Role of Diffusion Weighted MRI Imaging in Detection of Liver Metastases

Thesis

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Israa Abdulhameed Moulood

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List of Abbreviations

Abbr.	Full term
ADC	apparent diffusion coefficient
DW	diffusion weighted
HCC	hepatocellular carcinoma
IVIM	intravoxel incoherent motion
SE	spin echo
SNR	signal-to-noise ratio
SPIO	superparamagnetic iron oxide

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INTRODUCTION

Liver cancer,is one of the leading causes of all cancer related deaths. In fact, the secondary hepatic malignancies (liver metastases) are more common than the primary ones. Almost all solid malignancies can metastasize to liver [(1)].

Accurate diagnosis of liver metastases is essential for appropriate management of these patients. Multiple imaging modalities, including ultrasound ,computed tomography(CT), positron emission tomography, and MRI, are available for the evaluation of patients with suspected or known liver metastases[(2)].

There is growing interest in the applications of diffusion-weighted-imaging (DWI) in oncologic area . DWI has important advantages because it does not require contrast medium, a very quick technique and it provides qualitative and quantitative information that can be helpful for tumor assessment[(3)].

DWI is an imaging technique which provides tissue contrast by the measurement of diffusion properties of water molecules within tissues. Diffusion is expressed in an

apparent diffusion coefficient (ADC), which reflects the diffusion properties unique to each type of tissue[4].

Both low and high *b*-value DWI are effective in suppressing vascular structures that may mimic or obscure liver lesions, but low *b*-value DWI provides a higher signal-to-noise ratio, is less prone to cardiac motion-induced signal loss, and suffers less from eddy current-induced distortions. Previous studies have already shown that low *b*-value DWI is more sensitive than high *b*-value DWI in detecting malignant liver lesions [5].

Tumors are frequently more cellular than the tissue from which they originate and thus appear to be of relatively high signal intensity (restricted diffusion) at DWI[6].

DWI is being applied for the detection of liver metastases. In the liver, low b-value images (e.g., b = 50–150 s/mm^2) that suppress the high-signal flow from the hepatic vessels, resulting in black blood images, have been found to be useful for lesion detection Metastases appear as high-signal-intensity foci at DWI. Some of the challenges encountered in DWI of the liver are cardiac motion and susceptibility artifacts that can obscure or diminish visualization of the left lobe .The susceptibility effects may

result from air in the adjacent stomach or colon. Artifacts resulting from cardiac motion can be reduced by triggered acquisition by ECG or a peripheral pulse unit, thus improving image quality and signal-to-noise ratio in the left lobe of the liver .Images may also be acquired with the aid of respiratory triggering to minimize inadvertent breathing motion. However, these techniques increase the image acquisition time, which can render the examination more susceptible to bulk motion [6]

AIM OF THE WORK

To evaluate the role of DWI in diagnosis of liver metastasis.

Principles of DWI

To understand the concept of DWI, one must understand the principles of free versus restricted diffusion in the cellular microenvironment. Free water molecules are in constant random motion, known as Brownian motion, which is related to thermal kinetic energy. In contrast, the motion of water molecules within the cellular microenvironment is impeded by their interaction with cellular compartments, including the cell wall and intracellular organelles [(6)]. In other words, restriction in the diffusion of water molecules is directly proportional to the degree of cellularity of the tissue. This restricted diffusion is observed primarily in malignancies, hypercellular metastases, and fibrosis, which contain a greater number of cells with intact cell walls than does healthy tissue. In contrast, in a microenvironment with fewer cells and a defective cell membrane (eg the necrotic center of a large mass), water molecules are able to move freely ie, diffusion is less restricted.[(7)]

The most common method used for DWI is to incorporate two symmetric motion-probing gradient pulses into a single-shot spin-echo (SE) T2-weighted sequence, one on either side of the 180° refocusing pulse (Stejskal-Tanner

sequence) . This can be explained at the molecular level by the fact that a diffusion gradient causes the phase shift to vary with position, with all spins that remain at the same location (ie, restricted diffusion microenvironment) along the gradient axis during the two pulses returning to their initial state. However, spins that have moved (ie, free water molecules) will be subjected to a different field strength during the second pulse and therefore will not return to their initial state, but will instead undergo a total phase shift, resulting in decreased intensity of the measured MR signal[8]. The degree of signal attenuation depends on multiple factors as shown in the following equation:

$$SI = SI_0 \times \exp(-b \times D),$$

where SI0 is the signal intensity of the T2-weighted image with no diffusion gradient applied, b is the degree of diffusion weighting (b value), and D is the diffusion coefficient.[8]

The sensitivity of DWI to diffusion can be incrementally increased by increasing the amplitude, duration, and temporal spacing of the two motion-probing gradients. These gradient properties determine the b value (expressed in seconds per square millimeter), an index of the degree of diffusion weighting . Pulse sequence diagrams illustrate how a diffusion-weighted sequence incorporates

two symmetric motion-probing gradient pulses into a single-shot SE T2-weighted sequence, one on either side of the 180° refocusing pulse. Restricted diffusion (top) manifests as retained signal, whereas free diffusion (bottom) translates into signal loss. [8]

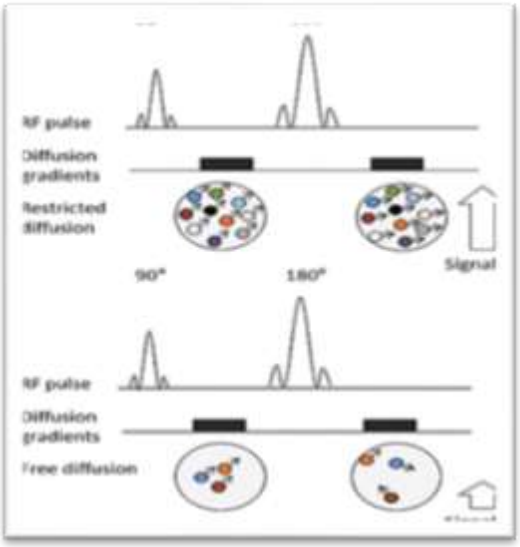

Figure (1): Pulse sequence diagrams illustrate how a diffusion-weighted sequence incorporates two symmetric motion-probing gradient pulses into a single-shot SE T2-weighted sequence [8].

It is not possible to distinguish between the solid and cystic components of these lesions without using a higher b value or an ADC map [9].