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Qualitative and Quantitative Image Analysis of MRCP Imaging in T2 SS-FSE and T2* FIESTA Fat Saturation

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ABSTRACT

The T2 weighted imaging of coronal MRCP can used a sequence derived from spin echo is the SS-FSE sequence and the gradient echo fast imaging is FIESTA. SS-FSE can be done with the fat saturation technique to suppress the fat signal so that it will be hypointense. The use of the breath-hold technique can also be used in both sequences. This study was to compared the differences in coronal MRCP image information between SS-FSE and FIESTA fat saturation to evaluate their ability to depict the image quality of MRCP. 15 patients performed 2D T2 SS-FSE and FIESTA fat saturation coronal MRCP. The images analyzed by qualitative study that was carried out by MRCP questionnaire which was examined by radiologist. Quantitative analysis was conducted by measuring the signal-to-noise ratio (SNR) values. The result is the FIESTA fat saturation sequence shows better image information and more optimized SNR than the SS-FSE on coronal MRCP because it can reveal more clear and informative anatomy such as common bile duct, pancreatic duct, cystic duct and intrahepatic duct. Finally, FIESTA fat saturation can be used as a effective alternative sequence and can improve billiary system of MRCP image quality

INTRODUCTION

Along with the development of technology in the field of radiodiagnostic imaging, Magnetic Resonance Imaging (MRI) modalities provide noninvasive anatomical and physiological information. MRI applies pulses and gradients to the system so that a weight is formed for the desired image in displaying the organs of the body. Sequence pulses in the MRI modality will display different types of tissue to differentiate anatomy and pathology in the image. These differences were controlled by using the weighted values of T1, T2, and proton density (Westbrook et al., 2011). MRI results in addition to being diagnostic evidence, can also help determine management and show the patient's prognosis (Kuperman, 2000).

An MRI examination that can be used to support the diagnosis of abnormalities in the biliary system is MRCP (magnetic resonance cholangiopancreatography) examination. In addition to MRCP, it can also be done by examination of ERCP (endoscopic retrograde cholangio-pancreatography), CT-scan, surgery or ultrasound (ultrasonography). However, the MRI modality is still the gold standard for the main diagnostic examination in showing soft tissues (Frisch et al., 2017).

MRCP has been shown to have a number of advantages with a wide range of clinical applications and accurate techniques in non-invasive imaging of the biliary system compared to ERCP which is the reference standard for imaging the pancreatic and bile ducts. MRCP has a relatively high reported sensitivity and specificity, similar to ERCP, for assessing the extent and morphology of biliary strictures. MRCP examination has a sensitivity of 96%, specificity of 86% and accuracy of 90% in determining bile duct obstruction, while in detecting choledocholithiasis, MRCP examination has a sensitivity of 86%, specificity of 90% and accuracy of 89%(Pressacco et al., 2003). In the diagnosis of soft tissue disease, MRCP is 100% sensitive compared to ultrasound (80.77%), which is more sensitive than CT scan (54.55%), so MRCP is an important non-invasive imaging modality in the preoperative evaluation of patients with obstructive jaundice (Singh et al., 2014).

Selection of the right pulse sequence is needed to display complex organs such as the abdomen. One of the MRI examinations of the abdomen is MRCP (magnetic resonance cholangiopancreatography). MRCP is a non-invasive imaging test, which is used for the evaluation of the biliary tract, pancreatic duct, and gallbladder. Basically, MRCP examination with T2-weighted sequences captures high-intensity signals from body fluids, relatively stationary or slow-moving fluids that fill in the lumen such as the pancreatic ducts and other biliary ducts appear hyperintense, surrounding tissue and blood flow of low signal intensity are seen black (Vitellas et al., 2000). MRCP imaging is used in axial, coronal, and 3D formats to show the liver, gallbladder, bile ducts, and pancreas. The use of coronal slices to identify to assess the condition of the common bile duct, cystic duct, hepatic duct, gallbladder and pathological conditions that occur in the ampulla (Safitri, 2017).

Sequence pulses that can be used to visualize organs on MRCP on T2 weighted imaging coronal slices are using a derivative sequence from spin echo (SE), namely the SS-FSE sequence (single-shot fast spin echo) or a derivative from gradient echo (GRE), namely FIESTA (fast imaging employing steady state acquisition). FIESTA sequences can be performed using fat saturation (fat sat) which is a technique to suppress fat signals so that the fat image will be black (hypointense). In addition, the use of the breath-hold technique can also be used in both sequences (Safitri, 2017).

SS-FSE or HASTE (half fourier transform single-shot turbo spin echo), MRI techniques for fast spin echo acquisition with faster scan times. The basic technique is to fill in incomplete k-space or MR data (partial Fourier technique). Half of the k-space filling is filled in one RF excitation or called "single-shot" (Naraghi & White, 2012). It is used to fill the k-space space in forming MR images with long ETL in a very fast manner. SS-FSE can be performed using the breath-hold technique. Some of the advantages of SS-FSE are very fast MR acquisition time, are not sensitive to movement, reduce artifacts due to movement and are good for applications that require long TE times such as MR myelography, MR urography, and MRCP. The lack of a blurry resulting image (quite blurry) is a result of the T2 filtering effect due to the large number of RF pulses (Elmaoglu and Celik, 2012).

FIESTA or balanced fast field echo (balanced-FFE), a steady-state coherent sequence with balanced gradients is used along all three axes. "Balanced" means that the gradient-induced dephasing during the TR interval is zero. In FIESTA, the balanced gradient refocuses both components at the exact center of the TR interval as a single echo. FIESTA sequences have a very high degree of magnetic field homogeneity and control over switching and gradient generation. The FIESTA application produces a bright T2 / T1 signal, TR is chosen to be as short as possible, TE = TR/2, and the flip angle (α) is set in the medium to high range (50°-80°) (Elster, 2017). The benefit of FIESTA sequences is that they have a short TR so that the imaging time is shorter. With short TR and TE, all tissues with a relaxation T2 time will demonstrate increased signal due to various refocused echo paths. In addition, FIESTA sequences include the highest possible signal-to-noise ratio (SNR), allowing to study physiological processes using breath-hold acquisition, speed in reducing movement artifacts, such as respiration and peristalsis (Chavhan et al., 2008).

Based on the advantages of these two sequences, by comparing the T2 2D SS-FSE and T2* FIESTA fat saturation obtain an image based on the speed and optimization of image results on MRCP.

METHODS

This study implemented T2 SS-FSE sequence with TR 1200 ms; TE 93 ms; FOV 360 mm; slice thickness of 6 mm; 256 x 256 matrix; flip angle 180^0 inspection parameters and used breath hold techniques. And T2* FIESTA sequence with TR 3.7 ms; TE 1.8 ms; FOV 360 mm; slice thickness of 6 mm; 256 x 256 matrix; flip angle 57^0 inspection parameters and used breath hold and fat saturation techniques.

The number of samples were 15 patients, who underwent an MRCP with standard preparation for each fasting 6 hours before the examination. Followed by MRCP examination, on coronal T2 slices, scanned T2 SS-FSE and T2* FIESTA fat saturation sequence with respiration control breath hold.

The qualitative assessment of MRCP image was carried out through a questionnaire which was examined by three radiology specialists, and the data of the image assessment results were analyzed using the Wilcoxon Signed Rank test. Questionnaires on the anatomy of the biliary system include gallbladder, cystic duct, common bile duct, intrahepatic duct, and as well as was evaluation of artifacts done by the following Likert scale:

Table 1. The Evaluation Standard of Visibility of Billiary System and Artifact

Biliary System	Artifact
scale 3 = good (image with clear quality means that the image information is firm, clear, bright, not blurry); scale 2 = sufficient (an image with fairly clear image information, meaning that it is visible but the boundary is not clear, must be observed carefully); scale 1 = poor (image with less clear quality, meaning if the assessed image is visible, but the boundary is not clear, blurry, difficult to observe).	scale 3 = good (no visible artifacts in the image); scale 2 = sufficient (artifacts appear but do not interfere with the image, meaning that the anatomical image assessment is not disturbed even though there are artifacts around it); scale 1 = poor (the artifact interferes with the diagnosis of the image, it means that the artifact interferes with the anatomical image assessment).

Quantitative image assessment was conducted by calculating the anatomical SNR value by the formula as follows:

$$SNR_{standard} = \frac{\text{average signal of the organ}}{\text{standard deviation of noise}} \quad (1)$$

The area of anatomical ROI and background noise was 1 cm^2, while the ROI of the bile duct corresponded to the size of the duct. Then, the SNR values of the gallbladder, cystic duct, common bile duct and intrahepatic duct were calculated. The image assessment data were analyzed through Paired T-test.

RESULTS AND DISCUSSION

Describe your research findings according to the research problem and purpose of the study. Discuss your findings according to the perspective of theory, concept or previous findings. Should describe this section in a comprehensive, simple and detailed manner. The author can make subchapters in this section.

The results of the MRCP examination images from each volunteer were taken 20 slices from each sequence, both T2WI SS-FSE sequences and FIESTA fat saturation. From the 20 slices, anatomical criteria of the gallbladder, common bile duct (CBD), pancreatic duct, cystic duct and intrahepatic duct were shown, and artifacts were assessed.

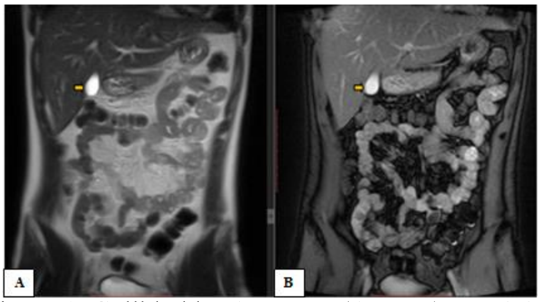

Figure 1. Gallbladder Anatomy (Arrows) on T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

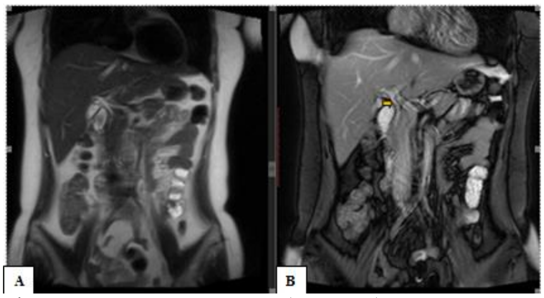

Figure 2. CBD Anatomy (Arrows) on T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

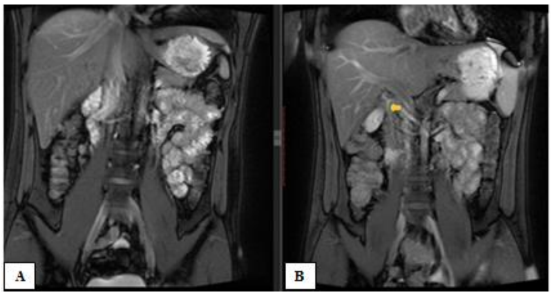

Figure 3. Pancreatic Duct Anatomy (Arrows) on T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

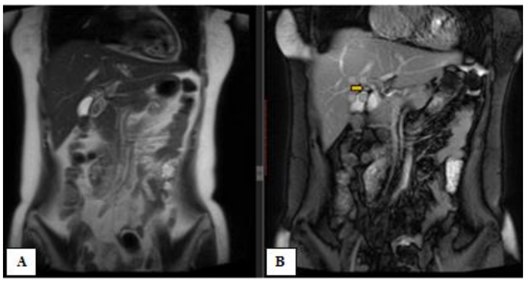

Figure 4. Cystic Duct Anatomy (Arrows) on T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

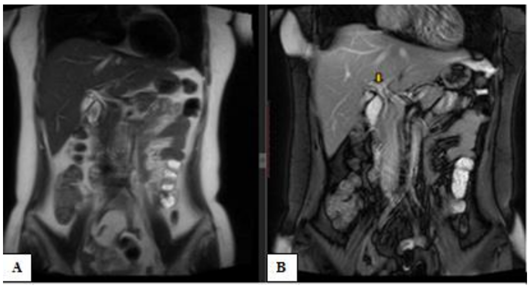

Figure 5. Intrahepatic Duct Anatomy (Arrows) on T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

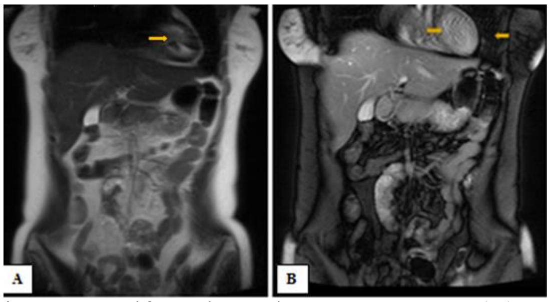

Figure 6. Artifact Shown in T2 2D SS-FSE (A) and T2* 2D FIESTA Fat Saturation (B)

In the qualitative study used wilcoxon signed rank test on 15 patients on the criteria of gallbladder, common bile duct (CBD), pancreatic duct, cystic duct and intrahepatic duct and artifacts between T2 SS-FSE sequences and FIESTA fat saturation.

Table 2. Comparison Interobserver Grading of MRCP Images Implemented Wilcoxon Signed Rank Test

Criteria	Sequence	Mean rank	p-value
GB	SS-FSE	2,00	0,257[a]
	FIESTA FATSAT	2,67	
CBD	SS-FSE	0,00	0,003
	FIESTA FATSAT	5,00	
PD	SS-FSE	0,00	0,003
	FIESTA FATSAT	5,00	
CD	SS-FSE	0,00	0,034
	FIESTA FATSAT	3,00	
IHD	SS-FSE	0,00	0,008
	FIESTA FATSAT	4,00	
Artifact	SS-FSE	2,00	0,257[a]
	FIESTA FATSAT	2,67	

[a] = $p > 0.05$, there was not a significant difference between T2 2D SS-FSE and FIESTA fat saturation

The following were the results of image quality in the SNR as the quantitative assesment. The anatomy were calculated, the results are as shown in Table 3:

Table 3. Comparison of SNR Values to MRCP Images by Paired T-test

Criteria	Sequence	Mean±SD	p-value
GB	SS-FSE	244,14±6,93	0,208[a]
	FIESTA FATSAT	233,69±6,85	
CBD	SS-FSE	40,12±1,64	0,004
	FIESTA FATSAT	59,33±2,46	
PD	SS-FSE	33,93±9,65	0,076
	FIESTA FATSAT	53,22±9,91	
CD	SS-FSE	47,87±1,59	0,014
	FIESTA FATSAT	54,92±6,32	
IHD	SS-FSE	41,71±6,82	0,001
	FIESTA FATSAT	64,76±6,44	

[a] = $p > 0.05$, there was not a significant difference between T2 2D SS-FSE and FIESTA fat saturation

The difference between T2 2D SS-FSE and T2* FIESTA fat saturation is because each sequence has advantages and disadvantages. In this study, each sequence has different parameter characteristics, such as time repetition (TR), time echo (TE) and acquisition time to get a good image for each sequence, in this case the T2 weighted imaging coronal slice. The TE value used in the T2 2D SS-FSE sequence is 93 seconds while the TE value for the T2* 2D FIESTA fat saturation sequence is only 1.8 seconds. Determination of the use of the right TE value will affect the resulting image weighting results, this is in accordance with Westbrook et al (2011) stated that the use of a longer TE gives a longer T2 decay time in water to maintain transverse coherence and the value of TE = TR/2 will make the refocusing on the T2* FIESTA sequence almost perfect on the transverse magnetization.

In the T2 2D SS-FSE and T2* FIESTA fat saturation sequence images, the coronal section of the MRCP examination has high contrast. However, the time required for T2 SS-FSE is longer than T2* T2* FIESTA fat saturation, namely T2 SS-FSE takes 48 seconds while T2* T2* FIESTA fat saturation only takes 19 seconds. In T2 SS-FSE sequences using single shot and half fourier acquisition and using echo train length (ETL) as much as 130, ETL is used to reduce scan time and fill K space faster, while in T2* FIESTA fat saturation sequences using a flip angle of 57^0 , so the scan time is shorter and transverse decay is faster than the T2 SS-FSE sequence. The use of a single shot and several lines of K space can be fulfilled by the presence of a turbo factor or ETL so that the K space will be fully filled faster so that the fulfillment of K space can improve image quality on T2 (Westbrook et al., 2011). Using a flip angle on T2* FIESTA fat saturation sequences causes faster rephase than RF 180^0 and shorter TE than spin echo sequences and TR can be reduced. The T2WI SS-FSE sequence has a good signal to noise ratio (SNR), but is insensitive to movement. While the T2* FIESTA fat saturation sequence is a sequence that has a fairly good SNR but is sensitive to organ movement.

Better image information on coronal section MRCP examination between T2 2D SS-FSE and T2* FIESTA fat saturation sequences was obtained from the results of the mean rank value in the Wilcoxon signed rank test per image information criteria. From these results, GB is stated that the T2* FIESTA fat saturation sequence is superior, but the difference in value between the two sequences is relatively small. According to the authors, the relative value percentage did not differ significantly in the T2 2D SS-FSE and T2* FIESTA fat saturation sequences because the signal intensity at the T2 weighting in both sequences produced hyperintense gallbladder images. In the T2 SS-FSE sequence using a long TE parameter that increases the signal intensity in the image, as well as in the T2* FIESTA fat saturation sequence, the presence of fat suppression in the sequence produces good image contrast so that it displays a bright homogeneous anatomical image of the gallbladder. According to Andrea et al (2016), the SS-FSE sequence has a longer TE acquisition compared to FSE resulting in lower SNR and CNR. According to Westbrook et al (2011), at T2 weighting, the liquid appears lighter and is controlled by a long TE thus giving the water a longer T2 decay time to maintain most of the transverse coherence.

T2* FIESTA produce a complex blend of image contrasts exclusively so that the liquid appears homogeneously bright and allows for a good organ image (Moeller & Reif, 2003). The T2* FIESTA sequences have efficient SNR and thus high spatial resolution images can be obtained and the image results are sharp, including short TR and consequent short acquisition times on T2 weighting (Pezeshk et al., 2017). Fat saturation is a selectivity technique for fat optimizing contrast visualization, enhancing T2-weighted images and tissue characterization (Grande et al., 2014).

On the anatomical criteria of CBD, pancreatic duct, cystic duct and intrahepatic duct, the Wilcoxon test results showed that the mean rank value of the T2* FIESTA fat saturation sequence was higher than T2 SS-FSE. This is due to differences in sensitivity levels and differences in parameter characteristics in each sequence. The T2* FIESTA fat saturation is more able to show the anatomical image of the biliary ducts with better signal, clearer contrast and tissue detail than the T2 SS-FSE sequence. T2* FIESTA have a short acquisition time and high anatomical sensitivity in images so that they can visualize parenchymal organs and ductal structures in the biliary system well. T2* FIESTA are increasingly being integrated, leading to imaging protocols and pathological characterization of the abdomen. According to Westbrook et al (2011), the use of fat saturation can increase the contrast in the T2-weighted tissue and especially the anatomical characteristics of the tissue and increase the SNR. Fat saturation also avoids chemical shift misregistration artifacts. Meanwhile, in the SS-FSE sequence, Andrea et al (2016) stated that the SS-FSE sequence had a long enough TE resulting in lower SNR and CNR and a decrease in anatomical consistency due to the effect of transfer magnification and artefact blurring during the encoding phase.

In addition to anatomical assessment, artifact assessment is also very important in image quality analysis. The T2* FIESTA fat saturation sequence has fewer artifacts than SS-FSE, but there is relatively no significant difference in the SS-FSE and T2*WI FIESTA fat saturation sequences due to the different characteristics of the parameters in the two sequences and the ability to breath hold in each. We can't control the patient properly so that sometimes it causes artifacts in the image. In MRCP images, coronal slices of T2* FIESTA fat saturation sequences sometimes cause ghosting artifacts in the resulting image, while in T2 SS-FSE sequence images sometimes blurring artifacts appear. According to Andrea et al (2016), a longer TE than SS-FSE can result in lower SNR and CNR and decreased anatomical consistency due to the transfer magnification effect and artifact blurring throughout the encoding phase.

T2* FIESTA sequence images are very sensitive to in-homogeneities in magnetic fields. This may cause the image to contain interference lines. These sequences are also highly susceptible to chemical shift artifacts (Bushong, 2017). In T2* FIESTA images, ghosting artifacts are produced because this sequence uses short TR and TE parameters and is mainly a result of organ movement and breathing. However, this sequence with the use of fat saturation has an advantage, Pezeshk et al., (2017) in his Journal states that the fat saturation technique can help remove pulsatile artifacts in the bile ducts that are sometimes seen in SS-FSE sequences. In the T2 SS-FSE image, the longer the TE, the higher the signal loss. This causes the appearance of blurring artifacts in the T2 SS-FSE image. SS-FSE sequences have the ability to reduce motion artifacts where the use of partial fourier acquisition in K-Space filling will reduce the gradient moment in the encoding frequency direction.

CONCLUSION

Coronal slice MRCP examination image information between T2 2D SS-FSE and FIESTA fat saturation sequences are different due to parameter characteristics between the two sequences. FIESTA fat saturation visualizes anatomy in the biliary system sharper and better contrast than T2 SS-FSE sequences on the coronal section. In addition, in terms of the possibility of the occurrence of artifacts, the two sequences tend to be quite good and the artifacts that appear do not interfere with the anatomical image. In the T2 2D SS-FSE, it has a longer TE so that it has decreased consistency due to the effects of transfer magnetization and blurring of artifacts during the encoding phase and results in a lower SNR than T2* FIESTA. The FIESTA fat saturation can be used as a effective alternative sequence and can improve billiary system of MRCP image quality.

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