Role of MRI diffusion in evaluation of multiple sclerosis

A Thesis for Partial Fulfillment Of
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Ahmed Mohamed Sanad

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List of Abbreviation

cMRI	Conventional magnetic resonance imaging.
MRI	Magnetic resonance imaging.
WM	White matter.
GM	Gray Matter.
SLF	Superior longitudinal fasciculus.
ILF	Inferior longitudinal fasciculus.
SFO	Superior front-occipital fasciculus.
IFO	Inferior fronto-occipital fasciculus.
UNC	Uncinate fasciculus.
CG	Cingulum.
FX	Fornix.
ST	Stria terminals.
MS	Multiple sclerosis.
CNS	Central nervous system.
CIS	Clinically isolated syndrome.
RIS	Radiologically isolated syndrome.
RRMS	Relapsing remittent multiple sclerosis.
SPMS	Secondary progressive multiple sclerosis.
PPMS	Primary progressive multiple sclerosis.
BBB	Blood brain barrier.
NO	Nitric oxide.
EDSS	Extended disability status scale.
FSS	Functional system score.
DIS	Dissemination in space.
DIT	Dissemination in time.
FLAIR	Fast fluid attenuated inversion recovery.
STIR	Short T1 inversion recovery.
CSF	Cerebrospinal fluid.

WI	Weighted.
CE	Contrast enhanced.
Gd	Gadolinium.
DWI	Diffusion weighted imaging.
DTI	Diffusion tensor imaging.
MRS	Magnetic resonance spectroscopy.
fMRI	Functional magnetic resonance imaging.
OCT	Optical coherence tomography.
CARS	Coherent anti-strokes Raman spectroscopy.
ADC	Apparent diffusion coefficient.
FA	Fractional anisotrophy.
RF	Radio frequency.
ICS	Intracellular space.
ECS	Extracellular space.
ROI	Region of interest.
TBSS	Tract based spatial statistics.
EPI	Echo planner imaging.
NPV	Negative predictive value.
PPV	Positive predictive value.
GBCA	Gadolinium based contrast agents.
SPSS	Statistical package for the social sciences.
T	Tesla.
TSE	Turbo spin echo.
TE	Echo time.
TR	Repetition time.
FOV	Field of vision.
PC	Personal computer.
SD	Standard deviation.

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Introduction

Multiple Sclerosis (MS) is a challenging disease in all aspects ranging from etiology to diagnosis and treatment. It is also a disease that has greater heterogeneity in terms of clinical forms, imaging appearance, and treatment response ***(Ge, 2006).***

MS is one of the demyelinating disorders of the central nervous system (CNS). The etiology of MS is yet not clear but genetic and environmental factors are two of the causes ***(Kahana et al., 2000).***

The diagnosis of multiple sclerosis (MS) is based on demonstrating evidence of inflammatory-demyelinating injury within the central nervous system that is disseminated in both time and space. Diagnosis is made through a combination of the clinical history, neurologic examination, magnetic resonance imaging and the exclusion of other diagnostic possibilities. Other so-called "paraclinical" tests, including the examination of the cerebrospinal fluid, the recording of evoked potentials, urodynamic studies of bladder function, and ocular coherence tomography, may be helpful in establishing the diagnosis for individual patients ***(Gelfand, 2014).***

The sensitivity of MRI is high in early and asymptomatic MS plaques. The sensitivity of MRI for spinal cord lesions varies from 68 to 89% in different papers. MS plaques generally occur in the white matter although 10% of the plaques are seen in the gray matter. The MS plaques are generally seen in the capsula interna, periventricular white matter, corpus callosum and pons ***(Ge, 2006).***

Complementary to the clinical evaluation, conventional magnetic resonance imaging (cMRI) plays a prominent role for diagnosis and assessment of patients with multiple sclerosis. It provides reliable detection and quantitative estimation of focal white matter lesions in vivo. Modern criteria involve MRI parameters for the diagnosis of MS and for predicting conversion to clinically definite MS in patients who present with a first clinical episode (eg, unilateral optic neuritis) suggestive of disease onset. A diagnosis of multiple sclerosis is based on showing disease dissemination in space and time and excluding other neurological disorders that can clinically and radiologically mimic multiple sclerosis ***(Andreadou, 2012).***

The study of T2 weighted images on conventional MRI is however, very limited. The main problem is related to the low specificity. Inflammation, edema, demyelination, gliosis and axonal loss are represented by areas of high signal on this sequence ***(Poser et al, 2006).***

Nowadays, it is popular to use diffusion weighted MRI to evaluate the lesions anywhere in the body. Diffusion weighted imaging (DWI) is very sensitive to alterations of the Brownian movements of water molecules. Moreover, DWI does not need contrast media and takes very short time. DWI describes the water molecular movements using a powerful diffusion gradient independent from T1 and T2 relaxation times. The disorder progress causes changes in the water molecular movements. In conventional MRI the effect of molecular movement of water on the images is very low. But in DWI the molecular movements of water create the images. The diffusion coefficient can be measured and mapped ***(Hannoun et al, 2015).***

SO, Diffusion MRI provides a unique information about the tissue and cellular microstructure in the human brain So, Diffusion MRI has been shown to be sensitive to evaluation of MS damage over time and to provide in vivo correlates of MS clinical severity ***(Pagani et al, 2007).***

Contrast enhancement in demyelinating lesions and blood–brain barrier (BBB) breakdown has been generally regarded as signs of active perivascular inflammation. In patients with contraindications or relative contraindications to gadolinum-based contrast agents, Diffusion-weighted imaging (DWI) may be needed for early and accurate diagnosis of active MS. As it has been widely used to detect diffusion alterations in active inflammatory lesions. SO it may substitute for contrast-enhanced T1-weighted imaging (CE T1WI) in detection of disease activity ***(Lo et al, 2014).***

Aim of work

The purpose of this study is to demonstrate the role of MRI diffusion (DWI-b0 &DWI-b1000) in the diagnosis of multiple sclerosis disease and whether it could be used to detect the disease activity or not .

Anatomy of the brain

The brain is composed of the cerebrum, cerebellum, and brainstem ***(Nabavi and Black, 2001).***

a) **The cerebrum** is the largest part of the brain and is composed of right and left hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement ***(Kamali and Flanders, 2014).***

b) **The cerebellum** is in the posterior fossa. It is separated from the occipital lobe by the tentorium and from the pons and midbrain by the fourth ventricle. It is connected to the brain- stem by three pairs of cerebellar peduncles. There are two hemispheres with the midline vermis between. The cerebellum is important in muscle coordination and in the regulation of muscle tone and posture ***(Ryan et al., 2011).***

c) **The brainstem** connects the cerebral hemispheres with the spinal cord and extends from just above the tentorial hiatus to just below the foramen magnum. The brainstem has three parts: from superior to inferior, the midbrain, the pons and the medulla ***(Ryan et al., 2011).***

➢ Cerebral hemispheres

The cerebral hemispheres fill the cranial vault above the tentorium cerebelli. Right and left hemispheres are connected by the corpus callosum and are otherwise partly separated by the median longitudinal fissure. The hemispheres consist of cortical