International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN:2347-6567

IJAMSCR |Volume 7 | Issue 3 | Jul - Sep - 2019
www.ijamscr.com

Research article *Medical research*

Application of Denoising Non-Local Mean Filter (NLM) in MRI Brain Image T2WI TSE SENSE

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ABSTRACT

The acquisition of MRI images takes a long time. One of the efforts to improve the examination acquisition time is by using a parallel imaging technique, namely SENSE. However, the SENSE technique has a weak-point that is reducing SNR. Reducing SNR induces an increase in the amount of noise. One of denoising method that is able to increase SNR is Non-local mean filter (NLM). Denoising at post-image acquisition is a cheaper and more effective alternative. This research is expected to produce faster scanning times and maintain the quality of MRI images. The purpose of this study is to analyze the effectiveness of denoising Nonlocal Mean Filter (NLM) on MRI brain image information T2WI TSE SENSE on r factor. Experimental research on MRI brain images with T2WI TSE sequences use parallel imaging SENSE application. R factor that is used in the application of SENSE is 2. The improvement of the image information is executed by using denoising Non-Local Mean (NLM) technique. The image evaluation is carried out by comparing pre- and post-using denoising qualitatively (brain anatomical information). The results of the parametric test show that there is a difference in anatomical information on MRI Brain T2WI TSE images by using parallel imaging SENSE between pre- and post-using denoising Non-Local Means (NLM) technique with p-value <0.001 (< 0, 05). Nonlocal Mean Filter (NLM) effectively enhances anatomic MRI brain information T2WI TSE SENSE r factor 2.

Keywords*:* MRI, T2WI TSE, SENSE, R factor, Non-Local Mean (NLM).

INTRODUCTION

Magnetic resonance imaging (MRI) is a non-invasive medical device. This is a very safe and painless tool that can be used [1].MRI uses high strength magnetic fields, radiofrequency pulses, and computers to produce images of organs, soft tissue, bones, and almost all internal body structures. The image result is very useful for the treatment and diagnosis of the patient [2]. MRI imaging techniques are relatively complex because the images produced depend on the number of protocols. The selection of the right protocol has an impact on the quality of the detailed images of the human body. Anatomy and pathology of body tissues can be carefully evaluated [3].

MRI imaging takes a long time until the image results can be evaluated and diagnosed by a doctor. Routine imaging times for various examinations vary from 20 to 60 minutes. Each protocol often includes 5 or more protocols. Before the examination technique is carried out, it takes at least a few additional minutes for the handling and preparation of the patient before the examination is carried out [4]. The time for the MRI examination must be limited, just as we limit the dose for CT scan. The time for the MRI examination is equivalent to the permitted dose of CT scan [4]. Radiographers often try to speed up the examination time. The length of time for the examination and adjustment of the work hours of the radiographer causes a limit on the number of patients who will carry out the examination.

Several factors caused by the acceleration of the examination time are: during the examination, the patient must be calm and must not move. Routine protocols should apply to patients in general [3]. This application is very difficult for patients who are not cooperative. Radiographers must consider the patient's condition, clinical indications and patient tolerance to the examination before choosing the scanning parameters [3]. Examinations repetition will slow down the completion of an MRI examination. The number of patients examined sometimes exceeds the limit per day. Radiographers strive to speed up inspection time and time efficiency. Using the Turbo Spin Echo (TSE) sequence can help speed up the time of the MRI examination. The active Echo Train Length (ETL) parameter on the sequence causes a faster inspection time [5]. Echo Train Length (ETL) or turbo factor is the number of pulse rephrasing or 180º multiple pulses in each Time Repetition (TR). Echo Train Length can be used to speed up scanning time [6].

A more significant way to reduce almost half the scanning time is by applying parallel acquisition techniques or parallel imaging techniques [7]. One of the most common parallel imaging techniques used is sensitivity encoding or SENSE [8]. Image with SENSE implementation produces image quality in terms of contrast and spatial resolution which is the same as a standard image. SENSE acquisition time required is only half of the scanning time in general but can reduce the value of the signal in anatomical images. The reduction of SNR in the application of SENSE depends on reduction factor (R-factor) or the number of elements in the phased array coil used [9]. Parallel imaging techniques utilize the elements in multiple phased array receiver coils by reducing the phase encoding line on K-space according to the 1 / R factor so that the sampling does not occupy all K space. SENSE causes data acquisition time to decrease and become faster according to the r-factor used [10].

The weakness of the application of the SENSE parallel imaging technique is reducing SNR. Decreasing SNR will increase the image noise [11]. Noise will make the pixel intensity values not reflecting actual pixel intensity values [12],[13]. Noise causes undesirable effects on medical image results [14]. Noise contamination make the visual quality of the image that should look good to be disturbed and corrupts the medical image [15]. Denoising technique is a step to eliminate noise on the MRI image that is applied after the scanning process. Denoising does not increase MRI scanning time. This method effectively increases the Signal-to-Noise Ratio (SNR) by reducing noise components while maintaining image features and improving image quality [16],[17]. Denoising is needed in medical image processing [18],[19]. The selection of appropriate denoising techniques will benefit from image processing and can provide easier medical diagnoses [14].

Denoising methods that can be applied to improve SNR on MRI images are obtained from the application of parallel imaging techniques[15], including the Nonlocal mean filter (NLM) [14],[20],[21]. Nonlocal mean filter (NLM) redundancy of information contained in the image to eliminate noise. The stored voxel intensity value is calculated as a weighted average of all voxel intensities in the image. Nonlocal mean filters (NLM) are the most commonly used nonlinear filters [14],[20].

Based on the literature review that has been described, this research was carried out with r-factor variations on the application of SENSE on the MRI image of the T2WI TSE brain sequence. The image that has been done is r-factor variation and then the application of denoising Transform Nonlocal mean filter (NLM) is applied. This research is expected to produce a faster scanning time and maintain the quality of the MRI image of the brain T2WI TSE optimal sequence by reducing noise components while maintaining image features by minimizing the noise impact of r-factor variations on the application of SENSE. The shorter the MRI examination times, the more MRI examinations can be done and the wider the range of diagnostic procedures that can be performed on patients [4].

METHOD

Type and Design of Research

This type of research is a quasi comparative experiment using a Pretest Posttest Without Control Group Design research design [22]. The study was conducted on the MRI image of the brain T2 TSE SENSE sequence of the application of r factor 2 axial pieces. The inspection parameters are set with values : Time Repetition (TR) 5000, Time Echo (TE) 81ms, Number of Excitation (NEX) 2, slice number 20, Flip Angle 150, Field of View (FOV) 250, bandwidth 63.64 MHz and matrix 512x512.

Population and Samples

The population of this study is volunteers in a healthy condition without pathology in the head who are willing to follow the research. Number of samples 15

Data analysis

Qualitative data analysis of MRI anatomical information are carried out by comparing the brain sequence of T2WI TSE SENSE with r factor 2 axial pieces between before and after denoising NLM. The Assessment by visual grading was carried out by three observers (radiologists) with a score of 0: Poor (invisible, unclear boundaries), score 1: less (vague, boundary is still visible but cannot be analyzed), score 2: Enough (pretty clear boundary), score 3: Good (clear boundary with sharp structural lines), score 4: perfect (sharp border, outline easy to analyze). Then a bivariate test is performed by using the Wilcoxon test both overall and per anatomic criteria. Inference, the hypothesis is accepted if the p-value <0.05, which means there is a difference in the MRI image information of the brain T2WI TSE SENSE sequence with r factor 2 axial pieces between before and after the NLM denoising technique, while to get the most optimal image using the mean rank from the Wilcoxon test results.

RESULTS

This study uses brain organ scanning material to obtain the desired MRI image. The MRI images of the brain are used to analyze anatomic information. The study was conducted by making an MRI image of the brain T2WI TSE sequence of SENSE parallel imaging application on r factor 2. T2WI TSE MRI image of the application of SENSE parallel imaging on r factor 2 then repairing image information with denoising Non-Local Mean Filter (NLM) techniques.

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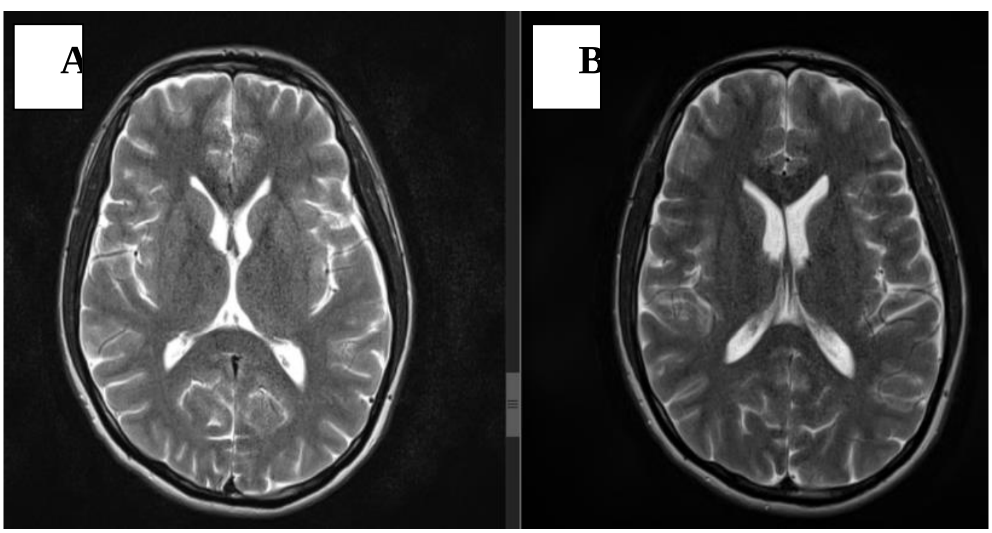

Figure 1. MRI images T2WI TSE SENSE brain sequences on r factor 2 axial sections as high as the thalamus, A) Pre-NLM denoising technique is visible noise in the anatomy section and B) Post-NLM denoising technique appears to reduce the noise in the anatomy with the appearance of boundaries and image structure more firmly and clear

Various tests of brain anatomy information are carried out in 2 stages, namely, overall evaluation of brain anatomy and assessment of brain anatomy criteria. Brain anatomy criteria are assessed based on 6 anatomical criteria, namely: thalamus, pons, cerebellum, white matter, gray matter, and ventricle. The table below describes the results of various tests of brain anatomy information on the MRI images of the T2WI TSE brain. The application of parallel imaging SENSE r factor 2 axial pieces between before and after denoising NLM.

Table 1 Overall Difference Test Information on Brain Anatomy of T2WI TSE SENSE R factor 2 Brain MRI Imagery Between Before and After Denoising NLM

Anatomy Information	***p-value***
r2 pre * *r2 post*	< 0,001

Information:

r2 pre : *r factor 2 before denoising NLM*
r2 post : *r factor 2 after denoising NLM*
* : *compared with*

Various tests were continued based on assessing brain anatomy criteria. Differences in anatomical information on brain images are assessed on 6 anatomic criteria shown in the following table:

Table 2 Different Tests of Brain Anatomical Criteria Information on T2WI TSE SENSE R factor 2 Brain MRI Images between Before and After Denoising NLM

Brain Anatomy	***P-value***
Thalamus	0,001
Pons	<0,001
Cerebellum	0,001
White Matter	<0,001
Gray Matter	0,008
Ventricle	1,00

Based on table 2, the results of the p-value for each anatomical criteria treatment is different. Different test results showed differences in the anatomical information of the thalamus, pons, cerebellum, white matter and gray matter on the MRI image of T2WI TSE brain application of parallel imaging SENSE r factor 2 between before and after denoising NLM with p-value <0.05. However, the results of different tests evaluating the ventricular anatomical criteria show that there is no difference in anatomic information on the MRI images of the T2WI TSE brain. The application of parallel imaging SENSE r factor 2 between before and after denoising NLM with p-value 1.00 (> 0.05)

The anatomical information is also seen based on mean rank values. The mean rank value aims to determine the increase in brain anatomy information between before and after the Non-local Means Filter (NLM) denoising technique. The mean rank value on the difference in overall brain antithesis information between before and after the NLM denoising technique can be seen in the table below:

Table 3 Mean Rank Value Difference Brain Brain Information on MRI Image of Brain T2WI TSE SENSE R factor 2 between Before and After Denoising NLM

Anatomy Information	*Mean rank*
	r2 pre * *r2 post*
r2 pre	0,00
r2 post	30,50

The mean rank value of differences in overall brain anatomical information on MRI images of the T2WI TSE brain. The application of parallel imaging SENSE r factor 2 before denoising NLM is 0.00 and after denoising it is 30.50. Analysis Enhanced anatomical information on brain MRI images was also assessed based on the anatomical criteria of the thalamus, pons, cerebellum, white matter, gray matter, and ventricle. The results of the mean rank test for different information on brain anatomy criteria differences in brain anatomy information on MRI images of brain T2WI TSE SENSE r factor 2 between before and after denoising NLM can be shown in the table below:

Table 4. Value Mean Mean Difference of Information on MRI Image of Brain T2WI TSE SENSE R factor 2 between Before and After Denoising NLM

	Thalamus	*Pons*	*Cerebellum*	*White Matter*	*Gray Matter*	*Ventricle*
*r*2 *pre*	0,00	0,00	0,00	0,00	0,00	0,00
*r*2 *post*	7,00	7,50	6,50	7,50	4,00	0,00

Table 4 describes the increase in anatomic information based on brain anatomical criteria. The increase in anatomic information occurred after an improvement in the MRI brain image of T2WI TSE application of parallel imaging SENSE r factor 2 using denoising NLM. Anatomy that has increased are the thalamus, pons, cerebellum, white matter and gray matter. The mean rank ventricle value of MRI brain image T2WI TSE application of parallel imaging SENSE r factor 2 is 0.00. The mean rank value shows that there is no increase in ventricular anatomic information between before and after the NLM denoising technique on MRI images of the T2WI TSE brain MRI application of parallel imaging SENSE (r factor 2).

DISCUSSION

Assessment of various tests was also carried out on 6 anatomical criteria for the thalamus, pons, cerebellum, white matter, gray matter, and ventricle. Five of the six anatomic criteria indicate differences in anatomic information on MRI T2WI TSE SENSE r factor 2 brain images before and after denoising. Sequentially, the p-value was obtained, namely thalamus 0.001; pons <0.01; cerebellum 0.001 white matter <0.01 and gray matter 0.008. Ventricular anatomy got p-value 1,00 which means there was no difference in ventricular anatomical information on MRI images of T2WI TSE SENSE r factor 2 brain between before and after denoising NLM.

Analysis of enhancement of anatomical criteria image information can be seen based on the mean rank value. A higher mean rank value means that there is an increase in anatomic criteria image information on the MRI image of the brain T2WI TSE SENSE r factor 2 after denoising NLM. The mean rank value of each brain anatomy criteria of T2WI TSE SENSE image factor r 2 after denoising NLM is : thalamus 7.00; pons 7.50; cerebellum 6.50; white matter 7.50; gray matter 4.00 and ventricle 0.00. The mean rank value per brain anatomical criteria of T2WI TSE SENSE image factor 2 before denoising NLM i.e. in the thalamus, pons, cerebellum, white matter, gray matter and ventricle is 0.00. An increase in information on the anatomy of the pons, cerebellum, white matter and gray matter.

The Improvements occur because the improvements have been made to eliminate noise using denoising NLM. If the noise value decreases, the dividing factor of the SNR will be small so that the value of the SNR will increase[23]. Increasing in SNR will help improve anatomic information improvement. Denoising Non-local Means Filter (NLM) uses the redundancy of information contained in the image to eliminate noise. The stored voxel intensity values are calculated as a weighted average of all voxel intensities in figure [14].

CONCLUSION

Based on the results and discussion in this study, it can be concluded that denoising Nonlocal Mean Filter (NLM) is effective in increasing anatomical information on MRI brain T2WI TSE SENSE r factor 2 axial pieces. T2WI TSE SENSE Brain MRI Image r factor 2 axial pieces applying NLM denoising techniques produce more optimal image information than before the application of NLM denoising techniques.

RECOMMENDATION

Non-local Means Filter (NLM) denoising technique efficiently preserves texture. This denoising uses the redundancy of information contained in the image to eliminate noise. The stored voxel intensity value is calculated as a weighted average of all voxel intensities in the image. Denoising is commonly used to reduce noise in MRI images. In the application of clinical practice, the NLM denoising technique requires precision, accuracy and sensitivity tests and appearance enhancements to facilitate both radiologists and radiographers in carrying out the image reconstruction program.

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How to cite this article: Shelly Angella, Ari Suwondo, Rini Indrati. Application of denoising non-local mean filter (NLM) in mri brain image T2WI TSE sense. Int J of Allied Med Sci and Clin Res 2019; 7(3): 1033-1039.

Source of Support: Nil. **Conflict of Interest:** None declared.