Comparison of SPACE and 3D TSE MRCP at 1.5T Focusing on Difference in Echo Spacing

Satoru Morita1*, Eiko Ueno1, Ai Masukawa1, Kazufumi Suzuki1, Haruhiko Machida1, Mikihiro Fujimura1, Shinya Kojima1, Masami Hirata1, Takahiro Ohnishi2, Kazuhiro Kitajima3, and Yasushi Kaji3

1Department of Radiology, Tokyo Women’s Medical University Medical Center East
2–1–10 Nishiogu, Arakawa-ku, Tokyo 116–8567, Japan
2Application group, Siemens-Asahi Medical Technologies, Tokyo, Japan
3Department of Radiology, Dokkyo University School of Medicine, Tochigi, Japan

(Received March 23, 2009; Accepted May 13, 2009)

Purpose: We compared the image quality of SPACE (sampling perfection with application optimized contrasts using different flip angle evolutions) and conventional 3D turbo spin echo (TSE) magnetic resonance cholangiopancreatography (MRCP) at 1.5 tesla with regard to difference in echo spacing.

Methods: Twenty healthy volunteers prospectively underwent navigator-triggered SPACE and 3D TSE MRCP at 1.5T with identical parameters, except for echo spacing. Quantitative analyses of signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), relative contrast, and contour sharpness index of each segment of the pancreaticobiliary tree were compared using paired t-tests. Qualitative analyses on a 5-point scale (1, excellent; 5, poor) scored by 2 independent radiologists were compared using Wilcoxon signed-rank test.

Results: The SNR, CNR, and contour sharpness index of each segment were significantly better for the SPACE sequence than 3D TSE ($P<0.05$). Relative contrast and subjective image quality were not significantly different ($P>0.05$).

Conclusion: We verified SPACE MRCP quantitatively superior to conventional 3D TSE MRCP at 1.5T as a result of shortening of echo spacing.

Keywords: echo space, MRCP, MRI, SPACE, variable flip angle

Introduction

Magnetic resonance cholangiopancreatography (MRCP) is a noninvasive imaging technique that provides detailed information on the anatomy and pathology of the pancreaticobiliary tree.1,2 Various sequences for MRCP based on heavily T2-weighted sequences with long echo times have been introduced at 1.5 tesla.3–5 In particular, a 3-dimensional (3D) thin multislice navigator-triggered technique using turbo spin echo (TSE) sequence is utilized to obtain high resolution 3D MRCP images.6,7

Three-tesla MR imaging has recently been attempted as well using 3D MRCP with SPACE (sampling perfection with application optimized contrasts using different flip angle evolutions) sequence.8,9 This reduces specific absorption rate (SAR) for 3.0T imaging by using a variable flip angle and reduces acquisition time when combined with the GRAPPA (generalized autocalibrating partially parallel acquisition) reconstruction algorithm. It also reduces echo spacing, an advantage not previously explored.

SPACE can also be used for 3D MRCP at 1.5T. It has been already reported superior to conventional 3D TSE MRCP at 3.0T.9 At 3.0T, it is necessary to reduce the flip angle or use a variable flip angle to limit the SAR, whereas at 1.5T, the SAR causes less disturbance, thus negating the need to use a variable flip angle. In addition, short echo time (TE), which can be produced by varying flip angle in 3.0T MR imaging, is not an original requirement for MRCP. Therefore, we hypothesized...
that the most irreplaceable factor for image quality of SPACE MRCP at 1.5T, other than the image acquisition time, might be the shortening of the echo spacing.

We herein report our prospective comparison in healthy volunteers of image quality with regard to difference in echo spacing utilizing SPACE sequence and conventional 3D TSE for navigator-triggered 3D MRCP at 1.5T.

Materials and Methods

Patients

Our institutional review board approved this single-institution study, and 20 healthy volunteers (14 men, 6 women; median age, 34.5 years, range, 23–55) with no history of biliary and pancreatic disease gave informed written consent.

MRCP imaging technique

We performed MRCP examinations on a commercially available 1.5T system (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany), employing a 6-element body phased-array coil and 6-element spine array coil connected to a 4-channel radiofrequency receiver.

After obtaining scout images, we obtained navigator-triggered SPACE and 3D TSE MRCP images of the pancreaticobiliary tree during free breathing. We used the same parameters except echo spacing for both sequences: repetition time (TR)/TE, 1×the respiratory cycle/602 ms; flip angle, constant 160°; matrix, 233×256; field of view, 350×350 mm; section thickness, 1.5 mm (voxel size = 1.5×1.4×1.5 mm); 40 slices per slab; 2 signals acquired; fat suppression, used; bandwidth, 391 Hz/pixel; echo-train length, 129; and coronal acquisition direction. Echo spacing for SPACE was 4.74 ms and for 3D TSE, 7.82 ms, which was prescribed using these parameter settings. We did not use parallel imaging for either sequence because it is critical to measure SNR when using parallel imaging.10 For navigator triggering, we used 2D-PACE with a standard protocol.3,6,7,11,12 These parameter settings were only used for this study.

Quantitative evaluation

We recorded the acquisition time for each MRCP, and 2 radiological technologists (A and B) conducted quantitative analysis using the images obtained by the 2 techniques. Mean signal intensities (SIs) of the middle extrahepatic duct, gallbladder, and pancreatic duct at the level of the pancreatic head were measured using an operator-defined region-of-interest (ROI). Mean SIs of the liver between the left and right hepatic ducts and the pancreas head lateral to the pancreatic duct were measured as the background signal. Noise was measured with the ROI on the air. The size of the ROI was chosen to include a large representative portion of the object with an upper limit of 500 pixels. The value of the SIs was divided by the corresponding standard deviation (SD) of the noise to derive the SNR. The CNR of the extrahepatic duct and gallbladder to the liver or of the pancreatic duct to the pancreas head was calculated as (object SI − background SI)/noise SD. The relative contrast of the extrahepatic duct and gallbladder to the liver or of the pancreatic duct to the pancreas head was calculated as (object SI − background SI)/(object SI + background SI) following previous reports.12,13 To score the sharpness of the ductal structures objectively, a contour sharpness index was calculated following previous reports using ImageJ software (National Institutes of Health [NIH], Bethesda, MD, USA).13,14 By measuring SI profiles perpendicular to the axis of the left hepatic duct and the pancreatic duct at the level of the pancreatic head, the maximum change in SI per pixel was quantified by the maximal slope of a line connecting these pixels. The degree of the angle alpha, which is the angle between this line and the x axis, was the contour sharpness index.

Qualitative evaluation

Maximum intensity projection (MIP) images in a frontal plane were automatically reconstructed after image acquisition and exhibited in random order with the image window and level adjusted individually to obtain comparable image settings using a commercial viewer (Centricity RA1000; GE Healthcare, Milwaukee, WI, USA). Two radiologists (C and D) qualitatively assessed all images; each had more than 5 years’ experience evaluating MRCP and was blinded to information regarding acquisition technique. They evaluated overall image quality of the pancreaticobiliary tree on a 5-point scale (1, excellent; 2, good; 3, fair; 4, poor; and 5, unacceptable). The depiction of predefined segments of the pancreaticobiliary tree were scored independently in the same way according to a past report:13 1, perfect visualization of entire ductal structure; 2, visualization of most of the ductal structure; 3, ductal structure partially visible; 4, detection of ductal structure almost impossible; and 5, ductal structure not visible. The ductal segments assessed were the extrahepatic, intrahepatic, cystic, and pancreatic ducts. If small segments, such as the cystic duct, could not be depicted because of interruption by gastrointestinal fluid, the source images...
were evaluated.

**Statistical analysis**

Statistical analyses were performed using SPSS version 16.0 (SPSS, Chicago, IL, USA). Quantitative analyses used a paired t-test to compare image acquisition time, SNR, CNR, relative contrast, and contour sharpness index between the 2 techniques. For qualitative analysis, the subjective image quality assigned by the 2 readers was averaged to compare subjective image quality using Wilcoxon signed-rank test. \( P<0.05 \) was considered statistically significant. Interobserver variability was assessed with \( k \)-statistics, measuring the degree of agreement between the 2 observers. Kappa values \( >0 \) were considered indication of positive correlation.

**Results**

Table 1 summarizes quantitative data and Table 2, qualitative data. Figure 1 shows representative images. Acquisition time was not significantly different between the SPACE and 3D TSE sequences (5.3 \( \pm \) 1.0 vs. 5.4 \( \pm \) 1.1 min, \( P=0.59 \)).

The SNR and CNR of each segment were significantly higher for SPACE than 3D TSE \( (P<0.05) \) (Table 1). Relative contrast was not significantly different \( (P>0.05) \) (Table 1). The contour sharpness index of each segment was significantly higher for SPACE than 3D TSE \( (P<0.05) \) (Table 1).

Subjective image quality was not significantly different in any of the segments \( (P>0.05) \), though only that of the pancreatic duct was slightly higher for the SPACE sequence \( (P=0.07) \) (Table 2). Interobserver variabilities were positive for all segments \( (\text{kappa}=0.05-0.51) \) (Table 2).

**Discussion**

We proved the quantitative superiority of the contour sharpness of the SPACE sequence for navigator-triggering 3D MRCP to that of conventional 3D TSE at 1.5T. This is directly attributable to the shortening of echo spacing in SPACE because all other acquisition parameters were uniform for the 2 sequences. This finding corresponds with the theory that short echo spacing reduces blurring.\(^{15,16}\) The difference in echo spacing is the most important difference other than image acquisition time between the 2 sequences at 1.5T.

Although the SNR and CNR of SPACE MRCP were superior to those of 3D TSE, relative contrast was not significantly different. We did not use parallel acquisition technique because it is critical to measure the SNR when using parallel acquisition technique.\(^{10}\) However, other problems of quantitative analysis have recently been discussed regarding background noise when reconstruction filters and multichannel coil are used.\(^{17}\) The relative contrast does not use background noise data. However, the background signals of the liver and pancreas of

---

**Table 1. Quantitative analysis of SPACE and 3D TSE MRCP**

<table>
<thead>
<tr>
<th></th>
<th>SPACE</th>
<th>TSE</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal-to-noise ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extrahepatic duct</td>
<td>210.5 ( \pm ) 82.1</td>
<td>140.1 ( \pm ) 62.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>227.7 ( \pm ) 110.6</td>
<td>176.9 ( \pm ) 115.2</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Pancreatic duct</td>
<td>82.5 ( \pm ) 59.3</td>
<td>47.8 ( \pm ) 28.1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Contrast-to-noise ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extrahepatic duct</td>
<td>206.8 ( \pm ) 81.6</td>
<td>137.2 ( \pm ) 61.7</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>224.1 ( \pm ) 110.2</td>
<td>174.0 ( \pm ) 114.4</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Pancreatic duct</td>
<td>76.8 ( \pm ) 59.5</td>
<td>43.7 ( \pm ) 28.9</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Relative contrast</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extrahepatic duct</td>
<td>0.96 ( \pm ) 0.02</td>
<td>0.95 ( \pm ) 0.02</td>
<td>0.48</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>0.96 ( \pm ) 0.03</td>
<td>0.96 ( \pm ) 0.02</td>
<td>0.53</td>
</tr>
<tr>
<td>Pancreatic duct</td>
<td>0.82 ( \pm ) 0.17</td>
<td>0.78 ( \pm ) 0.16</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Contour sharpness index</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left hepatic duct</td>
<td>89.2 ( \pm ) 0.5</td>
<td>88.0 ( \pm ) 2.0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Pancreatic duct</td>
<td>88.2 ( \pm ) 1.4</td>
<td>86.6 ( \pm ) 3.5</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

* Values are mean \( \pm \) standard deviation.
MRCP = magnetic resonance cholangiopancreatography, SPACE = sampling perfection with application optimized contrasts using different flip angle evolutions, TSE = turbo spin echo.
MRCP were too low to calculate relative contrast against the pancreaticobiliary tree. For these reasons, we cannot draw any conclusions from the quantitative difference of signal intensity and contrast between the 2 sequences.

We observed no significant difference in subjective image quality, although image quality of the pancreatic duct was slightly better for SPACE. This may indicate no large difference in image contrast between the 2 sequences. We think the quantitative differences observed in contour sharpness will be too small to detect visually because we used uniform acquisition parameters, including space resolution, in this study. However, slight differences such as those observed for the pancreatic duct will be meaningful in the clinical setting, where the evaluation of subtle findings is necessary.

Acquisition parameters of SPACE MRCP may be further optimized for clinical use. We limited them to adjust to those of the 3D TSE. So, we did not use parallel acquisition, such as GRAPPA, which would approximately halve the image acquisition time of the SPACE MRCP, because 3D TSE MRCP requires 2 respiratory cycles to acquire one k-space partition. Use of the GRAPPA technique would permit acquisition of an entire k-space partition in a single respiratory cycle using SPACE. Another inhibition is the setting of space resolution, which depends on required image acquisition time. The use of GRAPPA can reduce acquisition time and thereby enhance the space resolution of the SPACE sequence. Therefore, we believe that the use of GRAPPA and the effect of the shortening of the echo spacing will further increase the superiority of the image quality and acquisition time of SPACE MRCP over those of conventional 3D TSE MRCP.

Our study is limited because we evaluated only healthy volunteers, so we cannot know how the superiority of the SPACE sequence affects the identification and diagnosis of disease. The superiority of the SPACE sequence at 1.5T should be evaluated in patients.

### Table 2. Qualitative analysis of SPACE and 3D TSE MRCP*

<table>
<thead>
<tr>
<th></th>
<th>SPACE</th>
<th>TSE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall image quality</td>
<td>1.7 ± 0.8(0.35)</td>
<td>1.7 ± 0.7(0.27)</td>
<td>0.74</td>
</tr>
<tr>
<td>Extrahepatic duct</td>
<td>1.3 ± 0.4(0.25)</td>
<td>1.4 ± 0.5(0.10)</td>
<td>0.32</td>
</tr>
<tr>
<td>Intrahepatic duct</td>
<td>1.5 ± 0.5(0.29)</td>
<td>1.4 ± 0.5(0.05)</td>
<td>0.44</td>
</tr>
<tr>
<td>Cystic duct</td>
<td>1.7 ± 0.8(0.44)</td>
<td>1.6 ± 0.9(0.51)</td>
<td>0.62</td>
</tr>
<tr>
<td>Pancreatic duct</td>
<td>1.7 ± 0.8(0.22)</td>
<td>2.0 ± 0.8(0.05)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

* Values are mean ± standard deviation on a scale of 1–5 (1, excellent; 5, poor). Parentheses contain the (kappa) values between 2 reviewers.

MRCP = magnetic resonance cholangiopancreatography, SPACE = sampling perfection with application optimized contrasts using different flip angle evolutions, TSE = turbo spin echo.
Conclusion

In conclusion, we confirmed that the contour sharpness of SPACE MRCP is quantitatively superior to that of conventional 3D TSE MRCP at 1.5T as a result of shortening of echo spacing. Combining SPACE MRCP with GRAPPA will enhance image quality and acquisition time for clinical use.

References