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Denoising weighted bilateral filter and curvelet transform technique on MRI wrist joint image

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ABSTRACT

One of the disturbances in image information on the magnetic resonance imaging (MRI) wrist joint was the emergence of noise due to the acquisition process of the use of radiofrequency (RF) coil instruments, so that a denoising technique was needed. Denoising weighted bilateral filter and curvelet transform (WBFCT) technique was applied to coronal image of MRI wrist joint T2 turbo spin echo (TSE) fat suppression (FS) spectral attenuated inversion recovery (SPAIR) sequences to analyze differences in image information between before and after denoising WBFCT on image of the sequence.

This study was a comparative analytical with a quasi-experimental pretest posttest without control group design. The study used 16 volunteers with qualitative image evaluation used 3 radiologists with statistical data analysis and quantitatively used mean square error (MSE) and peak signal to noise ratio (PSNR) values as a result of post processing images.

Information on the coronal MRI wrist joint image T2 TSE FS SPAIR sequence has different image information between before and after denoising WBFCT (p-value <0.001), with a mean of MSE 387,995 and PSNR 70,5369 decibel (dB), respectively, after a denoising image WBFCT had more optimal image information than before denoising WBFCT.

Denoising WBFCT can produce information on the coronal MRI wrist joint image T2 TSE FS SPAIR sequences optimally.

Keywords: Denoising WBFCT, MRI Wrist joint, T2 TSE SPAIR.

INTRODUCTION

In checking the MRI wrist joint, it is necessary to pay attention to the RF coil that is used to produce optimal image information. In philips, MRI wrist joint uses an 8 channel volume coil with a small coil arrangement placed close to the anatomy to produce a low SNR compared to surface coil and non-uniform reception sensitivity [1]. The sensitivity of receiving the coil system to the MRI signal has a direct impact on image SNR. The volume sensitivity of the coil also plays an important role in the sensitivity of reception. The ideal placement for body part of interest is the isocenter scanner where the best place in terms of magnetic field homogeneity and gradient uniformity. This is a challenge in imaging the wrist joint. Placement of a wrist joint on an isocenter requires the position of the prone with the arm above the head or commonly called the "superman" position. This position allows the anatomy away from the isocenter and high-quality imaging with fat suppression techniques becomes difficult [2].

Wrist joint examination is one of the musculoskeletal examinations with an 8 channel coil that can produce a higher noise image compared to other anatomical examinations [1]. Generally in most MRI applications, coils are associated with noise images dominated by "body noise", which arises from random electrical fluctuations in the body [3]. Noise on MRI images appears during acquisition, storage and transmission and is based on the number of coils in the imaging system [4, 6]. Adjusting the anatomy of the wrist joint to the smaller coil size produces significant noise compared to the larger coil size [2]. Hardware such as acquisition of array coils, coil gradients, homogeneity and patient-based fields such as physiological noise including body movements, heart rate or breathing movements is one of the main sources of the emergence of noise [5]. This noise can certainly interfere with the visual quality of the MRI image produced.

The visual quality of MRI images plays an important role in the accuracy of radiologists in diagnosing clinical patients but can be seriously degraded by the appearance of noise during the image acquisition process [7]. In clinical practice, radiologists assess images to be less optimal in the presence of noise. The appearance of noise in the form of punctate, mottled, black and white on MRI images causes reduced contrast. Noise also causes the pixel intensity value does not reflect the actual pixel intensity value. Besides that noise can also influence in image processing and analysis such as registration, segmentation, classification and visualization thereby reducing the visibility of features or important information in the image [4, 5]. Therefore noise or denoising reduction is needed in medical image processing [6, 8, 11].

Denoising images has an important role in processing MRI images before the image is analyzed by a radiologist. The denoising process aims to obtain MRI image results that are more detailed and remove noise contained in the MRI image while maintaining important information [12]. Indicators in the assessment of images with the application of denoising are MSE and PSNR to measure the similarity of images denoising the original image [10]. Noise reduction techniques are categorized into two groups, namely the acquisition-based method of noise reduction and denoising post image acquisition. Noise-based acquisition method has limitations in terms of acquisition time related to patient comfort, so that denoising post image acquisition is an effective and inexpensive alternative choice [7].

The denoising method of post image acquisition is categorized based on the filter approach, transform approach and statistical approach. One of denoising technique based on filter and transform approaches is bilateral filter and curvelet transform [7]. Denoising MRI with bilateral filters is done on smoothed images while the edges are maintained [7], causing noise bias to be removed and original information restored and making this filter high quality and real time for medical images [13]. While the curvelet transform method has direction and anisotropy to represent the direction of the edges in the image, besides that the frame element of the transform method is indexed based on scale, position and orientation parameters [7]. The medical imaging technique of hybrid denoising multimodality with curvelet transform can eliminate noise coefficients without reducing structural and morphological information and proven to be efficient and reliable in removing all types of noise in medical imaging [14].

New denoising techniques have been developed by Routray et al [15], which in the research combined bilateral filter and curvelet transform techniques. This technique is called WBFCT. The WBFCT technique maintains edges and textures based on combinations, where deciphering images that are sound to low and high frequency sections using bilateral weighted filters and high frequency parts is processed with curvelet hard shrinkage. The WBFCT technique has the advantage of being able to maintain the curvelet transformation texture. This WBFCT technique also outperforms other image denoising methods with high PSNR parameter values. This technique needs to be applied in medical images such as in MRI images specifically to improve image quality.

METHOD

Type and Design of Research

This research is comparative analytic with quasi experiment using Pretest Posttest Without Control Group Design [16]. The study was conducted on the coronal MRI wrist joint images T2 TSE FS SPAIR sequences with examination parameters time echo (TE) 60ms, slice thickness 3mm, number of excitation (NEX) 2, slice number 20, field of view (FOV) 115 and matrix 512x512.

Population and Samples

The population of this study was healthy volunteers without pathologists who were willing to take part in the study at Premier Bintaro Hospital with a sample size 16 consisting of 7 men and 9 women who had MRI wrist joint scanning coronal of T2 TSE FS SPAIR sequences.

DATA ANALYSIS

Qualitative Analysis

Qualitative data analysis information of coronal MRI wrist joint image T2 TSE FS SPAIR sequences between before and after the WBFCT denoising was carried out by three observers (radiologists) with a score 1: bad (unclear anatomy, unclear boundaries and cannot be analyzed)), score 2: fair (the anatomy is quite clear, the boundary is quite clear and can be analyzed) and the score is 3: good (clear anatomy, clear boundaries with sharp and easily analyzed structural lines). Then the conformity testing (interobserver agreement test) was conducted using the Cohen's Kappa Test at "good agreement" level, followed by a bivariate test using the Wilcoxon Test both as a whole and per anatomical criteria. Conclusion, hypothesis is accepted if p-value <0.05, which means there is a difference in information on the coronal MRI wrist joint image T2 TSE FS SPAIR sequence between before and after the WBFCT denoising technique, whereas to get the most optimal image using mean rank from results Wilcoxon Test.

Quantitative Analysis

Quantitative data analysis was carried out by calculating the value of MSE and PSNR on the coronal MRI wrist joint image T2 TSE FS SPAIR sequence between before and after denoising WBFCT. The MSE value is close to zero and PSNR is more than 40dB, which means that the denoising WBFCT image reconstruction results in high image quality.

RESULTS

Qualitative Analysis

Assessment of differences information image on the coronal MRI wrist joint T2 TSE FS SPAIR sequences between before and after the WBFCT denoising technique qualitatively carried out by visual grading by observer (radiologist) with the following distribution.

Table 1. Distribution assessment scores of coronal MRI wrist joint image T2 TSE FS SPAIR sequence between before and after WBFCT denoising technique

Score	Anatomical Criteria											
	Cartilage		Bone Marrow		Muscle		Ligament		Joint Space		Liquid	
	Pre WBFCT	Post WBFCT	Pre WBFCT	Post WBFCT	Pre WBFCT	Post WBFCT	Pre WBFCT	Post WBFCT	Pre WBFCT	Post WBFCT	Pre WBFCT	Post WBFCT
1	25%	0	12,5%	0	6,25%	0	6,25%	0	0	0	0	0
2	75%	87,5%	75%	18,75%	81,25%	50%	81,25%	62,5%	43.75%	6,25%	37,5%	12,5%
3	0	12,5%	12,5%	81,25%	12,5%	50%	12,5%	37,5%	56,25%	93,75	62,5%	87,5%

Note : Score 1 : Bad, Score 2 : Fair, Score 3 : Good

From table 1 above shows the tendency of a score of 3 (good) to dominate the image after the denoising WBFCT technique compared to before the WBFCT denoising technique

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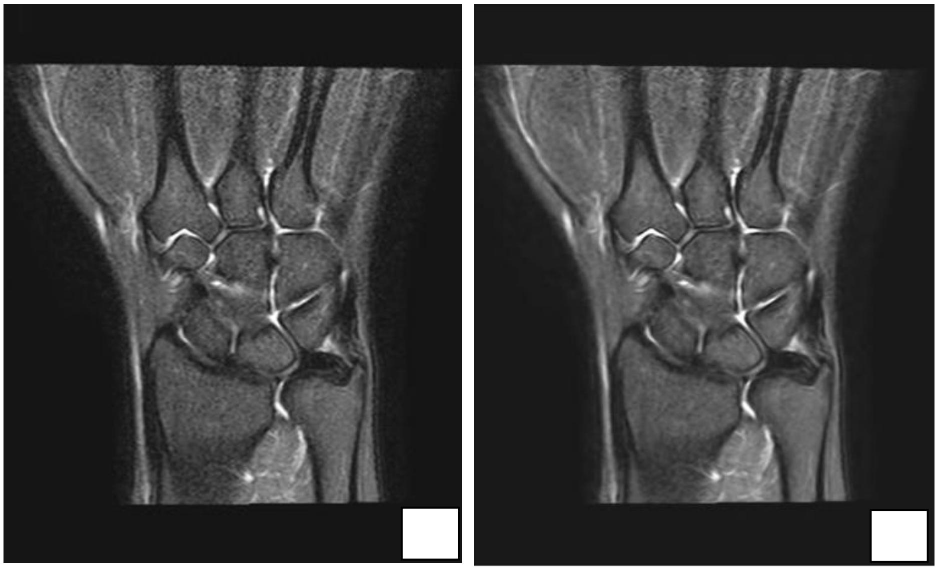

Figure 1. The results of the coronal MRI wrist joint image T2 TSE FS SPAIR sequence, A) before the WBFCT denoising technique appeared noise in the anatomy and B) after the WBFCT denoising technique appeared to reduce the noise in the anatomy with a bolder and clearer appearance of the boundary and image structure

Assessment of image information on the coronal MRI wrist joint T2 TSE FS SPAIR sequences between before and after the WBFCT denoising technique was carried out by the Wilcoxon test, the results of statistical tests as in Table 2 below.

Table 2. Wilcoxon test results on the coronal MRI wrist joint image T2 TSE FS SPAIR between before and after the WBFCT denoising technique

No	Anatomical Criteria	MRI wrist joint image	Mean rank	Significancy (p-value)	
				Per anatomical criteria	Overall
1	Cartilage	Before denoising WBFCT	0,00	0,014	<0,001
		After denoising WBFCT	3,00		
2	Bone marrow	Before denoising WBFCT	0,00	<0,001	
		After denoising WBFCT	7,00		
3	Muscle	Before denoising WBFCT	0,00	0,008	
		After denoising WBFCT	4,00		
4	Ligament	Before denoising WBFCT	0,00	0,025	
		After denoising WBFCT	3,00		
5	Joint space	Before denoising WBFCT	0,00	0,014	
		After denoising WBFCT	3,50		
6	Liquid	Before denoising WBFCT	0,00	0,046	
		After denoising WBFCT	2,50		

From table 2 above shows both overall and per anatomy there are differences in information on the coronal MRI wrist joint images T2 TSE FS SPAIR sequences between before and after the WBFCT denoising technique. Image information after the WBFCT denoising technique has more optimal image information with the highest mean rank compared to before the denoising WBFCT technique for each anatomy.

Quantitative Analysis

While quantitative image evaluation is done by calculating the value of MSE and PSNR. The following are the results of calculations as in Table 3 below

Table 3. Results of calculation of MSE and PSNR on MRI wrist joint images of T2 TSE FS SPAIR sequences of images before and after WBFCT denoising techniques were performed

Voluntir	MSE	PSNR (dB)
1	435,605	69,9387
2	396,507	70,3471
3	455,836	69,7415
4	363,491	70,7247
5	359,161	70,7767
6	216,176	72,9815
7	247,056	72,4016
8	370,551	70,6411
9	377,035	70,5658
10	355,174	70,8252
11	490,192	69,4259
12	451,425	69,7837
13	347,199	70,9238
14	417,162	70,1265
15	496,282	69,3723
16	429,069	70,0043
Average	387,995	70,5369

From table 3 above, it can be seen that the results of the MSE and PSNR images before and after the WBFCT denoising technique each had an average value of 387,995 and 70,5369 dB. The PSNR calculation results are above 40 dB.

DISCUSSION

The WBFCT technique is applied to the coronal MRI wrist joint image T2 TSE FS SPAIR sequences. Differences in image information from both images both before and after the denoising WBFCT technique were carried out, both overall and per anatomical criteria because the visual quality of the images was significantly different. This can happen because in the image before being done denoising WBFCT, there is noise due to the MRI image acquisition process itself. Noise on MRI can arise as a result of image acquisition and transmission errors [8]. MRI images obtained are susceptible to the emergence of Gaussian noise which has a significant effect on image quality, so that the image quality tends to decrease [8] and causes a reduction in contrast, detail and image information [5]. The process of image acquisition of the MRI wrist joint T2 TSE FS SPAIR sequence is very closely related to the MRI hardware instrument used, namely the RF coil [5]. Coil on MRI wrist joint examination with 8 channel volume coil type, having small coil arrangement placed close to anatomy will produce low SNR compared to surface coil and non-uniform reception sensitivity [1]. The sensitivity of receiving the coil system to the MRI signal has a direct impact on image SNR. The volume sensitivity of the coil also plays an important role in the sensitivity of reception. The ideal placement for body part of interest is in the isocenter scanner where it is the best place for magnetic field homogeneity and gradient uniformity [2].

The use of volume coils is a challenge in imaging the wrist joint. Placement of a wrist joint on an isocenter requires the position of the prone with the arm above the head or commonly called the "superman" position. This position allows the anatomy to be far from the isocenter and is prone to produce low quality images [2]. Mohan et al (2014) study states that MRI images obtained by using coils with parallel channel systems (multiple channel coils) cause very non-homogeneous noise, where the signal obtained in K-space becomes damaged in the presence of complex Gaussian additive noise [7]. Meanwhile the use of MRI instruments on the surface coil causes noise to decrease, but at coil volume causes noise to increase in the anatomic area, where the smaller the number of coil channels, the smaller the SNR value [3]. This certainly greatly affects the quality of the image of the MRI wrist joint which uses a volume coil RF type.

Whereas in the image after processing image reconstruction using the denoising WBFCT technique, there is reduced noise in the MRI wrist joint image T2 TSE FS SPAIR sequence. This is in line with the PSNR value obtained which is more than 40dB which causes the information on the MRI anatomy image of the wrist joint to be good with a clear anatomical appearance, clear structure with firm boundaries and easily analyzed by radiology specialists. In addition to the visual evaluation of radiologist, the evaluation of denoising WBFCT image processing performance is done by looking at the value of MSE and PSNR for error sensitivity or image quality assessment measures. The lower the MSE value, the better the image produced, while the higher the PSNR value, the better image reconstruction [8]. PSNR values fall below 30 dB indicating relatively low image quality, which is due to insertion clearly visible. However, the image quality is said to be high when the PSNR is in the value> 40 dB.

Based on the calculation of MSE and PSNR for both images, it shows an error value (MSE) of low or near zero in the range of 200 and a high PSNR value which is in the range of 72dB or more than 40dB. The results of the MSE and PSNR calculations in this study were more optimal than in the previous study where applying denoising Gaussian in the MRI brain T2 sequence sequence TSE image with the same bit (512x512), obtained the average MSE value of 2100 while for the PSNR value with a range of 38dB [8], and also more optimal than in other previous studies with the application of denoising WBFCT to grayscale images, that the image after WBFCT denoising reconstruction results in an average PSNR value of 30dB [15]. This means that the value of MSE and PSNR in that image reconstruction with denoising WBFCT on the coronal MRI wrist joint image T2 TSE FS SPAIR has produced high quality and more optimal images compared to the image before the WBFCT denoising technique was carried out. both overall and per anatomical criteria (see Figure 1).

The difference in the assessment of image information both qualitatively and quantitatively between before and after WBFCT on the MRI wrist joint images both as a whole and per anatomical criteria, is due to the process of reconstructing denoising WBFCT which can reduce overall noise. The denoising WBFCT technique has the advantage of combining weighted bilateral filters (WBF) and curvelet transform. WBF decomposes the noise input area into a low frequency part (most image information) and high (edge details and textures), aiming to filter noise and maintain image detail at high frequencies. Curvelet transform (hard shrinkage) processes in high frequency areas to maintain geometric (edge / texture) and image detail. Then a combination of high frequencies and low frequencies is carried out, so that the WBFCT can emphasize the texture and artifacts of the image by eliminating noise efficiently and in detail as well as more detailed geomterics [15].

The use of image processing in imaging modalities is an important part in efforts to improve, especially the reduction of the effects of noise in the image. From this study it was found that a new denoising image processing method was tried to be applied to the coronal MRI wrist joint image T2 TSE FS SPAIR, namely the WBFCT denoising technique. This technique can efficiently maintain texture, suppress artifacts and eliminate noise in the image. The use of this technique can improve image quality and can be used generally in other sequences and organs of MRI examination and specifically on other musculoskeletal MRI with the application of SPAIR fat suppression techniques. In addition, the Denoising WBFCT image processing technique can be used and carried out in other special medical imaging fields such as Ultrasonography (USG) and CT Scan images by running programs that have been created and duplicated into the computer's imaging modality.

The limitations of this study using denoising WBFCT can reduce noise in wrist joint voluntary MRI images without pathology, but have not been applied to MRI images that have a clinical history (with pathology) of both wrist joints and other organs and are also good in T2 TSE sequences or other sequences. Meanwhile on the implementation of clinical practice, the WBFCT denoising technique cannot be applied directly because there has never been a test of precision, accuracy and sensitivity and refinement of the display so that it can facilitate both radiologists and radiographers in carrying out the WBFCT image reconstruction program.

CONCLUSION

Based on the results and discussion in this study, it can be stated that the application of the WBFCT denoising technique on the coronal MRI wrist joint image T2 TSE FS SPAIR causes differences in image information compared to the prior application of the denoising technique WBFCT, where is the coronal MRI image wrist joint T2 TSE FS SPAIR sequence that apply the WBFCT denoising technique produce more optimal image information than before applying the WBFCT denoising technique.

RECOMMENDATION

The WBFCT denoising technique efficiently maintains texture, suppresses artifacts and removes noise in the image and can improve the quality and image information should be used in sequences that generate a lot of noise such as Gradient Echo (GRE) and other MRI examination organs from pathological people. Meanwhile denoising WBFCT image processing techniques can be used in other special medical imaging fields such as Ultrasonography (USG) and CT Scan images by running programs that have been created and duplicated into the computer's imaging modality. In the application of clinical practice, the WBFCT denoising technique requires a test of precision, accuracy and sensitivity as well as improvement in appearance so that it can facilitate both radiologists and radiographers in carrying out the image reconstruction program.

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