3-Tesla vs. 1.5-Tesla Magnetic Resonance Imaging in the Detection of Ischemic Deep White Matter Lesions

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ABSTRACT:

BACKGROUND:

Deep white matter ischemia (DWMI) is bilateral patchy or diffuse pattern of ischemia and demyelination in the deep white matter region of the brain. WM lesions (WMLs) increase in frequency with age and are associated with lower cognitive performance. Reported prevalence ranges from 5% to 90%, depending on study design, study population, and rating scales. Although the main pathophysiology is still under investigation, they are attributed to degenerative changes of long penetrating arteries and it has been postulated that chronic vascular diseases of the arteries and arterioles supplying these regions can play a role in the process. Deep white matter ischemia is imaged by using T2 weighted (T2W) sequences in addition to FLAIR sequences. Coronal section is used to enable precise sampling of WMLs

OBJECTIVE:

To assess 3T MRI vs. 1.5 MRI in evaluating the extent of DWMI.

PATIENTS AND METHODS:

A cross sectional study was conducted at the MRI unit of the Department of Radiology in Al-Imamain Al-Kadhimain Medical City in Baghdad. Data collection was obtained during the period starting on October 2015– June 2016. The study included 87 patients with the diagnosis of DWMI based on previous MRI data. Patients with initial MRI findings that show no evidence of DWMI as well as patients presented with trauma, migraine, epilepsy, tumor, TB and cerebral venous thrombosis were excluded. Each patient was examined by using 3T MRI, followed by a 1.5 T MRI two days later. The patient images were evaluated for 1.number of lesions, 2.size, 3.volume and 4.intensity of a selected prominent lesion.

RESULTS:

Of the 87 patients, 51 were male and 36 female. Their mean age was 59.48 ± 10.83 years. In all lobes there is a statistical significance ($P < 0.0001$) between 3T and 1.5T i.e. 3T platform was able to show a greater number of lesions in comparison with the 1.5T platform. It was seen with high statistic significance ($P <0.0001$) that one the 3T images, mean intensities, sizes, and volumes were higher across the board. The average additional number of lesions shown by 3T over 1.5T was 9.52 lesions with a standard deviation of 6.50.

CONCLUSION:

Three tesla MRI is significantly superior than1.5 tesla MRI in the number of detected lesions, determining size of a lesion, detecting lesion volume and intensity

KEYWORDS: diffusion weighted imaging (dwi), 3tesla mri, 1.5 tesla mri, ischemic white matter lesionsز

INTRODUCTION:

Deep white matter ischemia (DWMI) is bilateral patchy or diffuse pattern of ischemia and demyelination in the deep white matter region of the brain [(1)]. Whit matter lesions (also termed 'leukoaraiosis') are commonly seen on brain magnetic resonance imaging (MRI) in older people and are associated with symptoms common in old age, including impaired balance and gait, depression, cognitive impairment and dementia, as well as with worse functional outcome after stroke [(2, 3)], Reported prevalence ranges from 5% to 90%, depending on study design, study population, and rating scales [(4-6)].

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Although the main pathophysiology is still under investigation, they are attributed to degenerative changes of long penetrating arteries [3] and it has been postulated that chronic vascular diseases of the arteries and arterioles supplying these regions can play a role in the process [7]. The pathogenesis of WMLs in elderly subjects: degenerative changes of small vessels leading to chronic cerebral hypoperfusion, altered vascular permeability and blood–brain barrier dysfunction, and cerebrospinal fluid accumulation (8). DWMI are thought to represent ischemic small vessel disease of the brain and have been associated with stroke, dementia and normal aging (9, 10). White matter lesions can be divided into those in the subcortical and those in the periventricular region. There is evidence that periventricular white matter lesions are especially related to cognitive decline [11] whereas subcortical white matter lesions may be related to late onset depression [12].

Deep white matter ischemia is imaged by using T2 weighted (T2W) sequences in addition to FLAIR sequences. Coronal section is used to enable precise sampling of WMLs [13]. T2-weighted images (T2WI) and fluid-attenuated inversion-recovery (FLAIR) images showed diffuse high signal intensity in subcortical areas and the deep white matter. Diffusion-weighted images (DWI) showed high signal intensity, while apparent diffusion coefficient (ADC) map demonstrated decreased ADC value in the lesions [14]. Ischemic white matter hyperintensities (WMHs) are thought to represent ischemic small vessel disease of the brain and have been associated with stroke and dementia [15, 16].
The Fazekas scale is used to simply quantify the amount of white matter T2 hyperintense lesions [17]. This is obtained through the morphology of the lesion. The details of the Fazekas grading can be seen in Table 1 [18].

Table 1: Fazekas scale for deep white matter ischemia.

Absent	Grade 0
Punctuate focci	Grade 1
Beginning confluence	Grade 2
Large confluent areas	Grade 3

AIM OF STUDY:

To assess 3T MRI versus 1.5 MRI in evaluating the extent of DWMI.

PATIENTS AND METHODS:

Study design: A cross sectional studywas conducted at the MRI unit of the Department of Radiology in Al-Imamain Al-Kadhimain Medical City in Baghdad. Data collection was obtained during the period starting on October 2015– June 2016.

PATIENTS:

The study included 87 patients with the diagnosis of DWMI based on previous MRI data (patients have previous MRI images with the diagnosis of DWMI). Those patients have different presenting symptoms (headache, conscious disturbance, slurred speech, visual disturbance, and hemiplegia). Patients with initial MRI findings that show no evidence of DWMI as well as patients presented with trauma, migraine, epilepsy, tumor, TB and cerebral venous thrombosis were excluded. Signed consent forms were obtained from all patients included in our study.

METHODS:

All patients were examined using a 3T MRI scan (Philips Achieva 3T) then a re-examination was done by 1.5T (Philips Achieva 1.5T) two days following the initial 3T scan.All patients were imaged on the 3T and 1.5T platforms using T2W axial and T2 FLAIR coronal their parameters were shown in the Table 2.

Table 2: MRI measurement parameters.

	1.5T	3T
Manufacturer	Philips	Philips
Coil	Sense head coil	Sense head coil
No. of channels	8	16
Flip angle	90 degree	90 degree
Type of sequence	T2 axial, T2 FLAIR coronal	T2 axial, T2 FLAIR coronal
TR (sec)	T2 = 4.9, FLAIR = 6	T2 = 2.8, FLAIR = 6
TE (msec)	T2 = 110, FLAIR = 120	T2 = 80, FLAIR = 120
Field of view (mm)	230	230

Patients were assigned random numbers. This created a blind environment were the radiologist could subsequently examine the images without examinational bias. The images were examined using the Philips multi-modality DICOM Viewer software. The followings parameters were studied:

1. Number of Lesions: The radiologist would count and record the number of lesions in each lobe. Accordingly, the images were divided into four lobes; the frontal, parietal, temporal, and occipital lobes. The numbers of lesions were recorded according to its corresponding lobe.
2. Size and volume of lesion: A prominent lesion was selected by the examiner based on being the clearest, having the most well-defined borders out of all lesions. This lesion was selected from 3T images for comparison with the 1.5T images. The lesion must be seen on both 3T and 1.5T.The area of the selected lesion was measured in (millimeters) on both the 3T and 1.5T images. The measurement was repeated three times and the average was taken. The volume of the prominent lesion was calculated in cm3 (the volume was measured automatically by the machine).
3. Intensity of Lesion: The intensity of the prominent lesion for both 3T and 1.5T was recorded and compared on each image. The value of the intensity was recorded by the MRI machine according to the selected area (the intensity was measured automatically by selecting ROI (region of interest) over the prominent lesion). The same area was selected on both imaging platforms to compare intensities. Intensity is seen as the characteristic opacity of a lesion on MRI.
4. Lesion load: This is total number of lesions that appeared on 3T and 1.5T for each lobe accordingly. Total lesion load is calculated as the sum of lesion loads for all lobes
5. The Fazekas Scale: It is recorded on a scale from 0-3. The Fazekas scale (Table 1) was used to grade DWMI in both the 3T and 1.5T images.

Statistical analysis: Data of the studied group were analyzed by using the statistical package for social sciences (SPSS) version 21, 2013. Descriptive statistics were presented as frequencies, proportions (%), means and standard deviation (SD).Students' T-test was used to compare two means, while ANOVA test was used to assess the significance of differences for more than 2 means. Pearson's correlation (bivariate) was used to assess the correlation between two continuous variables (e.g. age and lesion count). Level of significance of < 0.05 was considered as significant.

RESULTS:

Eighty seven patients were included in this study, 51 male, and 36 female; their mean age was 59.48 ± 10.83 years. Out of the 87 patients, 69% were hypertensive, 17% hypertensive and diabetic, 3.5% hypertensive and hyperlipedemic, and 14% were neither hypertensive nor diabetic. The smoking population comprised 44.8% while non-smokers were 55.2%.

Number of Lesions: In all lobes there is a statistical significance between 3T and 1.5T i.e. 3T platform was able to show a greater number of lesions in comparison with the 1.5T platform. It was also found that the parietal lobe had a much higher number of lesions than the other three lobes. This was true for both 3T and 1.5T images. The average number of lesions in each lobe was recorded as shown in Table 5 and the results are illustrated in Figure 5.

Table 5: Mean number of lesions in the 4 lobes of the studied group.

	Frontal	Parietal	Occipital	Temporal
3 tesla	7.41 ± 6.64	34.34 ± 23.61	9.97 ± 5.78	1.28 ± 1.88
1.5 tesla	5.86 ± 5.13	27.9 ± 21.03	7.41 ± 4.46	1.07 ± 1.81
P value	< 0.0001	< 0.0001	< 0.0001	< 0.0004

Intensity, Size, and Volume of Lesions: The intensity of a prominent lesion was measured for each patient on both 3T and 1.5T. Along with the intensity, the size and the volume of the lesion were measured. This data was then analyzed further and the mean values for all the patients were subsequently recorded. It was seen with high statistic significance ($P < 0.0001$) that one the 3T images, mean intensities, sizes, and volumes were higher across the board. This demonstrates that 3T imaging provides significantly higher detail than its 1.5T counterpart. It is unclear whether the higher intensities were linked to greater image detail. The fact that the same lesions had larger sizes and volumes on the 3T images than the 1.5T clearly demonstrates the impact of 3T imaging, as shown in Table 6.

Table 6: Intensity, Size, and Volume of Lesions in the parietal lobe in the studied group.

	Intensity	Size (mm)	Volume (cm^3)
3 tesla	1.03 ± 0.19	8.16 ± 2.27	0.74 ± 0.76
1.5 tesla	0.95 ± 0.19	7.41 ± 2.63	0.57 ± 0.61
P value	< 0.0001	< 0.0001	< 0.0001

Lesion Load: the 3T lesion load is the difference between the sum of all the lesions in all the lobes for each patient on 3T and 1.5T images. It was seen that the 3T scans were able to show a significantly greater number of lesions in all lobes and all patients. The average additional number of lesions shown by 3T over 1.5T was 9.52 lesions with a standard deviation of 6.50. The mode, or the most commonly occurring number was at 12, a significant indication of advantages of increased resolution. There were no patients showing the same number of lesions on both 3T and 1.5T as the least was 1 additional lesion. The maximum number of additional lesions in one patient was 27. The results of 3T lesion load can be seen in Table 7.

Table 7: 3 tesla lesion load.

Mean	9.52
Standard deviation	± 6.50
Mode	12
Min	1
Max	27

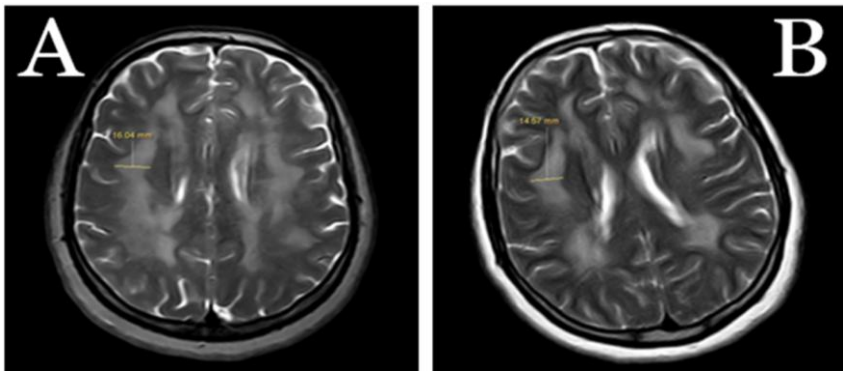

Figure : 43 year old female hypertensive patient presented with slurred speech. A and B are T2 axial images. A: the size of the lesion in 3 tesla is 16.04mm. B: the size of the same lesion in 1.5 tesla is 14.57mm

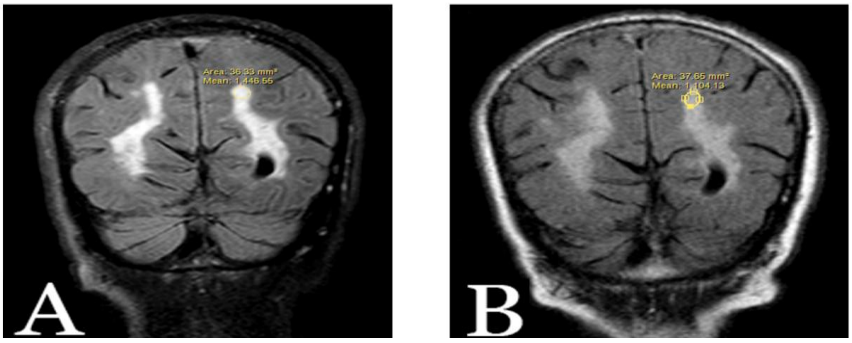

Figure: 66 year old male hypertensive and diabetic patient presented with blurred vision. A and B are T2 FLAIR coronal images. A: show the intensity of the lesion in 3 tesla MRI. B: show the intensity of the lesion in 1.5 tesla MRI.

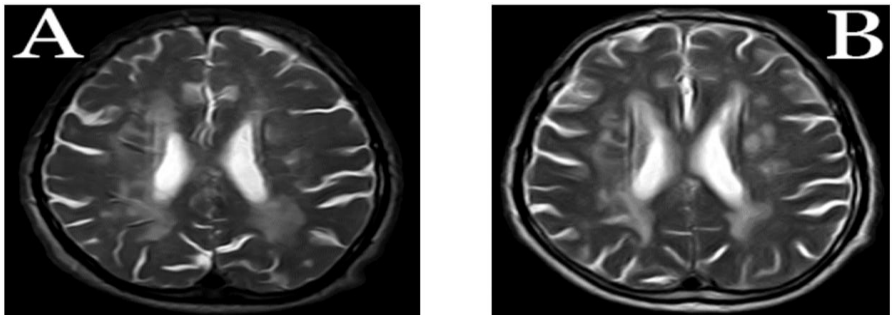

Figure : 55 year old female hyperlipidemic patient presented with numbness in the left lower .limb. slurred speech. T2 axial images showing Fazekas grade 3 lesions in 3 tesla MRI in A and in 1.5 tesla MRI in B.

DISCUSSION:

The use of 3-Tesla MRI scanners has been on the rise recently. As proper healthcare measures and guidelines are perpetuated it becomes easier to incorporate these machines in local hospitals and private clinics. [19].

The mean age of the patients was 59.48 ± 10.83, which was also slightly higher than other similar study [19]. This could be attributed to the fact that the selection process inclusive of chronic "age-related" risk factors such as diabetes, hypertension, and hyperlipidemia and not crippling conditions like multiple sclerosis. The selection criteria inherently shifted the mean age towards the right (i.e. increased).

In terms of the imaging results, it was found that in the 4 lobes that were imaged, the parietal lobe had the highest number of lesions on both platforms. The occipital and frontal lobes had a similar number of lesions, although the former had a slightly higher number, also on both platforms. The temporal lobe showed the fewest number of lesions although the means for both platforms were similar. The parietal lobe was selected to be further reviewed due to the immense number of DWMI lesions in that region. Leeuw et al [3] showed that periventricular and subcortical white matter lesion load increased with age in men and women and in all regions of the brain. However, at all ages tended to have a greater lesion load than men, particularly in the frontal lobes where this difference reached statistical significance for frontal capping.

On the 3T platform, the parietal lobe had a mean of 34.34 lesions with a standard deviation of 23.61. The 1.5T images showed a mean 27.9 lesions with a standard deviation of 21.03. The P-value for these statistics was < 0.0001, and henceforth can be considered of high statistical significance. It is therefore imperative to recognize the superiority of the 3T platform in increased detectability of lesions. This advantage was demonstrated with the same statistical significance on all the other lobes as well, with the exception of the temporal lobe. The results for the temporal lobe statistics had a P-value of 0.0004, are of high statistical significance.

Size was the next measurement to be tested, and was taken for the largest lesion in the parietal lobe, on both platforms. The same lesion was measured on both platforms. It was found that the mean size of the largest lesion in the parietal lobe on the 3T platform was 8.16 mm with a standard deviation of 2.74 mm. The same lesion on the 1.5T platform had a mean size of 7.41 mm with a standard deviation of 2.63 mm. These statistics had a P-value of < 0.0001 and were thus of high statistical significance. This illustrates that the 3T platformis significantly superior in providing a higher resolution that aidsin defining lesional borders. de Leeuw et al [3] showed that subcortical white matter lesion volume was highest in the frontal and parietal lobes, 20 and 100 times higher than in the occipital and temporal lobes, respectively. Although the frontal and parietal lobes are larger than the occipital and the temporal lobes, this difference cannot explain the vast difference in white matter lesion volume. Scheltens et al [21] found in a study of 24 "normal" elderly subjects (mean age 68.0 years) that the severity of white matter lesions was highest in the frontal lobe.

Intensity was found to be significantly greater on the 3T platform with a mean intensity of 1.03 against a mean intensity of 0.95 on 1.5T. Both intensities had a standard deviation of 0.19 and a P-value of < 0.0001, giving a high statistical significance to the fact that 3T platforms provide a greater intensity (and hence greater detail) in imaging DWMI lesions; these results were similar to a that in a previously reported study [16].

Volume was also found to be greater on the 3T platform for the same lesions mentioned

previously with the mean volume measuring at 0.74 cm3 with a standard deviation of 0.76 cm3. On the 1.5T images, the mean volume was 0.57 cm3 with a standard deviation of 0.61 cm3. The P-value was <0.0001 and considered of high statistical significance. This furthers the point made previously on size regarding the superior resolution for the 3T platform.

Lesion load was taken into account to illustrate with certainty, the difference in number of lesion detections across all lobes. It was found that on average (mean), the 3T platform provided the examiner with 9.52 more lesions than their 1.5T counterparts. This value had a standard deviation of 6.50. The minimum number of extra lesions shown was 1, with the maximum being 27. The most recurring value was 12, proving the point that the 3T platform is superior in detectability of DWMI lesions, similar findings regarding size, intensity, and lesion load were also found by Stankiewicz et al [20] and Wattjes MP et al [22].

CONCLUSION:

3T MRI is significantly superior than1.5T MRI in the number of detected lesions, determining the size of a lesion, detecting lesion volume and lesion intensity.

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