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Original Paper

Enhanced 3D Magnetic Resonance Cholangiopancreatography with Fast Gradient and Spin Echo Sequence: Technical Advancements and Clinical Implications

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Abstract

Objective: *The application of fast gradient and spin echo (GRASE) sequence in 3D magnetic resonance cholangiopancreatography (MRCP) was investigated.* ***Methods:*** *Sixty patients who underwent 3D MRCP examination using the Philips Ingenia 3.0T superconducting MR imaging system and a 32-channel phased array direct digital RF receiving coil in the hospital from June 2021 to June 2023 were selected. The acquisition times of the two sequences were compared, and the scanned images of the two sequences were subjectively and objectively evaluated, with the scanning sequence including turbo spin echo (TSE) sequence and GRASE sequence.* ***Results:*** *The display scores, image artifact scores, and overall image quality scores of the GRASE sequence on the common bile duct, gallbladder duct, main pancreatic duct, left and right hepatic ducts were higher than those of the TSE sequence, and the differences were statistically significant (P<0.05). The acquisition time of GRASE sequence was 16 seconds, which was about 96% shorter than that of TSE sequence (399.06±84.53) seconds. The contrast to noise ratio (CNR) of the GRASE sequence was higher than that of the TSE sequence, and the difference was statistically significant (P < 0.05); The signal to noise ratio (SNR) of the GRASE sequence was slightly higher than that of the TSE sequence, but the difference was not statistically significant (P > 0.05).* ***Conclusion:*** *The use of the GRASE sequence in 3D MRCP examinations can improve image quality, shorten acquisition time, and ensure CNR.*

Keywords

Magnetic resonance imaging, Magnetic resonance cholangiopancreatography, Turbo spin echo, Gradient and spin echo, Breath-hold

1. Introduction

Magnetic resonance cholangiopancreatography (MRCP) is currently the most commonly used water imaging technique in clinical practice, which is non-invasive, free from radiation damage, and highly repeatable. The main indications for MRCP include biliary stones, biliary tumors, biliary inflammation, pancreatic tumors, pancreatitis, biliary and pancreatic ductal variations, or deformities. Currently, the commonly used MRCP examination techniques in the clinic include 3D MRCP, 2D continuous thin-layer MRCP, and 2D thick-layer block projection MRCP. Among them, 3D MRCP often uses respiratory trigger or diaphragmatic navigation echo gating technology combined with fast spin echo (turbo spin echo, TSE) sequence. The above sequences all have excellent spatial resolution, but they have high requirements for the patient's breathing amplitude and rhythm, and the imaging time is long, which can easily lead to diaphragmatic drift, thereby reducing image quality. To solve the above problems, some studies have used fast gradient spin echo (gradient and spin echo, GRASE) sequence combined with breath-holding technology to collect images. GRASE sequence is a fast imaging sequence composed of TSE and echo planar imaging (EPI), which has a short acquisition time. This study mainly explores the application value of GRASE sequence in 3D MRCP, and the report is as follows.

2. Materials and Methods

2.1 General Data

Sixty patients who underwent 3D MRCP examination in our hospital from June 2021 to June 2023 were selected. Among them, there were 28 males and 32 females; aged 16 to 87 years old, with an average of (51±12) years old. This study was approved by the hospital's medical ethics committee, and all patients had been informed of the risks and precautions of magnetic resonance examination, and all had signed the informed consent form. Inclusion criteria: Patients clinically suspected of having biliary system diseases and agreeing to undergo MRCP examination. Exclusion criteria: Presence of abdominal effusion; Inability to cooperate with breath-holding.

2.2 Methods

A Philips Ingenia 3.0T superconducting MR imaging system and a 32-channel phased array direct digital RF receiving coil for 3D MRCP examination were used. Before the examination, all patients fasted for 4 to 6 hours and underwent breathing training; during the examination, the patients took a supine position, head first, hands raised to hold the head, and underwent breathing training again. The breathing gate was placed at the position with the largest breathing amplitude of the patient and properly fixed, with the subcostal margin as the center of the positioning [5].

After positioning, routine scanning of the liver, gallbladder, and pancreas was performed first, including coronal balanced turbo field echo (BTFE) sequence, axial T1WI sequence, axial fast spin echo T2WI with fat suppression technology (T2 TSE SPAIR) and windmill technique sequence, and axial diffusion-weighted imaging (DWI) sequence. After confirming the direction of the common bile duct and intrahepatic bile ducts on the T2 TSE SPAIR sequence, 3D MRCP scanning was performed using the TSE sequence, followed by breath-hold 3D MRCP scanning using the GRASE sequence. The specific scanning parameters are as follows: (1) TSE sequence: repetition time (TR) of 1104 ms, echo time (TE) of 662 ms, flip angle (FA) of 90°, matrix of 260×230, field of view (FOV) of 260×260, slice thickness of 1.6 mm, number of slices of 120, spatial resolution of 1.0 mm×1.0 mm×1.6 mm, sensitivity encoding (SENSE) acceleration factor of 2 in the phase encoding direction, SENSE of 1 in the slice direction, and echo train length (ETL) of 160; (2) GRASE sequence: TR of 322 ms, TE of 105 ms, FA of 90°, matrix of 176×138, FOV of 250×250, slice thickness of 2.4 mm, number of slices of 70, spatial resolution of 1.42 mm×1.77 mm×2.40 mm, SENSE acceleration factor of 4 in the phase encoding direction, SENSE of 1 in the slice direction, ETL of 10, and EPI factor of 7. After scanning both sequences, maximum intensity projection (MIP) images were automatically generated [6].

2.3 Image Analysis and Evaluation

2.3.1 Subjective Evaluation

The source images and reconstructed MIP images were transferred to the Philips dedicated post-processing workstation for anonymous processing and random distribution. One senior abdominal magnetic resonance diagnostic radiologist and one senior imaging technician independently and blindly evaluated the images (without providing sequence scanning parameters to the scorers), and the average score of the two evaluators was taken as the final score. The content of the subjective evaluation is as follows [7-9]: (1) Structure (including common bile duct, gallbladder duct, main pancreatic duct, left and right hepatic ducts, and common hepatic duct) display score: not displayed is 1 point; image is blurry, and the structure is unclear is 2 points; the structure is clearly displayed, but the contrast is poor is 3 points; the structure is clearly visible, and the contrast is good is 4 points. (2) Image artifact score: severe artifacts, undiagnostic is 1 point; many artifacts, but diagnostic is not affected is 2 points; few artifacts is 3 points; no artifacts is 4 points. (3) Background suppression score: background signal is strong, severely affecting diagnosis is 1 point; background signal is more, affecting image quality but not diagnosis is 2 points; background signal is less, basically not affecting diagnosis is 3 points; background signal suppression is excellent, and image quality is excellent is 4 points. (4) Overall image quality score: the image cannot be used for diagnosis is 1 point; the image quality is poor, and it can barely be used for diagnosis is 2 points; the image quality is medium, basically can be used for diagnosis is 3 points; the image quality is good, can be used for diagnosis is 4 points; the image quality is excellent is 5 points.

2.3.2 Objective Evaluation

The content of the objective evaluation is as follows: (1) Statistical acquisition time of TSE sequence and GRASE sequence. (2) The two scorers who conducted the subjective evaluation jointly measured the mean signal intensity SI_{CBD} of the common bile duct and the mean signal intensity SI_{tissue} of the surrounding tissue of the same layer of the common bile duct (if there is a different opinion, it can be negotiated until the opinion is unified), and set the region of interest (ROI) of the common bile duct ≥ 7 mm², and the surrounding tissue ROI ≥ 40 mm² when measuring; after the measurement, the contrast noise ratio (CNR) and signal-to-noise ratio (SNR) of the images were calculated [2]. The CNR was calculated as (CNR = $|SI_{CBD}-SI_{tissue}|/SD$, and the SNR was calculated as ($SNR=SI_{CBD}/SD$), where SD is the standard deviation of the background noise in the reconstructed image. Since the SD could not be calculated, the standard deviation of the signal intensity of the common bile duct was used instead.

2.4 Statistical Analysis

Data analysis was performed using SPSS 22.0 statistical software. Quantitative data were expressed as mean $\bar{x} \pm s$ standard deviation and were analyzed using paired t-tests. P-value of less than 0.05 was considered statistically significant.

3. Results

3.1 Subjective Evaluation Results

The GRASE sequence had higher scores for the display of the common bile duct, gallbladder duct, main pancreatic duct, left and right hepatic ducts, and overall image quality, as well as lower image artifact scores compared to the TSE sequence, with all differences being statistically significant (P<0.05), as shown in Table 1.

Table 1. Comparison of Subjective Evaluation Results for Two Sequences (Scores, $\bar{x} \pm s$, 60 Cases)

Scanning Sequence	Structural Display Score					Image Artifact Score	Background Suppression Score	Overall Image Quality Score
	Common Bile Duct	Cystic Duct	Main Pancreatic Duct	Left and Right Hepatic Ducts	Common Hepatic Duct			
GRASE Sequence	3.37±1.04	3.23±1.31	2.58±0.89	2.75±1.39	3.10±1.45	3.03±0.64	3.8±0.75	3.62±0.71
TSE Sequence	3.01±0.95	2.97±1.23	2.17±1.46	1.95±1.47	3.05±1.25	2.00±1.32	4.0±0.78	3.37±1.18
t	2.31	1.98	3.4	3.06	0.67	4.22	2.03	1.59
P	0.023	0.02	0.001	0.003	0.350	< 0.001	0.156	0.010

Note. GRASE denotes Gradient and Spin Echo, while TSE signifies Turbo Spin Echo.

3.2 Objective Evaluation Results

The acquisition time for the GRASE sequence was 16 seconds, approximately 96% shorter than that of the TSE sequence (399.06±84.53 seconds). The CNR of the GRASE sequence was significantly higher than that of the TSE sequence (P<0.05). The SNR of the GRASE sequence was slightly higher than that of the TSE sequence, but the difference was not statistically significant (P>0.05), as shown in Table 2.

Table 2. Comparative Objective Evaluation Results for Two Sequences ($\bar{x} \pm s$, 60 Cases)

Scanning Sequence	CNR	SNR
GRASE Sequence	16.35±1.54	18.04±1.45
TSE Sequence	13.82±1.98	17.90±1.90
t	3.45	0.21
P	0.002	0.838

Note. GRASE stands for Fast Gradient Echo, TSE stands for Turbo Spin Echo, CNR stands for Contrast-to-Noise Ratio, and SNR stands for Signal-to-Noise Ratio.

3.3 Typical Reconstructed MIP Images

Figure 1 shows the reconstructed MIP images of the same patient using both sequences. Figure 1A, obtained with the TSE sequence, had a total scan time of 348 seconds. The patient's breathing was relatively uniform, and the background suppression was good, but there was motion blur in the acquired images, and the common bile duct, gallbladder duct, main pancreatic duct, and left and right hepatic ducts were not clearly displayed. Figure 1B, obtained with the GRASE sequence, had a total scan time of 16 seconds. The patient's breath-hold was good, there was no motion blur, and the common bile duct, gallbladder duct, main pancreatic duct, left and right hepatic ducts, and common hepatic duct were more clearly displayed than in Figure 1A. However, the background suppression was worse than in Figure 1A. Both Figure 1A and Figure 1B met the diagnostic requirements.

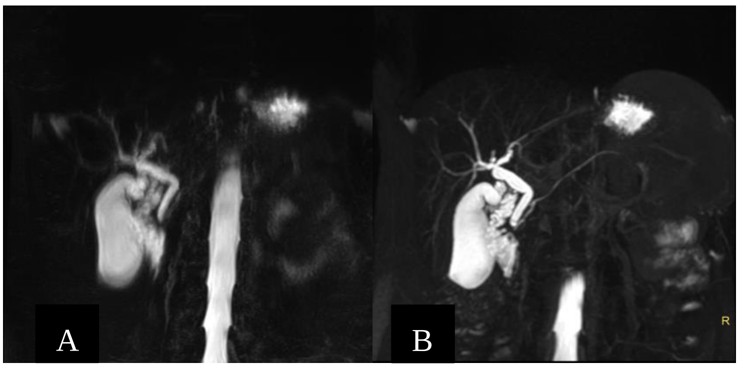

Figure 1. Reconstructed MIP Images of the Same Patient from Two Different Sequences

4. Discussion

The TSE sequence, previously commonly used in clinical 3D MRCP examinations, employs respiratory triggering technology, acquiring at the lowest point of the respiratory wave, once at the end of each breath. Due to the influence of the patient's breathing, images obtained with the TSE sequence are prone to respiratory motion artifacts, affecting image quality, and the acquisition time is also unstable [10-14]. In contrast, the GRASE sequence combines TSE and EPI technology, using 180° echo pulse phase recollection and echo gradient refocusing, two imaging factors. That is, the number of echoes collected during each TR interval is equal to the product of the two factors, allowing for the completion of multiple lines of K-space in one go, thus achieving rapid imaging. Additionally, the GRASE sequence uses a 90°pulse for excitation and a 180°pulse for phase recollection. Since the echo signals produced by the 180° pulse can be rapidly collected using multiple echo gradients, multiple echo signals can be collected at once, achieving the goal of rapid imaging [1]. Moreover, the GRASE sequence uses breath-holding to collect images, which is not affected by respiratory motion, and does not require uniform field preparation before scanning. Previous studies have confirmed that the GRASE sequence can eliminate motion artifacts while ensuring image quality and CNR [3].

The results of this study show that compared to the TSE sequence, the GRASE sequence had higher scores for the display of the common bile duct, gallbladder duct, main pancreatic duct, and left and right hepatic ducts, as well as lower image artifact scores, overall image quality scores, and CNR, all with statistically significant differences ($P<0.05$). This further confirms the effectiveness of the GRASE sequence in improving image quality, shortening scanning time, and maintaining CNR. Despite the advantages of the GRASE sequence, there are still some limitations. First, the image collection range of the GRASE sequence is limited. For patients with larger lesions in the intrahepatic bile ducts, due to the limited breath-hold time, the scanning range cannot be set too large. Second, due to the limitations of the equipment hardware, the patient should be positioned as flat as possible in the middle of the basic coil when positioning, otherwise, it may cause the image to be unable to be reconstructed and require a restart of the scan. Finally, patients who have difficulty in breath-holding cannot use the GRASE sequence, for which the TSE sequence is still recommended.

In summary, the use of the GRASE sequence in 3D MRCP examinations can improve image quality, shorten acquisition time, and ensure CNR.

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