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Original Research Article

Diffusion-weighted imaging in patients with acute cerebral ischemia: Comparison with conventional CT

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Abstract

Background: Cerebrovascular stroke are second major cause of mortality and morbidity after ischemic heart diseases in adults. Diagnosis of stroke is critical for guiding management of patient, time is crucial in diagnosis, if diagnosis is done and management started within golden period of 3 to 4.5 hours it will dramatically changes the prognosis as well as post stroke morbidity.
Material and Methods: This study is prospective cross sectional study of sample size 100 subjects with an objective of Comparison of imaging findings in conventional CT (NCCT head) with DWI sequence of MRI brain in detection of hyper-acute and acute cerebral ischemia and its correlation with NIHSS scale on the basis of ASPECTS.
Results: The mean CT-MCA ASPECTS score is 9.29 and the mean MRI DWI- MCA ASPECTS score is 6.77. The mean CT-PCA ASPECTS score is 9.96 and the mean MRI DWI- PCA ASPECTS score is 9.27. The concordance between CT MCA-ASPECTS and MRI DWI- MCA ASPECTS scores is low. The concordance between CT PCA-ASPECTS and MRI DWI- PCA ASPECTS scores is very low. Apparent ischemia in territory of MCA was detected in 73 patients (73%) by DWI sequence of MRI, but in only 25 patients (25%) by CT. Apparent ischemia in territory of PCA was detected in 29 patients (29%) by DWI sequence of MRI, but in only 03 patients (3%) by NCCT. The number of patients with ischemia detected by DWI sequence of MRI was significantly higher than for CT. Overall, the sensitivity of CT was extremely low compared with that of DWI sequence of MRI.
Conclusion: Stroke was better detected by DWI sequence of MRI. Disadvantage of MRI is that it takes longer time to scan, however only DWI sequence take less than 5 minutes. Advantage of CT is that its scan time is less than 1 minute and it detects hemorrhages easily. Disadvantages of CT are radiation dose and it is not able to detect changes of acute stroke in initial hours.
Key Message:
- Cerebrovascular ischemic stroke represents a major source of global mortality and morbidity.
- CT and DWI sequence of MRI plays critical role in taking decisions regarding management of patient.
- Adding DWI sequence to NCCT head to make a unique stroke protocol for institutes where MRI facility is available will help to reduce morbidity and mortality associated with ischemic stroke.

Keywords: DWI, NCCT, Stroke.

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1. Introduction

Stroke is a medical condition caused due to inadequate supply of blood (lack of oxygen and nutrients) to the brain cells which damages them and may result in their death. Blood flow may be interrupted due to either a clot in the blood vessel occluding the supply or a blood vessel rupture which disturbs the supply. Stroke caused due to a clot in the blood vessel is referred to as ischemic stroke and that due to a blood vessel rupture is referred to as hemorrhagic stroke. The inadequacy or the loss of oxygen and nutrients to the brain cells is referred to as ischemia which ultimately leads to their death termed as infarction or ischemic stroke. Ischemic stroke accounts for around 80% of all strokes. Stroke is the third most common cause of death, after cancer and ischemic heart disease. Even for stroke cases of minor severity, the recovery is often a long-term process. The future of a stroke survivor involves a series of physical, psychological, behavioral and social challenges.

Stroke lesions appear hyper-intense on DWI sequence of MRI and are inhomogeneous, with complex shapes and ambiguous boundaries with observed intensity variation,[1] which makes manual segmentation difficult and time consuming. However, early detection and segmentation of regions of ischemic stroke, regardless of size and location, is critical for treatment. The conventional methods for stroke segmentation fail to capture the smallest regions of infarction in the scan.

CT is extensively used for identification of suspected stroke in the initial stages. Subtle changes in scan may reflect regions of cytotoxic edema which results in ischemia. The changes are generally reflected in the contrast at the junction that separates the tissue of gray matter and white matter in the scan. Early identification of ischemic changes in non-contrast CT is a challenge and depends on the reviewer experience. In the first 6 hours from the onset of the stroke, the CT scan fails to capture the early ischemic changes in most cases. Thus, in an emergency setting, CT is primarily used to rule out any intracerebral hemorrhage.[2] Use of CT angiography and CT perfusion aids the analysis of stroke on a CT scan, however, at the cost of additional contrast material and radiation exposure. [3]

Conventional MRI is more sensitive to ischemic changes as compared to CT. A subtle change in the contrast is easier to identify on the MRI. However, such changes are not usually visible upto 3-4 hours from the onset of stroke.[4] A few of the limitations of MRI are its high cost and long scanning durations making it difficult to exploit its use in emergency setting.

Diffusion-weighted imaging (DWI sequence of MRI) is sensitive to the microscopic random motion of the water molecule protons. Clinical studies have proved that diffusion-weighted magnetic resonance imaging (DW-MRI) is more sensitive to early ischemic stroke than conventional MRI or CT and thus helps in the diagnosis of acute ischemic stroke at a stage when the lesions might not be detectable in other modalities.[5]

Alberta Stroke Program Early CT score (ASPECTS) is a 10-point quantitative topographic CT scan score. ASPECTS was developed to offer the reliability and utility of a standard CT examination with a reproducible grading system to assess early ischemic changes on pretreatment CT studies in patients with acute ischemic stroke of the anterior circulation.

Modern medicine provides several techniques for stroke diagnosis. Evaluating the patient on a neurological examination (NIHSS) [6], *in-vivo* imaging techniques such as Computed Tomography (CT), Magnetic Resonance Imaging(MRI), Diffusion Weighted Imaging (DWI sequence of MRI) for diagnosis and thrombolytic therapy with tissue plasminogen activator (tPA) within 3 hours of ischemic stroke onset, [7] are the established practices followed for stroke diagnosis and treatment. Identifying effective stroke treatment remains a difficult challenge since it is assumed that the penumbral tissue is only salvageable within the first few hours after onset of ischemia [8]. Therefore, the main therapeutic decisions are to quickly recanalize the main blocked artery to prevent the infarct expansion. This can be done by thrombolytic drugs that dissolve clots or mechanical extractions [9].

1.1 Aims and objectives:

- Comparison of imaging findings in conventional CT (NCCT head) with DWI sequence of MRI brain in detection of hyper-acute and acute cerebral ischemia.
- Imaging findings correlation with NIHSS scale on the basis of ASPECTS.

2. Materials & Methods

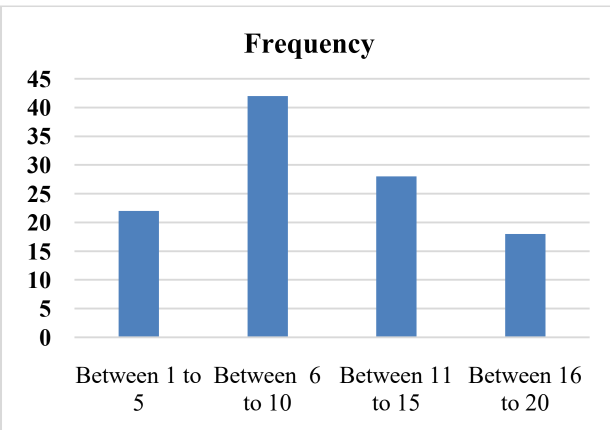
This is a hospital based prospective cross sectional study of sample size 100 subjects. The study was approved by ethical committee of institution(ethical committee approval letter -36107-09/MC/IEC/2018).The study population include all patients referred to the Department of Radio-Diagnosis with clinically suspected stroke for CT scan, within 5 days of onset of symptom including all age groups irrespective of sex from October 2018 to July 2020 underwent CT scan in 128 slice HITACHI CT scan machine, subsequently all MRI scans were performed on 1.5T HITACHI MRI machine present in department after taking informed consent. Clinical evaluation as per NIHSS format, MRI brain and NCCT head reporting as per ASPECT score. Data is collected, systematic analysis of data was done and statistical test applied.

2.1 Statistical test

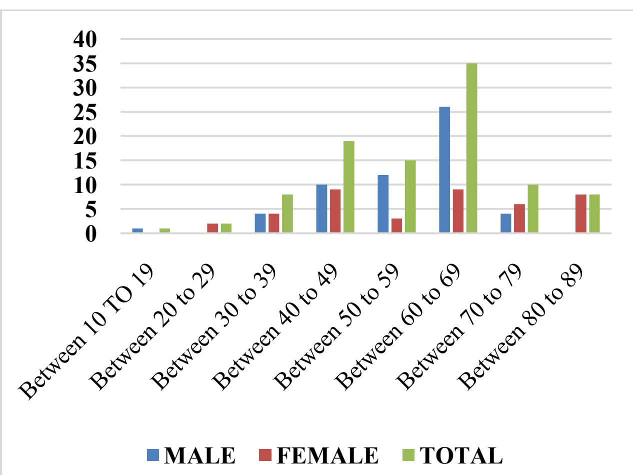
Descriptive statistical analysis were carried out with Statistical Package for Social Sciences (SPSS Complex Samples) Version 21.0 for windows, SPSS, Inc., Chicago, IL, USA, with Microsoft Word and Excel being used to generate graphs and tables. Results on continuous measurements are presented as Mean ± SEM and results on categorical measurements are presented in Number (%). Significance is assessed at a level of 1%. Correlation of data done by using Pearson correlation coefficient using SPSS.

3. Results

In present study, we used ASPECT score for detecting changes of stroke in brain in NCCT head and DWI sequence of MRI for diagnosis of infarct. All statistical calculations was done by SPSS software applying Pearson correlation coefficient, scatter graph generated and r value calculated with p value<0.01. Patients who were examined by both CT and DWI sequence of MRI, the present analysis included 100 patients mean age is 57. 16 years; mean NIHSS score is 9.81Graph 1], stroke (infarct) being more common in age group of 60-69 years [Graph 2].

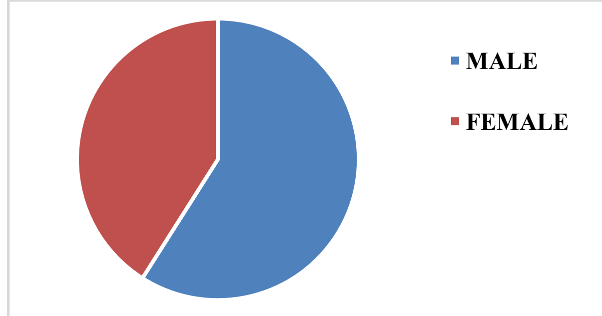


Graph 1. Showing distribution of NIHSS score in patients



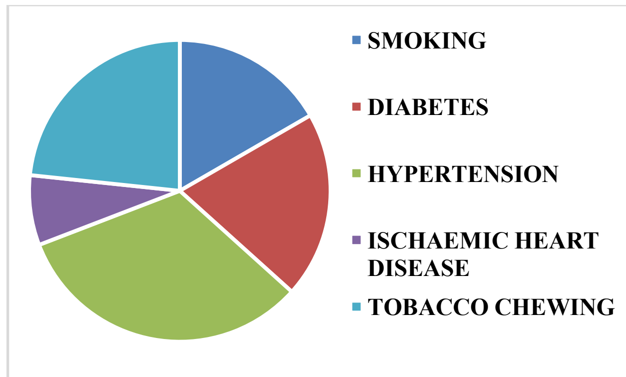
Graph 2: Shows distribution of patients in different age groups.

Out of total cases, 41 % were female and 59 % were male [Graph 3].



Graph 3: PIE chart shows male and female distribution of patients

This study showed that ischemic stroke is common in both sexes with male predominance. In our study, hypertension showed strongest positive correlation with ischemic stroke in territory of carotid artery [Graph 4].



Graph 4: PIE chart showing distribution of risk factors in patients.

The mean CT-MCA ASPECTS score is 9.29, and the mean MRI DWI- MCA ASPECTS score is 6.77 (*P*<.001). The mean CT-PCA ASPECTS score is 9.96, and the mean MRI DWI- PCA ASPECTS score is 9.27 (*P*<.001). The concordance between CT MCA-ASPECTS and MRI DWI- MCA ASPECTS scores is low (*r*=0.51; *P*<.001). The concordance between CT PCA-ASPECTS and MRI DWI- PCA ASPECTS scores is very low (*r*=0.10; *P*<.001). Apparent ischemia in territory of MCA was detected in 73 patients (73%) by DWI sequence of MRI, but in only 25 patients (25%) by CT (*P*<.001). Apparent ischemia in territory of PCA was detected in 29 patients (29%) by DWI sequence of MRI, but in only 03 patients (3%) by NCCT (*P*<.001). Stroke (infarct) detected by DWI sequence of MRI by ASPECT score in MCA territory is more common in 4 to 7 ASPECT score range (42 percent). Stroke (infarct) detected by DWI sequence of MRI by ASPECT score in PCA territory is more common in 8 to 9 score range(19 percent). The number of patients with ischemia detected by DWI sequence of MRI was significantly higher than for CT [Figure 1,2,3,4].

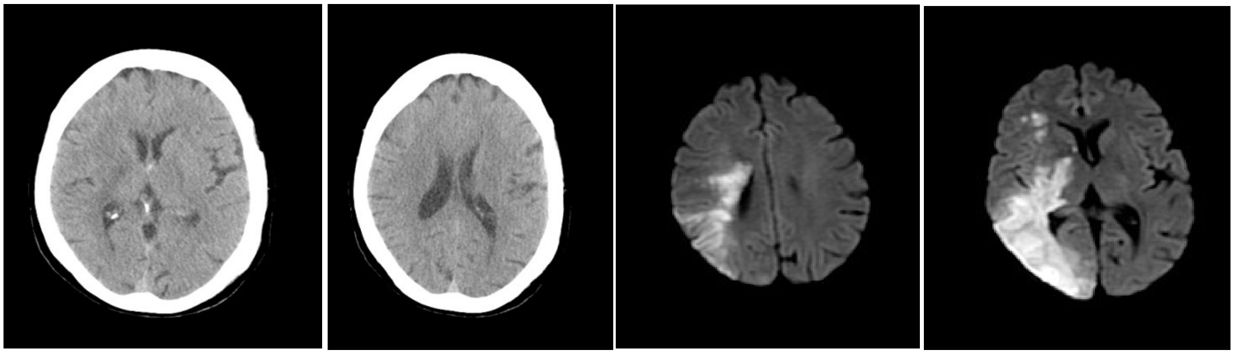


Figure 1 NCCT and MRI-DWI brain image shows different ASPECT score in same patient with subtle hypodensity in NCCT with involvement of internal capsule only , while in DWI , it shows restriction in internal capsule,lentiform nucleus,M1,M3,M5 and M6 area as per ASPECT distribution in MCA artery distribution in a patient of hemiparesis.

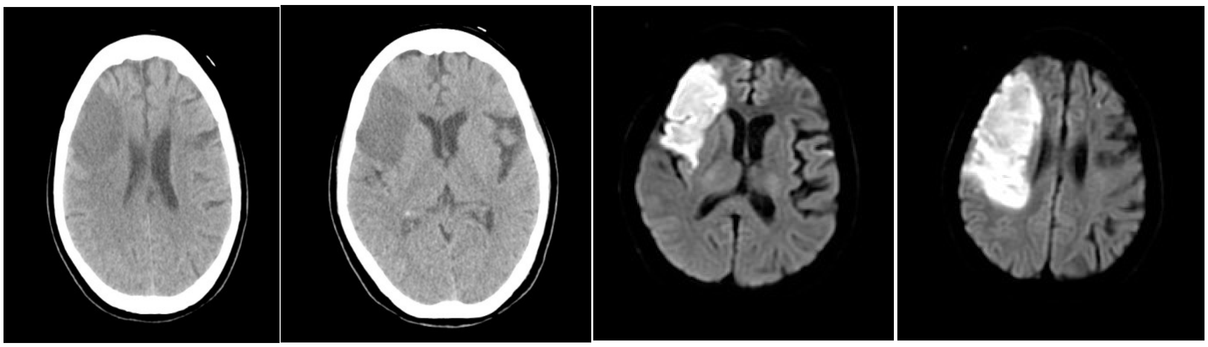
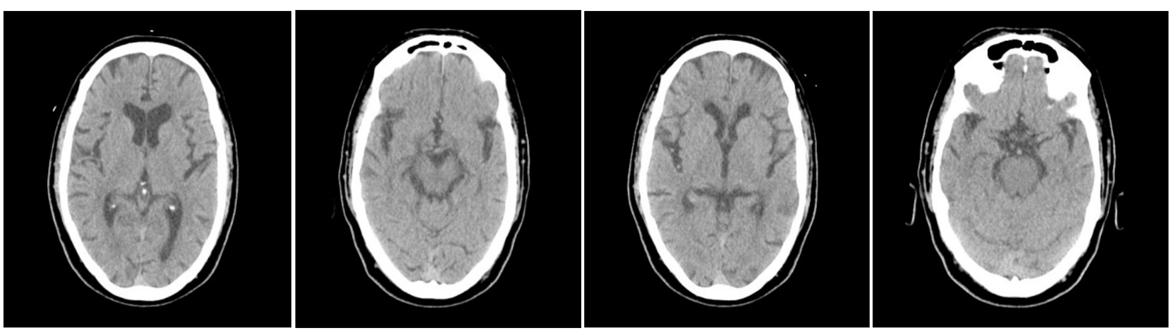
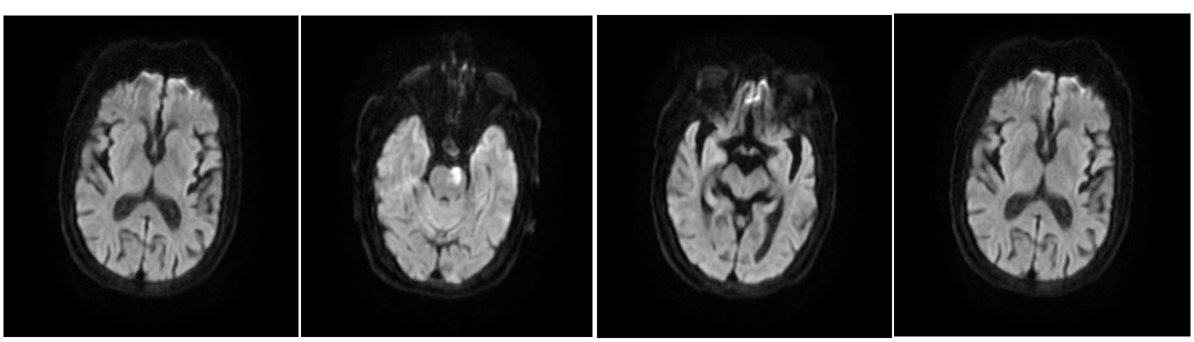


Figure 2: NCCT and MRI-DWI brain image shows different ASPECT score in same patient with hypodensity in NCCT with involvement of M1 and M4 area only, while in DWI it shows restriction in M1, M2, M4 and M5 area as per ASPECT distribution in MCA artery distribution in a patient of hemiparesis.



(A) (B)

Figure 3 (A,B) NCCT and MRI-DWI brain image shows different ASPECT score in same patient with normal NCCT, while in DWI it shows involvement of pons as per ASPECT distribution in PCA artery distribution in a patient presenting with altered sensorium



(A) (B)

Figure 3 (A,B) NCCT and MRI-DWI brain image shows different ASPECT score in same patient with normal NCCT, while in DWI it shows involvemnet of pons as per ASPECT distribution in PCA artery distribution in a patient who presented with altered sensorium

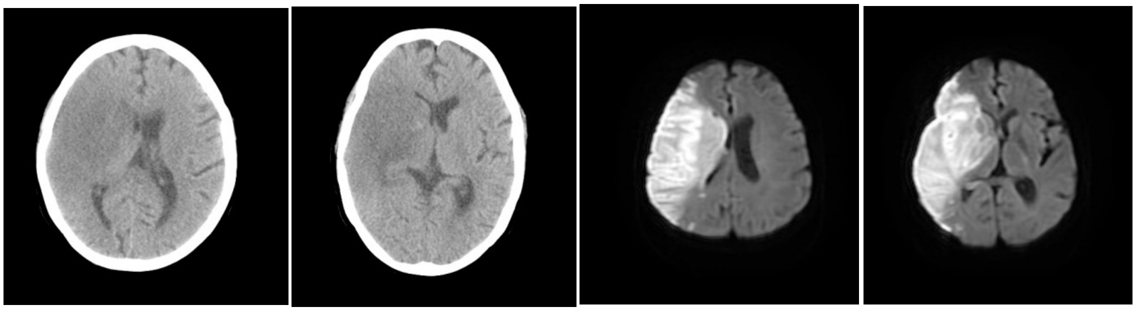


Figure 4: NCCT and MRI-DWI brain image shows same ASPECT score in same patient with subtle hypodensity in NCCT and restriction in DWI with involvement of internal capsule, lentiform nucleus, insular cortex, M1, M2, M3, M4, M5 and M6 in MCA artery distribution in a patient of hemiparesis

Overall, the sensitivity of CT was extremely low compared with that of DWI sequence of MRI. Pearson correlation coefficient for NIHSS with MRI DWI MCA ASPECT and CT MCA ASPECT is -0.596 and -0.586 respectively. Pearson correlation coefficient for NIHSS with MRI DWI PCA ASPECT and CT PCA ASPECT is -0.083 and -0.028 respectively. Negative correlation value suggests that ASPECT score decreases with increase in NIHSS score. Negative correlation with NIHSS is stronger for MRI DWI MCA and PCA ASPECT as compared to CT MCA and PCA ASPECT.

Our data indicates higher detection of ischemia within 72 hours of stroke onset with MRI DWI-ASPECTS than with CT-ASPECTS. We report that DWI sequence of MRI is more effective than CT for the diagnosis of acute and hyper acute stroke in a typical patient sample. Our sample was representative of the range of patients who are likely to present with a clinical suspicion of acute stroke. Therefore, our results are directly applicable to clinical practice. This study demonstrates that MRI DWI-ASPECTS scored approximately 2.5 point lower than CT-ASPECTS in patients with stroke within 72 hours of onset. There is a prevailing view that stroke MRI scan duration is in the order of 20 minutes and therefore much longer than CT, with the use of echo planar imaging as in our institute this time can be reduced to 5.5 minutes with use of FLAIR (2 minute 01 second) and DWI (1 minute 42 seconds) sequence only.

4. Discussion

In present study, we used ASPECT score for detecting changes of stroke in brain by NCCT head and DWI sequence of MRI for diagnosis of infarct. This study showed that ischemic stroke was common in both sexes with male predominance similar to that reported internationally [10-12]. In our study, hypertension showed strongest positive correlation with ischemic stroke in territory of carotid artery which is consistent with study done by Shivani *et al*.[13] Apparent ischemia in the territory of MCA was detected in 73 patients (73%) by DWI sequence of MRI, but in only 25 patients (25%) by CT (P<.001). Apparent ischemia in the territory of PCA was detected in 29 patients (29%) by DWI sequence of MRI, but in only 03 patients (3%) by NCCT (P<.001). Stroke (infarct) was detected by DWI sequence of MRI in the MCA territory is more common in 4 to 7 ASPECT score range (42 percent). Stroke (infarct) detected by DWI sequence of MRI in the PCA territory is more common in 8 to 9 ASPECT score range (19 percent).The number of patients with ischemia detected by DWI sequence of MRI was significantly higher than for CT. Using DWI sequence of MRI as the gold standard for each ASPECTS region, overall the sensitivity of CT was extremely low compared with that of DWI sequence of MRI. Negative Pearson correlation with NIHSS was stronger for MRI DWI MCA and PCA ASPECT as compared to CT MCA and PCA ASPECT. This is consistent with study done by Pamella whitney *et al*. [14]

Our data indicates higher detection of ischemia within 72 hours of stroke onset with MRI DWI-ASPECTS than with CT-ASPECTS. Better detection of ischemic lesions by DWI sequence of MRI has been reported by previous studies in patients with acute ischemic stroke within 72 hours of onset, especially within approximately 6 hours of onset. [15-19] The superior sensitivity of DWI sequence of MRI for detection of early brain ischemia has prompted the comparison of the ASPECTS scores between NCCT and DWI sequence of MRI. Two studies, which had similar concept to ours, have been published. In the study by Barber *et al*, [20] the delay to imaging time between modalities were similar to ours, whereas the study done by Nezu *et al*[21] had much shorter onset to imaging time and a smaller difference between CT and MRI acquisition. In contrast to our results, CT-ASPECTS performed well or better than MRI DWI-ASPECTS in predicting outcome. Study by Barber *et al* showed no difference in CT-ASPECTS and MRI DWI-ASPECTS agreements. Our study suggested that DWI sequence of MRI is more effective than CT for the diagnosis of acute stroke in a typical patient sample. Early reports that compared diffusion-weighted imaging sequence of MRI with CT estimated sensitivities of 86-100% for diffusion-weighted imaging and 42-75% for CT, but were limited by potential biases in patient selection and image assessment. [22-27] The evaluation of ASPECTS performance is dependent on the frequency and volume of early ischemic change present in the population studied. For example, if most of the patients have high ASPECTS scores, either because of short onset to scan times or milder strokes. Data to support this concept was provided by Weir *et al*, who demonstrated that ASPECTS predicted outcome in a graded fashion (linearly for ASPECTS, 6–10), but it had poor predictions for lower scores. The frequency of CT-ASPECTS 8 to 10 was greater in the studies done by Barber *et al* and Nezu *et al*, which may account for the good performance of CT-ASPECTS in those studies.

Our study demonstrates that MRI DWI-ASPECTS scored approximately 2.5 point lower than CT-ASPECTS in patients with stroke within 72 hours of onset. Previously, the reported difference of ASPECTS in both methods was 0.43 on average based on the previously mentioned study by Barber *et al*[28] and 1 when using the median based on another study involving 30 patients within 24 hours of stroke onset.[29] The time delay of MRI after CT, 102 minutes on average in the former study and 4.4 hours when using the median in the latter study, was proposed as a major reason for the discrepancy in ASPECTS.[20] Because the time delay was much smaller in the present study, the discrepancy in ASPECTS appears to be mainly due to the superior ability of DWI sequence of MRI as compared with CT.

There is a prevailing view that stroke MRI scan duration is in the order of 20 minutes and therefore much longer than CT. However, in centers that have been using MRI as the prime diagnostic imaging tool for years, standardized stroke MRI protocols last around 10 minutes. This duration could be further reduced to 5.5 minutes with the use of echo planar imaging FLAIR and DWI sequence only. The recent endovascular trials provides detailed timings for door-to imaging and imaging to the next workflow steps, but the precise duration of the complete MRI session is lacking. The 13-minute median MRI scan duration were recorded over a large panel of centers is representative of a real-world setting, since there was no attempt to standardize MRI protocols across centers. In contrast to MRI, CT is commonly considered as a snapshot in the stroke workflow. Although this was reasonable for non-contrast CT, it is no longer true when CTA is added, a requirement before endovascular treatment decision. As with MRI, the whole CT-scan duration is longer than the sum of CT and CTA acquisition times. SWIFT PRIME trial (Solitaire with the Intention for Thrombectomy as Primary Endovascular Treatment; CT/CTA: median, 9 minutes) provided a measurement of total scan duration (CT/CTA: median, 7 minutes; CT/CTA/CTP: median, 10 minutes).

Our study has some limitations major being the small sample size, for which study can be done with large sample size in future. Second is the time lag variation between NCCT head and MRI scanning which ranges from 10 minutes to 210 minutes. In future study with large sample size and strict timing interval between NCCT head and MRI brain can be done.

In conclusion, in our patients, DWI sequence of MRI detected ischemic lesions more frequently than CT within 72 hours of stroke onset in all ASPECTS regions. DWI sequence of MRI appears to be a useful tool for assessing ischemic lesions to determine the need for urgent therapy, including IV t-PA, in hyper acute patients. Adding DWI sequence of MRI to NCCT head in institutions where facility is available will be beneficial to diagnose ischemic infarct early for treatment. According to our study results we recommend that adding DWI sequence of MRI to NCCT head for evaluation of stroke, to make unique stroke protocol in institutions where facility is available will be beneficial to diagnose ischemic infarct early and can change treatment and prognosis.

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