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Role of Higher b Values (b=2000) in Early Diagnosis of Stroke in Patients Undergoing MRI Brain

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ABSTRACT

Objective: To evaluate the role of higher diffusion b values (b=2000) in Early Diagnosis of Stroke in Patients Undergo MRI Brain.

Methods: This study included 50 patients undergo MRI Brain with the symptoms of stroke. With the routine MRI Brain protocol an additional sequence of Diffusion (b = 2000) was acquired and analyzed based on three major parameters that are Number of Stroke Lesions, Area of Stroke Lesion & Size of the Largest Stroke Lesion.

Results: All lesions were hyperintense on the DW MR images with high and standard b-values. Only one additional acute stroke lesion was revealed with high b-value, which were not clearly appeared on standard b value and 1 false positive stroke lesions was revealed which were not appeared on b2000. Hence, b2000 images changed the mode of management in up to 5% cases in our study. However, all lesions were more conspicuous at high b-value increasing the diagnostic confidence.

Conclusion: Diffusion-Weighted Imaging (DWI) with higher b-values, particularly b2000 s/mm², represents a significant advancement in the magnetic resonance imaging (MRI) of acute ischemic stroke (AIS) patients at 1.5 Tesla field strength. The integration of b2000 data with conventional DWI and Apparent Diffusion Coefficient (ADC) maps provides a more robust and comprehensive assessment of ischemic brain tissue, crucial for timely and effective stroke management.

Keywords: *Magnetic Resonance Imaging (MRI), Diffusion Weighted Imaging (DWI), Apparent Diffusion Coefficient (ADC), Stroke, Acute Ischemic Stroke (AIS)*

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1. INTRODUCTION

DWI has fundamentally transformed the early detection and management of acute ischemic stroke (AIS), establishing itself as the most reliable and sensitive method for identifying cerebral ischemia within minutes of symptom onset [1,2]. This rapid diagnostic capability is of paramount importance because the therapeutic window for acute stroke interventions, such as intravenous thrombolysis, is exceedingly narrow, often less than 3 hours from symptom onset. Because of that DWI's indispensable role in the "time is brain" paradigm of acute stroke management. Diffusion-Weighted Imaging (DWI) is a specialized magnetic resonance imaging (MRI) technique that provides image contrast based on the microscopic molecular motion of water within tissues. At its core, DWI measures the degree of diffusion weighting applied through a parameter known as the "b-value," typically expressed in s/mm² [3,4,5].

The b-value is a user-selectable parameter that directly controls the sensitivity of the DWI sequence to water diffusion. Its adjustment is most readily achieved by altering the amplitude of the diffusion gradients [6,7]. While standard

clinical practice often employs b-values up to 1000 s/mm² for routine neuroimaging applications, and modern MRI scanners typically offer a range up to 4000 s/mm², there has been a growing interest in utilizing higher b-values, such as b2000 s/mm², for specific clinical applications, including prostate cancer detection and, increasingly, brain stroke assessment [8,9]

A crucial aspect of DWI is its capability to sense slow-moving water molecules and detect smaller diffusion distances when higher b-values are employed. This characteristic transforms the b-value into a "microscopic magnifying glass" for tissue structure. By increasing the b-value, the imaging sequence becomes exquisitely sensitive to increasingly subtle restrictions in water movement, which are indicative of microstructural changes within tissues [10,11]. This amplification of signal attenuation from restricted water motion allows higher b-values, such as b2000, to reveal microstructural alterations that might be imperceptible at lower b-values, thereby offering a deeper understanding of cellular integrity and organization in pathological states. This enhanced sensitivity is vital for discerning subtle tissue characteristics. The characteristic imaging finding of acute ischemic stroke on DWI is "restricted diffusion," which manifests as areas of high signal intensity (appearing bright) on DWI images and corresponding low signal intensity (appearing dark) on ADC maps [12].

The concept of "high b-value" is not a single threshold but rather a spectrum of microstructural sensitivity. The research material discusses a range of b-values, from the standard b1000 to b2000, b2500, and b3000. This indicates that each increment in the b-value probes water diffusion at progressively finer microstructural scales. This nuanced understanding suggests that the diagnostic utility of "high b-values" is not uniform; different b-values within the higher range might be optimal for detecting distinct pathological features or stages of a disease. For stroke, while b1000 is routine, b2000 is specifically investigated for its added value, implying a targeted application for enhanced sensitivity to subtle or early changes. The choice of b-value thus becomes a strategic decision to balance sensitivity with practical imaging constraints and the specific clinical question. [13,14].

The acquisition of high b-values typically involves applying strong diffusion-encoding gradients along multiple orthogonal directions (x, y, and z) to capture water diffusion in all spatial orientations. The isotropic DWI image, commonly referred to as the DWI, is then calculated as the geometric mean of these direction-specific images. While direct acquisition of b2000 images is feasible, it presents inherent challenges, primarily related to signal-to-noise ratio (SNR) and artifact susceptibility [15].

2. METHODOLOGY

Prospective, cross-sectional imaging study comparing brain diffusion-weighted MRI acquired at b=1000 s/mm² (b1000) versus b=2000 s/mm² (b2000). Each participant serves as their own control. The primary endpoint is diagnostic performance and/or lesion conspicuity at b2000 versus b1000.

Setting and participants

Population: Consecutive adults undergoing clinically indicated brain MRI (e.g., suspected acute ischemic stroke.

Inclusion criteria:

Patients able to undergo MRI

Imaging completed with both b1000 and b2000 sequences.

Exclusion criteria:

MRI contraindications, severe motion precluding interpretation, prior neurosurgery with extensive hardware causing non-diagnostic susceptibility artifacts, or incomplete protocol.

This study was following ethical clearance from the Institutional Ethics Committee, and in accordance with the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

Statistical Analysis

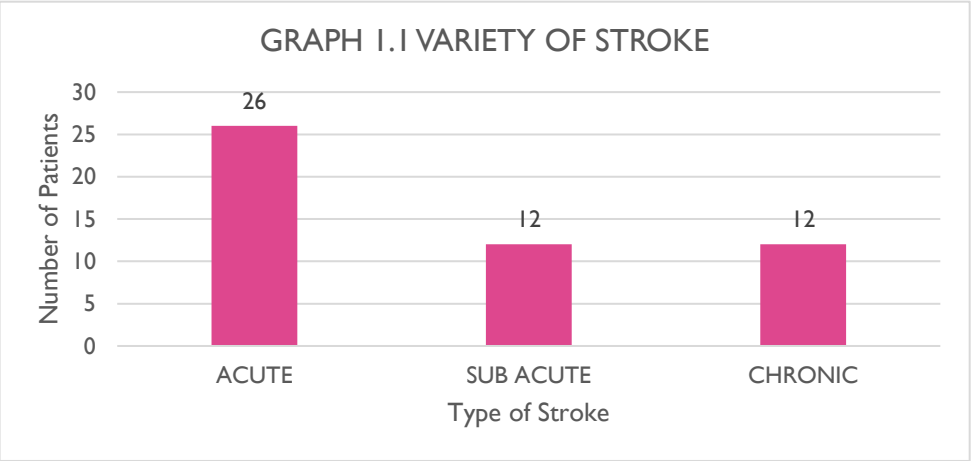
Data were analyzed using Microsoft excel. Mean, standard deviation and SPSS independent t-tests were analyzed. A p-value <0.05 was considered statistically significant.

3. RESULT

Total 50 patients meeting the inclusion criteria were included, out of which 26 were male and 24 were female. Patients from every age group undergo MRI Brain were considered in inclusion criteria with the early symptoms of stroke

(Numbness, Weakness, difficulty in speech & sudden severe headache. Data of all the patients was analyzed based on two major groups based on the diffusion b values that were b1000 & b2000, and these groups were further divided based on three sub groups that were Location of the Lesion, size of the lesion and number of lesions in each group. Data of these groups was compared statistically and we observed the following results.

Out of total 50 patients 26 (52%) patients having acute infarct, while 12 (24%) patients having sub-acute infarct and 12 (24%) patients having chronic infarct as shown in graph 1.1.



Graph 1.2 showing the patients of different age groups having acute stroke, out of four groups in the first group less than 20 years we had only 2 patients, in the second group ranges age from 21 to 40 years we had 5 patients, in the third group ranging the age from 41 years to 60 years we had 6 patients and in the fourth group having age of patients more than 60 years we had 13 patients.

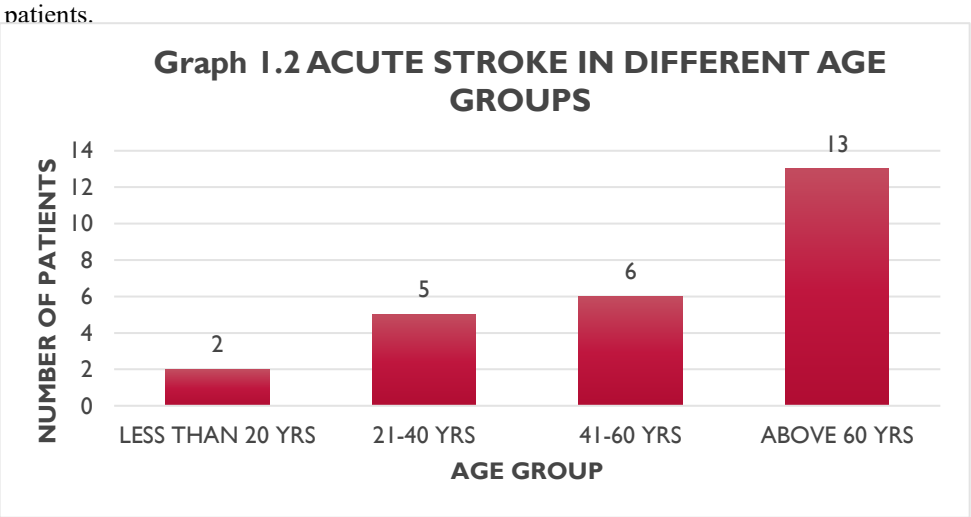


Table 1.1 Showing Variation in most common sites of brain having the stroke lesions with the number of lesions at that location.

MOST COMMON LOCATION OF LESIONS	TOTAL NUMBER OF LESIONS
RIGHT FRONTAL LOBE	9
LEFT OCCIPITAL LOBE	8
LEFT FRONTAL LOBE	6
RIGHT OCCIPITAL LOBE	4
RIGHT OCCIOPITAL LOBE	1
RIGHT TEMPORAL LOBE	1
RIGHT PARIETAL LOBE	1
LEFT PARIETAL LOBE	1

Table 1.2 Showing Variation in size of Acute stroke Lesion in (mm) at different B values (b1000 & b2000) of total 26 patients.

S. No.	(Size of Lesion in mm) b1000	(Size of Lesion in mm) b2000	% Difference
1	14.98	15.01	**0.20%**
2	14.14	14.45	**2.19%**
3	48.97	50.25	**2.61%**
4	11.35	12.97	**12.48%**
5	32.02	32.78	**2.37%**
6	19.42	20.42	**5.15%**
7	18.2	19	**4.40%**
8	37.78	37.78	**0.00%**
9	3.66	4.37	**19.40%**
10	21.6	21.9	**1.39%**
11	35.43	35.64	**0.59%**
12	37.7	38.2	**1.33%**
13	23.24	23.45	**0.90%**
14	33.6	35.9	**6.85%**
15	17.8	19.1	**7.30%**
16	70.7	71.07	**0.52%**
17	23.2	23.8	**2.59%**
18	68.7	69.6	**1.31%**
19	19.2	19.2	**0.00%**
20	5.41	5.78	**6.84%**
21	7.4	8.25	**11.49%**
22	37.31	43.56	**16.75%**
23	8.59	8.86	**3.14%**
24	3.66	4.37	**19.40%**
25	21.6	21.9	**1.39%**
26	14.14	14.45	**2.19%**

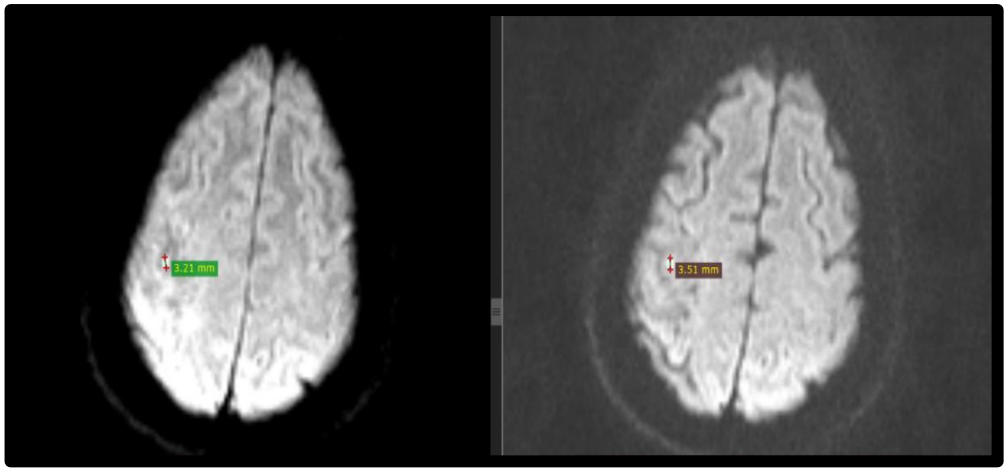


Figure 1.1 Sample MRI Image showing Measurement of Acute Stroke Lesion size on diffusion (b1000 & b2000)

Statistical Analysis:

Paired t-test was performed

• H_0 (null hypothesis): There is no difference between Group A (b1000) and Group B (b2000).

• H_1 (alternative): There is a significant difference.

$p \approx 0.055$ (slightly above 0.05).

• The difference is not statistically significant at 95% confidence, but it is borderline.

• Statistically: The small mean difference (+1.0 in Group B) is not significant at the 0.05 level, though it is very close.

4. DISCUSSION

The clinical implementation of b=2000 s/mm² DWI is accompanied by notable challenges. The inherent trade-off between signal purity and signal quality results in a reduced signal-to-noise ratio (SNR) and increased susceptibility to motion artifacts, magnetic susceptibility artifacts, and image distortion. These technical limitations often necessitate the use of advanced MRI hardware, such as 3T scanners with powerful gradients, and contribute to prolonged acquisition times, which can impact patient comfort and workflow efficiency. The compounding nature of these limitations underscores the complexity of achieving high-quality, diagnostically useful images at these elevated b-values [16]. From a patient handling perspective, the extended scan durations and heightened motion sensitivity demand meticulous patient preparation, clear communication, and the strategic deployment of motion-robust acquisition techniques. The need for advanced post-processing, including the calculation of Apparent Diffusion Coefficient (ADC) maps and the application of complex diffusion models, further integrates into the clinical workflow [17,18]. Our study demonstrates that the role of higher diffusion values, specifically b2000 s/mm², in MRI brain stroke patients at 1.5 Tesla is significant and evolving. DWI with b2000 offers substantial advantages in detecting acute ischemic stroke, particularly for small and subtle lesions, by providing improved sensitivity, enhanced conspicuity. This leads to a more accurate estimation of infarct volume and aids in differentiating true ischemic lesions from other pathologies or artifacts.

5. CONCLUSION

The integration of b2000 diffusion values into 1.5T MRI protocols for brain stroke patients represents a valuable enhancement to diagnostic capabilities. The ability to detect smaller and more subtle lesions, coupled with improved lesion-to-background contrast, contributes to more precise and timelier stroke diagnosis. Continued advancements in sequence design with increased sample size and computational methods will further optimize the clinical utility of high b-value DWI, solidifying its role as an indispensable tool in acute stroke management.

Limitations & Challenges of b=2000 DWI in Clinical Practice

Despite its significant diagnostic advantages, the implementation of b=2000 s/mm² DWI in routine clinical practice faces several inherent challenges and limitations, primarily related to image quality, artifact susceptibility, and practical workflow considerations.

Conflict Of Interest:

I declare that I have no conflicts of interest.

Funding:

No any financial support was taken for this study.

Ethical Clearance:

This study was ethically approved by College Research Committee

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