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RESEARCH ARTICLE

ROLE OF DIFFERENT PULSE SEQUENCES FOR BETTER CONTRAST USING MAGNETIC RESONANCE IMAGING.

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Abstract

This research study aimed to compare the image quality and contrast using different pulse sequences and to evaluate practical impact and efficacy of altering imaging parameters on image quality using magnetic resonance imaging. A tissue equivalent dosimeter gel system by using Xylenol orange dye with Fricke-Benzoic solution was developed and the gel system was irradiated using 6MV photons. Conventional spin echo (CSE), Fast spin echo (FSE), gradient recalled echo (GRE) and fluid attenuated inversion recovery (FLAIR) pulse sequences were used to analyze the effect of TR (repetition-time) and TE (echo-time) on contrast to noise ratio (CNR). The calculated percentage increase of contrast to noise ratio (CNR) for TR using pulse sequences CSE, FSE, GRE and FLAIR was 8%, 10%, 6% and 4% and the percentage decrease for TE is 3%, 4%, 5% and 11% respectively. The qualitative analysis include the effect of TR and TE on contrast to noise ratio according to which the increasing repetition time gives good contrast to noise ratio especially for conventional and fast spin echo sequence. It is better to keep echo time lower but this is an imperceptible parameter for contrast to noise ratio for T1-weighted images.

Introduction:-

MRI is a non-invasive method with diverse pulse sequences to measure doses in dosimeter gels and was first proposed by Gore et al in 1984.(Gore and Kang 1984) It is well known for its high contrast and ability to generate 3D images.(De Deene 2009) The basic factors considered to determine the image quality includes, spatial resolution, tissue contrast and signal to-noise ratio (SNR). Due to the co-dependency of these factors their simultaneous progress is complex.(Riddell, Richardson et al. 2014) Excellent tissue contrast relies on optimal selection of appropriate pulse sequences (spin echo, inversion recovery, gradient echo, turbo sequences and slice profile). Important pulse parameters are TR (repetition time), TE (time to echo), TI (time for inversion), and flip angle.(Yamada, Wisner et al. 2002) TI and T2 weighted images depend on a good selection of TE. Tissues vary in their T1 and T2 times which are manipulated in MRI by selection of TR, TI and TE, respectively. A contrast-to-noise ratio (CNR) is a summary of both SNR and contrast. It is the difference in SNR between two relevant tissue types (A and B):

$$CNR = SNR_A - SNR_B$$

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Recent developments in MRI technology have led to improvements in contrast and SNR by the optimization of imaging parameters to achieve best possible image quality.(Bucholz, Ghaghada et al. 2008) Due to the T1 and T2 relaxation properties in magnetic resonance imaging differentiation between various tissues in the body is possible.(Damadian 1971) Contrast of the image (pathological areas of the tissue) can be improved by the selection of one of the above parameters however with the possibility to reduce the MR image excellence by the effect of other parameters.(Bartusek and Smekal 2006)

In recent years different MRI techniques and pulse sequences have been reported for the clinical use which has the ability to enhance image quality and consequently improve diagnostic accuracy.(Li and Mirowitz 2003) Nevertheless pulse sequences with ideal optimum values for a specified body tissue are still intangible. This research work is an attempt in this direction in which different parameters affecting CNR in various clinical MRI sequences have been considered.

The Fricke gel dosimeter has been used as a reliable chemical radiation dosimeter for more than eighty years.(Maeyama, Fukunishi et al. 2014) Fricke gel dosimeters are tissue equivalent over a large range of photon energies (Sullivan, Adalsteinsson et al. 2006) having the ability to stabilize the spatial information of radiation induced oxidation and a step towards modern gel dosimeter.(Maeyama, Fukunishi et al. 2014) The aim of this study was to compare the image quality and contrast using different pulse sequences, and a quantitative evaluation of impact and efficacy of altering imaging parameters on image quality. Contrast to noise ratio is the focal point to be discussed in this work. The CNR is most likely the most decisive factor affecting image quality as it directly determines the eye's ability to distinguish regions of high signal from area of low signal.

Method and Materials:-

In this research work a series of images were obtained to observe the effect of variation of imaging parameter TR and TE using spin-echo, fast spin echo, Gradient Recalled echo and Fluid Attenuated Inversion Recovery sequences on image quality. A dosimeter gel was prepared using Xylenol Orange dye with Ferrous-Benzoic solution for this purpose which was exposed to a beam of 6MV X-rays with field size $5\times5cm^2$. The absorbed dose was 20Gy at its iso-centre. All the images were acquired with a matrix of 256×256 and flip angle 120, FOV of $200\times200mm^2$. For each scan four numbers of slices were obtained.

Results and Discussion:-

Conventional Spin Echo Images:-

The scanning was performed with spin echo sequence with echo time (TE) of 12ms, repetition time (TR) of five different values as 400, 500, 600, 700 and 800ms, slice thickness of 4mm, and FOV was $200\times200\ mm^2$.

The contrast between the area which was exposed to ionizing radiations and the area away from the beam target can be seen but it is not much clear. By analyzing the image while drawing different region of interest (ROI) in the slice at different positions as shown in the *figure (1a)* with equal area it was observed that the mean value of signal intensity in the area at the centre of the slice (the area which was exposed to radiations) was 883 whereas the mean value of signal intensity in the area away from the centre (the area at the ends) was observed to be 705.

The transverse slice of the image obtained with TR of 400ms and TE of 16ms is shown in the *figure (1b).* The mean value of signal intensity calculated in the area of beam target and away from the beam target was 528 and 402 respectively. A good CNR can be obtained with a greater value of TR and less value of TE for a spin echo image as calculated in table (I & II) respectively.

Fast Spin-Echo Images:-

The scanning was performed with fast spin-echo sequence with echo time 12ms and repetition time with five different values as 400, 500, 600, 700 and 800ms. Images were also taken with repetition time 400 and five different values of echo time as 12, 25, 37, 49 and 62ms.

The image of a transverse slice was obtained with sequence parameters, TR and TE to be 800 and 12ms respectively.

The contrast obtained from this image by selecting different ROI in the beam area and away from beam area showed the mean value of signal intensity to be 831 and 664. Another slice of image with sequence parameter TR of 400ms and TE of 37ms, the mean value of signal intensity calculated was 490 and 385 in the beam area and away from the target area respectively.

For fast spin echo the contrast to noise ratio obtained is inconsistent with spin echo for the choice of TR but there would be a careful attention would be taken for the choice of TE.

Gradient-Recalled Echo Images:-
The scanning was performed with Gradient recalled echo sequence with echo time 12ms and repetition time with five different values as 80, 90, 100, 110, and 120ms. Images were also taken with repetition time 80ms and five different values of echo time as 10, 12, 14, 16 and 18ms.

The image of a transverse slice was obtained with sequence parameters, TR and TE to be 120 and 12ms respectively.

By taking different ROI in the slice at the beam path and at a place far away from the beam path it can be clearly visualizing the contrast between these two areas. The mean value of signal intensity calculated at the centre of the slice was 399 and away from the centre were 317.

Another slice with sequence parameters TR of 80ms and TE of 18ms with signal intensity values 290 and 212 at the beam targeted area and away from beam area respectively, is shown in the *figure 3(a &b).* A good CNR is obtained at higher value of TR in Gradient Recalled echo but for TE its behavior is unstable.

Fluid Attenuated Inversion Recovery images:-
The results from MR imaging performed by applying inversion recovery pulse sequence are given below. The same gel composition was used for this sequence also. A set of images of five TR values as 2000, 2100, 2200, 2300 and 2400ms was obtained with sequence parameters TE and TI of 12ms and 600ms respectively. The image acquired with maximum contrast was by applying TR of 2100ms and TE of 12ms. The mean value of signal intensity for the beam targeted area calculated was 316 and away from the beam area was 134.

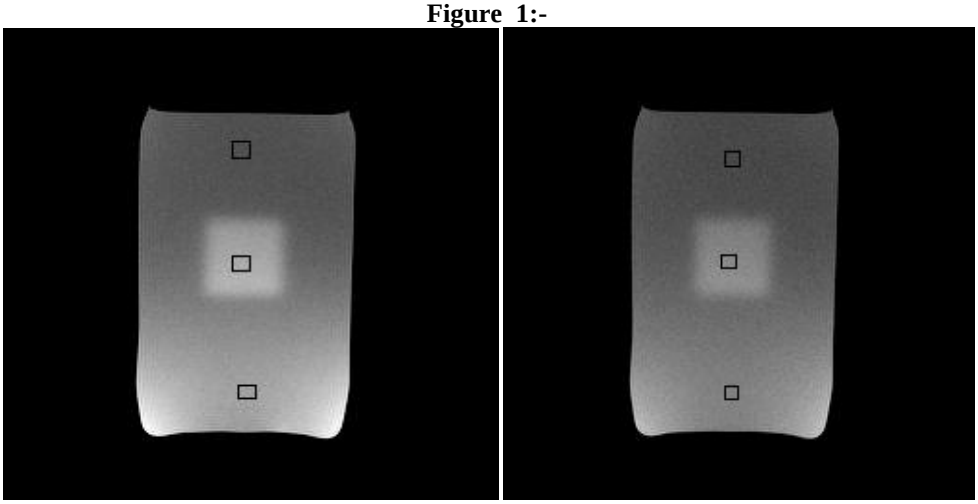
Some images were acquired while applying inversion recovery pulse sequence with a set of five different values of TE as 12, 25, 37, 49 and 62ms. Repetition time and inversion time were chosen to be 2000ms and 600ms respectively. The maximum contrast obtained by applying parameters, TR of 2000ms, TE of 37ms and TI of 600ms having mean values of signal intensity as 341 at the beam path and 153 at the area away from the beam.

In CSE, however with the increase of TR, CNR increased between the tissues (from 38% from 400 to 800 (ms). In FSE, CNR is created between tissues and this ratio is comparable to CSE. Contrast between tissues is high as TR moves from 400 to 500 (ms) though CNR moves up 49 % from TR 400 to 800 (ms). With the moderate signal intensity difference amongst tissues 25-0 Gray the contrast between signal strengths is evident even at small TR 80 ms in GRE. CNR increased through 27% as TR increases from 80 120ms. Within FLAIR signal strength of tissues is relatively higher than CSE, FSE and GRE at all values of TR. There is 18% increase in CNR as TR is increased from 2000 to 2400 ms. FLAIR turns out higher CNR even at lesser value of TR 2000 (ms). CNR between tissues is almost alike at all values of TR and 27% increased CNR obtained from TR 2000 to 2400 (ms). The numerical difference between two small intensities can be well differentiated in FLAIR. CSE creates CNR with the variation of TE for tissues have trivial signal strength Signal strength decreased with the rise of TE but this decrease is not tremendous .We have average 3% decrease in the signal strength i.e. CNR. However more appropriate TE is desirable to produce excellent contrast between tissues. Choice of TE in FSE is analogous to CSE to develop contrast among tissues. Signal intensity 4% decreased from TE 25 to 62 msec. GRE the percentage decrease of CNR is 5% but FLAIR creates maximum contrast between tissues of minute signal intensity difference. FLAIR can be a good choice to differentiate tissues of infinitesimal signal intensity. There is 11 % average decrease in signal intensity with the selection of high value of TE.

Conclusion:-

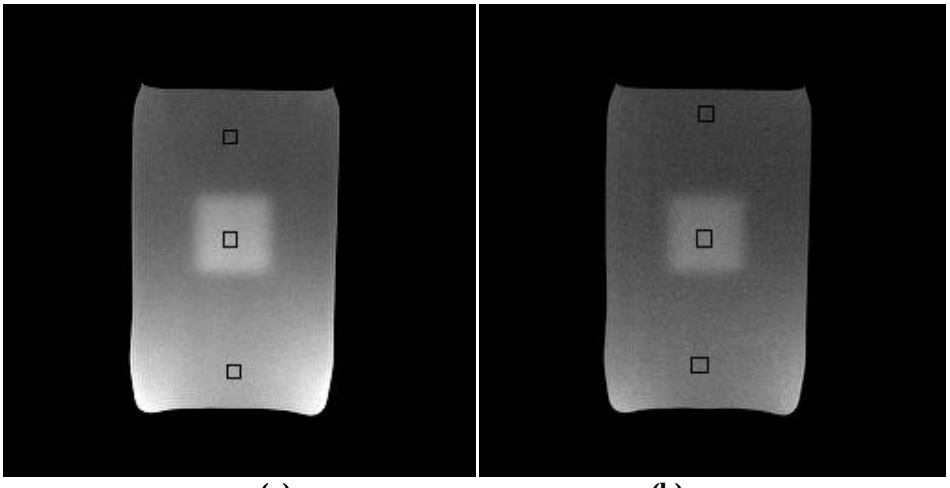
This research work demonstrate the impact of variation of key imaging parameters TR and TE on image quality for the frequently used pulse sequences CSE, FSE, GRE and FLAIR at diagnostic level. Inappropriate selection of parameters is able to build an insignificant image. This analysis showed that the role of TR and TE in T1-weighted images is crucial to maintain the image quality. With the choice of TR and TE in T1-weighted images CNR results of CSE and FSE are equivalent for the tissues of comparable signal intensities and for entities have moderate difference between signal intensities CSE provides remarkable contrast between tissues because of signal intensity difference is extremely high in T1-weighted study. FLAIR which is explicitly preferable for T2-weighted images also analyzed its importance in T1-weighted images. FLAIR gives better contrast to noise ratio at lower values of TR and higher values of TE. Results strongly suggested that it can also be used for diagnostic purpose with fine image quality of high T1/T2 weighted tissues in T1-weighted study as well.

Figure 1:-



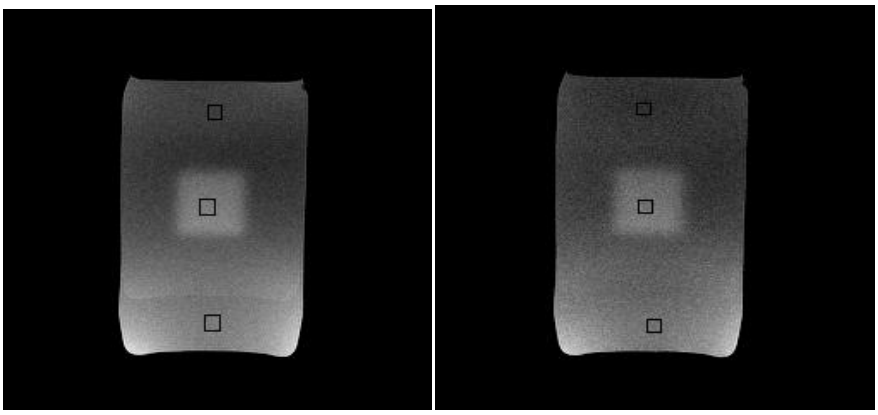
(a) **(b)**

Figure 1(a&b):- An MR image of transverse slice of gel phantom after exposing to 6MV X-rays. The image was acquired by applying spin-echo (SE) pulse sequence with TR of 800ms and TE of 12ms (a) and TR of 400ms and TE of 16ms (b), matrix size 256×256, slice thickness 4mm and FOV 200mm^2.



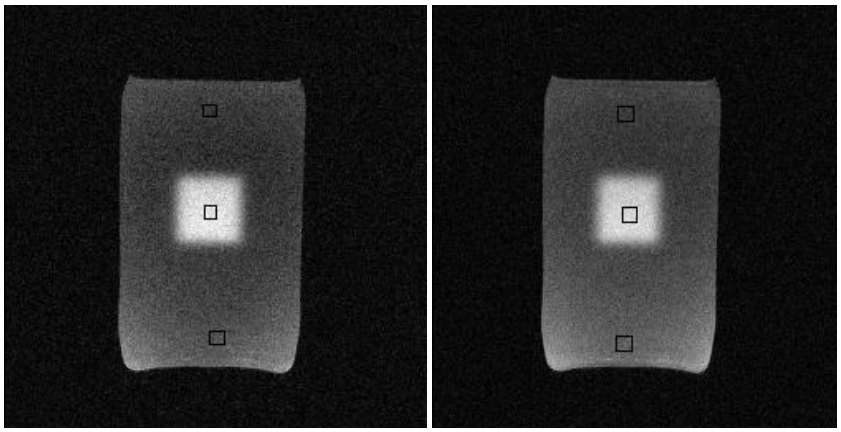
(a) **(b)**

Figure 2(a&b):- An MR image of transverse slice of gel phantom after exposing to 6MV X-rays. The image was acquired by applying fast spin-echo (FSE) pulse sequence with TR of 800ms and TE of 12ms (a) and TR of 400ms and TE of 37ms (b) , matrix size 256×256, slice thickness 4mm and FOV 200mm^2.



(a) **(b)**

Figure 3(a&b):- An MR image of transverse slice of gel phantom after exposing to 6MV X-rays. The image was acquired by applying gradient- recalled echo (GRE) pulse sequence with TR of 120ms and TE of 12ms (a) and TR of 80ms and TE of 18ms (b), matrix size 256×256, slice thickness 4mm and FOV 200mm^2.



(a) **(b)**

Figure 4 (a&b):- An MR image of transverse slice of gel phantom after exposing to 6MV X-rays. The image was acquired by applying inversion recovery (IR) pulse sequence with TR of 2100ms and TE of 12ms (a) and TR of 2000ms and TE of 25ms (b) and TI of 600ms, matrix size 256×256, slice thickness 4mm and FOV 200mm^2.

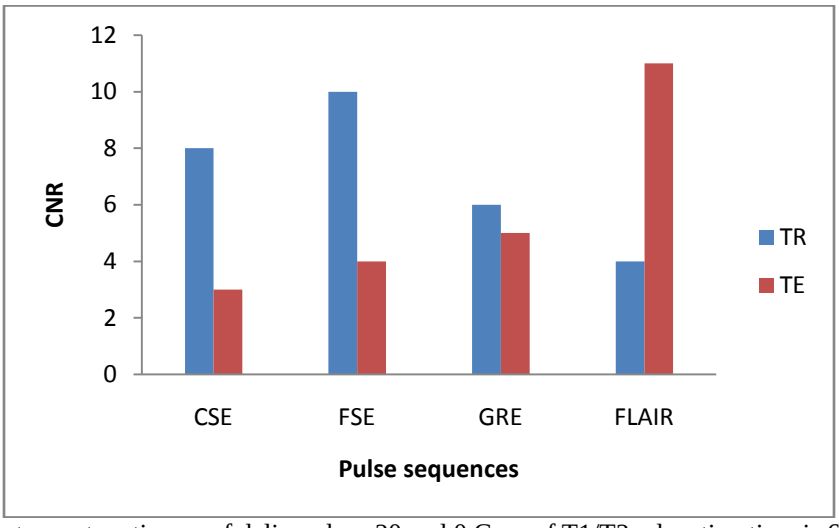


Figure 5:- CNR between two tissues of deliver dose 20 and 0 Gray of T1/T2 relaxation time is 653/81 (msec) and 812/166 (msec) respectively at the selected values of TR and TE in T1-weighted images.

Table 01:-

Sr. No	*Pulse sequences*	*TR (ms)*	*CNR*	*Percentage increase in CNR %*	*Average increase %*
1	CSE	400	32	12	8%
		500	36	11	
		600	40	5	
		700	42		
		800	44	4.7	
2	FSE	400	26.4	22	10%
		500	34	3	
		600	35.2	10	
		700	39	7	
		800	42		
3	GRE	80	17.5	9	6%
		90	19.3	8	
		100	21	8	
		110	23	1	
		120	23.2		
4	FLAIR	2000	18.7	10	4%
		2100	20	3	
		2200	19.3	1	
		2300	19	2	
		2400	18.5		

Table 02:-

Sr. No	*Pulse sequences*	*TE (ms)*	*CNR*	*Percentage decrease in CNR %*	*Average decrease %*
1	CSE	12	32	1	3%
		14	31.7	1	
		16	32	6	
		18	30	5	
		20	31.5		
2	FSE	12	26.4	0	4%
		25	26.4	11	
		49	29.4	0	
		37	29.4	5	
		62	31		
3	GRE	10	17.4	9	5%
		12	17.5	1	
		14	19.3	7	
		16	18	4	
		18	17.2		
4	FLAIR	12	18.7	12	11%
		25	21	14	
		49	18.4	8	
		37	20	13	
		62	23.5		

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