Original Article

The impact of variation in the pulse sequence parameters on image uniformity in Magnetic Resonance Imaging

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Abstract

Objective: To evaluate the practical impact of alteration of key imaging parameters of Magnetic Resonance Imaging on image quality and effectiveness provided by widely available fast imaging pulse sequences.

Methods: A tissue equivalent material for Magnetic resonance Imaging (MRI) has been produced from a polysaccharide gel, agros, containing gadolinium chloride chelated to Ethylene Diamine Tetra- Acetic acid (EDTA) with a sort of T1 and T2 values. Experimental variations in key parameters included echo time (TE) and repetition time TR. Quantitative analysis consisted of image nonuniformity.

Results: In T2 weighted images; any change in TE played a critical role in the signal homogeneity in all pulse sequences. The percentage of nonuniformity was incredibly high in T2 weighted image but the change of TR was insignificant in T2-weighted study. Involving T1 weighted images, percentage of nonuniformity was high in gradient recalled echo (GRE), also noticeable in fast fluid attenuated recovery (FLAIR) but quite acceptable in fast spin echo (FSE) and conventional spin echo (CSE).

Conclusion: Selection of parameters relatively simple in CSE both in T1, T2-weighted study that maintains image uniformity and quality as well. GRE is a very sensitive pulse sequence for any variation in parameters and loose signal uniformity rapidly (JPMA 59:231; 2009).

Introduction

The diversity of MRI techniques and pulse sequences are available in clinical use with the potential of image worth and diagnostic correctness.[1-5] Pulse sequences enable to control the way in which the system applies pulses and gradients. There are many different pulse sequences available, and each is designed for a specific purpose.[6] But the choice of a pulse sequence with optimised parameter for a specified body tissue with best image quality is very difficult.[7] Earlier researches have discussed image quality and artefacts in isolated MR sequences.

Same imaging parameter may have unlike results on the image among different pulse sequences. In this study, we have quantitatively analysed the impact of alteration in the imaging parameters on image quality in T1 and T2 weighted MR imaging, focused on virtual characterization of various imaging parameters, in order to provide general guideline for T1 and T2 weighted images among various fast pulse sequences.[8] It is important to understand the impact of changes in imaging parameters on image quality in MR pulse sequence in order to optimise clinical results.

T1 and T2 weighted pulse sequences are essential for the detection and characterization of many abnormalities using MR imaging.[9] In conventional spin echo (CSE) images, image degradation related to long acquisition times has a major limitation in body MR imaging.[10,11] A number of fast imaging techniques have been recently introduced that allow T1 and T2 weighted images to be obtained quite quickly.[12-15] FSE, GRE and FLAIR are fast imaging techniques that are frequently used in clinical settings of MRI.

With the introduction of these pulse sequences, optimisation of several new imaging parameters must be considered. For example, one must consider the potential impact of sequence parameters such as TE, TR etc on image quality.[16,17] In addition, standard imaging parameters can also affect the resultant image differently than in conventional techniques.[18]

The aim of this study was to quantitatively evaluate in a phantom model the impact of alteration of major imaging parameters on image uniformity for the most commonly used T1, T2-weighted MRI sequences. These pulse sequences are CSE, FSE, GRE and Flair. This information will be supportive for the choice of MR pulse sequence with appropriate parameter to maintain the image excellence.

Material and Methods

For this experiment a tissue equivalent material for MRI produced from a polysaccharide gel and agarose, containing gadolinium chloride chelated to EDTA in the department of medical physics, Ninewells hospital and medical school, Dundee, UK was used. By varying the amounts of each constituent, the T1 and T2 of the material of these phantoms varied independently.[19] The chelation of the gadolinium ions to the macromolecule, EDTA used in the preparation of body tissue equivalent material gives advantages especially in three ways. Firstly, the chelation removes the possibility of the ions undergoing any further chemical interaction with the gel matrix. Secondly, chelation may prevent the gadolinium ions from precipitating as a hydroxyl. Finally and very importantly, the qualitative relaxation behaviour of the Gd-EDTA solution is only slightly affected by the chelation and can be accounted for: the effect only becoming significant at the higher frequencies i.e. > 30 MHz.[20]

These five phantoms had T1/T2 relaxation times of 306/72, 458/93, 1296/200, 1279/180, 1430/170 (msec), respectively, which comprises the range of relaxation value for biological tissues at 1.5 Tesla.

MR imaging was performed on a Siemens MAGNETOM Avanto 1.5 T. CP Head Coil of MRI used during scanning of phantoms. All the phantoms were scanned simultaneously and kept stationary during the imaging. Imaging parameters that were held constant during the study included 200mm field of view (FOV) 256 (frequency) ×256 (phase) imaging matrix, and one signal average, 130 Hz/pixel band width (BW) and 4mm slice thickness.

Quantitative image analysis consisted of determination of image nonuniformity. Nonuniformity defined as e percentage of the standard deviation (SD) of image signal intensity relative to its mean signal intensity (M): Nonuniformity = SD/M ×100%.[21] Signal intensities were measured by selecting a region of interest (ROI) of area 1.5 cm in the central region of gel and this procedure was repeated in each pulse sequence for all parameters that changed during scanning. Image J software was used for the analysis of image nonuniformity. Alteration of key imaging parameters in the experimental protocol is mentioned in Table 1 and 2.

Results

The results of quantitative analysis in T1, T2-weighted pulse sequences are described in figures below. Image nonuniformity increases with increasing TE in T1, T2-weighted images and decreasing with increase of TR in T1 weighted pulse sequences.

Discussion

Image uniformity refers to the ability of the MR imaging system to produce a constant signal response throughout the scanned volume when the object being imaged has homogenous MR characteristics.[22]

Comparison of four basic pulse sequences CSE, FSE, GRE and FLAIR gives the signal homogeneity for different T1/T2 values of body tissue equivalent gel. Different pulse sequences show different values of signal homogeneity in T1 weighted images.

Image nonuniformity increases with the increase of TE in all pulse sequences, which reflects the signal loss with the rise of TE. This increase is presumably due to accentuated magnetic susceptibility effects with longer TE. The percentage of magnetic

Table 1: Change of TE.

Pulse sequence	Protocol	T1 W Parameters Changed parameters TE (msec)	T2 W Parameters Fixed parameters TE (msec)	Changed parameters TE (msec)	Fixed parameters TE (msec)
Spin Echo	Change of TE	10	400	20	2000
		12		30	
		14		40	
		16		50	
		18		60	
Fast Spin Echo	Change of TE	12	600	97	4000
		25		109	
		37		121	
		49		134	
		62		146	
Gradient Recalled Echo	Change of TE	8	40		70
		12		15	
		14		17	
		16		21	
		18		23	
Fast Fluid Attenuated Recovery	Change of TE	12	2000	97	4000
		25		109	
		37		121	
		49		134	
		62		146	

Table 2: Change of TR.

Pulse sequence	Protocol	T1 W Parameters Changed parameters TE (msec)	T2 W Parameters Fixed parameters TE (msec)	Changed parameters TE (msec)	Fixed parameters TE (msec)
Spin Echo	Change of TR	300	12	1800	20
		400		2000	
		500		2200	
		600		2400	
		700		2600	
Fast Spin Echo	Change of TR	400	12	3800	97
		500		4000	
		600		4200	
		700		4400	
		800		4600	
Gradient Recalled Echo	Change of TR	80	10	30	20
		90		40	
		100		50	
		110		60	
		120			
Fast Fluid Attenuated Recovery	Change of TR	2000	12	4000	97
		2100		4500	
		2200		5000	
		2300		5500	
		2400		6000	

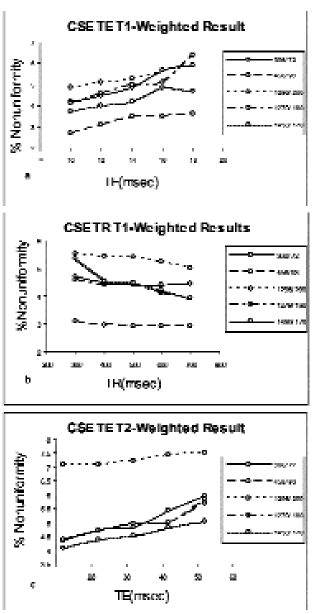

Figure 1: Nonuniformity vary with the changed values of TR and TE and this effect is slightly perceptible in high values of T1/T2 phantoms (a) With the increase of TR nonuniformity decreases quickly for gels of high T1/T2 phantoms in T1-weighted study, (b) the nonuniformity increased with the increase of TE in T1- weighted study, (c) percentage of nonuniformity is high with the increase of TE in CSE in T2 weighted results.

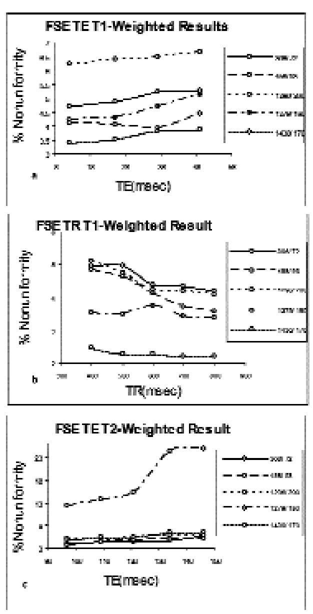

Figure 2: Nonuniformity for FSE varies with the variation of TR and TE in T1, T2-weighted study (a) the percentage of nonuniformity is not so high with diversity of TE, (b). Nonuniformity decreases with raise of TR but this change is not linear in FSE, (c) Percentage of nonuniformity is moderate in FSE while for phantom 1279/180 ratio of nonuniformity is noticeable in FSE in T2-weighted study.

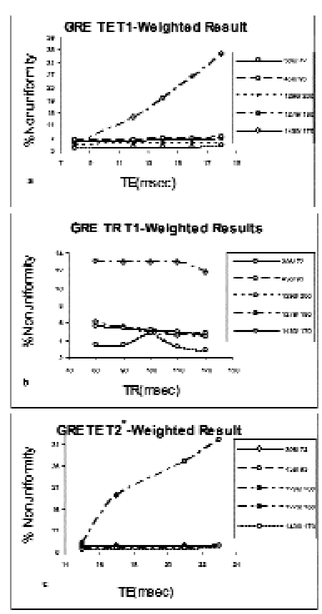

Figure 3: In GRE nonuniformity drastically increased for the gel of T1/T2 value is 1279/180, with the increases of TE and TR in T1, T2-weighted images. (a) Percentage of nonuniformity is very high for the phantom of 1279/180 with the variant of TE this change could not observe in other pulse sequence with the variant of TE. (b)With elevate of TR in GRE nonuniformity decrees but this change is very noticeable in the same gel. (c) Nonuniformity percentage is 24percentage of nonuniformity is very high for the phantom of 1279/180 with the variant of TE in T2*-weighted study.

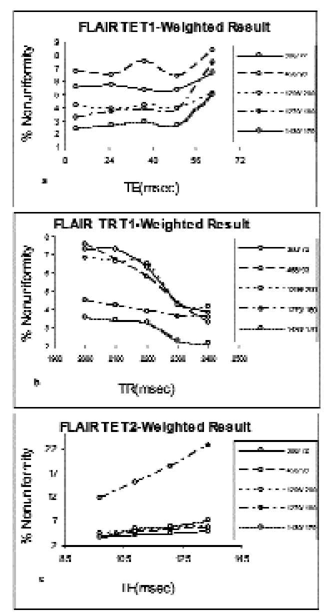

Figure 4: percentage of nonuniformity varies with TR and TE in T1, T2-weighted study, (a) FLAIR percentage nonuniformity extended with the boost of TE for those gels of T1/T2 value is small and nonuniformity percentage is a little bit high in FLAIR, (b) Very non-linear change observed through change of TR and this change is evident in the gels of T1/T2 values are small, (c) in T2-weighed study, the ratio of nonuniformity is perceptible for FLAIR percentage of nonuniformity is 12%.

susceptibility in CSE, FSE, GRE and FLAIR is changed.

In T1study, CSE, the increase in nonuniformity is noticeable with the rise of TE for those gels of higher T1/T2 value. As shown in figure 1a.The average increase in nonuniformity of CSE is 1.380%.

T1 weighted results of FSE demonstrate less magnetic susceptibility as compared to the other pulse sequence. As shown in figure 2a, ETL in FSE sequence, magnetic susceptibility effect decreases due to decreased dephasing from closely spaced refocussing 1800 pulses. This leaves little time for spins to diphase as they diffuse through regions of magnetic nonuniformity, thus decreasing T2* effect.[23] The average nonuniformity increased in FSE is 0.56%.

GRE showed the very high average value of nonuniformity 6.160% due to rise of TE. As shown in figure 3a, the TE control the amount of T2* dephasing. To minimize T2* the TE should be short.[6] The use of long TE provides greater T2* weighting in GRE. Very high nonuniformity value shows that the image nonuniformity is strongly influenced by magnetic susceptibility reduces image uniformity and degree of image quality. GRE sequence is inherently sensitive to magnetic susceptibility due to its lack of an 1800 refocusing RF pulse. Therefore it is advantageous to select a TE as short as possible, while achieving appropriate contrast, when applying GRE sequence.[24]

In FLAIR the average magnetic susceptibility is 2.103% with the longer TE, this result can be seen in figure 4a, which shows the greater magnetic susceptibility effects are greater with increasing echo delay time because the spins have more time to undergo dephasing.

Unique behaviour observed with the variation of TR in each pulse sequence. In CSE the average rate of decrease of nonuniformity is 0.62%, in FSE this ratio is 0.786% GRE showed the percentage of decrease is 1.106% and in FLAIR image nonuniformity reduced about 2.768%. However, nonuniformity was substantially increased with use of relatively short TR. Because increasing TR should not affect magnetic susceptibility. The nonuniformity variation with repetition and T1 relaxation time for the pulse sequence was found to be caused by nonuniform RF-transmission in combination with the inherent difference in allowance of T1 relaxation for different repetition time.[25]

Percentage of nonuniformity in each pulse sequence with the increase of TE is consequently high in T2 weighted images for equally short and long T2 values as compared to T1 result. As shown in figures 1c, 2c, 3c and 4c, the results of a phantom, T1/T2 value is 1279/180; nonuniformity significantly increases in each pulse sequence. This variation is mainly noticeable in GRE with 24% increase of nonuniformity. FSE showed 13% increase in nonuniformity. In FLAIR proportion of nonuniformity is 12 % while the signal loss in CSE is a smaller amount of 1.3% increase in nonuniformity. Magnetic susceptibility property in T2 weighted image is larger with increasing echo delay time because the spins have more time to undergo dephasing.

Effect of increasing TR, image nonuniformity of T2 object was not impacted by the alterations of TR and there is no recognizable trend in each pulse sequence with the change of TR. In consequence variation of TR is independent of magnetic receptiveness. Its contribution in nonuniformity is not identifiable.

Conclusion

This investigation showed that the role of TE in T2-weighted images is crucial and also conspicuous in T1 weighted images as well. The variation of TE can lose the signal uniformity of the image in each pulse sequences. All pulse sequences are sensitive for the variation of TE but GRE is most perceptive for an extremely inconsequential change in TE and remarkably lose the image uniformity. FSE and FLAIR are additionally less sensitive for modification of TE and percentage lost of signal homogeneity is rather less than that of GRE. Results showed that CSE is incredibly moderate pulse sequence at the choice of parameters. TR influences the image merit in T1-weighted study only and percentage of nonuniformity is less as observed in TE variation. Its concern in T2-weighted study is insignificant. Consequently, the selection of parameters relatively simple in CSE both in T1, T2-weighted study, that maintains image uniformity and quality as well during the scanning for all phantoms of short and long T1/T2 value and this feature is also dominant in FSE but only in T1-weighted imaging. Choice of the pulse sequence with accurate imaging parameters for image quality is vital for diagnostic techniques. Furthermore optimum clinical application of these pulse sequences requires careful attention to these imaging parameters to their complex interaction.

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