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Comparison of Pulse Sequences of Magnetic Resonance Imaging for Optimization of Timing and Image Quality

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ABSTRACT

Introduction: The present study aimed to three frequently used pulse sequences of magnetic resonance imaging (MRI) to assess the image quality of theses pulse sequences at short acquisition time.

Material and Methods: For the purpose of study two tissue equivalent gels were prepared. One gel was made from Polysaccharide and Agarose, whereas second gel was obtained from Ferrous Benzoic Xylenol Orange (FBX) which is tissue equivalent material. 6MV photons were used to irradiate FBX gel from linear accelerator with 25 Gray dose. Imaging parameters are performed in repetition time (TR) for experimental variations. The quantitative analysis included contrast-to-noise ratio (CNR) and signal to noise ratio (SNR).

Results: As evidenced by obtained results at 1.5 Tesla, Fast Spin Echo (FSE) and Fast Fluid Attenuated Inversion Recovery (FLAIR) were most comparable in SNR although, acquisition time of FSE is 62%, 9 %, and 15% less than FLAIR at different values of 4000ms, 4200ms and 4600ms of TR. CNR of Conventional Spin Echo (CSE) was 143% and 93% better than FSE and FLAIR respectively. The time difference between CSE and FSE was 6 min and 34 sec while this difference was 6 min and 43 sec between CSE and FLAIR.

Conclusion: FSE and FLAIR produced optimal image quality for many tissues. Their reduced acquisition time could make them perfect option for patients who cannot tolerate longer imaging time. Nonetheless long acquisition time cannot undervalue importance of CSE since it has yielded significantly higher contrast and SNR in T2-weighted images among other pulse sequences of MRI.

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Introduction

Magnetic resonance imaging (MRI) has been confirmed as a flexible medical imaging technique that yields excellent image quality, nonetheless its long acquisition time limits its application due to cost and considerations of patient comfort [1]. The motion of the patient during MRI degrades image quality and its diagnostic value [2]. Accordingly, the major drawback of MRI is its long acquisition time which leads to the deterioration of image quality by respiratory motion artifacts [3].

Every advanced pulse sequence possesses some negative aspects due to fast acquisition time. Parallel imaging is an effective way to reduce the time it takes to acquire a static image; however, it sacrifices the signal-to-noise ratio(SNR), and may introduce technique dependent artifacts [4].In broad-spectrum image quality is inversely related to image acquisition speed [5].

The choice of the pulse sequence and acquisition parameters is so great that poses a challenge to the selection of acquisition parameters which are appropriate for the patient [6]. MRI scan time reduction is still a critical issue, especially when the acquisition of diagnostic images in a clinical setting is taken into account [7].

With the choice of fast acquisition pulse sequences, it is vital to maintain the image quality (i.e. contrast-to-noise ratio (CNR), and (SNR), and image uniformity. Each pulse sequence behaves distinctively due to its characteristics and parameters [8, 9].

The acquisition time of T2-weighted images becomes longer in MRI with the larger value of repetition time (TR). To optimize the diagnostic strategy, the image should have high quality and be acquired at short acquisition time [10]. To reduce the likelihood of patient movement, the scan time should always be as short as possible [11].

Different techniques were compared to enhance the pathology for a more precise diagnosis [12, 13]. Different pulse sequences were compared to analyze and adopt a suitable technique for a specific organ. Ali CaglarOzen et al (2016) compared the ultra-short echo time sequence for MRI of an ancient mummified human hand to analyze appropriate imaging protocol for MRI of extremely short T2 [14] . Chang Li (2012) compared optimized soft tissue suppression schemes

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for ultra-short echo time MRI to achieve a quantitative performance of commonly used soft tissue suppression methods [15]. Rahmer J (2007) compared dual echo acquisition and magnetization preparation for the improvement of short T2 contrast [16].

For the purpose of present study, a human-tissue-equivalent MRI phantom was made in the medical physics department, Ninewells hospital and medical school, Dundee, the UK in 2007 from a polysaccharide gel and agarose which contain gadolinium chloride chelated to Ethylene Diamine Tetra- Acetic acid (EDTA). T1 and T2 of the material of these phantoms widely varied with alteration in the amounts of every ingredient.

An image that is obtained in a short scan time, with a good spatial resolution and high SNR is preferable yet is hard to achieve as increasing one factor certainly reduces one or both of the other two. The diagnostic precision can be accomplished only by the knowledge of the perceptive relationship between a pulse sequence and parameters of tissue. The uniqueness of the current research is the selection of the most appropriate pulse sequence and ideal parameters for a particular tissue of T1/T2 relaxation time at the clinical level. This can maximize the SNR and CNR at the shortest acquisition time in T2-weighted images more efficiently, reduce the time and makes the diagnostic methodologies more reliable. To this end a continual range of TR was applied to obtain the optimized image quality at short acquisition time. Furthermore, the present study primed to make sure how much CSE sequence is effective in the presence of other fast pulse sequence. The most commonly used pulse sequences, namely CSE, FSE and FLAIR used in the present experiment.

Materials and Methods

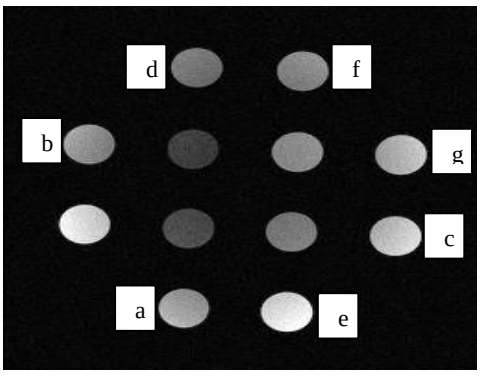
For the chelation of the gadolinium ions to the macromolecule, ethylenediaminetetraacetic acid (EDTA) was used in the preparation of human-tissue-equivalent substance EDTA turned out to be very effective in different ways such as eliminating the probability of the ions experiencing any additional chemical reaction with the gel matrix. Chelation may stop the gadolinium ions to trigger as a hydroxyl.It is important to note that, the qualitative relaxation activities of the gadolinium EDTA (Gd-EDTA) solution is moderately affected by the chelation and the results can only turn out to be significant at the higher frequencies i.e. > 30 MHz [17].

Seven phantoms of 12mm diameter were used In the current study. The T1/T2 relaxation times of these phantoms were as follows: 608/134, 759/155, 917/135,986/220, 1050/164, 1180/221 and 1296/200ms. MR was performed on 1.5 T units (Siemens MAGNETOM Avanto, UK) shows in figure 1.

Signal intensities were calculated by placing a region of interest (ROI) of 1.5 mm in the gel in five different places taking the average of signal intensity and then copying the ROI for the same dimension of background noise. SNRs are calculated using the following formula: SNR = SI/N, where N is the standard deviation of the background and SI is the mean signal intensity of the ROI of the gel. On a final note Image J software (National Institutes of Health and the Laboratory for Optical and Computational Instrumentation, US) is used for SNR analysis.

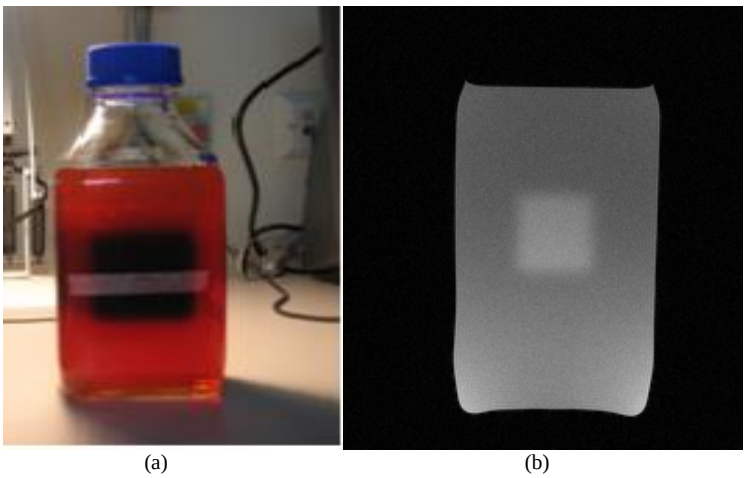
CP Head Coil of MRI was used during phantom scan. Imaging parameters which were held constant during the study included CSE, FSE, FLAIR (number of acquisitions, 1; percentage sampling, 100; field of view, 100×100 mm; pixel per mm resolution, 1.280; slice thickness, 4 mm) FSE (echo train length, 7) and FLAIR (inversion time, 860 ms; echo train length, 5)

We compared the results with the standard data of the MHRA (Medicine and Healthcare Products Regulatory Agency) Evaluation 04133 Siemens Magetom Avanto 1.5 T [18]. Percentage error indicates the error between the observed value and true value. The optimized value was approximated by the curve fitting method using MATLAB software package [version 7.7, (R2008b)].



a	608/134 msec
b	759/155 msec
c	917/135 msec
d	986/220 msec
e	1050/164 msec
f	1180/221 msec
g	1296/200 msec

Figure 1. Polysaccharide, comprise the range of relaxation value for biological tissues at Siemens MAGNETOM Avanto 1.5 Tesla.



(a) (b)

Figure 2. FXG phantom (a) after irradiation; deliver dose was 25 Gray with Linear Accelerator, 600 MV X-ray energy, (b) magnetic resonance imaging of FGX phantom in CSE

The second gel, Ferrous Benzoic Xylenol Orange (FBX) was made by using Ferrous Ammonium sulfate (Aldrich Ammonium Iron (II) SulphateHexahydrate, gelatine (from bovine skin, Type B), 99% A.C.S Reagent), Xylenol Orange Tetrasodium salt (Sigma-Aldrich), sulphuric acid (Sigma-Aldrich) , and Benzoic Acid (Sigma-Aldrich) formulated in 1998 by Kelly RG [19].

The stock solution was prepared by the addition of 1ml of Xylenol Orange, 5ml of Benzoic Acid and 25ml of sulphuric acid to a container of one liter and was set kept at room temperature. The process of gel preparation started by the addition of 40gm of gelatine to 700ml of distilled water that already contained 25ml of sulphuric acid; thereafter, it was heated by a hot plate with a temperature of 40°C. The gelatine was liquefied in the gel after continuous stirring for 30 minutes. Subsequently, 0.1mm ferrous sulfate was mixed in 100 ml benzoic acid Xylenol orange stock solution in another beaker and the solution was then added to gelatine liquid. The final volume of one liter of the gel was produced by the addition of 25ml of the solution. The preliminary concentration of oxygen present in the solution was directly associated with the response of Fricke gel dosimeter. During the gel preparation it was allowed to be exposed to the air and then for the irradiation it was poured in to six test containers, capacity:10ml with separate. The storage temperature for these gel phantoms was 5°C [20].

The gel irradiation was performed using 6MV photons from a Varian Clinic 600C Linear accelerator (Varian, United States) to a dose of 25GY at 95.5cm SSD (Source to surface distance) with a $5\times5cm^2$ field size shows in figure 2(a). One sample of FBX phantom was irradiated to make it abnormal then contrast to noise ratio(CNR) was calculated in normal tissue (non-irradiated part of FBX) and abnormal tissue(irradiated part of FBX phantom). MR was performed on 1.5 Tesla (Siemens MAGNETOM Avanto, UK) CP body Coil of MRI was used during phantom scans. The phantom was scanned by FSE, FLAIR and CSE pulse sequences shows in figure 2(b).

Signal intensities for quantitative image analysis were obtained by placing an ROI of area 1.5 mm in the surrounding of the gel in five different places. For the measurement of background noise, a similar area of ROI was taken. This process was repeated in all pulse sequences. CNRs are calculated using the following formula:

$CNR = SNR_A - SNR_{B`}$

where SNR_A is the contrast to noise ratio of the irradiated portion of the phantom and SNR_B is the non-radiated part.

In the current study, the Imaging parameters for FLAIR, FSE, and CSE were kept constant in T2-weighted study (The number of acquisitions, 1; field of view, 100×100 mm; slice thickness, 4 mm; For T2-weighted study (echo train length, 21; Inversion time of FLAIR, 2500ms) and for FSE (echo train length, 21).

T1/T2 measurements of Gel FGX was performed by the application of the procedure employed in the study conducted by Bartusek et al.[19] and Afzal et al. [21]. It is worthy to note that, MATLAB Simulink version (R2008b) was sued in the present study shows in table 1.

Table 1. Calculated values of T1 and T2 by three methods Bartusek et al [19], Afzal et al[21] and MAT LAB

Dose	T1 (ms)	T2 (ms)
25 Gray	628	58
O Gray (No dose)	812	166

Results

The obtained results indicated that the long acquisition time of CSE made it less important than other pulse sequences for T2-weighted images. CSE and FLAIR both produced required SNR; however, FLAIR is preferred due to its short acquisition time and T1/T2 of the tissue is 608/134 (msec) as depicted in table 2(a). The acquisition time of FLAIR is 56% less than CSE for accurate SNR of the image shows in figure 3(a).

Table 2(a). Comparison among CSE, FSE and FLAIR for the effect of TR on image quality (SNR and CNR) and acquisition time in T2 weighted images for the tissue equivalent Gel of T1/T2 608/134, 759/155,917/135 and 986/220 msec

Sr. No	Pulse Sequences	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)
1	CSE	608/134	1800	130.23	-11.40	5.9	759/155	1800	153.43		5.9
			2000	140.72	-4.17	6.29		2000	188.21	19.88	6.29
			2200	186.83		7.08		2200	196.39	25.08	7.08
			2400	149.44		8.59		2400	201.07	28.07	8.59
2	FSE	608/134	4000	127.52	-13.24	0.48	759/155	4000	141.78	-3.54	0.48
			4200	133.44	-9.22	1.29		4200	148.05		1.29
			4400	139.02	-5.42	1.5		4400	154.30		1.5
			4600	160.33	2.12	2.18		4600	155.76		2.18
3	FLAIR	608/134	4000	128.19	-12.79	1.28	759/155	4000	143.99	-2.04	1.28
			4500	133.19	-9.39	1.42		4500	149.73		1.42
			5000	134.43	-8.55	1.5		5000	151.26		1.5
			6000	154.59		2.58		6000	153.61		2.58
Sr. No	Pulse Sequences	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)	T1/T2 of phantom (ms)	TR (ms)	CNR	Percentage Error %	Acquisition Time (min: sec)
1	CSE	917/135	1800	169.85	8.18	5.9	986/220	1800	124.39	-15.64	5.9
			2000	186.43	18.74	6.29		2000	139.46	-5.12	6.29
			2200	190.23	21.16	7.08		2200	145.72		7.08
			2400	187.61	19.49	8.59		2400	149.55		8.59
2	FSE	917/135	4000	111.76	-39.12	0.48	986/220	4000	135.31	-7.95	0.48
			4200	124.47	-36.75	1.29		4200	141.76	-3.561	1.29
			4400	139.90	-34.15	1.5		4400	148.07		1.5
			4600	149.75	-28.53	2.18		4600	155.30		2.18
3	FLAIR	917/135	4000	152.92	-33.76	1.28	986/220	4000	130.37	-11.31	1.28
			4500	149.83	-30.43	1.42		4500	134.51	-8.49	1.42
			5000	146.86	-29.55	1.5		5000	135.06	-8.11	1.5
			6000	144.87	-21.73	2.58		6000	141.75	-3.56	2.58

TR: repetition time, SNR: signal to noise ratio, MRI: magnetic resonance imaging, CSE: Conventional Spin Echo, FSE: Fast Spin Echo, FLAIR: Fluid Attenuated Inversion Recovery

Table 2 (b): Comparison among CSE, FSE and FLAIR for the effect of TR on image quality (SNR) and acquisition time in T2 weighted images for the tissue equivalent Gel of T1/T2 1050/164, 1180/221 and 1296/200 (msec).

Sr. No	Pulse Sequences	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)
1	CSE	1050/164	1800	158.06		5.9	1180/221	1800	140.68	-4.76	5.9
			2000	162.18	3.30	6.29		2000	150.88		6.29
			2200	165.16	5.19	7.08		2200	156.62		7.08
			2400	166.33	5.94	8.59		2400	159.58	1.64	8.59
2	FSE	1050/164	4000	120.02	-18.35	0.48	1180/221	4000	139.54	-5.06	0.48
			4200	124.97	-14.98	1.29		4200	145.79	-0.82	1.29
			4400	127.54	-13.23	1.5		4400	152.29		1.5
			4600	146.27		2.18		4600	155.36		2.18
3	FLAIR	1050/164	4000	133.31	-9.31	1.28	1180/221	4000	140.58	-4.36	1.28
			4500	139.82	-4.88	1.42		4500	146.24		1.42
			5000	141.91	-3.45	1.5		5000	147.43		1.5
			6000	159.56		2.58		6000	152.34		2.58

Sr. No	Pulse Sequences	T1/T2 of phantom (ms)	TR (ms)	SNR	Percentage Error %	Acquisition Time (min: sec)
1	CSE	1296/200	1800	169.75	8.12	5.9
			2000	195.49	24.51	6.29
			2200	200.60	27.77	7.08
			2400	203.09	29.35	8.59
2	FSE	1296/200	4000	123.82	-15.76	0.48
			4200	128.08	-12.86	1.29
			4400	133.62	-9.09	1.5
			4600	137.85	-6.22	2.18
3	FLAIR	1296/200	4000	133.38	-9.26	1.28
			4500	140.73	-4.26	1.42
			5000	142.76	-2.87	1.5
			6000	147.13		2.58

TR: repetition time, SNR: signal to noise ratio, MRI: magnetic resonance imaging, CSE: Conventional Spin Echo, FSE: Fast Spin Echo, FLAIR: Fluid Attenuated Inversion Recovery.

Table 3. Comparison among CSE, FSE and FLAIR for the effect of TR on image quality and acquisition time in T2 weighted images for the tissue equivalent FBX Gel of T1/T2 628/58 and 812/166 (msec)

Sr. No	Pulse Sequences	T1/T2 of phantom (ms)	TR (ms)	CNR	Percentage increase in CNR%	Acquisition Time (min: sec)
1	CSE	628/58,812/166	1800	41.86	13%	5.51
			2000	47.29	7%	6.49
			2200	50.68	7%	7.07
			2400	54.26		7.48
2	FSE	628/58,812/166	3800	18.02	17%	0.45
			4000	21.14	2%	0.47
			4200	21.56	3%	0.59
			4400	22.28		1.14
3	FLAIR	628/58,812/166	3500	17.07	19%	0.43
			4000	20.33	19%	0.46
			4500	24.14	16%	0.54
			5000	28.02		1.05

TR: repetition time, CNR: contrast-to-noise ratio, MRI: magnetic resonance imaging, CSE: conventional spin echo, FSE: fast spin echo, FLAIR: fluid Attenuated inversion recovery.

As depicted in table 2 (a), T1/T2 of tissue was measured at 759/155 (msec). For CSE, the results suggested that the minimum value of TR best fits the standard requirements of SNR. Nevertheless, FLAIR or FSE can be considered a better choice for a pulse sequence due to the speedy acquisition time. The acquisition time of FSE and FLAIR were 79% and 80%, less than CSE, respectively for a highly accurate SNR measurement shows in figure 3(b).

CSE can only produce SNR of the image with minimum TR as demonstrated in table 2 (a) for T1/T2 of the tissue 917/135 (msec). Other pulse sequences are available with poor SNR with a short acquisition time.CSE and FSE equally exist in the significance range of SNR and T1/T2 of the tissue were measured at 986/220 (msec), as illustrated in table 2(a). Nonetheless, FSE was found to be most favorable in T2-weighted images owing to its acquisition time. The acquisition time of FSE was 79% less than CSE for the accurate measurement of image SNR shows in figure 3(c,d) .

As displayed in Table 2(b),for the tissue having T1/T2 value 1050/164 (msec), FSE was the most promising choice owing to its excellent SNR at short acquisition time with the highest value of TR. CSE and FLAIR also produced good SNR at different values of TRs with minimum error. FLAIR can be a good choice due to its acquisition time as compared to CSE. The acquisition time of FSE and FLAIR were 63% and 56%, less than CSE, respectively for a highly accurate SNR measurement shows in figure 4(a).

Accordingly, CSE, FSE and FLAIR equally produced accurate SNR, whereas FSE and FLAIR can be preferable options due to acquisition time and T1/T2 of the tissue obtained as 1180/221(msec), as depicted in table 2(b). The acquisition time of FSE and FLAIR were 76% and 77% less than CSE, respectively, for accurate SNR of the image shows in figure 4(b).

As demonstrated in table 2(b), T1/T2 of the tissue was measured at 1296/200 (msec). FLAIR turned out to be is the only choice to produce SNR of the image with minimum errors at the quickest acquisition time shows in figure 4(c).

In T2-weighted study, the acquisition time of CSE was greater than FSE and FLAIR as depicted in Table 3 and T1/T2 of the tissues were obtained as 628/58 and 812/166. However, CNR of CSE is 144% and 94% better than FSE and FLAIR, respectively. Consequently, CSE is preferable with elongated time to create contrast between tissues in T2-weighted images shows in figure 4(d).

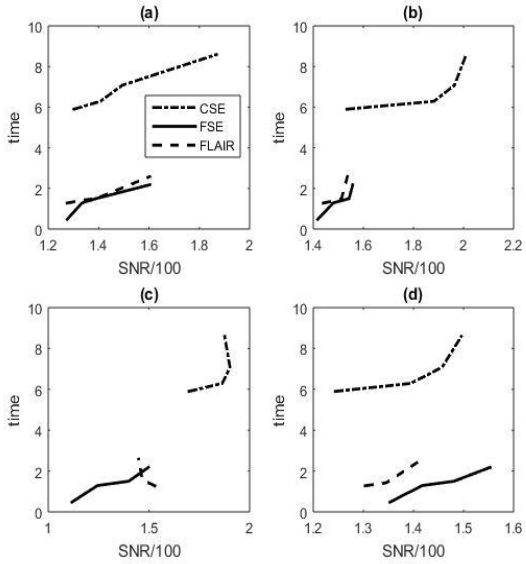


Figure 3. Comparison between the pulse sequences for the appropriate sound to noise ratio(SNR) at short acquisition time (a) T1/T2 of the phantom is 608/134 msec. (b) T1/T2 of the phantom is 759/155 msec.(c) T1/T2 of the phantom is 917/135msec. and (d) T1/T2 of the phantom is 986/220 msec

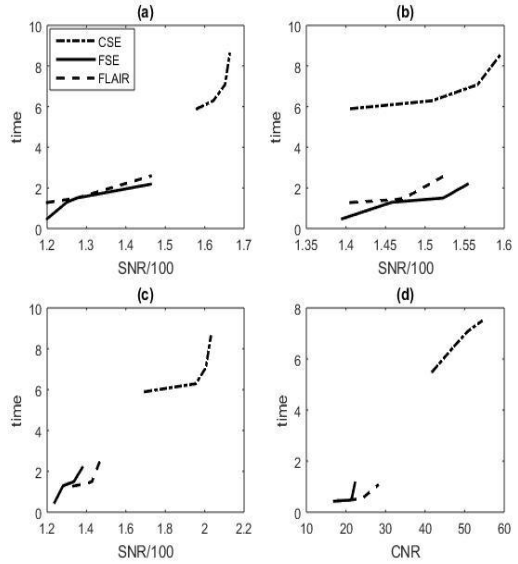


Figure 4. Comparison between the pulse sequences for appropriate SNR at short acquisition time. (a) T1/T2 of the phantom is 1050/164 msec. (b) T1/T2 of the phantom is 1180/220 msec. (c) T1/T2 of the phantom is 1296/200 msec ,and (d) Comparison among pulse sequences for good CNR at short acquisition time,T1/T2 of the phantoms are 628/58 and 812/166 (msec)

Discussion

The acquisition time is a critical issue at the clinical level for T2 weighted MRI. For the purpose of the current study, the three most important pulse sequences which are frequently used for the diagnostic purpose at the clinical level were selected. We compared the SNR for Polysaccharide gel and CNR for FBX gel. We observed the performance of different pulse sequences

by comparing their SNR and CNR at a suitable acquisition time.

Various combinations for TR in each pulse sequence were tested and studied to find out the most favorable combination of parameters in each pulse sequence for the improved image quality with reasonably short acquisition time. Each pulse sequence had a tendency to perform more efficiently by the selection of proper parameters.

SNR is used in imaging to characterize image quality and the SNR of the image elevates with the increase in TR. The transversal relaxation time (T2) of a phantom or a tissue is vital for TR response [22] since TR controls the amount of longitudinal magnetization for a tissue to produce a maximum MR signal. TR is a factor that increases the acquisition time of the image as well. When TR is reduced to decrease image acquisition time, image noise and contrast can become limiting factors [23].

In the T2-weighted study, with the variation of TR, SNR of CSE and FLAIR were comparable for phantom 608/134 (msec) and 1050/164 (msec) as depicted in tables 1(a,b). However, the immense acquisition time difference between CSE and FLAIR keeps them totally separate. The acquisition time of FLAIR was found to be 63% and 56% less than CSE respectively. CSE was extremely good for 917/155 (msec) as illustrated in, table 1(a). While other pulse sequences couldn't maintain SNR at selected values of TR, FSE had a percentage error of -39% to -28% and FLAIR encompassed -33% to -21% for the same phantom. CSE also produced equally good SNR to FLAIR and FSE for high T1/T2 weighted phantoms 1180/221 (msec) in table 1(b). Nonetheless, but the acquisition time of CSE is 372% and 398% greater than FSE and FLAIR, respectively.

In T2-weighted study, the signal intensity difference between tissues was enormously sharp and the deliver doses were 25 gray and 0 gray with T1/T2 at 628/48 (msec) and 812/166 (msec), as depicted in table 2. CSE at long TR produced a superlative contrast amongst tissues which can be observed in table2. This peak of excellence in CNR is highly appreciable and desirable at the diagnostic stage. The acquisition time of CSE is better than FSE and FLAIR In the T2-weighted study of MRI. The acquisition time of CSE is 556% and 612% better than FSE and FLAIR respectively; however, CNR of CSE is 144% and 94% better than FSE and FLAIR with the selection of TR. Consequently, CSE is preferable with elongated time to create contrast between tissues in T2-weighted images as observed in the tables 1 (a) and 2.

Tables 1(a,b) demonstrate that FSE showed extremely good results for the phantoms 759/15 and, 1180/221(msec). In the same vein, FSE exhibited good SNR with low percentage error for the phantom 608/134, 986/220 and 1296/220 (msec) in tables 1(a,b) respectively. FSE cannot be a good choice for the phantom having T1//T2 value 917/135(msec), percentage error is relatively high and ultimately SNR is very poor for phantom 1050/164 (msec) as illustrated in table 1(b). The CNR in FSE could not produce that level of accuracy since it is produced by CSE. The use of a long turbo factor made FSE less significant in T2-weighted studies (i.e. the contrast averaging) which can be attributed to the effect of averaging of all the echoes into a single k-space [24]. FSE is also inclined by the magnetization transfer (MT) which lessens the contrast between abnormal and normal tissues. Nonetheless, the contrast of the tissues can change by varying the echo factor [25]. Optimum parameters are desirable to get better CNR in the T2-weighted study of FSE.

FLAIR is comparable to FSE for several tissues, regarding the SNR and acquisition time of the image. FLAIR is an excellent option for the tissues having T1/T2 value 608/134 and 1296/200 (msec) as displayed in tables 1 (a,b) respectively.

FLAIR is equivalent to T2-weighted CSE and although 55 % CNR is improved with the optimum choice of TR, it is still 48% less than that of CSE. The FLAIR which is greatly inclined towards TI (the time that corresponds to the null point of certain tissues) nulls the signal of certain tissues to make the image contrast more evident among tissues [26]. Images with poorly chosen inversion time constrained the contrast among the neighboring tissues. Signal intensity differences of pathological tissues are strongly dependent on the inversion time and repetition time. Most preferable inversion time is required to obtain intense contrast between tissues. These results provide a guide for the use of T2-weighted pulse sequences for specific tissues and the importance of the accurate selection of optimal imaging parameters at the diagnostic stage. Every study has some limitations that should be addressed in the paper. Our study has several limitations worth noting. Image quality parameters such as SNR, CNR, and spatial resolution are interlinked to each other accordingly, it is complicated to improve one parameter without changing other parameters. The minimum scan time in MRI imaging is affected by TR, while the spatial resolution is determined by matrix size, FOV and slice thickness. Consequently, the increase in matrix size or decrease of FOV and slice thickness results in the elevation of spatial resolution at the expense of increased scan time.

Research gaps are exists in the selection of pulse sequence for particular organ in reasonable acquisition time in MR imaging technique [14-16]. This research improved the diagnostic accuracy with the optimization of the pulse sequence with apposite parameters for specific tissues. Sequential Variation in the choice of the pulse sequence's parameters made comprehends this consequence change on the image quality and acquisition time of MRI.

Bearing these limitations in mind, it is recommended that future researches be conducted to estimate the performance of optimized 3D sequences to find the best sequence in the early diagnosis of abnormalities with minimal artifacts. Image quality factors, including SNR, resolution, and acquisition time, are all interconnected

and change of one parameter affects the others. In this regard, researchers should decide on more important factors for the examination of a particular body part, patient and suspected abnormality.

Conclusion

To achieve high image quality at short acquisition time, we evaluated parameters optimally in three pulse sequences. The accuracy of T2 weighted images of MRI is highly influenced by the appropriate value of TR in each pulse sequence. The obtained results confirmed that the CSE produced the best SNR and remarkable contrast for numerous tissues in T2- weighted images. In addition, the results proved that the long acquisition time of CSE makes it less attractive, however, it cannot devaluate its importance in T2- weighted study of MRI. FSE could be the most favorable choice due to its short acquisition time along with high image quality if it gives the optimum image quality by overcoming the difficulties of a complex interaction of imaging parameters and echo train length. FLAIR is also comparable to FSE for several tissues regarding SNR. T2-weighted FLAIR can also become a favorable pulse sequence due to appreciable SNR in reasonable acquisition time for various tissues in T2-weighted study of MRI. A comparison of pulse sequences regarding the acquisition time gave the initiative to choose a pulse sequence with image excellence in the short acquisition time. A pulse sequence with all image equalities with minimum acquisition time should be our preference at clinical MRI.

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