Accuracy of Diffusion Weighted Imaging in the diagnosis and evaluation of Acute Ischemic Strokes

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ABSTRACT

Objective: To assess the accuracy of application of diffusion weighted imaging in the diagnosis and evaluation of acute onset ischemic strokes.

Study Design: Cross sectional validation study.

Place and Duration: Department of Diagnostic Radiology, Mardan Medical Complex, Hospital, Mardan from 15th October 2020 to 15th April 2021.

Methodology: Patients whose presentation was highly suggestive of acute stroke, were undergone a non-contrast Computed tomography scan of the brain immediately by Asteion VP single slice. Those found negative for acute hemorrhage on Computed tomography images were subjected to Magnetic resonance imaging on Achieva 1.5 Tesla. Diffusion-weighted imaging technique of MRI scan was done in addition to the conventional T1W, T2W, and FLAIR scans of MRI which were also done. DWI was performed as early as possible not later than 24 hours after symptoms onset. Both DWI imaging technique and conventional routine T1W, T2W and FLAIR scans of MRI were repeated after 7 days.

Results: The mean age of the sample was 57.6 + 5.9 years. On Diffusion-weighted imaging, stroke was observed in 60.2% of patients. Later on follow-up conventional magnetic resonance imaging scans were done after 7 days, stroke was recorded in 69.9% of patients confirming the diagnostic accuracy of DWI imaging in sub-acute stroke in early diagnosis.

Conclusion: Conventional MRI scans like T1W, T2W and FLAIR have diagnostic accuracy only after some days. It has poor diagnostic accuracy in early onset sub-acute ischemic strokes. On the other hand, DWI imaging scans of MRI can be a useful tool for early detection of ischemic strokes as it diagnosed stroke in 60.2% of patients which were later confirmed by conventional MRI scans done after 7 days. Conventional MRI scans have high accuracy of detection of strokes but only after some days. So DW1 imaging may be applied for early diagnosis of strokes in sub-acute onset strokes.

Keywords: Ischemic stroke, Magnetic Resonance Imaging, Diffusion Weighted Imaging, Hemorrhage, Computed Tomography

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INTRODUCTION

Stroke is defined as the sudden onset of neurological deficits caused by a vascular lesion to the central nervous system, such as cerebral ischemia, intracranial hemorrhage, or subarachnoid hemorrhage. The term "cerebral infarction" refers to the loss of brain cells as a result of ischemia caused by a vascular blockage.[1] Ischemic stroke is the most common type of stroke. It is the world's largest cause of mortality and permanent disability. A stroke is a medical emergency because the sooner people are treated, the less brain damage they will suffer. Imaging is critical in the first assessment of patients suspected of having a stroke.[2] Intravenous tissue plasminogen activator (tPA) given within 4.5 hours is currently the only approved treatment for acute ischemic stroke.[3] Tissue plasminogen activator (tPA) is a thrombolytic agent that restores blood flow and prevents infarct growth by causing clot lysis within the vessel.[4] Because of its wide availability, non-contrast CT is currently employed for acute stroke. It is very sensitive to acute intracranial bleeding,

which is an important differential diagnosis of ischemic stroke. Because non-contrast CT has low sensitivity in the first few hours, improved ischemic stroke diagnosis accuracy is required for the development and deployment of thrombolytic and other stroke therapies.[5] In the hyper acute phase, i.e., the first 24 hours, conventional MRI sequences rarely show indications of a stroke. MRI signals, on the other hand, become more apparent and well defined after 48-72 hours. On T1-WI images, the ischemia area shows as a hypo-intense area, but on T2-WI and FLAIR images, it appears as a hyper-intense area.[6]

Diffusion-weighted imaging (DWI), a new MRI method, is particularly sensitive for identifying super acute ischemic stroke.[7] DWI assesses the net movement of water in tissue due to random (Brownian) molecular mobility of water and displays extremely severe ischemic tissue alterations within minutes to a few hours after artery closure due to cytotoxic edema. Because FLAIR sequences detect vasogenic edema associated with preexisting infarction, they are less effective than DWI in detecting acute infarctions. According to research, DWI-positive–FLAIR-negative stroke lesions are highly selective for 3 hours onset stroke.[8]

DWI outperforms conventional MRI in detecting acute ischemic stroke and enhances stroke detection accuracy in the first 48 hours following the onset of the stroke. The advantage of DWI is that it may be obtained quickly. It takes 1.5 to 3 minutes to complete alongside standard MRI.[9]

According to a prevalence survey, the number of persons who had their first stroke was 68 percent in 2010, stroke survivors were 84 percent, and stroke-related deaths were 26 percent in 2010 and the illness burden has increased dramatically since 1990, especially in low- and middle-income nations.[10]

In identifying ischemic stroke, DWI has a sensitivity of 92 %, a specificity of 75 %, and a positive predictive value of 99.8%.[11] Diffusion-weighted MRI provides for early sensitive identification of ischemic injury and is the clinical gold standard for distinguishing stroke from TIA, with a positive and negative predictive value of 98.5 percent and 69.5 percent, respectively.[12]

The rationale of this research is to go over the basics of DWI, think about how it might be used in hyper acute strokes and in the early management of strokes. The study wants to find the diagnostic accuracy of DWI in the early diagnosis of acute ischemic stroke, so that it can be employed as the first line of defense because it is rapid, reliable and operationally efficient and can diagnose ischemic strokes in early phase as compared to conventional MRI scans like T1W and T2W which diagnoses ischemic strokes only after some days. So this study was conducted with an objective to assess the accuracy of application of diffusion weighted imaging in the diagnosis and evaluation of acute onset ischemic strokes.

METHODOLOGY

This cross sectional-validational study was conducted in the Department of Radiology, Mardan Medical Complex, Hospital Mardan. The Sample size was 166, taking sensitivity of 92% and specificity of 75% and the prevalence of 68%.[11] with a 95% confidence interval and 12% margin of error for specificity and 5.1% margin of error for sensitivity. Consecutive, non-probability sampling was done and the target population age was between 30 to 70 years including both genders. This study included patients who had signs and symptoms that were highly suggestive of arterial ischemic stroke and who had DWI performed within 24 hours after onset of symptoms, as well as individuals who had neurological abnormalities that lasted longer than 24 hours. Patients who had had thrombolytic therapy or who had an intracranial hemorrhage were not included in this study. In addition, patients with other intracranial pathologies (e.g., tumors, infections) or contraindications to either modality were excluded from the study. After receiving approval from the hospital's ethical and scientific council, this study was carried out. The study included all patients who met the inclusion criteria. The patient was informed about the operation. All patients were informed about the study's purpose and advantages, as well as the potential dangers. Written informed consents were obtained.

Patients, whose presentation was highly suggestive of acute stroke, underwent a non-contrast CT scan of the head immediately by Asteion VP single slice. Those found negative for acute hemorrhage on CT images were subjected to MRI on Achieva 1.5 Tesla. Diffusion-weighted images in addition to conventional T1W, T2W, and FLAIR. DWI was performed as early as possible not later than 24 hours after symptoms onset. Diffusion-weighted images and conventional MR images were repeated after 7 days.

Diffusion-weighted images and "Follow up MRI scans" were reported by a single expert radiologist, a fellow of CPSP, to minimize the subjective error. All of the above data, including name, age, gender, and address, was entered into a pre-designed proforma. To prevent bias in the study results, an exclusion criterion was used.

Data Analysis: The statistical package for social sciences (SPSS) version 20 software was used to examine the data. For age, the mean SD was computed. Gender, blunt trauma, radiologic findings of stroke lesions on diffusion-weighted images, and stroke lesions on follow-up MRI scans were among the qualitative factors provided in the form of frequencies and percentages. Table I was used to calculate the sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of diffusion-weighted images.

Table – I: Categories of Stroke and non-stroke results on MRI scans (N=166)

	Yes	No
Stroke on DWI Scan	True positive	False positive
No Stroke on DWI Scan	False-negative	True negative

Sensitivity= a/ (a + c) ×100
Specificity =d/ (d + b) ×100
PPV =a/ (a + b) ×100
NPV =d/ (d + c) ×100
Accuracy = (d + a) /overall patients
a = true positive, b=false positive, c=false negative, d=true negative
Sensitivity and specificity were stratified by age and gender.

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RESULTS

A total of 166 patients were studied and their average age was 57.6 + 5.9 years. A minimum of 47.5 years and a maximum of 67 years were included. The distribution of the sample by age categories is shown in Table II. We discovered that in our study, 66.9% of the patients were male and 33.1 percent were female when we distributed the patients by gender. (Table III)

Table – II: Age-wise distribution of patients with their mean and standard deviation values. (N=166)

Age of patient	Range	Min	Max	Mean	Std. Deviation
	19.5	47.50	67.00	57.6	5.9
Age Categories			Frequency		Percent
Up to 55 years			62		37.3
> 55 to 65 years			87		52.4
> 65 years			17		10.2
Total			166		100.0

Table – III: Gender-wise distribution and frequency of stroke on DWI (N=166)

		Frequency	Percent
Gender	Male	111	66.9
	Female	55	33.1
	Total	166	100.0
Stroke on DWI	Yes	100	60.2
	No	66	39.8
	Total	166	100.0

On DWI, Stroke was observed in 60.2% of patients (Table IV) while on follow-up MRI scans, stroke was recorded in 69.9% of patients (Table IV).

On applying the formulae for calculation, the sensitivity of DWI was found to be 71.5% and specificity 66%. The positive predictive value of the DWI is 83% and the negative predictive value is 50%. Table V) The subsequent tables elaborate on the sensitivity and specificity of different age groups and gender. Table VI)

Table – IV: Frequency of stroke on follow-up MRI scans along with the values of percentage. (N=166)

Stroke on Follow up MRI	Frequency	Percent
Yes	116	69.9
No	50	30.1
Total	166	100.0

Table – V: DWI & follow up MRI scans 2x2 table of the samples used in the study. (N=166)

		Stroke on Follow up MRI		Total
		Yes	No	
Stroke on DWI	Yes	83 (TP)	17 (FP)	100
	No	33 (FN)	33 (TN)	66
Total		116	50	166

Sensitivity of DWI: TP/TP + FN = 71.5%
Specificity of DWI: TN/TN + FP = 66%
Positive Predictive Value DWI: TP/TP + FP = 83%
Negative Predictive Value DWI: TN/TN + FN = 50%

Table – VI: Sensitivity and specificity of DWI in different age groups and gender of the sample. (N=166)

		Sensitivity	Specificity
Age Groups	Up to 55 years	100%	50%
	> 55 to 65 years	66.2%	100%
	> 65 years	47.1	NA
Gender	Male	57.1%	73.5%
	Female	100%	50%

DISCUSSION

In our area of the globe, the most common reason for admission to a neurology unit is a stroke[13]. A stroke is defined by the World Health Organization as the rapid beginning of a new neurological deficit that lasts at least 24 hours and is caused by a blockage or rupture in the cerebral artery system. A neurological examination and a computed tomography (CT) scan of the brain must confirm certain localizing findings, and there must be no evidence of an underlying non-vascular aetiology[14]. A stroke is classified as "Transient" if complete recovery happens within 24 hours, "Evolving" if a neurological deficit worsens after 6 hours, and "Complete" if a fixed non-evolving deficit is formed. Ischemic strokes account for roughly two-thirds of all strokes, which are further classified as either thrombotic or embolic.[15] Ischemic stroke (70.1%) is far more common than the hemorrhagic type (29.9%) in Pakistan as well.[16] Ischemic stroke has been linked to several fixed and modifiable risk factors. The primary fixed risk factors are age, gender, and race, while the most important modifiable risk factors are hypertension (65%) , diabetes mellitus (36.3%) ,smoking (32%), obesity (18%) and dyslipidemia (32.7%).[15-17] Antiplatelet and lipid-lowering drugs, control of blood sugar and blood pressure, and modification of lifestyle play the key role in secondary prevention of ischemic stroke.[18,19] As nothing can be done for fixed risk factors, secondary prevention by improving the modifiable risk factors is, therefore, the key to decreasing the incidence for strokes.[20,21].

Urgent brain imaging has become necessary in patients being investigated for thrombolysis to rule out intraparenchymal bleeding and early infarct signs[22] and is now conducted with non-contrast brain computed tomography (CT). However, available structural imaging modalities (CT and MRI) do not accurately diagnose developing ischemia lesions within the first 6 to 12 hours.

Nuclear magnetic resonance (NMR) methods have been used since the 1940's[23]. In 1973, Lauterbur was the first to obtain images. Structural MRI is the imaging method of choice for most neurologic disorders. In regions including the cerebellum, brainstem, and deep white matter, structural MRI is more sensitive than CT in identifying ischemic stroke lesions[24]. When combined MRI and magnetic resonance angiography (MRA) is available, it is often the imaging modality of choice for

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evaluating the extent of infarction beyond the first 12 hours and studying the extra cranial and intracranial cerebral arteries without the need for invasive procedures. Over the last 6 to 10 years, diffusion-weighted imaging (DWI) sequences that are sensitive to water self-diffusion a n d may detect ischemia lesions at the early stages of the investigation as well as perfusion sequences have been developed. These methods were discovered early on for their potential clinical value in the early detection of ischemia and the analysis of stroke patients. These techniques are now possible with the current generation of clinical MRI scanners, and they are becoming more commonly used in clinical settings[25].Because of its availability and rapid imaging time, a computed tomographic scan is the most often used imaging modality in selecting patients for reperfusion treatment. MRI has been demonstrated to produce similar results as computed tomography and some studies have even found that MRI- selected patients had a better prognosis and a decreased risk of symptomatic intra-cerebral hemorrhage.[26]

DWI on stroke diagnosis showed a sensitivity of 90.4 percent in a previous study[27], whereas smaller research reported a false-negative rate of 5.8 percent when imaging was done within 48 hours[27]. Another MRI research reported that 33% of patients had negative DWI, but these patients were assessed 12 days after symptom onset and had mild strokes with a median national institute of health stroke scale of 2, thus the results are not comparable to ours[28].

Strokes in the posterior circulation are more likely to be DWI negative than strokes in the anterior circulation, as previously observed. DWI negative was shown to be 9 percent in a study[29].

CONCLUSION

Diffusion weighted imaging scans of MRI has more sensitivity and specificity for sub-acute onset ischemic strokes when conventional MRI imaging scans of DW1,DW2 and FLAIR fails to show good accuracy in diagnosis. Although, conventional MRI scans can better diagnose ischemic strokes after some days but delayed diagnosis has implications for management. So DW1 MRI imaging scans can be applied in early diagnosis and detection of ischemic strokes.

AUTHOR'S CONTRIBUTION

Afridi SQ: Conceived idea, Designed study, Data collection, Data analysis, Literature search, Manuscript writing, Final approval
Baig H: Data collection, Literature search, manuscript writing
Janan Z: Data collection, Data analysis, manuscript writing.
Begum T: Data collection, Literature search
Shuaib M: Literature search, Proofreading

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