ORIGINAL ARTICLE

Pulse Sequence Single Shot Fast Spin Echo for Reducing Motion Artefact on MRI of the Brain

Muhaimin[1,2], Lailatul Muqmiroh[2,3], Risalatul Latifah[2], Amillia Kartikasari[2], Anggraini Sensusiati[2,3]

[1] Postgraduate School, Universitas Airlangga. Jl. Dharmawangsa Dalam 28-30 Surabaya, 60286 Indonesia
[2] Faculty of Vocational Studies, Universitas Airlangga. Jl. Dharmawangsa Dalam 28-30 Surabaya, 60286 Indonesia
[3] Departement of Radiology, Husada Utama Hospital, Surabaya, Indonesia

ABSTRACT

Introduction: This research was motivated by the increase of brain MRI examinations in emergency medicine. In an emergency, patients are often uncooperative, and they raise motion artefact on the image. Therefore, fast scanning techniques such as pulse Sequence Single Shot Fast Spin Echo (SS-FSE) is required to reduce the artefact. This study was conducted to determine the effectiveness of using SS-FSE technique to minimize motion artefact. **Methods:** This study was an observational analytic with prospective methods. Scanning was conducted to 16 normal patients (volunteers). Two neuro radiologists retrospectively and independently reviewed all images. Observations used standard diagnostic of brain MR Image by evaluating the anatomical and morphological structure. **Results:** Based on the results of the analysis of each organ that was assessed, it was obtained that the average of the image for overall organs on the brain; 76% looks sharp, 21% looks moderate (minimum blurred), and 3% looks blurred. **Conclusion:** SS-FSE technique affects reducing motion artefact due to object movement in MRI brain. The overall image SS-FSE produced has good image quality.

Keywords: Single shot, MRI brain, Motion artefact

Corresponding Author:
Lailatul Muqmiroh, MMed (Rad)
Email: lailatul.muqmiroh@vokasi.unair.ac.id
Tel: +6281 938310717

INTRODUCTION

Diagnostic imaging is a rapidly developing scientific discipline to support the emergency medicine. MRI and CT scans are advanced diagnostic imaging in emergency patients. In general, in detecting injuries to soft tissues, such as the brain, MRI is superior to CT (1). MRI is more sensitive than CT in detecting the acute ischemic strokes. In emergency cases, patients often experience movement that rise the motion artefact on the image. Thus, fast scanning techniques are needed to reduce the artefact. The main source of artefact in the brain is from flow motion of the carotid and vertebral arteries. However, uncooperative patients tend to cause more motion artefacts (2).

T2 weighted imaging is the mainstay of most brain Magnetic Resonance Imaging protocols (3). T2 weighted images have excellent tissue contrast for evaluation of pathological conditions in the organs evaluated(4). The role of T2WI images is very important to be able to evaluate the pathological state of the tissue. Therefore, this image must be made in MRI scanning especially on the brain MRI.

Spin Echo (SE) and Fast Spin Echo (FSE) techniques are most commonly used on head scanning. This techniques can produce excellent image quality (4). However, this technique requires long acquisition times (generally several minutes) (3). The scanning time is considered to be still quite long if the patient's condition is uncooperative. Usually, emergency patients come in an uncooperative state. So, Fast scanning technique is needed for uncooperative patients. This method has been wideley applied in clinical diagnosis (5). In fast imaging procedure, it is advantageous for both patient and hospitals since rapid data acquisition will reduce motion artefact, flow artefact as well as the scan time and expense.

Single Shot Fast Spin Echo (SS-FSE) is a technique for obtaining spin echo images in a very short time (6)(7). In this technique, K-Space is fully charged in one TR (Time Repetition) acquisition(4). SS-FSE is a combination of Fast Spin Echo techniques and Partial Fourier techniques. Partial Fourier is a technique of transforming signal data into image data by taking half a line from K-Space in one TR acquisition. So, this technique will reduce scanning time and all data can be obtained in one TR acquisition. However, this technique will reduce SNR (*Signal Noise to Ratio*) in the resulting image (3,4,8).

So far, the Single Shot technique has not been widely used on brain MRI, especially in uncooperative patients. Thus, it is essential to determine the effectiveness of using SS-FSE technique to reduce motion artefact due to object movement of patients in brain MRI examination.

MATERIALS AND METHODS

Patients

This research was an observational analytic with prospective methods. The use of SS-FSE imaging was approved by our institutional and hospital review board. Data were taken from 16 normal patients (volunteers) who were willing to do brain MRI examinations. Patient criteria used in this study were normal adults, men and women aged 20-50 years. The patients had no history of brain injury. Patients did not use pacemakers and were not traumatic claustrophobia. Before the examination, all patients were given the written informed consent for undergoing MRI and for being a part of the study.

MRI Examination Technique

All examination were performed on a 1.5 T MR system (Achieva, Philips, Netherland). An 8 channel sense head coil was used in this study. Axial T2 weighted SS-FSE images were obtained with the following parameters: time repetition, 12.000ms; time echo, 90ms; flip angle, 90; matrix size, 244 x 163; field of view, 220 x 183 mm; signal averages, 1; echo train length 59; no fat saturation; slice thickness, 5 mm; gap, 1 mm; total slices, 20; and scan time 24s.

Patients were scanned by rotational movement as in Figure 1. Object movement was limited to the area of the head coil used. Movement of the object was guided by MRI operator with a stopwatch so that all samples receive the same speed of movement wich is one movement per second. Axial scanning is made from a 3-localizer plan (sagittal, coronal, axial) as shown in Figure 2. The incision angle is aligned with the talairach line.

Image Analysis

All MR images were analysed using Philips workstation and reviewed by two radiologists in an independent and retrospective manner. MR imaging reports and clinical history were unknown to the observers. The spreadsheet

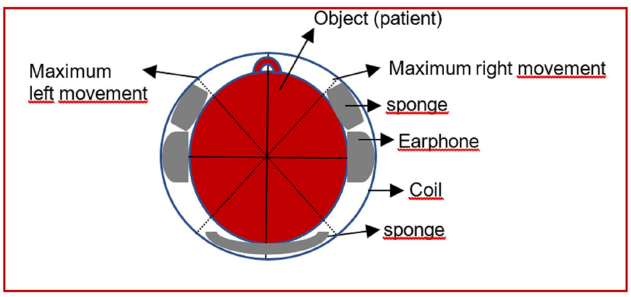

Figure 1: Simulation of object placement in the coil. Object placed in the midle of the coil. Patients use earphones to reduce noise and hear instructions from the operator. Sponge is used to limit movement space.

Figure 2: Axial slice planning in brain MRI. Axial scanning is made from a 3-localizer plan (sagittal, coronal, axial). The incision angle is aligned with the talairach line.

containing SS-FSE image numbers and corresponding brain slice segments wase provided for the observers. Image quality was evaluated independently by observer. Observations used standard diagnostic of brain MR Image by evaluating the anatomical and morphological structure of each part of the organ include: brain parenchim, cerebellum and brain stem, corpus callosum, sulcus gyrus and ventricel, Sinuses, and orbits. Observations were conducted with four point criteria (1: absent or invisible, 2: blurred, 3: moderate or minimum blurred, 4: sharp). A score of 1 indicates that the organ is invisible and image is uninterpretable. Score 2 shows that the organ is visible but blurred and difficult to be interpretable. Score 3 shows that the organ looks good with minimum blurred but it does not affect the interpretation. Scores 4 show sharp and good quality of overall picture. The statistics descriptive was used to analyse the effectiveness of the SS-FSE for reduction motion artefact in brain MRI.

RESULTS

SS-FSE brain MR examinations were performed in 16 patients and were reviewed by two neuro radiologist. Brain anatomy was exceptionally well visualized on this technique. We obtained average of the image for overall organs on the brain which is 76% looks sharp, 21% looks moderate (minimum blurred), and 3% looks blurred. (Table I). Brain parenchym, sulcus-gyrus, and ventricle gets the highest scores on the sharp criteria that is 85% and 15% looks moderate (minimum blurred), no blurry and invisible image. Cerebellum and brain stem gets a score of 81% looks sharp and 18% looks moderate, no blurry and invisible image. Corpus callosum gets a score

Table I: Observations result for the anatomical structure of each part of the organs.

	Invisible		blurred		moderate		sharp	
	freq	percent	freq	percent	freq	percent	freq	percent
Brain Parenchym	0	0%	0	0%	5	15%	27	85%
Cerebellum and brain stem	0	0%	0	0%	6	18%	26	82%
Corpus Callosum	0	0%	0	0%	7	21%	25	79%
Sulci-Gyri dan Ventricle	0	0%	0	0%	5	15%	27	85%
Sinuses	0	0%	1	3%	9	25%	22	72%
Orbits	0	0%	1	3%	9	25%	22	72%
Average	-	-	1	3%	6,8	21%	24,2	76%

of 79% looks sharp and 21% looks moderate, no blurry and invisible image. Sinuses and orbits gets a same score that is 72% looks sharp, 25% looks moderate, and 3% looks blurred.

The overall image of SS-FSE produced has good image quality. Overall sample can visualize the brain anatomy as well and image can be interpreted by a radiologist. This is evident in the results of statistical calculations which obtained the mean score of the organs: (brain parenchym, 3.84; cerebellum and brain stem, 3.81; corpus callosum, 3.78; sulcus-gyrus and ventricle, 3.84; sinuses and orbits, 3.66) and standard deviations <1 (Table II). There are organs that look blurred in some image, but this can be tolerated.

DISCUSSION

This research was performed to determine the effectiveness of SS-FSE technique to be able to reduce motion artefact due to the movement of patients on T2W image axial slices. This study demonstrates the ability of SS-FSE technique to obtain the depict of anatomy and morphology without motion artefact. Anatomy of the brain, including brain parenchim, cerebellum and brain stem, corpus callosum, sulcus gyrus and ventricel, Sinuses, and orbits are well delineated in this technique. Prior literature has focused on the role of pulse sequence SS-FSE for reduction motions artefact on the intestinal peristaltic or cardiac motion. SS-FSE can visualize normal and abnormal fetal anatomy without motions artefact (9). However, that matter was not motion artefact from the uncooperative patients. So, this study is very helpful to be applied to uncooperative patients.
In our study, we show that SS-FSE can reduce motion artefact due to object movement. We get significant results from this study that average of the image which is 76% looks sharp and 21% looks minimum blurred (moderate) for overall organs on the brain (table 1). Moreover, we obtained mean score of the organs: (brain parenchym, 3.84; cerebellum and brain stem, 3.81; corpus callosum, 3.78; sulcus-gyrus and ventricle, 3.84; sinuses and orbits, 3.66) and standard deviations <1 (table 2). Therefore, SS-FSE is proven to be effective in reducing motion artefacts in brain MRI.

At present, examination of the brain MRI routinely uses FSE technique. FSE is the standard technique for most imaging. FSE technique may be used for almost every examination. Image contrast T2 weighted is useful for demonstrating pathology(4). However, this technique requires long acquisition times (generally several minutes) and more than one repetition of radiofrequency to fill all the line of K-Space(3) (10). Another drawback from this method is that this technique cannot be used to uncooperative patients. Since moving object will change the received signal of spatial locations, so that the image will contain the motion artefacts.

SS-FSE is a modification technique of FSE. All necessary lines of K space in one repetition will be filled by collecting MR signals, and generating multiple echoes in single TR period. Readout gradient and phase encode gradients must be rapidly switched on/off to change the direction. SS-FSE is a combination of Fast Spin Echo techniques and Partial Fourier techniques. Partial Fourier is a technique of transforming signal data into image data by taking half a line from K-Space in one TR acquisition. Therefore, the resulting image is without substantial motion artefact. Figure 3 shows, the difference between FSE and SS-FSE on moving objects. FSE image looks very blurred and cannot visualize anatomy of the brain. SS-FSE image looks very good and could visualize anatomy as well.

SS-FSE is relatively robust to reduce motion artefact and has greatly decreased acquisition times (11). In this study, the scan time required is only 24 seconds. However, SS-FSE imaging has its own drawbacks compared to FSE imaging. SS-FSE images have a reduced SNR owing to

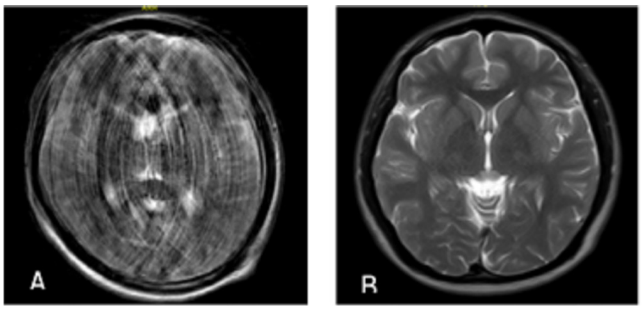

Figure 3: Comparation of motion artefact betwen FSE and SS-FSE Image. A: T2W image FSE technique (scan time 2 minute), B: T2W image SS-FSE technique (scan time 24 second. Picture A looks very blurred and cannot visualize the anatomy of the brain. Picture B looks very good and could visualize anatomy as well.

Table II: Scores for ability to determine the effectiveness of pulse sequence SS-FSE to reduce motion artefacts in brain MR image

		Brain Parenchym	Cerebellum and brain stem	Corpus callosum	Sulcus Grus and Venticles	Sinuses	Orbits
N	Valid	32	32	32	32	32	32
	Missing	0	0	0	0	0	0
Mean		3.84	3.81	3.78	3.84	3.66	3.66
Std. Deviation		0.369	0.397	0.420	0.369	0.545	0.545
Range		1	1	1	1	2	2
Minimum		3	3	3	3	2	2
Maximum		4	4	4	4	4	4

the greatly reduced scan time and Specific Absorption Rate (SAR) speed limitations due to excessive Radio Frequency (RF) energy deposition (11,12). Figure 4 shows, the difference image quality between FSE and SS-FSE. FSE image looks very sharp, has minimum nois and has image contrast look as well. SS-FSE image looks less sharp and has a lot of noise. So, SS-FSE is a good technique for uncooperative patients. In another report, the SSFSE technique is less sensitive for the detection of small lesions (less than 5mm in diameter) (13). However, the report needs to be reviewed because the resolution matrix used in the SS-FSE technique is low. Therefore, in routine examination, we are recommend to keep using FSE technique.

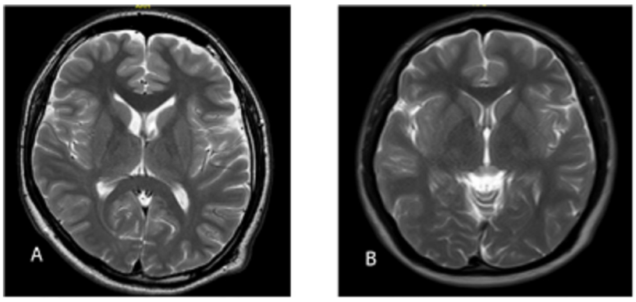

Figure 4: Comparation of image quality betwen FSE and SS-FSE Image. A: T2W image FSE technique (scan time 2 minute), B: T2W image SS-FSE technique (scan time 24 second). FSE image looks very sharp, has minimum noise and has image contrast look as well. SS-FSE image looks less sharp and has a lot of noise.

In this study, we did not assess the accuracy of MRI in the diagnosis of pathology (desease) because we used normal patients. Furthermore, only axial T2W image was reviewed. Aditionally, to produce accurate diagnoses, it required several sequences with various slice fields. There are many limitations in this study, we only use qualitative method to analyse for image quality. Thus, the result are less objective. Further studies are also needed for disease evaluation.

CONCLUSION

In conclusion, we have shown that SS-FSE technique is effective in reducing motion artefact due to object movement in MRI brain. SS-FSE is a good technique for uncooperative patients. However, this technique is not recommended for routine examinations (cooperative patient) because the image quality decreases.

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REFERENCES

1. Fox CJ. Clinical Emergency Radiology. 1st ed. Fox CJ, editor. New York: Cambridge University Press; 2008.
2. Westbrook C. Handbook of MRI Technique. 4th ed. Wiley-Blackwell; 2014.
3. Loening AM, Litwiller D V, Saranathan M, Vasanawala SS. Increased Speed and Image Quality for Pelvic Single-Shot Fast Spin-Echo Imaging with Variable Refocusing Flip Angles and Full-Fourier Acquisition. Radiology [Internet]. 2016 Aug 26;282(2):561–8. Available from: https://doi.org/10.1148/radiol.2016151574
4. Westbrook C, Roth C, Talboth J. MRI in Practice. 4th ed. Wiley-Blackwell; 2011.
5. Li N, Bolding M, Twieg DB. Spin-echo SS-PARSE: a PARSE MRI method to estimate frequency, R2 and R2' in a single shot. Magn Reson Imaging [Internet]. 2010;28(9):1270–82. Available from: http://www.sciencedirect.com/science/article/pii/S0730725X10001694
6. Chen F, Taviani V, Malkiel I, Cheng JY, Tamir JI, Shaikh J, et al. Variable-Density Single-Shot Fast Spin-Echo MRI with Deep Learning Reconstruction by Using Variational Networks. Radiology [Internet]. 2018 Jul 24;180445. Available from: https://doi.org/10.1148/radiol.2018180445
7. Carballido-Gamio J, Xu D, Newitt D, Han ET, Vigneron DB, Majumdar S. Single-shot fast spin-echo diffusion tensor imaging of the lumbar spine at 1.5 and 3 T. Magn Reson Imaging [Internet]. 2007;25(5):665–70. Available from: http://www.sciencedirect.com/science/article/pii/S0730725X06003146
8. Schulz J, P. Marques J, ter Telgte A, van Dorst A, de Leeuw F-E, Meijer FJA, et al. Clinical application of Half Fourier Acquisition Single Shot Turbo Spin Echo (HASTE) imaging accelerated by simultaneous multi-slice acquisition. Eur J Radiol [Internet]. 2018;98:200–6. Available from: http://www.sciencedirect.com/science/article/pii/S0720048X17305120
9. Huppert BJ, Brandt KR, Ramin KD, King BF. Single-Shot Fast Spin-Echo MR Imaging of the Fetus: A Pictorial Essay. RadioGraphics [Internet]. 1999 Oct 1;19(suppl_1):S215–27. Available from: https://doi.org/10.1148/radiographics.19.suppl_1.g99oc09s215
10. Pokorney AL, Miller JH, Hu HH. Comparison of 2D single-shot turbo-spin-echo and spin-echo echo-planar diffusion weighted brain MRI at 3.0 Tesla: preliminary experience in children. Clin Imaging [Internet]. 2017;42:152–7. Available from: http://www.sciencedirect.com/science/article/pii/S0899707116302005
11. Semelka R, Kelekis N, Thomson D, Brown M, Laub G. HASTE MR imaging: description of technique and preliminary results in the abdomen. J Magn Reson Imag ing. 1996;6(4):698–699.
12. Bhosale P, Ma J, Choi H. Utility of the FIESTA pulse sequence in body oncologic imaging: review. AJR Am J Roentgenol. 2009;192(6).
13. Patel MR, Klufas RA, Alberico RA, Edelman RR. Half-fourier acquisition single-shot turbo spin-echo

(HASTE) MR: comparison with fast spin-echo MR in diseases of the brain. Am J Neuroradiol [Internet]. 1997 Oct 1;18(9):1635 LP – 1640. Available from: http://www.ajnr.org/content/18/9/1635.