywords include "ischemic stroke, infarct, diagnostic imaging, imaging performance, imaging accuracy". For this research, the following Boolean MeSH keywords were entered into the databases: (((“ischemic stroke”[MeSH Terms] OR “infarct stroke“[All Fields] AND “diagnostic imaging”[All Fields]) OR (“ischemic stroke”[MeSH Terms] OR “stroke”[All Fields] AND “imaging”[All Fields]) AND (“diagnostic imaging”[MeSH Terms] OR “imaging performance”[All Fields] OR “imaging accuracy”[All Fields] OR “diagnosis”[MeSH Subheading] OR “stroke imaging”[All Fields]))).

Data retrieval

Before initiating this thorough analysis, the writers carefully evaluated the pertinence of each article by closely examining its title and abstract. Only research that satisfied the objectives and satisfied the criteria for inclusion in the article were considered more important. An identifiable and consistent pattern emerged after doing multiple searches. Full-text submissions were restricted to the English language alone. The screening procedure was meticulous and yielded content that was highly pertinent to the study's topic and satisfied all predetermined criteria for inclusion. Research that failed to meet these standards was generally disregarded, and its conclusions were not deemed noteworthy. The assessment covered a wide range of data, including factors, titles, authors, publishing dates, venues, and study procedures.

Quality Assessment and Data Synthesis

The authors themselves carefully examine the abstract and title of each article to select those that require further investigation. Consequently, each document that was initially being considered had to undergo a thorough scrutiny. The evaluation findings had a significant impact on the selection of the review papers. By utilizing this criterion, the article selection process was accelerated, allowing for a more thorough evaluation of prior research and the circumstances under which it was appraised.

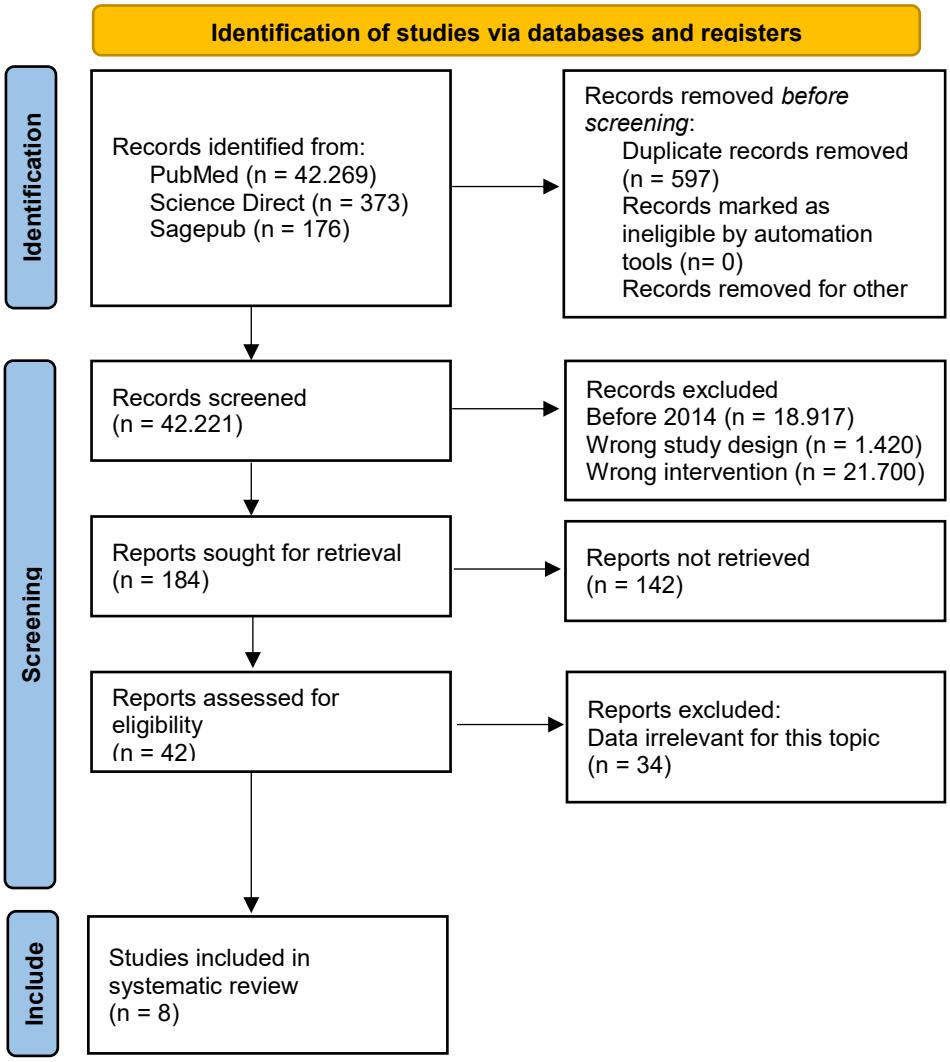

Figure 1. Article search flow chart

RESULT

In order to commence the investigation, our team meticulously collected a diverse array of documents from esteemed sources such as Science Direct, PubMed, and SagePub. Following a comprehensive three-stage evaluation procedure, we have chosen eight papers that are deemed extremely pertinent to our current systematic investigation. Afterwards, we chose specific subjects to examine more closely and thoroughly assessed each report with great attention to detail. To accelerate our investigation, we have supplied a succinct overview of the assessed material in Table 1.

Table 1. The literature included in this study

Author	Origin	Method	Sample	Result
Reid et al.[11] (2018)	Canada	Experimental study	89 patients	A study of 89 stroke patients found that multiphase computed tomography angiography (mCTA)-venous imaging significantly improved early ischemia identification, outperforming Non-contrast CT (NCCT) and mCTA-rLMC. Inter-observer reliability was almost perfect for all ASPECTS regions except the internal capsule. mCTA-venous was identified as the most important imaging covariate for predicting 24-h National Institutes of Health Stroke scale (NIHSS) and 90-day mRS.
Busto et al.[12] (2023)	Italy	Review	-	The cerebral collateral circulation is crucial for maintaining the viability of ischemic penumbra, which can be saved through reperfusion therapies. Computed tomography angiography (CTA) can assess collateral extent in acute ischemic stroke patients using single-phase CTA (sCTA) and multi-phase CTA (mCTA). Both methodologies have high prognostic predictive value, but

				mCTA appears superior in evaluating collaterals and identifying patients suitable for reperfusion therapies. This review analyzes their applications and potential for mCTA as the preferred method.
Klein et al.[13] (2023)	USA	Cross Sectional study	1.506 participants	The study found that interventionists were more likely to proceed directly to EVT in patients with favorable ASPECTS (Alberta Stroke Program Early CT Score) and preferred CT/CTA alone for patient selection. Interventionists were more likely to follow clinical guidelines when faced with uncertainty, while non-interventionists followed their assessment of evidence. This highlights the importance of evidence-based decision-making in patient care.
Nukovic et al.[14] (2023)	Boosnia & Herzegovina	Review	-	Ischemic strokes, caused by a thrombus blocking an artery, are a leading cause of physical and mental impairment. The choice of imaging modality depends on expertise, availability, and hospital infrastructure. Magnetic resonance imaging is more sensitive for smaller infarcts, while

				computed tomography is more commonly used for detecting and monitoring ischemic strokes.
Roest et al.[15] (2023)	Netherlands	Retrospective Study	141 patients	At focused view CTA, median scores for various anatomic structures were all 4, with C2 to C5 segments of internal carotid arteries and V1 to V3 segments of vertebral arteries ranging between 3 and 2. Unmodified CTA had a significantly higher median score of 5, indicating higher anatomic structures.
Samaniego et al.[16] (2023)	USA	Review	-	The diagnostic workup for acute ischemic stroke requires significant advancements in imaging technologies. Key areas include enhancing imaging capabilities, refining clot analysis, predicting reperfusion response, optimizing post-reperfusion therapy, and detecting early ischemia.
Frias et al.[17] (2024)	USA	Review	-	Imaging plays a crucial role in the diagnosis and treatment of acute ischaemic stroke (AIS), with noninvasive imaging being a crucial tool for accurate interpretation and early identification of potential therapy candidates, highlighting the evolution of AIS

				therapies and potential paradigm shifts.
Gonzalez et al.[18] (2024)	Germany	Experimental study	57 patients	Imaging techniques can enhance understanding of thrombus behavior and visualization in acute ischemic stroke. Understanding T1 and T2 relaxation times of target tissues can improve MRI sequences, determining signal intensities on imaging. Fibrin content and erythrocytes contribute to T1 relaxation times, influencing clot signal intensity.

Reid's study on stroke revealed that mCTA-venous assessment is more accurate in detecting early ischemia than NCCT and mCTA-rLMC score, and is predictive of clinical outcome, suggesting inclusion in future endovascular trials.[11]

Busto et al. proposed the generation of CTP maps from mCTA for EVT patient selection, reducing acquisition time and radiation dose. They also highlighted the importance of the cerebral collateral cascade, which assesses collateral extent, tissue-level collaterals, and venous outflow, in identifying AIS patients who benefit from reperfusion therapies.[12]

Klein's study revealed that interventionists tend to use less advanced imaging techniques in selecting LVO patients in the late window, relying more on evidence assessment rather than published guidelines, highlighting gaps in clinical guidelines and clinician belief in advanced imaging.[13]

Nukovic's research highlights the importance of neuroimaging in ischemic stroke patients for correct diagnosis and timely treatment. CT, MRI, angiography, and perfusion techniques provide valuable information for clinicians, aiding in the selection of the best treatment option. Artificial intelligence is expected to enhance efficiency and reduce errors in neuroimaging.[14]

Roest et al. demonstrated the potential of Focused view CTA for selectively analyzing stroke-related arteries, suggesting further improvements should focus on accurately visualizing smaller, tortuous internal carotid and vertebral artery segments.[15]

Samaniego's neuroimaging workshop identified 10 key areas of imaging promising for enhancing stroke outcomes. These include early stroke detection, BBB damage identification, clot characterization, and vessel wall imaging. Collaboration between investigators, industry, and regulators is crucial for advancing imaging research and improving patient outcomes.[16]

Frias emphasizes the importance of diagnostic neuroradiologists staying updated on imaging techniques for AIS patients, acknowledging the rapid progress of the field and the need for future research to refine management strategies.[17]

Gonzalez's study reveals that fibrin content is a key biomarker for T1 relaxation times, causing an increase in clot signal intensity. T2w DRIVE images show thrombi with higher fibrin intensity, while T1w TSE images show thrombi with more erythrocytes. These findings could improve MRI sequences for clot visualization.[18]

DISCUSSION

Imaging, such as CT and MRI, is essential for stroke patients to get the right diagnosis and the best treatment. Artificial intelligence can help make the process faster and reduce mistakes, especially for conditions like acute ischemic strokes. MRI takes time and is unavailable in all stroke units, but it can be made more efficient using compressed sensing. New software can automatically score the extent of early damage in the brain and measure blood flow on CT scans. This saves time and helps identify patients who can benefit from thrombectomy. We still need to consider ethics and do more studies for future improvements in imaging for neurological conditions.[14] Strokes caused by blockages often use imaging methods like non-contrast CT (NCCT) and CT angiography (CTA) to see how the brain is affected. NCCT is the first test for assessing strokes and has become very important since IV tPA therapy was introduced. The ASPECTS method measures early changes in ten areas of the brain and is often used with NCCT. CTA is essential for assessing strokes, and helping doctors find the blocked blood vessel, which is crucial for treatment. It also gives important information about the clot, the presence of other blockages, and the brain's structure. CT perfusion (CTP) is useful for assessing strokes, but its role is still being studied, especially for strokes in the back of the brain.[17,19] NCCT helps us find early changes in the brain, but it can be tricky to interpret. The ASPECTS system helps standardize how we assess early damage, which is important for deciding on treatment.[20] However, different doctors may rate the damage differently because it's hard to define clear boundaries for what's abnormal. New methods, like relative NCCT maps and net water uptake, can help with this problem. Using artificial intelligence to help find strokes could be very helpful, especially for remote healthcare and mobile stroke units. It might help more patients get the right treatment faster.[16,21]

The study shows that using multi-modal CT imaging can greatly improve the accuracy of diagnosing follow-up infarction in stroke patients.[11] This method allows for the characterization of different tissue states without needing additional imaging or post-processing techniques. It is especially useful for patients with unknown stroke onset or those who arrive late.[6,7] The imaging process aims to rule out intracranial hemorrhage, show a target vessel, assess collateral status, evaluate the extent of risk tissue, and determine the ischemic core. The different imaging parameters measure various aspects of the ischemic lesion. Ultimately, the advantage of using multi-modal CT imaging for predicting tissue outcomes and making decisions about endovascular thrombectomy (EVT) is demonstrated. This method has the advantage of covering the whole brain, is readily available after the scan, and does not require expensive automated software. The current approach for assessing perfusion lesion source images using multi-modal CT imaging is straightforward and reliable for accurately detecting severe ischemia in each ASPECTS region.[11]

Remember that standard CTA (sCTA) has limitations due to its lack of temporal resolution, which can lead to overestimation of collaterals and underestimation of collateral supply.[22] On the other hand, multiphase CTA (mCTA) provides three time-resolved images, allowing for more accurate collateral assessment. It also shows higher interrater reliability and superior accuracy in predicting functional outcomes at 3 months.[22,23] mCTA is superior to sCTA as a prognostic predictor in patients admitted at 4.5-15 hours after symptom onset and treated with standard medical therapy and IVT and/or EVT.[24] It also outperforms sCTA in analyzing venous outflow at the level of cortical veins, which is an indirect indicator of collateral extent and tissue perfusion.[12] Perfusion imaging plays a significant role in identifying infarcts, especially in patients with large core infarcts. It can help detect occlusions that are difficult to identify on CT, particularly those of smaller, more distal arterial branches. CT has effective analogs with MRI, for example, diffusion-weighted imaging (DWI) can identify ischemic changes in the brain within 3 minutes of insult. MRI also aids in evaluating patients with AIS, particularly in elucidating prognosis after treatment. The Pons-Midbrain and Thalamus score (PMT) has been shown to correlate with clinical outcomes following mechanical thrombectomy, outperforming PC-ASPECTS. Emergent noninvasive imaging of the brain and cervicocerebral arteries is essential for patients with suspected AIS.[8,17]

The study shows that using specific MRI protocols can help improve the visualization of blood clots that occur during an acute ischemic stroke.[25] The main factors used to determine the characteristics of the blood clots were fibrin and iron content, which affect the T1 and T2 relaxation times of the clots, respectively. By analyzing these factors, the study was able to categorize different types of clots. The study also found that advanced imaging techniques can help in the selection of stroke patients for EVT (endovascular treatment), although some studies have questioned this approach and indicated that good outcomes can still be achieved using CT without advanced imaging.[18] Despite the associated increased costs, staffing, radiation dose, and image acquisition time, advanced imaging is readily available for the majority of respondents, and a significant percentage of patients undergo this type of imaging.[26,27] Additionally, it was observed that most interventionists tend to follow stroke guidelines, with a preference for advanced imaging or CT/CTA for making treatment decisions. Lastly, the study showed that in cases of M1 occlusion or wake-up strokes occurring 9 hours after last known well, interventionists were more inclined to proceed directly to EVT.[28,29]

CONCLUSION

Advanced imaging techniques, such as CT and MRI, are crucial for stroke patients to receive accurate diagnoses and treatment. Artificial intelligence can speed up the process and reduce mistakes, especially for acute ischemic strokes. Non-contrast CT (NCCT) and CT angiography (CTA) are essential for assessing strokes, while the ASPECTS method measures early changes in ten brain areas. Multi-modal CT imaging can improve the accuracy of diagnosing follow-up infarction in stroke patients, especially for patients with unknown stroke onset or late arrivals. Perfusion imaging plays a significant role in identifying infarcts and aiding in evaluating patients with AIS. Advanced imaging techniques can also help in selecting stroke patients for endovascular treatment, although some studies suggest good outcomes can still be achieved using CT without advanced imaging.

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