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Preparations In a DWI sequence diffusion sensitization gradients are applied at both sides of the 180° refocusing pulse. The parameter which decides the diffusion weighting is called “b value” and is represented in s/mm2. It is proportional to the square value of the duration and amplitude of the gradient applied.

Diffusion is evaluated on trace images qualitatively and quantitatively by the parameter which known as apparent diffusion coefficient (ADC). The tissues with restricted diffusion are bright on the trace image and hypo-intense on the ADC map. The algorithms which used in the acquisition of DWI make several assumptions, e.g.,

infinitely rapid gradient changes, perfect field homogeneity, and RF pulses perfectly shaped, etc. However, with the accessible technology, gradient coils are capable of generating gradient magnitudes and switching rate of the order of 40 mTm-1 and 200 Tm-1·s-1 respectively. Such discrepancies limit DWI accuracy and lead to lower quality of image and image artifacts [74].

The main limitations of DWI are experienced in body imaging and are hugely due to being an Echo-Planar Imaging sequence [59,60]. DWI is vulnerable to different artifacts, e.g., T2 black out, ghosting, T2 shine through, distortions and blurring. Tissues with very long relaxation times may tend to keep signal on high b value

images. This is defined as “T2 shine through” effect.

The corresponding bright signal of such lesions on the ADC map helps to distinguish it from restricted diffusion, which looks dark on ADC maps. T2 blackout effect is the term used on the ADC map for low signal because of a lack of sufficient water protons and not restricted diffusion. For such an effect, the diagnostic sign is the low signal on T2 weighted fat saturated images.

Another disquieting limitation of DWI is the questionable reproducibility of ADC values. ADC values can differ even if the same MR system is used. This variability was attributable to the low SNR inherent, distortions and artifacts related to SS EPI sequence. During EPI sequence, diffusion gradients rapid on/off transition leads to eddy-current related distortions leading to image degradation and systemic errors in calculations of ADC. Table 1 Display _Post processing _Acquisition Time (min)* _Maximal Gradient Strength (sec/mm2) _No. of Gradient Directions _3.0

T and High Gradient Strength Capabilities _ _Technique and Reference _ _Gray-scale sections _None _1–3 _?1000 _1 _Optional _ _Diffusion weighted imaging _ _Technical Requirements of Diffusion MRI Techniques Usefulness compared to other modalities and sequences MRI provided an excellent contrast resolution not only from tissue (proton) density, but also from tissue relaxation properties.

After primary focus on T1 and T2 relaxation properties researchers investigated other methods for generating contrast using other properties of molecules of water. Diffusion weighted imaging (DWI) was the result of such researchers' efforts as Stejskal, Tanner and Le Bihan[2] [Le Bihan D. Diffusion MRI: what water tells us about the brain. EMBO Mol Med. 2014;6:569–573.].

Diffusion-weighted MR Imaging Diffusion-weighted MRI is considered as the simplest form of diffusion imaging. DWI is considered as one of the components required to reconstruct the complete probability density function as in diffusion spectrum imaging. Also, DWI is the outcome, which is unprocessed, of a single pulsed gradient SE sequence being applied in single gradient direction, and it matches up in q-space to one point. Although such an image is fairly simple, it contains some diffusion information.

In ,Figure 13, the right splenium of the corpus callosum appears dark, whereas the left splenium appears bright. In regions like the right splenium, in which the

main direction of diffusion is aligned with the diffusion gradient applied, the signal intensity decreases markedly and the region appears on the image darker.

Diffusion in the ventricles is free and substantial in all directions including the direction of applied gradient, and so the whole of the ventricles appears dark. In spite of its simplicity, DWI is frequently used in stroke investigations (,15). Indeed, in an acute stroke, increased water mobility restrictions is produced by the local cell swelling and hence, bright image appearance because of high signal intensity in the lesion area. The advantage of DWI is the shortness of the acquisition time, because one image only is required. / Figure 13.Diffusion weighted image (right) from signal sampling at a single point in 3D q-space (left).

Brain areas in which diffusion is intense in the direction of the gradient applied ?? appear darker due to a leakage in the measured signal that results from de-phasing. DWI may be useful to demonstrate persistent or progressive tumor despite the lack of contrast enhancement. Pseudo-progression is seen in the edema setting associated with the inflammatory response, rather than the true tumor progression.

DW-MRI is applied in neoplasms of the neck and head. Diffusion weighted image could be used to distinguish malignant from benign and inflammatory lung lesions and helps to differentiate small cell cancers from non-small cell cancers. DWI can differentiate benign renal cysts easily from solid neoplasms.

DW MRI's exquisite sensitivity to microstructural changes allows us to detect the abnormalities long before conventional image changes. DWI improves endometrial and cervical tumors diagnosis [62]. DW MRI is particularly useful in determining the depth of myometric invasion in endometrial cancer patients. Hepatobiliary pancreatic cancers DWI is useful in the characterization and detection of focal liver lesions and can be used as an alternative to Gadolinium-enhanced MRI in renal dysfunction patients.

DW MRI clinical applications include the monitoring of treatment response and prognosis in patients receiving systemic and focal ablative pancreatic and hepatic malignancies therapies [43-46]. Hardie et al[47] compared the usefulness of DWI in liver metastases detection. They reported that diffusion weighted image has 66.3% sensitivity compared to 73.5% for CE-MRI and therfore it can serve as a useful alternative for this purpose.

DW MRI in diffuse hepatic parenchymal disease such as hepatic fibrosis and

non-alcoholic fatty liver disease has been investigated. Bowel disorders DWI is useful and helpful for detecting nodal and hepatic metastases, colorectal cancer and predicting, for locally advanced rectal cancer, the response after radio-chemotherapy [50-52].

DWI detects changes in lesion vascularity induced by therapy during anti-angiogenic therapy before significant size changes are evident [53,54]. DWIBS has been reported as a useful instrument for detecting colorectal cancer nodal metastasis [55]. Besides its usefulness in abdominal malignancies, DWI was also found to be helpful in inflammatory bowel disease.

Qi et al[56] reported that diffusion weighted image combined with MR enterography (MRE) has higher accuracy in diagnosis (92%) than MRE alone (79%) for the activity of disease. It was also found useful when detecting and characterizing complications and extraintestinal manifestations [57]. Use of DWI with MR enterography improves the detection of mesenteric and small bowel tumors compared to unenhanced MR-enterography.

As there are a lot of techniques of diffusion MR, we can list them as following: Diffusion-weighted MR Imaging Trace and ADC imaging Diffusion tensor imaging q-Ball imaging Diffusion spectrum imaging Hence we are going to clarify in table 1 the advantages and drawbacks of this various techniques, Drawbacks _Advantages _Information Obtained _Technique _ _Provides unidirectional diffusion measurement only, limited information. Voxel intensity is not a natural physical unit but a measure of restriction.

_ Short acquisition time, no post processing, images easy to interpret. Examination well tolerated by patients. Adequate hardware capabilities readily available. _Diffusion measurement in one direction _Diffusion-weighted imaging _ _Hypothesis based (hypothesis not always true). Limited information (no measurement of orientation or anisotropy) _ Short acquisition time, nearly no (or automated) post processing, images easy to interpret.

Voxel intensity has physical meaning. Examination well tolerated by patients. Adequate hardware capabilities readily available. _Estimated diffusion coefficient _Trace and ADC imaging _ _Hypothesis based (hypothesis not always true). Does not provide accurate map of complex fiber architecture. Tractography results are vulnerable to severe artifacts. _Short acquisition time, some post processing required (automated on recent imaging systems).

Provides information about diffusion orientation and anisotropy. Examination well tolerated by patients. Adequate hardware capabilities readily available. _Estimated diffusion tensor _Diffusion tensor imaging _ _Hypothesis based. Although results seem correct in important brain areas, accuracy is not guaranteed in all brain regions. Further validation is required.

Hardware requirements are high. _ Feasible with reasonable acquisition time. Provides information about diffusion orientation and anisotropy, accurate depiction of fiber crossings. Examination tolerated by most patients. _Estimated map of orientation distribution function values _q-Ball imaging _ _Hardware requirements are high, and acquisition time is comparatively long.

Whole-brain studies were not tolerable for patients. Recent improvements in hardware and imaging techniques have made shorter acquisition times possible, allowing future patient studies. _ Principle based, hypothesis free, has already received theoretical and practical validation.

Provides accurate depiction of fiber crossings with a specific angular resolution. Maps the whole field of diffusion, increasing the possibility of quantitation and providing 6D data. Provides diffusion tensor information. _Full 3D diffusion probability density function map, true 6D images _Diffusion spectrum imaging .

_ _Table 1 Advantages and Drawbacks of Diffusion MRI Techniques

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