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Original Article

One step diagnosis of multiple sclerosis disease activity, dissemination in time and space using diffusion weighted MRI

Moustafa E.M. Radwan [a,c,*], Khaled O. Aboshaera [b]

[a] Department of Radiodiagnosis, Assiut University, Egypt
[b] Department of Neurology and Psychiatry, Assiut University, Egypt
[c] Department of Radiodiagnosis, Taibah University, Al-Madinah Al Munwarah, Saudi Arabia

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ABSTRACT

Objectives: To assess the value of DWI with its two components (DWI-b1000 and DWI b0) images in assessment of active MS and in defining dissemination in time (DIT) and dissemination in space (DIS) in those patients.
Methods: Brain MRI studies were performed using T1WI, T2WI, FLAIR and DWI and CE T1WI.
Results: Twenty-one patients (Males/Females = 6/15) of age range 18–50 years were included. Forty lesions were hyperintense on DWI-b1000 that had significant link to enhancement seen on contrast-enhanced T1WI (100%) indicating disease activity. Using the 2010 revised McDonald criteria: In 9 patients (42.85%), there were [Asymptomatic active lesions ($n = 17$)]. Those lesions were simultaneously present along with [Non-active demyelinating lesions]; DIT could be diagnosed in these cases based alone on MRI findings. In 12 patients (57.14%), there was simultaneous presence of [Symptomatic active lesions ($n = 23$)]. Those lesions were present along with [Non-active demyelinating lesions]; DIT could be diagnosed in these cases based on both clinical and MRI findings.
Conclusion: DWI-b1000 is of the same sensitivity as CE T1WI in detection of MS active lesions and in detection of DIT and DIS. DWI-b0 can substitute the T2WI in detection of demyelinating lesions and in confirmation of the MS disease beyond the active stage.

1. Introduction

Although the decision to diagnose multiple sclerosis (MS) is commonly based originally on history, clinical data, CNS imaging by MRI through detecting multiple lesions on MRI Imaging over different times can reinforce, add value, or even substitute some given criteria from clinical examination [1,2].

Confirmation of lesions disseminated in time (DIT) and disseminated in space (DIS) is required for the diagnosis of MS [3–5]. Based on the revised McDonald MRI criteria, diagnosis of MS can be confirmed by the detection of "any two, any new" lesions. DIS is diagnosed when there is $\geqslant 1$ T2-weighted imaging (T2WI) lesion in each of $\geqslant 2$ of 4 diagnostic sites: periventricular, juxtacortical, posterior fossa and spinal cord. DIT is diagnosed when any new T2WI lesion, regardless of timing, is detected by MRI or if contrast enhanced lesions are concurrently visualized along with non-contrast enhanced lesions [6].

* Corresponding author at: Department of Radiodiagnosis, Faculty of Medicine, Assiut University, Assiut, Egypt.
E-mail address: ezeldienmos@yahoo.com (M.E.M. Radwan).
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In patients with clinical symptoms suggestive of MS, the 2010 revisions of McDonald criteria permit for the first time the establishment of MS diagnosis based on one single MRI study that can show DIS and DIT (a concurrent visualization of non-contrast enhanced lesions along with non-symptomatic contrast enhanced lesions) [6]. The diagnosis of DIT can be established by the presence of new T2WI or gadolinium enhanced lesion on a follow-up MRI, using baseline MRI examination as a reference, irrespective of when the baseline MRI was done [7].

With the use of Gadolinium, the active lesions will show enhancement pattern on contrast enhanced T1WI (CE T1WI). This is attributed to the disturbance of the blood brain barrier. The pattern of enhancement can be homogeneous, ring, or heterogeneous. Almost all T2WI lesions will have gadolinium enhancement when they first develop, however the period during which these lesions remain active with enhanced pattern, is usually short. It ranges from few days to few weeks [8–11]. The distinction between active and chronic lesions is somewhat arbitrary because several factors can affect enhancement such as the following: the dose of gadolinium (Gd), the delay and characteristics of image acquisition, and steroid treatment of acute attacks [12–14].

Diffusion-weighted imaging (DWI) is a non-invasive MRI sequence that supplies image contrast dependent on the molecular movement of water. It is achieved by applying a pair of magnetic field gradient pulses in a T2-Weighted MR imaging (T2WI) sequence. The sensitivity to water diffusion is defined by the gradient factor *b* or (*b* value) sec/mm^2 which is a factor that reflects the strength and timing of the gradients used to generate diffusion-weighted images. The higher the *b*-value, the stronger the diffusion effects [15].

DWI sequence is actually T2 weighted sequence, sensitized to diffusion by gradients. The quantitative evaluation of diffusivity can be gained by obtaining two sets of images with dissimilar *b*-values. In clinical rehearsal, one of the *b*-values would measure 1000 sec/mm^2 while the other *b*-value is 0 sec/mm^2, (yielding the so-called b0 images). At a *b* value of 0 sec/mm^2, T2-weighted contrast predominates while at high *b*-values, diffusion and T2-weighted contrast competes but the contrast is largely produced by the diffusion properties [16].

Recent advance in MR systems has made it possible to acquire whole brain diffusion-weighted imaging (DWI) in less than one minute. Therefore, many institutions have added DWI to a routine protocols for MRI brain scanning [16]. The use of DWI in the MRI protocol for imaging MS appears to be of clinical value and does not have significant increase in the whole scanning time [17].

As a practical matter, most routine clinical DWI for examining the central nervous system currently use *b*-values (b1000 and b0). The diffusion weighted sequence through applying the two *b* values (b1000 and b0) will provide two images: one is DWI-b1000 image that represents the diffusion properties and can be used in the detection of the acute/ active demyelinating MS plaques which appear as bright signal. The other image obtained from DWI is DWI-b0 image. This DWI-b0 image is obtained without any additional time and has the T2WI sequence properties. In theory it is expected that the presence of DWI sequence including both the DWI-b1000 and DWI-b0 Images can provide full evaluation of MS cases; DWI-b1000 can be used for detection of MS active lesions. In the same time DWI-b0 can substitute the T2WI in detection of demyelinating lesions and in confirmation of the MS disease beyond the active stage without the need for extra scanning time [18].

2. Aim of the work

The aims of this study were to assess the value of DWI with its two components (DWI-b1000 and DWI b0) images in assessment of active MS and in defining dissemination in time (DIT) and dissemination in space (DIS) in those patients.

3. Patients and methods

3.1. Patients

The Inclusion Criteria for selection of patients in this current study were as follows: (1) Patients who were diagnosed as definite MS according to the McDonald's clinical diagnostic Criteria for diagnosing multiple sclerosis by experienced consultant neurologist [6]. (2) The start of the MS disease was in the age from 15 to 50 years; (3) Baseline MRI scans were done within 14 days from start of symptoms. Exclusion criteria were patients who received drugs such as interferon or steroids before start of MRI scanning to exclude the possibility of their impact upon the edema or contrast enhancement of lesions.

Twenty-one patients met these criteria during the period of this prospective study that was conducted in Assiut University Hospital between March 2012 and November 2015. This study was approved by the Review Board of the institution and informed consent was attained from all patients prior to scanning.

3.2. Methods of examinations

All patients were subjected to the following:

(1) Full history taking and clinical examination: history was taken from the patients. Neurological clinical examination was conducted.
(2) Radiological and imaging investigations: Brain MRI was acquired using 1.5-Tesla Philips Superconducting Magnet System (Gyroscan ACS-NT) power track 6000 at Assiut University Hospital according to the following protocol; Axials; T1WI, T2WI, and FLAIR sequences, Sagittal T2WI or FLAIR, and Axials, coronals, and sagittals CE T1WI after injection of 0.1 mmol/kg of Gd DTPA. DWI was done using a single-shot echo planar spin-echo sequence with two *b* values (1000 and 0 sec/mm^2).

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