

Accuracy of Diffusion-Weighted Magnetic Resonance Imaging in the Detection of Acute Cerebral Infarcts

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ABSTRACT

Aim: To determine the accuracy of diffusion weighted MRI in the detection of acute cerebral infarcts, in patients with neurological signs of stroke, by comparing with CT findings

Duration & place of study: This study was conducted from 2nd November 2011 to 1st may 2012 in the department of radiology, Pakistan Institute of Medical Sciences Islamabad.

Study Design: Cross-Sectional Study

Methods: Total 66 patients of acute stroke were included. At presentation, CT brain and diffusion weighted MRI was done to see the accuracy.

Results: Total 66 patients were selected for study. The mean age of patients was 50.38 years with standard deviation of 13.011 years. Out of 66 patients, 37 (56.06%) were male and 29 (43.94%) patients were female. DWMRI had sensitivity of 98%, specificity of 100%, positive predictive value of 100% and negative predictive value of 67%. CT scan had sensitivity of 64%, specificity of 50%, positive predictive value of 97% and negative predictive value of 4%.

Conclusion: Diffusion weighted MR imaging of brain is highly accurate in the diagnosis of acute stroke and provides superior lesion contrast compared with that of CT scan imaging.

Keywords: Cerebrovascular accident (CVA), Diffusion-weighted MRI brain, CT scan brain

INTRODUCTION

Stroke is a global health problem. It is the leading cause of adult disability and second leading cause of mortality worldwide (World Health Report, 2003). Stroke is responsible for three million deaths (and rising) in developing countries and is a major cause of mortality and morbidity in Asian countries. Stroke is the third most common cause of death in the United States¹. The overall prevalence of stroke among American Indians/Alaska Natives (6.0%), multiracial persons (4.6%), and blacks (4%) were higher than the prevalence among whites (2.3%). The prevalence of stroke among Asians/Pacific Islanders (1.6%) and Hispanics (2.6%) were similar to the prevalence among whites. The crude prevalence rates of stroke among South Asians living in India vary from 52 to 842 per 100 000 for all ages. Of the few available studies, one Pakistan-based stroke study showed prevalence rates of 52% for ischemic strokes².

Despite the lack of high quality epidemiological data, the burden of stroke seems to be high in Pakistan as in other south Asian countries. Not only the mean age of patients with stroke is less compared to patients in the developed world,

approximately 20% of patients are under the age of 45 years³.

Cerebrovascular accident (CVA) or stroke is defined as an acute focal neurological deficit resulting from cerebrovascular disease. Approximately 80-85% strokes are due to cerebral infarction. The three most common causes of cerebral infarction are large-vessel atherosclerosis, small vessel disease and cardiac embolism. Secondary preventive treatment after cerebral infarction is dependent on etiology and risk factors⁴.

Current treatments for patients with established stroke are relatively ineffective and risk factor interventions are the real hope of reducing stroke morbidity and mortality in populations. Certain risk factors have consistently been identified as significant predictors of stroke outcome (mainly fatal stroke): age, hypertension, alcohol intake (inverse prediction), previous stroke, and atrial fibrillation. Other risk factors much less consistently associated with stroke include smoking, diabetes, previous CHD, left ventricular hypertrophy, excessive alcohol intake, and family history of stroke⁵.

Diffusion-weighted MRI (DWI) is an established MRI technique that is very sensitive to acute cerebral ischemia. In clinical practice, DWI has been shown to be superior to conventional MRI and CT in the examination of patients with acute stroke within 24 hours of presentation. For DW MRI, sensitivity of 94% and specificity of 97% has been reported previously.^{6,7}

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Multimodal magnetic resonance imaging (MRI), including diffusion-weighted imaging (DWI), has excellent capacity to delineate the presence, size, location, and extent of hyper-acute ischemia, but unproven reliability in identifying early parenchymal hemorrhage. The advent of thrombolytic therapy and other interventional therapies for acute ischemic stroke has led to increasing interest in using MRI to select and stratify candidates for treatments. Currently, many stroke centers obtain both CT and MRI in the initial evaluation of patients with stroke. The use of both modalities is time consuming and expensive⁸.

While conventional T1 and T2-weighted MRI pulse sequences are sensitive for the detection of sub-acute and chronic blood, they are less sensitive to parenchymal hemorrhage during the initial 6 hours after stroke symptom onset. A growing data have suggested that hyper-acute parenchymal blood can be accurately detected using gradient recalled echo (GRE) pulse sequences that are sensitive to static magnetic field in homogeneity.⁹

MATERIALS AND METHODS

This cross sectional study was conducted in the Department of Diagnostic Radiology, Pakistan Institute of medical Sciences (PIMS) Islamabad, from 2nd November 2011 to 1st may 2012. Sample size calculated by using WHO sample size calculator taking sensitivity 94%, specificity 97%, prevalence 52%, Desired Precision 8% and confidence level 95% comes out to be 66. Consecutive Non Probability Sampling technique was used.

Patients with new onset of neurological signs were included presenting with any motor deficit/limb weakness, aphasia, persisting for more than an hour and presenting within twenty four hours of symptoms. Patients with hemorrhagic stroke and any contraindications to MRI scan were excluded

Data collection procedure: All patients presenting with new onset of focal neurological signs were examined with detailed history and physical examination. After taking permission from the ethical committee of the hospital all patients were investigated by array of biochemical tests for the purpose of management. Informed consent was taken and each patient was subjected to conventional CT. All patients with focal neurological signs and no signs of hemorrhage on conventional CT were subjected to DWMRI. Philips 1.5 Tesla Achieva Nova was employed. DWI scans was acquired with diffusion gradients along each of the principal axes with different b values, as per protocol. The volume data was transferred to a work station and interpretation was made with evaluation of images by

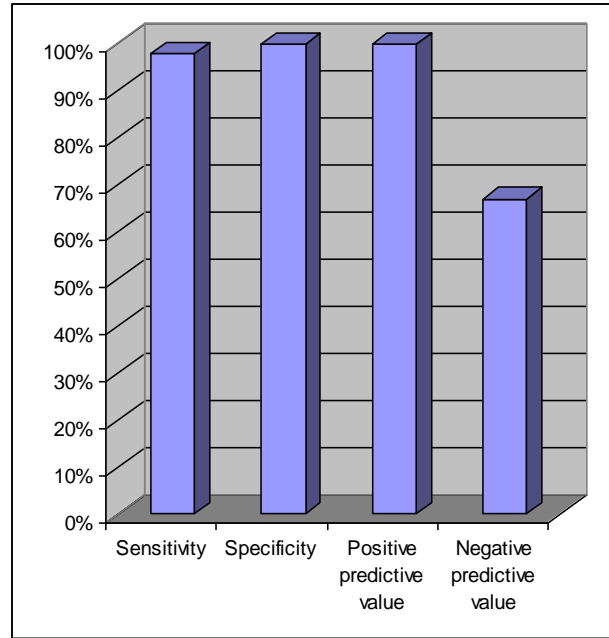
post graduate trainee (unaware of the CT findings) and verified by the supervisor. The clinical data and images obtained in patients with stroke was examined and results of CT and DW MRI was entered in a proforma.

Statistical analysis: All data was entered and analyzed using SPSS version 14.0. Frequency and percentage was calculated for gender and positive findings on DWMRI and CT and true positives. Mean ± SD was presented for age.

RESULTS

Total 66 patients were selected for the study. The mean age of patients was 50.38 years with standard deviation of 13.011 years. Mean age of patients was 54 years and mode age of patients was 58 years. Minimum age of patients was 19 years and maximum age of patients was 70 years with range of 51 years .Out of 66 patients, 37 (56.06%) were male and 29 (43.94%) patients were female .

Fig. 1: Sensitivity, Specificity, PPV and NPV of DWMRI



When we saw the age wise distribution of patients, 7(10.61%) were in 10-29 years of age group, 21 (31.82%) were in 30-49 years of age group and 38 (57.58%) were in 50-70 years of age group. 36 male patients and 28 female patients had clinical stroke while 1 male and 1 female patient had no clinical stroke .36 male patients and 27 female patients had acute cerebral infarct on DWMRI while 1 male patient and 2 female patients had no acute cerebral infarct on DWMRI. 23 male patients and 19 female patients had acute infarct on CT scan while

14 male and 10 female patients had no acute cerebral infarct on CT scan. When we saw the validity of DWMRI, it was found that DWMRI had sensitivity of 98%, specificity of 100%, positive predictive value of 100% and negative predictive value of 67% (Fig.1). The validity of CT scan was found to have sensitivity of 64%, specificity of 50%, positive predictive value of 97% and negative predictive value of 4% (Fig. 2)

In 10-29 years of age group, 7 patients had acute cerebral infarct and no patient had cerebral infarct on DWMRI, in 30-49 years of age group 20 patients had acute cerebral infarct and 1 patient had no cerebral infarct on DWMRI while in 50-70 years of age group, 30 patients had acute cerebral infarct and 2 patients had no cerebral infarct on DWMRI. In 10-29 years of age group, 5 patients had acute cerebral infarct and 2 patients had cerebral infarct on CT scan, in 30-49 years of age group 11 patients had acute cerebral infarct and 10 patients had no cerebral infarct on CT scan while in 50-70 years of age group, 26 patients had acute cerebral infarct and 12 patients had no cerebral infarct on CT scan .

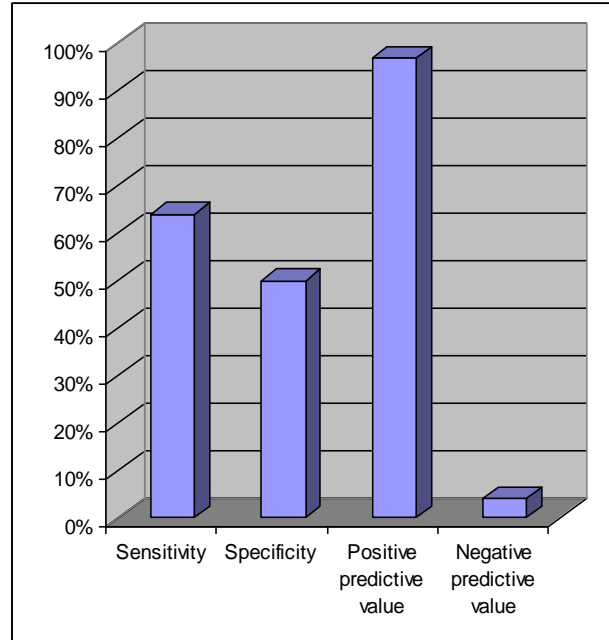
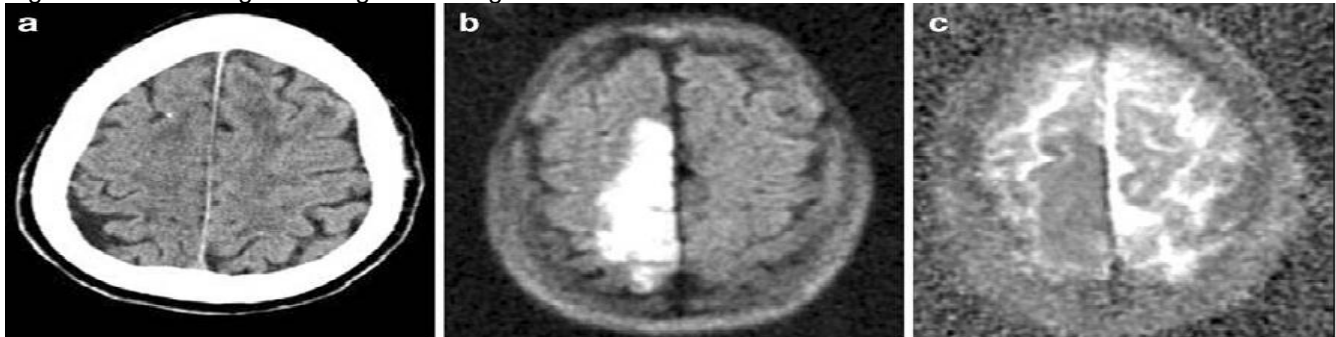


Fig. 2: Sensitivity, Specificity, PPV and NPV of CT scan

Fig. 3: Diffusion weighted images showing infarct



(a): CT done on admission shows slight sulcal effacement in the right frontal lobe. (b): MRI was performed right afterwards, and on DWI there is a clearly visible hyperintensity, (c): seen as a hypointensity on the ADC map.

DISCUSSION

Diffusion-weighted MR imaging provides information that is fundamentally different than that available with CT or conventional MR imaging. In acute ischemic stroke, CT and conventional MR imaging demonstrate changes that are largely dependent on the same physiologic parameter: an increase in tissue water. This results in hypoattenuation and loss of gray matter–white matter differentiation on CT scans and hyperintensity on T2- or proton-density–weighted MR images. In distinction to these modalities, diffusion-weighted MR imaging can depict cytotoxic edema. This pathophysiologic event occurs very early as adenosine triphosphate levels decrease in ischemic brain¹⁰.

In our study the mean age of patients was 50.38 years with slandered deviation of 13.011 years. In a study conducted by Marx JJ et al¹¹ showed that mean age of patients was 63.5 years that was slightly higher than our study. In another study conducted by Barber PA et al¹² showed that the mean age of patents was 68 years with slandered deviation of 13.9 years. In both studies the mean age of patients was higher than the mean age of patients in our study and it might be shorter life span in our population.

In our study 56.06% were male and 43.94 were female. The results of our study were comparable with some international studies. Study conducted by Marx JJ et al¹¹ showed that 67% were male and 33% were female. In this study male patients were slightly

higher than the male patients in our study. In another study that was conducted by Barber PA et al¹², it was shown that 69% were male patients and 31% were female patients.

In our study sensitivity and specificity of DWMRI were 98% and 100% respectively and that of CT scan, the sensitivity and specificity were 64% and 50% respectively. In a study conducted by Mullins ME et al¹³ showed that five hundred seventy-three patients underwent CT at presentation, with 42% sensitivity (95% CI: 37%, 46%) and 91% specificity (95% CI: 82%, 96%). A total of 173 patients underwent a second CT examination, with 77% sensitivity (95% CI: 70%, 84%) and 79% specificity (95% CI: 49%, 95%). Of 498 MR images, 411 were DW, with 94% sensitivity (95% CI: 1%, 96%) and 97% specificity (95% CI: 88%, 100%), and 87 were conventional, with 70% sensitivity (95% CI: 58%, 81%) and 94% specificity (95% CI: 70%, 100%). In another study conducted by Fiebach JB et al¹⁴ showed that the sensitivity of infarct detection by the experts was significantly better when based on DWI that was 91% as compared to CT scan that was 61%. In this study the accuracy of DWMRI was 91% and that of CT scan was 61%. In these studies and in our study, CT and DWMRI performed with the same delay after onset of ischemic stroke resulted in significant differences in diagnostic accuracy and these results were comparable to our study in term of sensitivity, specificity and accuracy.

Saur et al¹⁵ showed his CT assessment of early ischemic changes, with a resultant sensitivity of 73% (versus 93% for diffusion weighted imaging) based on the consensus ratings of three neurologists, and 87% (versus 98% for diffusion-weighted imaging) based on the consensus ratings of three neuroradiologists. These results were novel and noteworthy because, as the authors point out, earlier studies comparing CT and diffusion-weighted imaging findings were confounded by the relatively long time interval between the admission CT and initial diffusion-weighted examinations. The author's concluded that diffusion-weighted imaging depicted early ischemia with higher sensitivity than that of CT and it received strong recent confirmation.

In another study conducted by Brazzelli M et al¹⁶ showed that the summary estimates for DWI were: sensitivity 99% (95% CI 0.23 to 1.00), specificity 92% (95% CI 0.83 to 0.97). The summary estimates for CT were: sensitivity 39% (95% CI 0.16 to 0.69), specificity 100% (95% CI 0.94 to 1.00).

Our study showed that CT and DWI are comparable for detecting and quantifying signs of cerebral ischemia in acute disabling stroke when they are of good quality and are assessed systemically. However, this does not imply the two modalities are

equivalent. DWI is more sensitive than CT at detecting ischemic tissue changes.

We found diffusion-weighted MR imaging to be significantly superior to CT in the diagnosis of acute stroke with clinical interpretation and to both CT and conventional MR imaging with blinded interpretation. Diffusion-weighted MR imaging helps identify those brain areas that are most likely to be irreversibly damaged, not areas that are ischemic yet viable.

Although there have been several studies about diffusion-weighted MR imaging of patients with acute stroke, this study is different in several important ways. The results of our investigation help confirm those of previous studies, which suggested the high sensitivity of diffusion-weighted imaging in acute cerebral infarction and, to our knowledge, are the second to document a high specificity¹⁷⁻¹⁹.

An area of great interest in acute stroke imaging is the appearance of transient ischemic attacks at diffusion MR imaging. In six patients with a negative diffusion-weighted MR image, transient ischemic attack was the final clinical diagnosis. This suggests that diffusion-weighted MR imaging is insensitive to transient ischemia, even though it may be sufficiently severe to produce symptoms²⁰.

A negative image is highly accurate in the exclusion of most acute cerebral infarctions. The exceptions may be very small penetrator artery infarcts in the brain stem, which are symptomatic owing to their location in neurologically compact structures and so small as to challenge detection. The high accuracy of diffusion-weighted MR imaging in excluding the probability of stroke could have a substantial effect on the treatment of patients who present with acute onset of stroke like, neurologic symptoms. In many circumstances, a negative diffusion-weighted MR image may spare patients prolonged and extensive diagnostic evaluations and may prevent unnecessary risks of anticoagulation. Thus, the information provided with diffusion weighted MR imaging can facilitate the proper deployment of scarce health care resources and help ensure the likelihood that treatment regimens are appropriately matched to patient needs²¹.

CONCLUSION

In conclusion, we have found, under clinical circumstances that diffusion-weighted MR imaging of the brain is highly accurate in the diagnosis of acute stroke and provides superior lesion contrast compared with that of CT scan imaging. Our results indicate that diffusion-weighted MR imaging may have an important role in the treatment of patients who present with new onset of a stroke like, neurologic deficit.

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