Diagnostic Accuracy of Diffusion-Weighted MR Imaging Versus CT Brain in Hyperacute Stroke – A Prospective Study, Rohtas, Bihar

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ABSTRACT

BACKGROUND

The purpose of imaging is multifaceted, ranging from selecting the most appropriate patients for treatment, to avoiding those who are unlikely to benefit. In the present situation, imaging methods basically include cross-sectional imaging by computed tomography (CT) or magnetic resonance imaging (MRI). The target of the assessment is the vessels that supply the brain parenchyma and its associated part at the same / distant perfusion level. In this study, we wanted to evaluate the diagnostic accuracy of diffusion-weighted MR imaging with non-enhanced CT in the diagnosis of hyperacute stroke.

METHODS

This prospective study was conducted in Radiology Department at Narayan Medical College Rohtas, Bihar. The study group includes a sample of 45 patients who had come to the Department of Radiology within 6 hours of onset of stroke symptoms. Non-enhanced computed tomography (NECT) and MRI were done in all the patients and the results were studied. Study subjects were recruited as following inclusion and exclusion criteria. Data was collected, entered and analysed using Microsoft Excel, Epi Info and statistical package for social sciences (SPSS) software.

RESULTS

The hyperintense ischemic lesions on diffusion-weighted imaging (DWI) were typically more visually distinct and easier to distinguish than the EIS on CT scans, resulting in better overall values. When the five regions were looked at separately, DWI had higher sensitivity than CT studies, which was close to the overall EIS ranking. The basal ganglia and the insular ribbon had the greatest sensitivity in both modalities. Eight of the 14 patients were classified in the consensus rating of CT and DW imaging, resulting in a sensitivity of 57 percent for both methods, with a bad value of 0.40 for CT and a good value of 0.68 for DW imaging.

CONCLUSIONS

DW imaging had a higher sensitivity and interrater agreement than CT imaging in detecting early infarction.

KEYWORDS

Stroke, Computed tomography, MRI, Ischaemia

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BACKGROUND

The availability and supply of oxygen and nutrients are essential for the proper functioning of neurons and synapses. Even in few hours, any disruption in these can cause permanent damage to the functional neural networks. Other cells in the body, on the other hand, have the power to repair and regenerate but not in the brain. Approximately 1.9 million neurons die per minute due to nutritional deficiency, which equates to 3.6 years of ageing per hour if left untreated.[1] Cerebrovascular accident (stroke) is a neurological deficiency that occurs when part (s) of the brain is damaged by rapid focal disruption of cerebral blood flow. Depending on the mechanism of brain injury, stroke events are classified as ischemic and haemorrhagic. Ischemic stroke is (80 – 85 %) caused by blockage blood supply to the brain. This blockage can be caused by the formation of a thrombus (thrombus) in one of the major arteries in the head or neck.[2]

The clinical appearance plays a big role in determining whether or not a person has had a stroke. Stroke mimics account for 19 % to 30 % of suspected stroke presentations, with a wide range of underlying causes. DWI can now accurately identify ischemic lesions thanks to developments in MRI technology (88 percent to 100 percent sensitivity, 95 percent to 100 percent specificity). It's possible to get a false-negative DWI result, and a meta-analysis of 3,236 acute ischemic stroke patients found that 6.8 % of them had DWI-negative acute ischemic stroke. False-negative DWI was linked to less serious strokes, a longer period between onset and scan, small vessel disease, and posterior circulation localization, such as in patients with small punctate infarcts in the brainstem (e.g., medulla) or deep grey nuclei (e.g. thalamus).[3]

The purpose of imaging is multifaceted, ranging from selecting the most appropriate patients for treatment, to avoiding those who are unlikely to benefit. In the present situation, imaging methods basically include cross-sectional imaging by computed tomography (CD) or magnetic resonance imaging (MRI). The target of the assessment is the vessels that supply the brain parenchyma and its associated part at the same / distant perfusion level.[1] It is important to assess the ischemic penumbra as early as possible when evaluating an acute ischaemic stroke (AIS) patient. Positron emission tomography (PET), single photon emission computed tomography, and contrast-enhanced computed tomography are some of the current techniques for ischemic penumbra assessment.[4] Since the 1980s, magnetic resonance imaging has been playing a critical tool in the assessment of acute stroke patients. If the patient is > 6 hours after last known normal status and has large vessel occlusion, computed tomographic perfusion or diffusion-weighted image (DWI) / magnetic resonance (MR) perfusion scans should be obtained, according to new 2018 guidelines. Despite the fact that a variety of MR sequences have recently been developed and used due to their unique clinical value, DWI is widely used in acute care hospitals and provides a wealth of information about acute stroke.[5]

The most reliable imaging test for acute ischemic stroke is magnetic resonance imaging, especially diffusion weighted imaging and apparent diffusion coefficient maps. In general, MRI is thought to be superior to computed tomography in diagnosing acute stoke.[6] This is especially true for patients who present to the ED within 6 hours of the onset of symptoms (i.e., the hyperacute phase). However, because MRI is not as easily available in most EDs as non-contrast computed tomography (NCCT), deciding to get an MRI right away after a negative NCCT can be difficult from a practical and logistical standpoint, particularly when patients' symptoms (e.g. dizziness, imbalance, vision difficulty) are ambiguous and non-specific.[7]

MRI has significantly higher sensitivity and specificity than CT in the diagnosis of acute ischaemic stroke in the first few hours after onset, especially with the use of DWI. DWI is, indeed, able to detect ischaemic changes within minutes after onset. It is true, however, that a stroke may appear normal on DWI if it is very acute or may be seen beyond the first minutes. Patients without a lesion are more likely to be women or have previous stroke.[8]

Diagnosis of stroke largely depends on clinical presentation. Stroke-mimics account for 19 % - 30 % of suspected stroke presentations, with diverse underlying aetiology. Physicians need to consider a broad differential diagnosis when evaluating a patient presenting with a focal neurological deficit. With recent advances in MRI technology, ischemic lesions can be identified with high accuracy using diffusion-weighted image (DWI; 88 % – 100 % sensitivity and 95 % – 100 % specificity).[3]

With the above background this study was conducted at Narayan Medical College and Hospital, Jamuhar, Sasaram with following aims and objectives.

Objectives

1. To study the diagnostic accuracy of diffusion-weighted MR imaging with non-enhanced CT in the diagnosis of hyperacute stroke.
2. To study the role of diffusion-weighted MR imaging and non-enhanced CT in diagnosing hyperacute ischemic stroke and deciding thrombolytic treatment/therapeutic protocols aimed at reversing the cerebral ischemic insult.

METHODS

This prospective study was conducted in Radiology Department at Narayan Medical College Rohtas, Bihar from July 2020 to March 2021. The study group includes a sample of 45 patients who had come to the Department of Radiology within 6 hours of onset of stroke symptoms. NECT and MRI were done in all the patients and the results were studied. Informed consent was taken from all the patients enrolled in the study as per the guidance of the ethical committee and ethical approval was taken from institutional ethics committee. Study subjects were recruited as following inclusion and exclusion criteria.

Inclusion Criteria

Patients who presented within 6 hours of onset of stroke symptoms including subtle focal neurological deficits.

Exclusion Criteria
Patients with haemorrhagic stroke were excluded from the study. Patients with surgical clips and contraindications for MR imaging, were excluded from the study.

Patient Evaluation
A complete prospective evaluation of all patients was carried out as per our questionnaire.

Imaging Methods and Analysis
Clinical data was collected from all patients and all of them underwent unenhanced CT and MRI imaging.

CT

CT currently forms the basics of acute stroke imaging due to its easy availability, quick data acquisition capability, and reasonably good demonstration of findings. The first and the foremost consideration is to rule out haemorrhage so that intravenous therapy can be immediately instituted if the patient is in the window phase. This is followed by exclusion of other pathologies (clinical mimics) and identification of signs of ischemia. CT scans were performed with a thin-section CT scanner in single-section mode (Somatom Plus 4; Siemens Medical Systems, Erlangen, Germany). Tube current was set to 600 mAs infratentorially for 2 - mm (thickness) sections and 480 mAs supratentorially for 6-mm sections (field of view, 210 - 210 mm; matrix size, 512- 512). These criteria were only used in patients suspected of having a hyperacute stroke to prevent excessive radiation exposure during routine CT scanning. Image analysis was performed on hard copies with a reduced, but standardised, window setting: 30/80 HU (center / width) for 2 - mm sections and 35/50 HU for 6-mm sections, based on a previously suggested narrow window width. To further minimise image noise, a soft image reconstruction algorithm was used.

MRI

A 1.5 Tesla MR system with a standard head imaging coil and high-speed gradients was used for imaging. The DWI was conducted over 18 axial sections (18, 7 mm thick sections with no intersection gap, matrix 96 x 128, field of view 240 mm with single acquisition) using a single shot, gradient echo, echo planar pulse sequence with diffusion gradient b values of 0 and 1000 s/mm2 along all three orthogonal axes. Automatic post-processing of diffusion weighted images yielded trace images from the primary data. The apparent diffusion co-efficient (ADC) trace maps were created using the DWI, which was acquired along the three main axes**.** The ischemic lesions' mean ADC was computed. The sulcal and ventricular cerebrospinal fluid, both of which have a high ADC value, were excluded from the study. Axial diffusion weighted imaging (DWI), fluid attenuated inversion recovery (FLAIR), sagittal and axial T1 weighted images, axial T2 weighted images, gradient sequence (GRE) and multi slab three-dimensional time of flight magnetic resonance angiography are some of the MR imaging sequences available (TOF MRA).

An axial 5 mm thick T2 weighted sequence (3000/100/20), coronal FLAIR sequence with 4 mm thickness (TR/TE 800/112, T1 -2800 msec), and sagittal and axial 5 mm thick T1 weighted spin echo sequence (TR/TE-550/15) were all part of the standard scanning protocol. With the MR sequences, the total image acquisition and reconstruction processing time was about 12 minutes on average. (Ten to fourteen minutes).

Statistical Analysis
Data was collected, entered and analysed using Microsoft Excel, Epi Info and statistical package for social sciences (SPSS) software.

RESULTS

Both modalities took an average of 24.5 minutes to obtain images (range: 10 – 41 minutes). Prior to CT, DW imaging was performed in 12 patients. The average time between symptom onset and CT imaging was 158 minutes (range, 50 – 305 minutes) for CT and 166 minutes (range, 23 – 319 minutes) for DW imaging (P - 0.06, paired t test, two-tailed). Thirty scans were compiled in the first three hours. Follow-up imaging was conducted after a mean delay of 5.2 days (range, 1 – 12 days). The average NIHSS score at the time of entry was 13.3 (range: 3 – 23).

Table 1 summarizes the consensus rating's blinded data. Overall, 33 of 45 patients (73 percent sensitivity) agreed on the presence of EIS on CT scans, with a moderate value of 0.57. The presence of parenchymal hyperintensity was confirmed by DW imaging in 42 of 45 patients.

The hyperintense ischemic lesions on DW images were typically more visually distinct and easier to distinguish than the EIS on CT scans (Figs. 1 and 2), resulting in better overall values. When the five regions were looked at separately, DW imaging had a higher sensitivity than CT studies, which was close to the overall EIS ranking. The basal ganglia and the insular ribbon had the greatest sensitivity in both modalities.

Any EIS, EIS by Region	73 (58–85)	0.57 (0.51–0.62)	93 (82–99)	0.85 (0.78–0.91)
Frontal Parietal	52 (34 – 69)	0.30 (0.23 – 0.37)	79 (61 – 91)	0.61 (0.53 – 0.68)
Temporal Basal	38 (19 – 59)	0.40 (0.33 – 0.47)	75 (53 – 90)	0.56 (0.49 – 0.63)
Ganglia Insular	45 (26 – 64)	0.42 (0.35 – 0.49)	62 (42 – 79)	0.58 (0.51 – 0.66)
ribbon	67 (47 – 87)	0.31 (0.24 – 0.38)	86 (64 – 97)	0.80 (0.73 – 0.86)
Any EIS > one-	67 (43 – 85)	0.38 (0.31 – 0.45)	85 (68 – 95)	0.72 (0.65 – 0.79)
third of MCA	57 (29 – 82)	0.40 (0.33 – 0.47)	57 (29 – 82)	0.68 (0.61 – 0.75)
Unblinded Data Set				
Any EIS	76 (60 – 87)	0.67 (0.61 – 0.72)	96 (85 – 99)	0.88 (0.82 – 0.95)
Any EIS > one-third of MCA	57 (29 – 82)	0.53 (0.46 – 0.61)	57 (29 – 82)	0.68 (0.61 – 0.75)

Table 1. Sensitivity and Interrater Agreement in the Consensus Rating

14 patients were reported as having lesions that covered more than one-third of the middle cerebral artery (MCA) territory (major infarction). Eight of the 14 patients were classified in the consensus rating of CT and DW imaging, resulting in a sensitivity of 57 percent for both methods, with

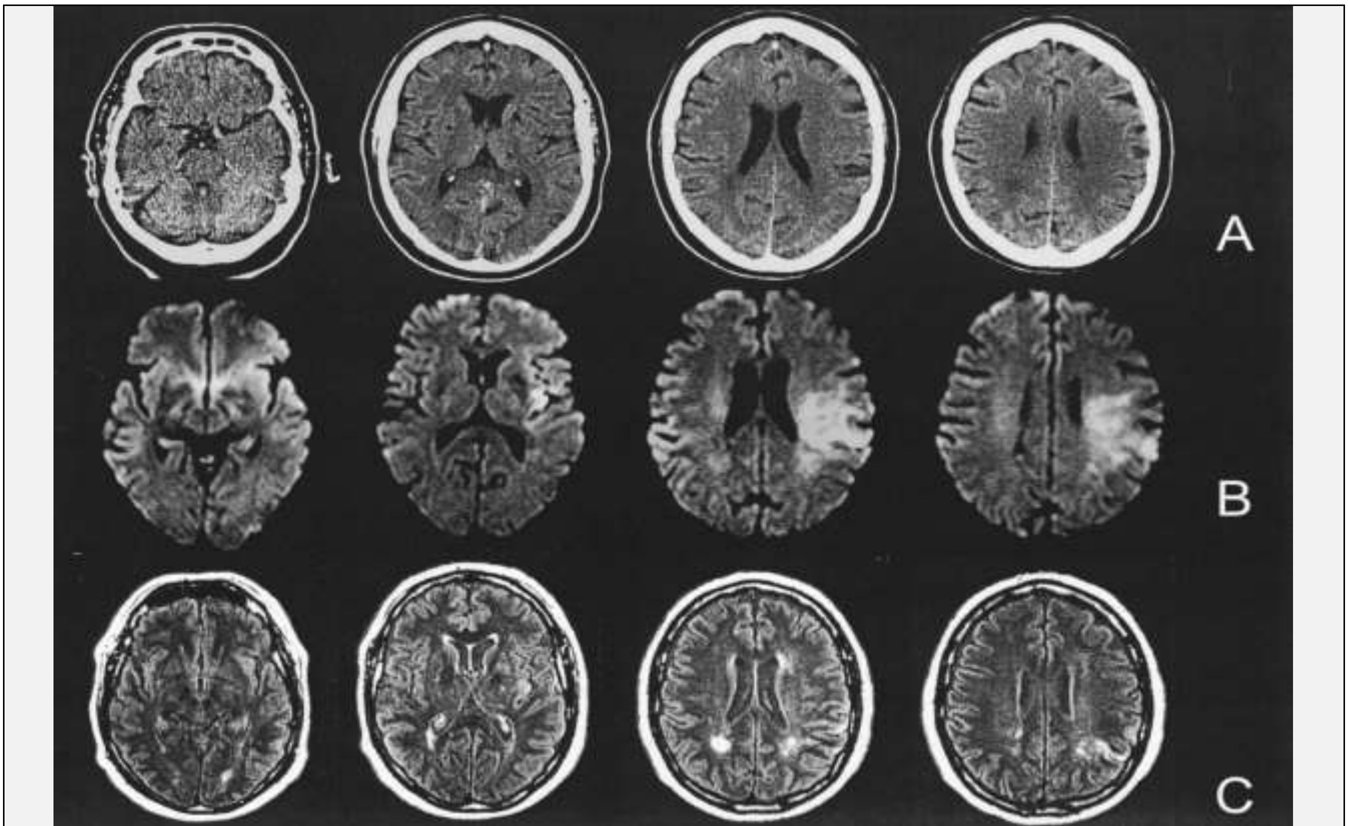

Figure 1. Case of a 62-Year-Old Patient with Aphasia and Right Hemiparesis. (A) CT Scans Obtained 100 Minutes after Symptom Onset, (B) DW Images Obtained 120 Minutes after Symptom Onset, and (C) Follow-up Flair Images. DW Images were Rated Positive by all Raters and Show Hyperintensity in the Left MCA Territory. CT Scans were Rated Normal by Five of the Six Raters. With the Knowledge of the DW Images, There Might be a Subtle Hypoattenuation in the Left Insular Ribbon Region on CT Scans. However, the Follow-up Flair Images Reveal Only Small Ischemic Lesions of the Left Insular Ribbon and Parietal Regions, with Normalization of Large Parts of the Former Diffusion-Restricted Area

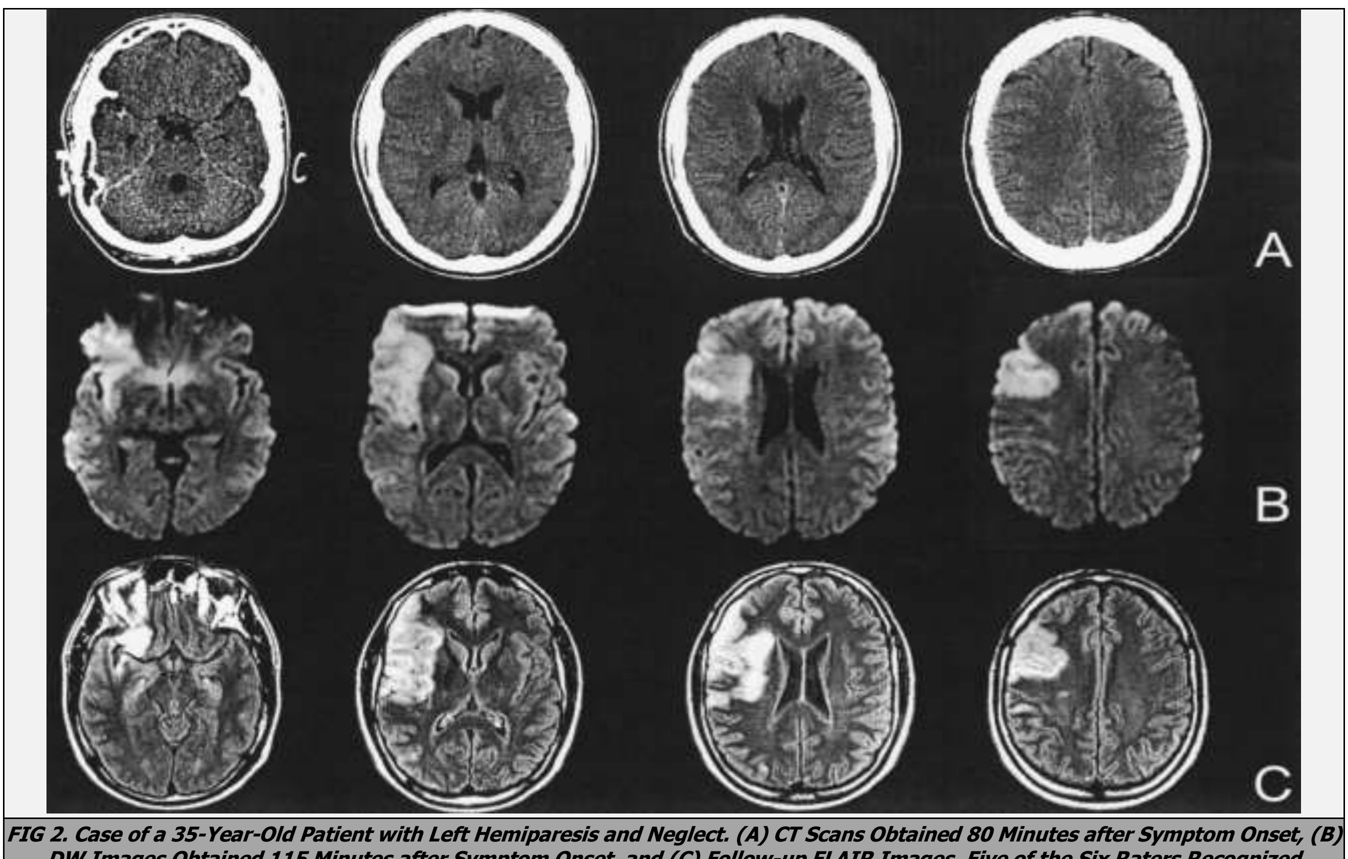

FIG 2. Case of a 35-Year-Old Patient with Left Hemiparesis and Neglect. (A) CT Scans Obtained 80 Minutes after Symptom Onset, (B) DW Images Obtained 115 Minutes after Symptom Onset, and (C) Follow-up FLAIR Images. Five of the Six Raters Recognized Parenchymal Hypoattenuation of the Right Insular Ribbon and Frontotemporal Regions on the CT Scans. DW Images and Follow-Up Flair Images after 7 Days Illustrate a Right MCA Stroke Caused by an MCA Trunk Occlusion.

a bad value of 0.40 for CT and a good value of 0.68 for DW imaging. CT scans showed the hyper attenuating MCA sign in 22 patients (44 %), with a low value of 0.29 (95 percent CI: 0.33 – 0.47). The hyper attenuating MCA sign was seen in five of six patients with evidence of occlusion of the internal carotid artery (ICA) bifurcation and ten of twelve patients with occlusion of the MCA trunk on MR angiograms.

	CT	DW Imaging
Sensitivity (%) Any EIS	87 (73 – 95)	98 (88 – 100)
Any EIS > one-third of MCA	57 (29 – 82)	57 (29 – 82)
Interrater agreement (n value) Any EIS	0.65 (0.59 – 0.70)	0.84 (0.78 – 0.90)
Any EIS > one-third of MCA	0.17 (0.10 – 0.24)	0.63 (0.56 – 0.70)

Table 2. Sensitivity and Interrater Agreement for Different Modality

Note: Numbers in parentheses are 95% CIs.

In Table 2. EIS was observed on CT scans in 39 of 45 patients, resulting in an 87 percent sensitivity. On DW images, radiologists observed parenchymal hyperintensity in 44 of 45 patients (sensitivity, 98%). Finally, the relationship between imaging results, vessel status, time intervals, and NIHSS score was investigated. The sensitivity for detecting EIS increased to 100 % for both modalities in patients with occlusion of the ICA bifurcation and MCA trunk occlusion.

Patients with EIS on CT scans had a mean time period of 166.3 minutes (range 80 – 305 minutes) between symptom onset and imaging, while patients with regular CT scans had a mean time interval of 140.5 minutes (range 50 – 237 minutes) (two-sample t test, two-tailed, P - 0.067). EIS were seen on 20 of 30 CT scans obtained in the first 3 hours (sensitivity, 66.7 percent) compared to 13 of 15 CT scans obtained after 3 hours (sensitivity, 86.7 percent; Fisher's exact test, two-tailed, P = .283). In comparison, 26 of 29 patients had hyperintensity observed on DW images within the first 3 hours (sensitivity, 90 percent). In the first three hours, interrater agreement for CT dropped to n = 0.36 (95 percent CI: 0.29 - 0.44), while inter-rater agreement for DW imaging stayed unchanged (n = 0.69; 95 percent CI: 0.39 - 0.99). Patients with EIS on CT scans had a mean acute NIHSS score of 15.3 (range, 4 – 23) compared to 8.2 (range, 3 – 17) in patients without EIS on CT scans (two-sample t test, two-tailed, P = .0053). In the consensus ranking.

DISCUSSION

DW imaging had a higher sensitivity for detecting acute ischemia in previous studies of CT and DW imaging.[8] Because the time interval between symptom onset and imaging in these studies was useful for DW imaging, it was criticised. We took pictures of both modalities in a short amount of time and found that DW imaging was superior to CT imaging for diagnosing stroke within the first 6 hours of symptom onset. For detecting EIS, CT imaging had a sensitivity of 73 % and DW imaging had a sensitivity of 93% in our study. CT sensitivities for detecting EIS in previous studies within 6 hours ranged from 41 % to 92 percent.[9]

DW imaging values, on the other hand, were consistently above 90 %. We found a modest interrater agreement of 0.57 for CT scans compared to an outstanding agreement of 0.85 for DW imaging due to the subtle nature of EIS on CT scans. The raters in our study were aware of the general suspicion for stroke and, as a result, were more sensitive to subtle findings on CT scans that may have been ignored otherwise.[10]

Both CT and DW imaging had a sensitivity of 57 percent for detecting EIS that covered more than one-third of the MCA territory. However, since infarcts may have developed and the "true" scale of the ischemic lesion at the time of initial CT and MR imaging cannot be known with certainty, this estimate is flawed. Due to the different temporal evolution of EIS on CT scans and signal strength variations on DW images, DW imaging has a higher sensitivity. DW imaging is susceptible to extracellular to intracellular water changes that occur with ischemia cell depolarization, while EIS on CT scans is due to a net water uptake in ischemic brain tissue.[11] Zhang X et al.[12] in their systematic review conducted at China concluded that among CT methods, CTP showed higher sensitivity, negative predictive value (NPV), and accuracy; among MRI methods, DWI had relatively higher sensitivity, NPV, and accuracy.

The noticeable decrease in CT attenuation, on the other hand, began later than the ADC decrease and progressed linearly over time. Patients with ICA bifurcation and MCA trunk occlusions had the highest rates of EIS on CT scans, and the basal ganglia and insular ribbon had the highest sensitivity of all investigated regions. This is consistent with earlier findings of CT sensitivities ranging from 81 percent to 100 percent in patients with MCA trunk occlusion.[13,14] Our relatively high CT detection rate for EIS compared to other studies is attributed to the patient population we studied, which mainly consisted of patients with large-vessel embolic occlusions.

Our research shows that CT has a low sensitivity for detecting EIS. There is contradictory evidence regarding the clinical efficacy of EIS as a predictor of thrombolytic therapy responsiveness. Asiri A et al.[2] in their metanalysis conducted at Saudi Arabia concluded that MRI has comparable sensitivity as CT in detecting acute ICH. Importantly, CT is quicker than MRI in neuroimaging, so it has remained the favoured imaging modality for assessing patients with suspected stroke in the emergency room. Just a few studies looked at applicability, and found that non-contract CT was faster and easier to use than MRI for diagnosing acute strokes in the emergency room. However, since 2005, neuroimaging technology has increasingly advanced, and MRIs can now be completed much more quickly than before. For example, it showed that a 6-minute multimodal MR protocol can be used to assess patients with acute ischaemic stroke and takes the same amount of time to acquire as the multimodal CT protocol. Furthermore, a 6-minute multimodal MR protocol can provide good diagnostic efficiency while cutting acquisition time in half.

CONCLUSIONS

DW imaging had a higher sensitivity than CT imaging in detecting early infarction. We agree that the combination of DW imaging, perfusion-weighted imaging, and MR angiography will continue to advance toward the diagnostic norm in stroke centers, since the accurate identification of early ischemia with DW imaging is accompanied by knowledge about the perfusion deficit and vessel condition, enabling the determination of tissue at risk for infarction, and the target of thrombolysis.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.
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